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This textbook would not have been possible without my mentors in thoracic and esophageal surgery, including Ernest Rosato (The Hospital of the University of Pennsylvania), Robert Ginsberg (Memorial Sloan Kettering Cancer Center), Manjit Bains (Memorial), Mike Burt (Memorial), David Skinner (New York Hospital), Nasser Altorki (New York Hospital), Griffith Pearson (Toronto). Each of you contributed significantly to my surgical skill and understanding of esophageal surgery and I feel blessed to have been mentored by all of you.

This textbook was made possible by my two co-editors. Thanks to Arjun Pennathur for his undying support and loyalty, and to Rod Landreneau for his support and help during this process and for helping me to build a world-class center for thoracic surgery. A special thanks to my assistants at Pitt, including Erin Dupree, Kathy Lovas and Shannon Wyszymierski.

James D. Luketich

“I wish to recognize Jim Luketich for his exceptional clinical skills and his dedication to advancing the care of patients with esophageal disease. I must also recognize my surgical mentors, Walter Becker, Robert McClelland, William Fry, Marvin Kirsh, and Mark Orringer, for their patience with me and their support through trying times.”

Rod Landreneau

I would like to thank my mentors—Dr. Alex G. Little, Dr. Ronald A. Malt, Dr. Leslie W. Ottinger, Dr. James D. Luketich, and Dr. Pam A. Lipsett who, in addition to their mentorship, encouraged me, and provided me with several opportunities. Finally I am indebted to all my teachers, colleagues, students, residents and patients who have all taught me the finer points in the care of the surgical patient.

Arjun Pennathur
I would like to dedicate my contributions to this textbook of esophageal surgery to my family, including my wife Christine, who gives so much meaning to my life and makes it all worthwhile, and to the kids (now adults) Jim, Jr., Derek, Bobby, and Patty. And of course, I must make special mention of our most recent additions to the family, my wonderful Sam and Alex, who make life so much fun!

James D. Luketich

I dedicate this book to my wife, Sandy, who has been my inspiration and my most important advisor and supporter. I also dedicate this effort to the “Js”; may they be challenged, brave, and succeed along the “Road of Right”.

Rodney J. Landreneau

I am grateful to God for the Blessings and Grace.

I would like to dedicate this work to my family, in particular my parents for their support and teaching us the value of hard work, honesty and education. I would like to thank my family for their encouragement and support—my grandparents who lived by setting an example, my brother, and sister, my wife Revathi and our children Krithika and SriGanesh. I am indebted to their unwavering support, patience and their persistence.

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This series of mini-atlases is an outgrowth of *Mastery of Surgery*. As the series editor, I have been involved with *Mastery of Surgery* since the third edition, when I joined two greats of American surgery, Lloyd Nyhus and Robert Baker, who were the editors at that time. Surgical atlases were common in those days, and *Mastery of Surgery* was one of several quality atlases which existed then; of particular quality were those by Dr. John Madden of New York, Dr. Robert Zollinger of Ohio State, and two others, with which the reader may be less familiar. The first was by Professor Pietro Valdoni, Professor of Surgery at the University of Rome, who ran 10 operating rooms simultaneously, and as the Italians like to point out to me, a physician to three popes. One famous surgeon said to me, what can you say about Professor Valdoni? “Professor Valdoni said to three popes, ‘take a deep breath,’ and they each took a deep breath.” This superb atlas, which is not well known, was translated from the Italian by my partner when I was on the staff at Mass General Hospital, Dr. George Nardi. The second was a superb atlas by Dr. Robert Ritchie Linton, an early vascular surgeon whose atlas was of very high quality.

Atlases, however, fell out of style, and in the fourth and fifth editions of *Mastery of Surgery*, we added more chapters that were “textbooky” types of chapters to increase access to the growing knowledge base of surgery. In discussing with Brian Brown and others at Lippincott Williams & Wilkins, as well as with some of the surgeons who subsequently became editors of books in this present series, it seemed that we could build on our experience with *Mastery of Surgery* by creating smaller, high-quality atlases, each focusing on the key operations of a sharply circumscribed anatomical area. This we have accomplished because of the incredible work of the editors who were chosen for their demonstrated mastery in their fields.

Why the return of the atlas? Is it possible that the knowledge base is somewhat more extensive with more variations on the various types of procedures—that as we learn more about the biochemistry, physiology, genetics, and pathophysiology in these different areas, there have come to be variations on the types of procedures that we do on patients in these areas? This increase in the knowledge base has occurred simultaneously at a time when the amount of time available for training physicians—and especially surgeons—has been steadily declining. Although I understand the hypothesis that brought the 80-hour work week upon us, which limits the time that we have for instruction (though I do believe that it is well-intentioned), I still ask the question: Is the patient better served by a somewhat fatigued resident who has been at the operation and knows what the surgeon is worried about, or a comparatively fresh resident who has never seen the patient before?

I don’t know, but I tend to come down on the side that familiarity with the patient is perhaps more important. And what about the errors of hand-off, which seem to be more of an intrinsic issue with the hand-off itself (which we are not able to really remedy entirely), rather than poor intentions?

This series of mini-atlases is an attempt to help fill the void created by inadequate time for training. We are indebted to the individual editors who have taken on this responsibility and to the authors who have volunteered to share their knowledge and experience in putting together what we hope will be a superb series. We have chosen surgeons who are inspired by their experience of teaching residents and medical students (a high calling indeed), a quality matched only by their devotion and superb care they have given to thousands of patients. It is an honor to serve as the series editor for
this outstanding group of mini-atlases, which we hope will convey the experiences of
an excellent group of editors and authors to the benefit of students, residents, and their
future patients in an era in which time for education seems to be increasingly limited.

Putting a book together—especially a series of books—is not easy, and I wish to
acknowledge the staff at Lippincott Williams & Wilkins, including Brian Brown, Brendan
Huffman, and many others. I would also like to thank my personal staff in the office,
in particular, Edie Burbank-Schmitt, Ingrid Johnson, Abigail Smith, and Jere Cooper.
None of this would have been possible without them.

Josef E. Fischer, MD, FACS
Boston, Massachusetts
“Whoever saves a single life, it is considered as if one saved the entire world.”
—from the Talmud

As part of the growing and well-known series, *Master Techniques in Surgery*, edited by Dr. Fischer, this book focuses on esophageal surgery. These specialty volumes complement the well-known *Mastery of Surgery* book, also edited by Dr. Fischer. Although there are many standard textbooks in general surgery, thoracic surgery, and some on esophageal surgery, this book is unique in that it focuses on the technical aspects of esophageal surgery. Esophageal surgery is complex, and this textbook, which is entirely devoted to surgery of the esophagus, should serve as a useful complement to some of the existing comprehensive textbooks in esophageal, general, and thoracic surgery, as well as serve as link between a classical textbook and an atlas.

The contributions to the text are led by world-renowned surgeons with expertise in complex esophageal surgery. This book is intended for anyone interested in esophageal diseases—including medical students, gastroenterologists, general and thoracic surgery residents and other trainees, faculty, and practicing surgeons. The textbook covers the spectrum of surgical techniques to treat esophageal diseases, and is organized in six sections, each covering a specific area of esophageal surgery.

Gastroesophageal reflux (GERD) is a very common condition in Western countries, and surgeons are referred many patients who have failed medical therapy or have developed complications related to reflux. Section 1 is devoted to the surgical treatment of GERD. Surgical treatment of paraesophageal hernia is also discussed in this section. There are a total of 13 chapters in this section by leading experts in the field, covering a wide gamut of surgical approaches to GERD from commonly used procedures such as the laparoscopic Nissen fundoplication to the Hill Repair to complex transthoracic approaches such as the Belsey fundoplication. In addition, complex esophageal procedures—the management of giant paraesophageal hernia and reoperative antireflux surgery—are described in detail in this section. Further, an endoscopic approach to fundoplication is also described. There is now increasing evidence that obesity correlates with GERD, and therefore, we have included a chapter on gastric bypass in this section as well.

In Section 2, the surgical treatment of esophageal motility disorders, such as achalasia and esophageal diverticula, are addressed. Included in this section are chapters describing both the open and the minimally invasive approaches to achalasia and repair of cricopharyngeal (Zenker’s) and epiphrenic diverticula.

The incidence of esophageal cancer is increasing at an alarming rate, primarily because of an increasing incidence of adenocarcinoma particularly in the Western countries. Surgical resection is an important component of treatment; however, it is a complex operation. In Section 3, the techniques and approaches for esophageal resection are addressed, and this includes a total of nine chapters describing the open approaches as well as the minimally invasive approach to esophageal resection. Open and minimally invasive resection of benign esophageal tumors are covered in Section 4.

In Section 5, endoscopic ablative therapies, such as radiofrequency ablation and mucosal resection, for the treatment of Barrett’s esophagus are addressed. While esophagectomy is the standard treatment for esophageal cancer, less invasive therapies may be applicable in the high-risk patient with Barrett’s esophagus and high-grade
dysplasia, as well as in very highly selected patients with intramucosal adenocarcinoma. Finally, in Section 6, the techniques for the treatment of other conditions, such as esophageal perforation and diaphragmatic hernia, and the techniques of stenting and dilation are addressed.

The readers should find this text very useful in updating their knowledge, and it will serve as a practical guide in esophageal surgery. We would like to thank the publisher, and in particular Brendan Huffman, Keith Donnellan, and Aptara project manager Abhishan Sharma for their hard work and persistence in getting this work completed. We would also like to thank Shannon Wyszomierski for the excellent editorial assistance she provided in completing this work.

We hope readers find this book to be a very interesting and a valuable reference in esophageal surgery.

James D. Luketich, MD
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Laparoscopic Nissen Fundoplication
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Surgical fundoplication is the gold standard for the treatment of gastroesophageal reflux disease (GERD). Incompetent lower esophageal sphincter (LES) complex and hiatus hernia (HH) play important roles in the pathophysiology of GERD. Although first described nearly 70 years ago, antireflux procedures gained popularity with the recognition of the pathophysiology of GERD and the ability to objectively document distal esophageal acid exposure (24-hour pH). Minimally invasive techniques were adapted in early 1990’s to allow for laparoscopic fundoplication and this has led to an exponential increase in the number of antireflux procedures. A complete 360-degree fundoplication (Nissen fundoplication) is the most common antireflux procedure performed. The goal of the procedure is to create a tension-free infradiaphragmatic fundoplication around the distal esophagus. This chapter describes indications for Nissen fundoplication and the technique of laparoscopic Nissen fundoplication (LNF).

INDICATIONS/CONTRAINDICATIONS

Chronic or recurrent GERD with breakthrough symptoms on medical therapy is the most common indication for LNF. LNF should only be considered in patients with documented evidence of pathologic GERD.

Objective evidence of GERD is given as follows:

- Reflux esophagitis—endoscopic/pathologic
- Peptic stricture
- Barrett’s esophagus (BE)
- Abnormal 24-hour pH score
- Abnormal impedance pH score

In patients with typical symptoms like heartburn and regurgitation, especially with good relief with medical therapy, at least one type of objective evidence of reflux should be sought before proceeding with surgery. In patients with atypical GERD symptoms, a minimum of two types of objective evidence of GERD should be sought, in addition to ruling out other causes, before LNF is offered to the patient. The best indicator of success of LNF is a good response to medical therapy.
Indications for LNF are as follows:

- Breakthrough symptoms of heartburn and regurgitation on maximal medical therapy.
- Respiratory symptoms attributable to pathologic GERD.
- Laryngopharyngeal reflux symptoms with documented pathologic GERD.
- Volume regurgitation associated with nocturnal symptoms.
- Drug-dependent patients with documented abnormal 24-hour pH score especially with a mechanically defective LES.
- Evidence of esophageal damage: Stricture, reflux esophagitis, or BE.

LNF is contraindicated in patients with severely impaired esophageal motility or scleroderma. In patients with severely delayed gastric emptying and a competent LES/no HH, a gastric drainage procedure rather than LNF should be considered. In patients with both delayed gastric emptying and pathologic GERD, an LNF with distal gastrectomy and Roux-en-Y (RNY) reconstruction should be planned. The presence of high-grade dysplasia (HGD) or esophageal adenocarcinoma (EAC) is an absolute contraindication for LNF. In patients with a history of HGD and/or superficial adenocarcinoma that has been documented to regress with endoscopic ablative or resection therapy, LNF can be carefully considered. There is uncertain evidence that LNF significantly decreases the progression of BE to EAC, and LNF should not be done for that reason alone. Patients with undilatable peptic stricture or short esophagus are better served with esophageal resection or Collis gastroplasty with fundoplication respectively, rather than LNF.

**PREOPERATIVE PLANNING**

In addition to general preoperative evaluation to assess patient fitness to undergo surgery, a detailed assessment should be done. History of symptoms and response to medical therapy should be carefully documented. It is important to remember that patient-perceived symptoms can be due to different etiologies. For example, it is common for a patient with achalasia to be treated medically for GERD prior to correct diagnosis. In such situations though, delay in diagnosis is erroneous, but mere institution of medical therapy would not be harmful, while proceeding with fundoplication would be disastrous. Hence it is imperative that the operating surgeon plays an active role in establishing diagnosis and completely understanding individual patient pathophysiology. As mentioned previously, surgery should only be undertaken after the objective documentation of GERD in an appropriate clinical setting.

- **Esophagogastroduodenoscopy (EGD):** An upper endoscopy should always be performed prior to surgical intervention. This allows for direct assessment of esophageal mucosa and cardia competence/HH and histologic diagnosis of BE (if present).
- **Contrast study:** An upright and supine barium esophagram delineates the size and type of HH. We routinely use both liquid and solid material to help assess esophageal motility. The 13-mm tablet helps reveal subtle strictures that might be missed on endoscopy.
- **Esophageal manometry:** Esophageal motility helps determine the type of fundoplication that should be performed. Though there is no evidence to support a tailored fundoplication based on esophageal motility, most surgeons in the United States proceed with partial fundoplication in patients with ineffective esophageal motility. Introduction of high-resolution manometry holds the promise to better delineate motility disorders and aid the surgical decision process.
- **24-hour pH:** Prolonged distal esophageal acid exposure is the gold standard for objective assessment for GERD. Impedance pH is used to document nonacidic reflux and, in my opinion, is of real use only in very select patients. One must note that distal esophageal pH changes are a marker of reflux, not the disease itself (which is reflux of gastric contents). Dual pH monitoring is used to document proximal esophageal acid exposure in patients with extraesophageal symptoms.
- **Wireless (Bravo) 48-hour pH:** Recently, wireless pH monitoring using a radiotelemetric capsule, attached to the wall of the esophagus (Bravo pH monitoring system;
Medtronic, Minneapolis, MN), has become widespread. The Bravo capsule allows prolonged monitoring and is better tolerated by patients than pH probes placed on a transnasal catheter. Although the Bravo probe does not assess impedance pH (non-acidic reflux), it promotes a more typical diet and daily activities during the monitoring period, and is a useful tool for assessing esophageal acid exposure.

**Gastric emptying study:** A nuclear medicine gastric emptying study should be done in patients with significant bloating and also in patients with pathologic GERD if they appear to have a competent LES and no HH. These results should be interpreted cautiously as there may be poor symptom correlation.

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**Surgery**

The goal of surgery is to create a tension-free infradiaphragmatic fundoplication over the distal esophagus. This recreates a 2 to 3 cm intra-abdominal length of the esophagus and places the high-pressure gastric fundus around the gastroesophageal junction (GEJ), restoring a competent LES complex.

Patients with documented delayed gastric emptying are asked to be on a clear liquid diet for 2 to 3 days before surgery. Antiplatelet agents and anticoagulants are withheld appropriately. A single dose of a first generation cephalosporin (cefazolin, 1 g) is given within 30 minutes of incision. Deep vein thrombosis (DVT) prophylaxis is administered with 5000 U subcutaneous heparin and lower extremity sequential compressive devices. Surgery is done under general anesthesia and specific precautions should be paid to prevent aspiration during induction. We routinely give ondansetron iv 30 minutes before finishing the case. In patients with history of postoperative nausea, we have low threshold to use propofol drip and give dexamethasone iv at induction.

**Room Setup**

Use of dedicated minimally invasive operating room suite is helpful. We use three overhead hanging monitors near the head of the bed. The surgeon stands between the legs of the patient, first assistant to his/her right (left side of the patient), and the camera holder on the left (right side of the patient). After the start of the case, the instrument Mayo stand is placed from the left of the patient over the chest. The instrument table is on the left near the foot-end. The instrument cords are over the right shoulder of the patient. In addition, endoscopic equipment should be available for assessment (Fig. 1.1).

**Positioning**

The patient is positioned in an inverted-Y (modified lithotomy) position. An operating bed with a great deal of vertical range and degree of incline capacity should be used. We use the AlphaMaxx bed (Maquet Getinge AB, Rastatt, Germany). Legs are on split extensions with footboards. Both arms are tucked in; if there is a need to extend one or both arms, the arm boards should be positioned to prevent hyperextension at the shoulders (one must keep in mind that the patient may slide downward when the reverse Trendelenburg position is used during the case). The patient is prepped, draped from mid-chest down to the pubis symphysis (Fig. 1.2). If there is a high degree of suspicion for short esophagus, the left chest is also prepped in the field as we use a left thoracoscopic Collis gastroplasty.

**Peritoneal Access**

Peritoneal access is obtained as per surgeon’s preference. We use a Veress step needle to obtain pneumoperitoneum through a 5-mm skin incision made just to the left of midline, a third of the way up between the umbilicus and the xiphoid. An Optiview 5-mm cannula (Endopath Ethicon Endosurgery, Cincinnati, OH) is inserted using a zero-degree 5-mm laparoscope. Alternatively, an open technique using a Hasson cannula can be used. A pneumoperitoneum of 12 to 15 mm Hg is achieved. After initial diagnostic
Figure 1.1 This shows the room set up. Scrub table (ST) comes across the patient’s chest from the left side. Monitor (A) is over the head of the bed; monitor (B) and (C) on the left and right of the patient near the head of the bed are adjusted for use by the camera holder and the first assistant, respectively. The endoscopy system (ES) is available to be placed from the left near the anesthesiologist. Patient is positioned in inverted-Y position.

Figure 1.2 Surgical field extends from above the xiphoid to the pubic symphysis and from the mid axillary line on each side. The surgeon stands between the patient’s legs.

laparoscopy, the table is slowly positioned in a steep reverse Trendelenburg position. The patient’s blood pressure should be closely monitored as increased intra-abdominal pressure and positioning significantly decrease cardiac venous return and can affect hemodynamic status. In such a situation, pneumoperitoneum is evacuated and the table is flattened. Resuming abdominal insufflation and repositioning the table more slowly after a fluid bolus is usually uneventful. Further, cannulae are inserted under laparoscopic guidance.

Remaining Cannula and Liver Retractor

A 5-mm cannula is placed one to two fingerbreadth below the costal margin in the left anterior axillary line; this is for the assistant’s instruments. A 5-mm incision is made
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and the fascial opening created with a trocar just to the left of the xiphoid. Through this, a Nathanson liver retractor is inserted and positioned to retract the left lobe of liver superiorly. The retractor is attached to a table-mounted system using the Iron Intern (Automated Medical Products, Edison, NJ). Another 5-mm cannula is placed (using the surgeon’s left hand) 4 cm to the right of midline between the camera port and the xiphoid. It is directed toward the hiatus, and may traverse the falciform ligament. Finally we use a 12-mm cannula in the left upper quadrant below the costal cartilage in the midclavicular line. Using a 12-mm cannula allows the use of needles without “skiing,” though some surgeons use all 5-mm trocars (Fig. 1.3). Different liver retractors are available and can be used depending on surgeon preference and familiarity. Many different cannula placements have been described and the surgeon should use the one they feel most comfortable with.

Procedure

The steps of the Nissen fundoplication include: (1) Hiatal dissection; (2) Division of the short gastrics; (3) Esophageal mobilization; (4) Crura closure; and (5) 360-degree complete fundoplication. In the following descriptions, the directions are mentioned as they pertain to the patient.

Dissection of the Hiatus

Using an atraumatic grasper, the assistant retracts the gastric fat pad inferiorly and to the left stretching the gastrohepatic ligament. The hepatic branch of the anterior vagus nerve can be identified traversing from the stomach to the liver. The dissection starts with hook cautery above the nerves, preserving them. The nerves can be sacrificed to increase exposure, though routine division is not required. In one out of five patients, an aberrant left hepatic artery is present in the gastrohepatic ligament alongside the vagal branches. If less than 4 mm in diameter, the vessel may be divided between clips or with a harmonic scalpel. However, larger vessels should be preserved. It is our policy to routinely preserve the hepatic branches of the vagus nerve and the left aberrant hepatic artery (if present). The gastrohepatic ligament is divided up to the arch of the crus (Fig. 1.4).

The hook cautery is used to incise the peritoneum and the phrenoesophageal membrane at the right limb of the crus. It is of utmost importance to identify the correct plane between the right limb of the crus and the esophagus. The closed tip of grasping
forceps in the surgeon’s left hand is placed in this defect to retract the crus to the right of the patient. The right hand of the surgeon bluntly dissects the crus from top to bottom (Fig. 1.5). If one is in the correct plane, this dissection proceeds rapidly and with no bleeding. The dissection is carried down to the dissection of the crus posteriorly and along the arch on to the left crus anteriorly. Retraction on the gastric fat pad by the assistant is adjusted to provide maximal tension for exposure as needed. Extreme care is taken in this dissection as if to dissect the crus away from the esophagus and not vice versa. Staying close to the crus will also avoid injury to the vagi. With experience, this can proceed rather rapidly.

Dissection is carried along the arch of the crus on to the left side. Occasionally, starting a new plane at the topmost part of the left limb of the crus is needed for this. The gastric fat pad is retracted by the surgeon’s left hand instrument and dissected off the crus to enter the mediastinum. The anterior vagus nerve is identified and preserved. Dissection is carried along the left limb of the crus to connect with the previous dissection. The posterior vagus nerve is identified.

Figure 1.4 The gastrohepatic ligament has been divided above the aberrant left hepatic artery, and the caudate lobe of the liver can be seen.

Figure 1.5 The right crus dissection is started by dividing the peritoneum and phrenoesophageal ligament near the arch.
Division of short gastric vessels can be done prior to dissection along the left limb of the crus. This exposes the left limb of the crus, allowing for better visualization, and is especially beneficial in obese patients.

**Division of Short Gastric Vessels**
The next step is adequate mobilization of the gastric fundus in preparation for a tension-free fundoplication (Fig. 1.6). This is done by dividing the short gastric vessels close to the greater curvature for a distance of 12 to 15 cm from the angle of His. After measuring the distance to identify the most distal aspect of dissection, a blunt atraumatic grasper in the left hand of the surgeon is used to grasp the stomach 1 to 2 cm away from the greater curvature. An atraumatic grasper in the assistant’s hand retracts the omentum opposite to suspend and expose the greater curvature. A harmonic scalpel is used to divide 1 cm away from the gastric edge to enter the lesser sac. Through this opening, the instrument controlled by the left hand of the surgeon then grasps the back of the stomach lifting and rotating it as short gastric vessels are divided in a cephalad fashion. The assistant’s instrument is vital and is repositioned as needed for optimal visualization and traction. It is important to lift the stomach anteriorly with the left hand. Placing the patient in a steep reverse Trendelenburg position greatly improves exposure with gravity retracting the often bulky omentum.

As the top of the fundus is reached, the assistant retracts the posterior gastric wall toward the patient’s right lower quadrant while the surgeon retracts the anterior fundus using his or her left hand. This stretches the highest short gastric vessels for division. If the fundus is closely adhered to the spleen, the electrocautery is used to incise the peritoneum between the fundus and the spleen. This increases the distance between the fundus and the spleen to safely proceed with the harmonic scalpel. Posterior short gastric vessels (also called pancreaticogastric vessels) are also divided. Complete mobilization of the fundus is performed exposing the left limb of the crus. Hiatus dissection is now completed, if it was not done earlier.

**Creating a Retroesophageal Window**
With the assistant retracting the esophagus cephalad, a retroesophageal window is made just anterior to the decussation of the crus (Fig. 1.7). A 15-cm one-fourth inch Penrose drain is placed in the window and the two ends are secured using an endoloop. Care is taken to identify and include both vagi along with the esophagus in the Penrose drain. This is used as a handle for further retraction of the esophagus. The window is enlarged in cephalocaudal direction bluntly.
Some authors do not use a Penrose drain; however, we believe this is especially useful when extensive mediastinal dissection is required as it allows for atraumatic retraction of the esophagus.

**Esophageal Mobilization**

Circumferential mobilization of the esophagus is carried in to the mediastinum. This can be done with a “chopsticks” motion using two blunt dissectors; however, perforating esophageal arteries from the aorta may need to be divided with harmonic scalpel or between clips. The assistant provides retraction using the Penrose drain as a handle. Gentle dissection avoids bleeding, which can quickly obscure dissection planes. The instruments should move parallel to the esophagus. Dissection is carried until at least 3 cm of intra-abdominal length of the esophagus is obtained. Care is taken to avoid entering either pleural cavity. Mediastinal dissection is quite easy in most cases. However, in patients with long-standing disease, there can be significant periesophageal adhesions requiring more deliberate mobilization.

If either pleural cavity is entered, the anesthesiologist is informed and asked to watch for hypotension and/or increased peak airway pressures. Usually, intermittent aspiration of the pleural cavity is done and lowering of insufflation pressure to 10 or 12 mm Hg is all that is needed. Pleural drains are not usually required. Very rarely, if hemodynamic status warrants, a small diameter chest tube may need to be inserted and can be removed in the recovery room.

**Assessing Esophageal Length**

The traction on the esophagus is released and the distance from the arch of the crus to the GEJ is measured (Fig. 1.8). The exact location of the GEJ is of considerable debate but the most accurate is to dissect the gastric fat pad at the angle of His and identify the junction of the longitudinal muscle of the esophagus to the smooth gastric serosa. Alternatively, endoscopic identification of GEJ can be used but may be less accurate in patients with BE. If at least 3 cm of intra-abdominal esophageal length cannot be achieved, a Collis gastroplasty is performed and has been described elsewhere (including Chapter 6 in this text).

**Crus Closure**

The right and left limbs of the crus are approximated with interrupted braided nonabsorbable suture. We use 0 Ethibond (Ethicon, Inc, Johnson and Johnson, Somerville, NJ) in a figure-of-eight fashion (Fig. 1.9). Alternatively, simple stitches can be used. The closure is started posteriorly and carried anteriorly and sutures tied as they are placed. Extra care is needed with the first stitch on the left limb to avoid injuring the aorta. We recommend placing the left grasper between the aorta and the left crus as a precaution.
For the right limb, the needle is grasped in the middle with the needle holder and the hand is pronated as the needle is inserted in the hiatus. The curved shaft of the needle faces the esophagus. The left hand grasper retracts the caudate lobe of the liver. The right hand is supinated, driving the needle though the crus. The needle is let go off and then regrasped on the other side, while traction on the caudate lobe is maintained to allow continued exposure. Stitches are either tied (extracorporeal or intracorporeal) or secured using mechanical devices (e.g., Ti-knot® LSI solutions, Victor, NY).

We do not recommend using autosuturing devices as the depth of the bites may be suboptimal. Crus closure is calibrated snug around a 60F bougie.

The posterior vagus nerve is then dissected gently off the distal esophagus, and a new Penrose drain is placed encircling just the esophagus and the anterior vagus nerve. The window is widened for the infradiaphragmatic portion of the esophagus (Fig. 1.10).

**Complete 360-degree Nissen Fundoplication**

The posterior limb is identified 6 cm away from the angle of His and 2 cm posterior to the greater curvature (as identified by the divided short gastric vessels) (Fig. 1.11). This
is delivered through the window between the posterior vagus and the esophagus onto the right side of the patient. Marking the proposed posterior fundoplication site with a 2-0 suture greatly simplifies this step. The posterior limb is then released to see if it lays there without tension or retraction. This is called the “drop test”. The posterior fundus is then grasped with the instrument in the left hand of the surgeon and the gastric fat pad is retracted in the anterior-caudal direction by the assistant. An appropriate part of the anterior fundus is grasped by the right hand and “shoeshine” maneuver performed to make sure there is no redundant fundus. After a 60F bougie is placed by the anesthesiologist orally and it is tracked laparoscopically as it traverses through the GEJ into the stomach. The right and left limbs of the fundoplication are overlapped and the correct part of anterior fundus is identified so that the two limbs of fundoplication overlap for 1 to 2 cm around the esophagus (distended with 60F bougie) with minimal tension. A test stitch is placed, incorporating the anterior and posterior fundus, with 2-0 prolene and tied with a Ti-Knot device (LSI solutions, Victor, NY). The goal is to have the two fundoplication limbs meet in a 9 o’clock orientation. The fundoplication is then assessed.

**Figure 1.10** The crus has been completely closed.

**Figure 1.11** The proposed site of the posterior fundoplication limb is marked with a stitch 6 cm below the GEJ and 2 cm posterior to the greater curvature vessels.
With a correctly constructed fundoplication, the greater curvature lays in its natural position rather than rolling behind superiorly. Secondly, there is space to comfortably insert a grasper between the fundoplication and the esophagus.

The bougie is removed and the test stitch is replaced with a pledged fundoplication U-stitch. This is placed anchoring the fundoplication limbs to each other and to the distal esophagus. We use a double-armed, 2-0 prolene with 1- × 0.5-cm pledgets (Fig. 1.12). First, the stitch is passed through the anterior fundus, then a partial thickness bite of the esophagus 2 cm above the GEJ at about 9 o’clock position, and then through the posterior fundus. The second needle is passed in similar sequence about 1 cm below the previous stitch. The stitch is tied. Our preference is to place one more stitch incorporating just the anterior and posterior fundus 1 cm below the pledged stitch. A completed fundoplication lays tension free below the hiatus in 9 o’clock orientation (Fig. 1.13).

An intraoperative endoscopic evaluation is done to evaluate the fundoplication intraluminally (Fig. 1.14) and, if distorted, the fundoplication is dismantled and redone.

The liver retractor is removed. The fascial defect at the 12-mm cannula site is closed using an exit device. The remaining trocars are removed under direct vision and the
pneumoperitoneum evacuated. Skin is closed with absorbable subcuticular stitches and local anesthetic is infiltrated for analgesia.

**POSTOPERATIVE MANAGEMENT**

- **Nausea/gagging:** It is important to prevent postoperative nausea, which may result in gagging and retching. We prescribe metoclopramide (10 mg) and ondansetron (4 mg) to be given intravenously, alternating every 3 hours. Higher doses of ondansetron are used as needed. Additional measures include use of promethazine suppository, scopolamine patch, and oral dexamethasone (10 mg q6h). In patients with persistent nausea, an abdominal x-ray is done to rule out gastric distension. Nasogastric decompression is needed if gastric distention is present.

- **Pain control:** Oral liquid pain medication is used as needed. Essential home medications are usually started on day 1 and are given in either liquid form or have to be crushed.

- **Diet:** We routinely start patients on clear liquid diet on the first day postoperatively that is advanced as tolerated to a mechanical soft diet by the next day.

- **Bloating:** Postoperative bloating is managed with simethicone gel tabs given every 2 to 4 hours as needed. Acute gastric distension is an extreme presentation with patient in extremis and requires emergent decompression.

Most patients are discharged on postoperative day 1 or 2 on a soft diet. Oral antiemetics, pain medications, along with a laxative to be taken as needed, are given. Patients are instructed to avoid lifting objects greater than 9 kg (20 lbs) for 4 to 6 weeks after surgery. The first follow-up visit is usually 2 weeks after discharge, when the diet is advanced as tolerated.

**COMPLICATIONS**

- **Intraoperative:**
  1. Bleeding, especially from short gastric vessels or solid organ damage (liver and spleen).
  2. Esophagogastric perforation: If there is any question of perforation, intraoperative endoscopy is done.

- **Acute postoperative:**
  1. Acute gastric distension—needs quick diagnosis and urgent decompression.
  2. Gagging and retching can lead to acute herniation and should be prevented.
3. Esophagogastric leak.
4. Acute dysphagia even to liquids: Unusual, but is probably due to hematoma/edema at the fundoplication. Usually resolves with conservative management in 1 to 3 days. An oral contrast study may be done to rule out a slipped wrap that would require surgical reintervention.

**Long-term postoperative:**
1. Gas-bloat syndrome: Bloating and increased flatulence are not infrequently reported, and nothing more than reassurance is needed in most cases.
2. Dysphagia: If dysphagia persists beyond 6 weeks, an endoscopy with dilation may be needed.
3. There is a continued need to prevent gagging and retching.

**RESULTS**

Patient satisfaction and symptom resolution has been reported in more than 85% to 95% of patients from centers of expertise during long-term follow-up (5 to 10 years). There are also several reports of high use of postoperative proton pump inhibitor (PPI) medications; however, most of the patients who resume PPI treatment do not have objective evidence of continued reflux. Up to 5% to 10% of patients may need reoperative intervention.

**CONCLUSIONS**

LNF is an excellent procedure for durable cure of GERD when performed at experienced centers.

**Recommended References and Readings**

Laparoscopic Partial Fundoplications

Andrew S. Kastenmeier and Lee L. Swanstrom

Introduction

In 1956, Rudolph Nissen published the results of his 360-degree “gastroplication” in two patients. This quickly spawned a “gold rush” of alternative procedures that were uniformly claimed to be more physiologic than the effective but side-effect–prone classic Nissen. The procedures designed by Ronald Belsey and Lucius Hill were based on large clinical trials (Belsey), detailed cadaveric studies (Hill), and endoscopic investigation (Belsey and Hill). Central to these procedures was the restoration of intra-abdominal esophageal length and recreation of the esophagogastric angle to restore the reflux barrier. In the 1960s, two French surgeons independently developed novel partial fundoplications: Jacques Dor at the University of Marseilles described an anterior partial wrap and Andre Toupet at the city hospitals of Paris described a posterior partial wrap; each proposed to decrease side effects of the Nissen, such as gas bloat, dysphagia, and the inability to belch.

Since Dallemagne described the laparoscopic Nissen in 1991, the volume of antireflux surgeries worldwide has dramatically increased. Laparoscopic versions of most partial fundoplications were soon reported. Partial fundoplications that have stood the test of time and have successfully been modified to a laparoscopic technique include the Hill, the Dor, and the Toupet. Each of these will be discussed in detail. The Belsey Mark IV is also occasionally utilized; however, because this procedure is performed transhi- trachally it will be discussed in detail in another chapter of this book (Chapter 5).

INDICATIONS

There are three schools of thought regarding the indications for a partial fundoplication: (1) That they are unneeded, since the 360-degree Nissen fundoplication has been shown to work with normal and abnormal esophageal motility; (2) that they are better tolerated than a Nissen and should be universally applied, and finally (3) that they are useful in select cases based on an individual’s esophageal motility status (tailored approach). For the sake of this chapter, we will take the position that a tailored approach to antireflux surgery is reasonable, recognizing that there are good arguments for both extremes as well. Because a complex dynamic exists between esophageal motility, lower esophageal
sphincter function, gastric function, parasympathetic input, anatomic orientation, and eating behavior, the optimal procedure should be selected for each individual based on a thorough preoperative interview, physical examination, and physiologic evaluation.

Indications: A partial fundoplication should be considered in patients who have a documented need for antireflux surgery and one or more of the following indications.

- Patients undergoing an esophagomyotomy (for achalasia, hypertensive lower esophageal sphincter (LES), epiphrenic diverticulum, etc.)
- Presence of a named primary esophageal motility disorder
- Very poor esophageal body motility (peristaltic amplitude <30 mm Hg, >50% simultaneous or dropped peristaltic waves in the esophageal body)
- Severe aerophagia
- Inadequate fundus for a full fundoplication
- Psychological or physical disorders that would not allow the patient to tolerate difficulties with vomiting, belching, or eating large volumes
- Failure of a full fundoplication due to dysphagia
- Surgeon preference

**CONTRAINDICATIONS**

Although there are no absolute contraindications to a partial fundoplication compared with a full fundoplication, there are absolute contraindications to antireflux surgery. These include the following.

- Inability to tolerate general anesthesia
- Severe chronic obstructive pulmonary disease (COPD)
- Uncorrected coagulopathy
- Advanced pregnancy
- Inability to provide informed consent

**PREOPERATIVE PLANNING**

The goals of the preoperative evaluation are to confirm the need for an antireflux operation, identify associated pathology that may alter the surgical approach (behavioral, psychological, or associated foregut pathology), and assess overall operative risk. Evaluation always begins with a detailed history and physical examination.

- A standardized symptom assessment questionnaire is a useful tool for documenting primary and associated pathology as well as for postoperative follow-up.
- Every patient being considered for an antireflux operation should have a complete physiologic evaluation that includes 24-hour pH monitoring (± impedance) and esophageal manometry.
- The pH monitoring provides objective evidence of whether reflux exists, rates the severity of reflux, and provides a baseline against which postoperative pH studies can be measured in the event that symptoms fail to resolve or if symptoms recur.
- Esophageal manometry is used to identify the type and severity of esophageal motility disorder and evaluate the characteristics of the lower esophageal sphincter. Manometry can also provide important clues regarding esophageal length and the presence of a hiatal hernia (Fig. 2.1). Dysfunctional esophageal motility can be the primary reason for the presenting complaint or it can be a subclinical manometric finding. In either case, manometric findings are often the primary factor guiding the selection of an antireflux technique. Surgeons are strongly encouraged to learn manual interpretation of esophageal manometry tracings, as computer interpretation is unable to differentiate a primary intrinsic motility disorder from a reversible distal esophageal hypocontractility that is secondary to chronic reflux.
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Every patient should have an upper endoscopy to evaluate for cancer, Barrett’s esophagus, a hiatal hernia, diverticula, strictures, esophagitis, and gastric pathology. It is also useful to grade the esophagogastric flap valve as seen in retroflexion based on the Hill standardized scale (Fig. 2.2). Any mucosal lesion should be photographed, biopsied, and described in detail in the endoscopy report. The preoperative endoscopic evaluation is optimally performed by the operating surgeon, because relevant surgical information is often not included in the report when endoscopy is done by someone who is not involved in surgical planning. Upper gastrointestinal contrast studies can provide additional information regarding pharyngeal function, esophageal dilation, esophageal length, hiatal hernia size, and hiatal hernia configuration. Such imaging studies are not mandatory, but should be ordered at the discretion of the operating surgeon if concerns for an alternate or additional pathology are raised during the initial phase of the work-up.

Gastric emptying studies, computed tomography (CT) scans, and direct laryngoscopy are examples of additional tests that are occasionally necessary to arrive at a comprehensive diagnosis (Table 2.1).

Figure 2.1 High-resolution manometry is useful to assess esophageal body motility and to screen for hiatal hernia.

Figure 2.2  
A: Retroflexed endoscopic view of a competent (Hill grade I) valve. 
B: Retroflexed endoscopic view showing a Hill grade IV valve.
Positioning
After induction of general anesthesia, the patient is placed in a split-leg position. The patient will be placed in a steep reverse Trendelenburg position during the operation, so it is imperative to secure the patient to the bed and eliminate the possibility of sliding on the table. These goals can be achieved with the aid of tape, a vacuum beanbag mattress, and/or footboards. The arms can be tucked or placed on arm boards and be slightly abducted. The surgeon stands to the patient’s left and the assistant between the legs as seen in Figure 2.3.

Examination Asymptomatic Classic GERD Dysphagia Atypical Symptoms
Barium upper GI 0 0 + +
Upper endoscopy + + + +
Esophageal manometry + + + +
24-hr pH + + + +
Dx-pH probe (RESTECH) 0 0 0 +
Gastric emptying study 0 0 0 +

TABLE 2.1 Preoperative Esophageal Tests Vary According to Presentation
Also, note the locations of video monitors at the patient’s head and to the right of the head in the direct sight line of both the surgeon and the assistant surgeon. Alternatively, the surgeon can operate from between the legs and the assistant from the patient’s left.

Port Placement
The technique for intra-abdominal access is based on surgeon preference, but is generally similar for all fundoplications. The authors prefer using a Veress needle to insufflate the abdomen. Trocar size is also a matter of preference. The authors’ first port is the camera port, a 10-mm trocar placed 12 cm from the xiphisternum and 3 cm left of the midline. This trocar should be well above the level of the umbilicus. The laparoscope is then inserted and visual exploration of the abdominal cavity is undertaken. Prior to placement of the remaining trocars, the patient is placed in a steep reverse Trendelenburg position. This position allows gravity to gently pull the abdominal viscera out of the hiatus and toward the pelvis. The locations of the remaining trocars are shown in Figure 2.4. Each of these trocars is 5 mm in size and placed under direct visualization. An articulated liver retractor is placed through the right upper quadrant trocar and is used to elevate the left lobe of the liver; the retractor handle is then secured to a table-mounted instrument holder. The surgeon’s left hand instrument works through the trocar that is just below and to the right of the xiphoid process, while the right hand works through the 5 mm trocar in the left upper quadrant. The assistant’s left hand works through the trocar that is 10 cm from the xiphisternum and in the midline.

Dissection
The assistant uses an atraumatic instrument to grasp the epigastric fat pad and retract the stomach downward. Ultrasonic shears are then used to divide the hepatogastric ligament over the caudate lobe. Approximately 15% of patients have a replaced left hepatic artery arising from the left gastric artery and coursing through the hepatogastric ligament. This vessel should be spared if possible, as there are instances, albeit rare, where division results in hepatic ischemia. Dissection is carried toward the hiatus until the right crus is identified.
The phrenoesophageal ligament is incised at the apex of the hiatus allowing entrance into the mediastinum. The mediastinal esophagus is then mobilized using a combination of blunt dissection and ultrasonic dissection. Division of the phrenoesophageal ligament proceeds first along the right crus. Care must be taken to preserve the peritoneal covering of the crura, as this allows a more robust crural closure. Throughout the dissection, the vagi are repeatedly identified and protected by keeping them closely approximated to the esophagus.

The dissection is then carried into the retroesophageal space. From here, the attachments to the left crus and the fundus can be taken down. The mediastinal dissection is complete when there is 2.5 to 4 cm of tension-free intra-abdominal esophagus (Fig. 2.5). Attention is then turned to the short gastric vessels, which we routinely divide to a variable extent for partial fundoplications to ensure that there is no upward tension on the wrap. Short gastrics are taken with the ultrasonic shear, starting at the caudal aspect of the upper third of the greater curvature for Toupet, the midpoint of the splenic hilum for Dor, and only the proximal few centimeters for the Hill repair. The stomach is retracted toward the patient’s right, allowing visualization of the retrogastric attachments, which are divided for complete mobilization of the fundus.

**The Toupet Fundoplication**

The Toupet repair was described as a more physiologic alternative to the Nissen in 1963. Initially a 180-degree posterior wrap with no primary crural closure, it was quickly modified to be a 270-degree wrap with hiatal closure.

**Modifications:** Crural repair, increased wrap circumference from 180 degrees to 270 degrees

**Operative Technique—The Repair**

For the Toupet, the gastric fundus must be completely mobilized, both by dividing the short gastric vessels of the upper third of the stomach and by freeing the stomach off the retroperitoneum. With the assistant providing caudal traction on the epiphenric fat pad, the mobilized fundus is approached from the right, through the retroesophageal...
window, and brought posterior to the esophagus from left to right. This portion of the fundus is then grasped along the line of divided short gastric vessels with the surgeon’s left hand, while the greater curvature on the left side is held with the right hand and a “shoeshine” maneuver is performed. With the two ends of the wrap retracted away from the esophagus and cephalad toward the diaphragm, the surgeon slides the fundus back and forth behind the esophagus (Fig. 2.6). This maneuver should result in a 1:1 reciprocal movement within each hand. This ensures that the wrap is fully mobilized, is not twisted, and is neither too tight nor too floppy.

The assistant then grasps the right side of the wrap and retracts it over the esophagus and toward the left upper quadrant. Retraction of the fundus in this manner displaces the esophagus to the left and exposes the posterior hiatus. This allows simultaneous crural closure and fixation of the posterior fundus. A 2-0 woven polyester suture on a curved, GI needle is cut to a length of 6 inches. Using an intracorporeal suturing technique, each suture incorporates the posterior fundus, the left crus, and the right crus. All knots should be tied so that there is approximation of the crura without strangulation. The crural closure begins posteriorly and typically requires three to four stitches. Care must be taken to avoid approximating the crura too tightly around the esophagus in order to prevent resistance to emptying. The right side of the wrap is then approximated to the right crus using several interrupted sutures, the last being high on the right crus. These sutures are then repeated on the opposite side to approximate the left side of the wrap to the left crus. By fixing the wrap to the hiatus, tension is relieved from the sutures placed between the fundus and esophagus.

Prior to placement of the final sutures, a 56-French bougie is advanced in the esophagus and the right wing of the wrap is sutured to the 10-o’clock position of the esophagus over a length of 3 to 4 cm. These sutures are repeated between the left wing of the wrap at the 2-o’clock position of the esophagus. A well-constructed Toupet fundoplication should cover 270 degrees of the distal esophagus, have a length of 3 to 4 cm, be tension free, be secured to the diaphragm, and have no esophageal impingement at the hiatus (Fig. 2.7).

The Dor Repair

- Modifications: Crural repair, laparoscopic
- Minimize dissection posteriorly, still take short gastric vessels as this can reduce torsion/ dysphagia
Operative Technique—The Repair

If there is no hialt hernia, only the anterior 180 degrees of the hiatus needs to be opened. If there is a hialt hernia, the entire hiatus and distal esophagus have to be mobilized as described above. Once the esophageal dissection and mobilization are complete, the esophagus is gently retracted to the left, exposing the posterior hiatus. Any hialtal defects are closed posteriorly using a 2-0 woven polyester suture on a curved, tapered CI needle to gently reapproximate the posterior hiatus. All crural sutures should be tied such that there is approximation without strangulation or narrowing of the hiatus.

Upon completion of the crural closure, attention is turned to the fundoplication. The upper gastric fundus is mobilized by dividing the uppermost short gastric vessels. A point on the greater curvature of the fundus that is 3 cm from the angle of His is sutured to the midpoint of the left crus. The right margin of the gastric fundus is then sutured to the left margin of the esophagus using several interrupted stitches. This maneuver establishes appropriate intra-abdominal esophageal length and accentuates the angle of His, allowing recreation of the gastroesophageal flap valve (Fig. 2.8).

A 56-French esophageal dilator is then inserted and carefully advanced into the stomach. The greater curvature of the fundus is wrapped anteriorly over the esophagus. The superior portion of the fundus is sutured to the anterior hiatus. Sutures are then placed between the greater curvature and the right margin of the esophagus. A well-constructed Dor fundoplication should cover 180 degrees of the anterior distal esophagus (Fig. 2.9).

The Hill Repair

More properly termed an “esophagogastropexy,” the Hill repair has several characteristics in common with partial fundoplications. Hill’s intent was to stably fix the gastroesophageal junction (GEJ) into the abdominal cavity and to restore and accentuate the angle of His. Laparoscopic practitioners have described some slight modifications from the original description by Hill including no celiac dissection or mobilization of the median arcuate ligament, no intraoperative manometry, and a crural closure.

- Standard hialtal dissection is performed as has been described, with the goal of 2.5 to 3 cm of intra-abdominal esophageal length.
With the exception of the most cephalad one or two vessels, the short gastric vessels are not routinely divided in the Hill repair. However, the back of the gastric cardia is completely mobilized off of the retroperitoneum.

The esophagus is retracted to the left to expose the posterior hiatus and crural decussation. The crura are then gently approximated posteriorly using interrupted woven polyester sutures that are tied intracorporeally. This usually can be done with two to four sutures.

**Operative Technique—The Repair**

The repair consists of four interrupted woven polyester sutures that imbricate the anterior phrenoesophageal bundle and the posterior phrenoesophageal bundle. With the same stitch, this is approximated to the crural decussation overlying the aorta. These sutures are full length, and both ends are brought out of the trocars and

**Figure 2.8** Attaching the greater gastric curvature to the left crus accentuates the angle of His and the internal “flap valve.”

**Figure 2.9** The finished 180-degree anterior (Dor) fundoplication.
carefully clipped to the drape. Once the sutures have been placed, they are tied down, starting with the first one placed, over a 48-French bougie. An extracorporeal knot-tying technique is used. These sutures serve to reconstruct the angle of His by tightening the oblique sling musculature of the GEJ. The 48-French bougie was determined by Hill to be the proper size to prevent obstructive stenosis of the GEJ. Finally, the anterior gastric cardia is folded up over the repair and tacked to the anterior rim of the hiatus with interrupted sutures—somewhat like a Dor repair, but without any “wrapping.” This further accentuates the reconstructed angle of His (Fig. 2.10). Hill

Figure 2.10 The Hill esophagogastropexy.
was an advocate of intraoperative manometry to tailor the repair for each patient. Although we do not routinely utilize manometry, we do frequently evaluate the quality of the repair with intraoperative endoscopy and not infrequently will remove the fourth Hill stitch if endoscopically it seems too tight.

**POSTOPERATIVE MANAGEMENT**

An overnight stay is typical after a partial fundoplication. Immediately after surgery, patients are kept NPO, but are generally started on a liquid diet 6 hours after surgery and advanced to a puree diet if no nausea is present. Nausea can lead to retching and vomiting, which can cause acute wrap herniation and early wrap failure; therefore, these symptoms must be treated aggressively with antiemetics.

In more complex cases (redo surgery, myotomy, large paraesophageal hernia, inadvertent gastrotomy, etc.), patients have a closed-suction drain placed at the time of surgery. On postoperative day 1, the drain fluid is evaluated for amylase and a watersoluble contrast swallow study is performed. If the results are normal, patients are started on a liquid diet and subsequently advanced as mentioned above. These patients typically are discharged home on the second postoperative day.

Patients are maintained on a puree diet for at least 2 weeks. In addition, they are instructed to avoid bread, meat, raw vegetables, and large pills. Medications are generally crushed or converted to a liquid form until the patient tolerates solid food. Patients are advised to expect some dysphagia for 2 to 6 weeks. Patients are also instructed to avoid heavy lifting for 6 weeks.

**COMPLICATIONS**

Complications can occur at any point in the course of surgery. They can be general, associated with any operation (myocardial infarction, deep vein thrombosis, pulmonary embolism, bleeding, infection), or can be those that are more specific to laparoscopy (access injuries to vascular or hollow visceral structures and physiologic reactions to pneumoperitoneum). Finally, there are those that are specific to the dissection and fundoplication.

Intraoperative complications during a laparoscopic fundoplication include dissection injuries to a hollow viscus, injuries to the vagus nerves, and bleeding. The most common visceral injuries are to the stomach, followed by the GEJ, and more rarely the esophagus itself. Injuries most often occur as a result of traumatic retraction, and proper tissue handling is the most effective prevention. Atraumatic instruments should always be used and grasping of the hollow viscera should be minimized. The anterior fat pad can provide a safe retraction point, or a Penrose drain can be used to encircle the esophagus and provide atraumatic retraction. Injury can also occur as a result of bougie insertion. This occurs in less than 1% of cases, but can occur due to anatomic distortion, poor tissue quality, associated pathology (esophagitis, diverticulum, kyphosis, strictures), poor communication between the surgeon and the person advancing the bougie, or inexperience with bougie insertion. Should an injury occur, early detection is imperative to avoid further morbidity. With adequate skills, a laparoscopic suture repair is preferred, but consideration should be given to an open repair based on surgeon experience and the clinical scenario. Gastric perforations are easily oversewn in a single layer with an absorbable suture or can be stapled. Esophageal perforations can usually be oversewn laparoscopically or a thoracotomy or laparotomy can be performed to gain appropriate access and exposure. Closure of the esophageal mucosa and muscularis is imperative after an esophageal perforation in order to prevent a future diverticulum. It is our practice to routinely leave a drain near such a perforation, and consideration of a protective covered stent can be entertained. On postoperative day 1,
we then obtain a contrast imaging study and routinely measure drain amylase levels in search of postoperative leaks.

Bleeding during a partial fundoplication procedure is generally limited to the short gastric vessels, the spleen, the liver, or an unrecognized replaced/accessory left hepatic vessel. The harmonic scalpel, ligasure, clips, suture ligation, endoloop, and/or direct pressure can usually be employed laparoscopically to gain control of bleeding. Conversion to open surgery should be considered, but is rarely necessary. Although rare, an uncontrollable splenic laceration would be one indication for rapid conversion to an open procedure. Again, if prevention fails, then early recognition and immediate repair is imperative to prevent further morbidity.

An unrecognized perforation can manifest as abdominal pain, tachycardia, hypotension, or fever in the early postoperative period. Any of these symptoms warrant immediate concern and should prompt an immediate localization study, such as a CT scan, a water-soluble contrast swallow study, or an immediate return to the operating room for exploration. Ongoing bleeding can also have a similar presentation. Sources include those previously described, as well as trocar sites. Resuscitation, correction of coagulopathy, and close monitoring can be appropriate; however, a return to the operating room for exploration and control of hemorrhage may be necessary.

Late postoperative complications related to partial fundoplication can be troublesome and frustrating for surgeon and patient alike. Dysphagia is the most common complaint and should be expected in all patients during the initial first few postoperative weeks. Tissue dissection causes tissue edema and swelling that often results in an expected transient dysphagia. We therefore counsel our patients preoperatively regarding this phenomenon and maintain them on a puree diet for at least 2 weeks after surgery. If significant dysphagia persists after 6 weeks, we generally recommend upper endoscopy and empiric dilation. Persistent severe symptoms are rare and should prompt a repeat physiology work-up and consideration of a wrap takedown. Return of reflux symptoms may indicate a wrap failure and warrants repeating the pH study, esophageal manometry, upper endoscopy, and the contrast esophagram. These studies help determine if there is an objective evidence of recurrent reflux, an underlying motility disorder that has progressed, and wrap disruption or herniation. These studies are imperative before attempting any sort of revisional surgery (Table 2.2).

**RESULTS**

The results of partial fundoplications vary based on indication. In the context of a Heller myotomy, a partial fundoplication is almost universally accepted as the standard of care for reflux prevention. Although both the Dor and the Toupet are currently used in the context of a Heller myotomy, the Dor fundoplication has the largest body of literature supporting its use in this setting. Advocates of the Dor claim the added theoretical benefit of covering the anterior esophageal mucosa in case an inadvertent perforation has occurred. The Toupet is advocated based on the idea that it may hold the edges of
the myotomy open. There is, however, very little literature directly comparing the Dor and the Toupet. No studies are randomized and the few that exist have small study sizes.

Controversy also remains regarding the efficacy of partial fundoplications as a treatment for primary reflux disease. As noted, the Dor is primarily used in the setting of a myotomy and there is little evidence to support its use as a primary antireflux operation. The Hill has been shown to have good results and durability for reflux disease; however, there is little data regarding the results of the laparoscopic Hill. Only one comparative study between the laparoscopic Hill and laparoscopic Nissen is available and it showed equivalence between the procedures. There is equal controversy surrounding the use of the Toupet as a primary treatment for reflux disease, with US surgeons reporting poor results and surgeons of most other countries reporting equivalence or superiority. This disagreement exists for several reasons. First, there is discrepancy between existing studies. Second, studies report different measurements of success. For example, success can be measured by the rate of side effects (dysphagia, gas bloat, inability to belch, inability to vomit), recurrence/persistence of subjective reflux symptoms, objective evidence of reflux, wrap disruption/herniation, return to proton pump inhibitor use, or patient satisfaction scores. As has been frequently noted, symptom recurrence is not necessarily associated with objective evidence of reflux recurrence. In the short term (<12 months), the Toupet appears to have a lower incidence of dysphagia and gas bloat and equivalent control of reflux. The literature is contradictory regarding outcomes a year or more after surgery. Many of recent European studies show that over the long term, the Toupet is an equivalent antireflux operation to the Nissen. Other studies, mainly performed in North America, suggest that there is a high rate of objectively measured recurrent reflux. In addition, some studies suggest that the higher incidence of side effects associated with the Nissen is transient and that rates equilibrate between the approaches after approximately one year. Other studies suggest that the lower side effect rate in the Toupet persists over time.

The practice of performing a tailored approach to fundoplication has also been called into question of late. While some surgeons tailor the degree of lower esophageal sphincter augmentation to the individual’s esophageal motility, there is little agreement regarding this practice. Some have avoided this argument all together by performing a Toupet fundoplication on all patients. Others, who primarily perform the Nissen fundoplication, will perform a partial fundoplication in instances where dysphagia is significant and manometry shows ineffective esophageal motility (IEM). Still others will perform a Nissen on those with IEM, which suggests that most of the dysmotility and dysphagia are secondary to reflux and is therefore reversible after effective antireflux surgery. The literature does not clearly support one method versus the other. What is clear is that we are not good at predicting who is at risk of postoperative dysphagia among patients without a named motility disorder. It is our practice to consider all aspects of the preoperative work-up in the decision regarding the type of antireflux surgery. Dysphagia and distal IEM are most commonly secondary to reflux and it is believed that they are usually reversible with a proper antireflux operation. That being said, there are some patients with profound symptoms or manometric findings that are unusual enough that we recommend a partial fundoplication.

**CONCLUSIONS**

Partial fundoplications are essential techniques in the armamentarium of any dedicated antireflux surgeon. Regardless of whether one prefers a partial fundoplication over the Nissen in all cases, as an alternative for dysmotility, or only in cases of the most extreme esophageal dysfunction, the techniques of partial fundoplication are essential to master. As with any antireflux surgery, the patient outcomes are dependent on the meticulous performance of the partial wrap.
Part I Surgical Treatment of Gastroesophageal Reflux and Paraesophageal Hernia

Recommended References and Readings

Fundoplication: Open Transabdominal Approach

Thomas W. Rice

INDICATIONS

Reconstruction of the esophagogastric junction (EGJ) that includes fundoplication is indicated in the treatment of (1) gastroesophageal reflux disease (GERD) and (2) symptomatic mechanical obstruction resulting from Type III and Type IV (paraesophageal) hiatal hernia.

GERD

To avoid the pitfalls of indiscriminate surgery seen in the laparoscopic experience of the recent past, surgery for GERD must be used in highly selected patients to treat specific symptoms and reverse or halt documented, severe mucosal damage resulting from quantified abnormal reflux of gastric contents into the esophagus. Surgery for GERD should be considered only if (1) a trial of aggressive medical treatment using proton pump inhibitors (PPI) with dose escalation and lifestyle modifications has failed, (2) mucosal damage has been identified and quantified, (3) abnormal gastroesophageal reflux has been documented, and (4) a repairable problem in the reflux barrier has been found.

Symptom Control

Heartburn is the main symptom indication for surgery in GERD patients. There are three typical clinical scenarios: (1) Heartburn initially controlled by PPI therapy that has become refractory or is poorly controlled despite dose escalation, (2) heartburn well controlled, but side effects of PPI therapy are intolerable, and (3) volume regurgitation despite effective heartburn control. GERD-related dysphagia in the above scenarios may not be as effectively treated by surgery, but it is an indication nonetheless. Beware of patients with typical symptoms that do not respond to medication, those demanding immediate surgery for relief of intolerable symptoms, and those with scleroderma, because their outcome with surgery is poor. Age itself should not change these indications. Need for lifelong medical therapy in a young patient with well-controlled symptoms is an indication for surgery only if a durable repair can be ensured.
Atypical symptoms, such as cough, laryngitis, hoarse voice, sore throat, asthma, chest pain, and abdominal bloating, should be associated with typical GERD symptoms and responsive to PPI therapy if surgery is to be considered. If symptoms are only atypical, they must be proven to be GERD related and responsive to PPI therapy or demonstrated to be the result of acid reflux before surgery is prescribed.

**Mucosal Injury**
Poorly controlled or recurrent ulcerative esophagitis after aggressive PPI therapy is an indication for surgery. Other causes that result in lack of healing, such as pill-induced injury, must be ruled out. Most strictures can be managed initially with medical therapy and dilatation. As with esophagitis, unsuccessful medical therapy or recurrent strictures despite effective medical therapy are indications for surgery. The ability of any therapy to completely reverse Barrett’s esophagus (BE) or prevent its progression to cancer has not been demonstrated; therefore, indications for surgery in a GERD patient with non-dysplastic BE are identical to those for the GERD patient without BE.

**Mechanical Obstruction**
Mechanical obstruction caused by paraesophageal hernias, typically with organoaxial volvulus, is an indication for repair of the EGJ with fundoplication. Uncommonly, this is an acute presentation with ischemia or infarction. More typically, the symptoms are chronic and progressive and include early satiety, postprandial discomfort, attack of unremitting postprandial epigastric pain, and chronic blood loss secondary to Cameron ulcers.

### CONTRAINDICATIONS

**Obesity**
An often ignored but essential part of physical examination is measuring and recording weight and height and calculating body mass index (BMI). Overweight (BMI 25 to 29) and obese (BMI 30 to 34) GERD patients should be counseled on weight loss and encouraged to reach their ideal weight before elective surgery. Because obesity and GERD are interrelated, successful and sustained weight loss may eliminate need for surgery. Although there is disagreement concerning impact of obesity on outcome of antireflux surgery, the health benefits of weight loss in severely (BMI 35 to 39) and morbidly (BMI ≥ 40) obese GERD patients should make weight loss surgery the operation of choice in these patients.

### PREOPERATIVE PLANNING

**Investigations**
The preoperative barium esophagram has been neglected, misused, and in some cases abandoned, with the advent of modern investigations of GERD and hiatal hernia. However, it provides valuable information about the mucosa, esophageal complications, reflux of gastric contents, reflux barrier, and esophageal function. It should, whenever possible, be ordered by the surgeon and performed by a radiologist, experienced in preoperative assessment of GERD and hiatal hernia, who is a member of the multidisciplinary team evaluating and treating the patient. If dysphagia is the predominant symptom and the diagnosis is in question, the examination should start as a timed barium esophagram.

Esophagogastroduodenoscopy (EGD) with biopsy has replaced the upright air-contrast phase of the barium esophagram for mucosa evaluation. EGD and biopsy both
Chapter 3  Fundoplication: Open Transabdominal Approach

diagnose and assess esophageal injury by visual and histopathologic mucosal examination. Visual assessment of esophageal injury is graded using the Los Angeles classification. Histopathologic findings, although nonspecific, are confirmatory in the clinical setting of GERD. The finding of specialized columnar epithelium (BE) in the tubular esophagus is secondary to GERD. In the absence of dysplasia, surveillance esophagoscopy and biopsy are required in patients with BE regardless of therapy. EGD should be performed by the surgeon prior to surgery. The finding of a hiatal hernia identifies failure of two elements of the reflux barrier: loss of (1) intra-abdominal esophagus and (2) extrinsic sphincter. The following must be recorded: measurements from the incisor teeth to the squamocolumnar junction, gastric rugal folds, and diaphragmatic hiatus; length of hiatal hernia; length of the esophagus; type of hiatal hernia; presence of volvulus of the intrathoracic stomach; presence of mucosal abnormalities (strictures, rings, etc.); and presence of mural abnormalities (submucosal tumors, leiomyoma, etc.).

The definition of GERD requires causation of symptoms or complications by abnormal reflux of gastric contents into the esophagus. Ambulatory pH monitoring performed off medication both quantifies acid reflux and relates symptoms to acid exposure. It has evolved from an in-hospital test to an ambulatory wireless 48-hour study. Once reserved for diagnostic dilemmas, in the 21st century it is essential before any proposed operation. It is invaluable in diagnosing GERD and documenting the preoperative state for later comparison. Excessive acid exposure on pH testing is a surrogate for reflux of gastric contents into the esophagus, and in the majority of patients it is adequate to diagnose GERD. Abnormal pH monitoring is the investigation most predictive of successful outcome of surgery for GERD. The uncommon patient in whom duodenal reflux must be confirmed and quantified, ambulatory bilirubin monitoring is required. Similarly, in the patient in whom nonacid reflux must be assessed, combined impedance and pH monitoring is necessary.

Esophageal manometry excludes unsuspected motility disorders or motility disorders masquerading as GERD, confirms adequate esophageal peristalsis for GERD surgery, and quantifies preoperative resting pressure and relaxation of the lower esophageal sphincter for later comparison. High-resolution manometry has replaced conventional manometry because it provides a spatially enhanced pressure topogram, which is a dynamic representation of the esophageal body and reflux barrier. It isolates the esophageal hiatus from the lower esophageal sphincter (LES), increasing understanding of function of the EGJ and facilitating treatment decision-making. For modern esophageal evaluation, high-resolution manometry is invaluable and highly recommended.

If gastric emptying abnormalities are suspected by history or investigations, gastric clearance assessment with radionucleotide tracers is necessary.

**Patient Preparation**

Patient preparation for surgery is that for general anesthesia and upper GI abdominal surgery. Lifelong smoking cessation and realization of ideal weight and adequate nutrition are important for avoidance of complications following elective surgery and optimizing long-term outcome. A bowel prep is not standard and is reserved for special situations, such as the chronically constipated patient. Perioperative antibiotics and DVT prophylaxis are prescribed.

**SURGERY**

**Positioning and Instrumentation**

After placement of an epidural catheter for perioperative pain management and induction of general anesthesia, the patient is placed supine on the operating table. The arms are placed at the patient’s side and secured. The operating table, initially flat, will be
placed in 20-degree anti-Trendelenburg position to facilitate exposure. Both a sternal retractor, which lifts the sternum and costal arch up and cephalad, and an abdominal wall retractor, which separates the abdominal wound edges laterally, are used.

**Technique**

A midline abdominal incision starting at the xiphoid process and extending half the distance to the umbilicus is usually adequate for exposure and repair. Reconstruction of the EGJ follows three principles: restoration of intra-abdominal esophagus, reconstruction of an extrinsic sphincter, and reinforcement of the intrinsic sphincter.

**Restoration of Intra-abdominal Esophagus**

The left lateral segment of the liver is mobilized by dividing the triangular ligament, then retracted laterally to expose the esophageal hiatus. The pars lucida of the lesser omentum over the caudate lobe of the liver is divided. If possible, but not mandatory, the hepatic branch of the vagus and accompanying vasculature should be preserved. This exposes the right crus. Dissection of the right crus is performed on its medial surface inside the hiatus to protect its peritoneal covering. The dissection is carried anteriorly to define the apex of the hiatus and posteriorly to define the confluence of the crura (Fig. 3.1).

The stomach is delivered into the abdomen using a hand-over-hand technique. The short gastric vessels are divided, including the highest branch that typically obscures the inferior portion of the left crus as this vessel passes posteriorly into the retroperitoneum. This vessel is frequently not divided, leading to difficulty with later steps in the operation. This fundic mobilization allows the stomach to be retracted medially, exposing the left crus, which is prepared similarly to the right crus. The dissection inside the hiatus proceeds anteriorly to meet the right crural mobilization at the apex of the hiatus and posteriorly to define the confluence of the crura. These steps divide the “hernia sac.” Division, not removal of the hernia sac (removal is never complete from an infra-diaphragmatic approach), is a key element of this dissection.

*Figure 3.1* The left lateral segment of the liver has been mobilized and the lesser omentum divided. Dissection of the right crus is performed on its medial surface inside the hiatus to protect its peritoneal covering. The dissection is carried anteriorly to define the apex of the hiatus and posteriorly to define the confluence of the crura. The hernia sac is divided but not necessarily completely excised. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2013. All Rights Reserved.)
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The hiatal dissection indirectly mobilizes the distal esophagus, which is encircled with an umbilical tape or penrose drain. The dissection of the esophagus then proceeds both bluntly and sharply in the posterior mediastinum until adequate length of intra-abdominal esophagus is obtained. If the pleura is breached, particularly with large paraesophageal hernia mobilization, drains may be placed into the respective pleural spaces.

In certain patients, such as those with the much disputed diagnosis of short esophagus, this esophageal dissection alone is inadequate to restore a sufficient length of intra-abdominal esophagus. The diagnosis of a short esophagus should be made preoperatively. It is suspected in patients with a history of peptic stricture or repeated esophageal dilatation, long-segment BE, sliding (Type I) hiatal hernia more than 4-cm long, paraesophageal (Type III and Type IV) hiatal hernia, or nonreducible hiatal hernia on upright air-contrast barium esophagram. In such patients, adequate intra-abdominal length is obtained by adding a Collis gastroplasty. This begins with dissection of the esophagogastric fat pad, which is a key component of the preparation of the abdominal esophagus, regardless of the need for a Collis gastroplasty (Fig. 3.2). This mobilization selectively vagotomizes the gastroplasty segment. A 50-Fr bougie is passed orally and held against the lesser curve and used as a guide and mold for formation of the gastroplasty tube. A 3- to 6-cm long tube of stomach is constructed along its lesser curve using surgical staplers. With adoption of laparoscopy, esophageal lengthening has evolved into a simple wedge gastroplasty, because of technical difficulties presented by laparoscopy and misunderstanding of the principles of constructing a Collis gastroplasty. Predictably, acid production in this unprepared gastric segment perpetuates GERD. A Collis gastroplasty must be added in patients with short esophagus to assure sufficient intra-abdominal esophageal length and thus eliminate one cause of the repair being under tension (Fig. 3.3).

Failure to restore adequate intra-abdominal esophageal length produces a repair under tension that will eventually fail. In patients with failed surgery, review of the operative report may identify inadequate restoration of the intra-abdominal esophagus as a reason for failure of the initial surgery.

Figure 3.2 Mobilization of the esophagogastric fat pad is essential to both identify the EGJ and permit direct apposition of the peritoneal surface of the fundus to the bare surface of the distal esophagus. This selectively vagotomizes the segment, allowing its use as a gastroplasty tube if necessary. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2013. All Rights Reserved.)
**Figure 3.3** A Collis gastroplasty is constructed if necessary to provide a sufficient intra-abdominal length of esophagus in patients with short esophagus. A 50-Fr bougie is passed orally and held against the lesser curve and used as a guide and mold for formation of the gastroplasty tube. **A:** The first step is production of the linear stapler entry site using a circular stapler approximately 3 to 5 cm below the esophagogastric junction. **B:** A linear cutting endostapler is then used to create a gastric tube along the lesser curve. The bougie is removed after construction of the gastroplasty. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2013. All Rights Reserved.)

**Reconstruction of Extrinsic Sphincter**

The esophageal hiatus, which serves as the extrinsic sphincter, is composed of a right and left crus arising from the right crus of the diaphragm (Fig. 3.4A). The right crus of the esophageal hiatus is nearly vertical and lies over the vertebrae, the left crus of the esophageal hiatus is slightly more semicircular, slightly longer, and has no underlying support. Progressive herniation of the stomach into the posterior mediastinum results in minimal change of the length of the right crus but bowing and further elongation of the left crus (Fig. 3.4B).

Suture closure of the esophageal hiatus to approximate its normal size is the essence of hiatal reconstruction. The bougie placed to facilitate Collis gastroplasty is removed. Its presence gives a false sense of security, since a tight repair can still be constructed about a bougie regardless of its size. Also by stiffening the EGJ the chance for injury during reconstruction is increased. Posterior to the esophagus, deep suture bites into each crus, with slightly wider spacing on the left crus, constitutes standard reconstruction (Fig. 3.5). Although debated, an anterior stitch placed at the apex of the hiatus is highly recommended. This repair should be done with robust (size 0 or 1) nonabsorbable suture. On completion of this reconstruction, the hiatal aperture should permit the insertion of the surgeon’s index finger to its distal interphalangeal joint posterior to the esophagus containing an 18F nasogastric (NG) tube. For a severely disrupted hiatus, a complex reconstruction is required. The left crus is plicated to normalize crural length, permitting a standard hiatal reconstruction (Fig. 3.6).

The importance of hiatal reconstruction was not appreciated or stressed in the early laparoscopic experience (Figs. 3.5 and 3.6). Recurrent hiatal hernia was the most common cause of failure in early experience of laparoscopic GERD surgery. Attempts to solve this problem led to reinforcing of marginal hiatal reconstructions or primary reconstruction of the esophageal hiatus with prosthetic mesh. This strategy presents three problems: (1) It treats the hiatus as a hole to be covered, ignoring its function in the reflux barrier; (2) it disregards the dynamic nature of the reflux barrier, resulting in the disastrous complication of mesh erosion into the gastrointestinal tract; and (3) it obstructs if applied aggressively. The use of biosynthetic mesh to reinforce hiatal reconstruction has not reduced recurrence in repair of paraesophageal hiatal hernia in
long-term follow-up. The use of mesh in reconstruction of the external sphincter should be discouraged.

**Reinforcement of Intrinsic Sphincter**

The most problematic, variably conducted, and operator-dependent portion of reconstruction of the EGJ is fundoplication, reinforcement of the LES. The prior steps attempt to restore and reconstruct; however, reinforcing the LES produces an unnatural and potentially problematic volvulus of the gastric fundus, which utilizes the capacitance portion of the stomach. Typically in North America, this involves division of short gastric vessels and a 360-degree total fundoplication (Nissen) (Fig. 3.7). Although controversial and cited as a cause of postoperative dysphagia, for accomplished surgeons, constructing a fundoplication without division of short gastric vessels (Rossetti modification) can produce results similar to those reported with division of these vessels. Similar agreement over the extent of fundoplication has not been reached. Some surgeons, mostly outside the United States, have favored 270-degree partial posterior fundoplication (Toupet), citing less dysphagia, fewer postprandial fundoplication symptoms, and similar reflux control compared with total fundoplication. However, a study with long-term follow-up reported resolution of post-fundoplication symptoms with time and similar long-term results regardless of the extent of fundoplication. In the United States, the general feeling is that Nissen fundoplication provides better reflux control with more, but transient symptoms. The debates continue, but these issues illustrate how surgeon dependent and subjective this portion of the operation can be.
Figure 3.5 Standard reconstruction of the esophageal hiatus. 
A: Nonabsorbable sutures are placed with deep bites into each crus, avoiding the inferior vena cava on the patient’s right and aorta on the left. Anteriorly 1 to 2 sutures are necessary for durable hiatal reconstruction. Posteriorly, unequal spacing of sutures is required: normal distance between sutures in the left crus, and slightly smaller distance between sutures in the right crus. This serves to shorten the minimally elongated left crus. A sufficient number of sutures is placed to return the hiatus to its original, normal size. B: The sutures are tied, completing the reconstruction. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2013. All Rights Reserved.)

For Nissen and Toupet fundoplications, the previously mobilized fundus is passed posterior to the intra-abdominal esophagus to lie freely on the right side of the patient’s intra-abdominal esophagus. The to-and-fro rocking of the fundus, the so-called “shoe-shine” maneuver, assures the tension-free delivery and positioning of the fundus. The prior esophagogastric fat pad mobilization is essential to both identify the EGJ and permit direct apposition of the peritoneal surface of the fundus to the bare surface of the distal esophagus.

Total fundoplication requires encircling the distal 2 to 3 cm (2 cm anteriorly) of the esophagus or Collis gastroplasty with the fundus (Fig. 3.7B). The first (lowest) fundoplication suture passes through the anterior seromuscular layer of the fundus lying on the patient’s left adjacent to the esophagus. The suture is then passed through the anterior esophageal musculature at 12 o’clock just above the EGJ and through the adjacent anterior seromuscular layer of the fundus lying on the patient’s right adjacent to the esophagus. A second suture is similarly placed 1 cm above this. The final (highest) fundoplication suture is placed 1 cm above the second suture (2 cm above the first fundoplication suture) in an identical fashion. These sutures are tied, creating a loose,
floppy, 360-degree, total fundoplication that covers the distal 2 cm of the esophagus and lies in the abdominal cavity under no tension. The superior aspect of the right and left leaves of the fundoplication may be sutured to the diaphragm to reinforce the intrabdominal location of the fundoplication.

Toupet fundoplication requires posterior 270-degree encirclement of the distal 3 cm of the esophagus or Collis gastroplasty with the fundus. The portion of the fundoplication that lies on the patient’s left may be constructed first. The first (lowest) fundoplication suture passes through the anterior seromuscular layer of the fundus lying on the patient’s left, adjacent to the esophagus. The suture is then passed through the anterior esophageal musculature at 2 o’clock just above the EGJ. A second suture is similarly placed 1.5 cm above this. The final (highest) fundoplication suture is placed 1.5 cm above the second suture (3 cm above the first fundoplication suture) and passes through the anterior seromuscular layer of the fundus lying on the patient’s left adjacent to the esophagus, through the anterior esophageal musculature at 2 o’clock, and finally through the left crus just below its apex. These sutures are tied.
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Creating the left anterior aspect of the fundoplication. The right-sided sutures are placed next. The first (lowest) fundoplication suture passes through the anterior seromuscular layer of the fundus lying on the patient’s right adjacent to the esophagus. The suture is then passed through the greater curve aspect of the rightward lying fundus, then through anterior muscularis propria of the esophagus, and finally through the greater curve aspect of the leftward lying fundus. Usually three sutures are used to construct a 2 cm long (measured anteriorly) fundoplication. The use of a bougie during construction of the fundoplication is discouraged, since it does not guarantee either a loose or floppy fundoplication. In fact, it may foster poor technique by allowing the surgeon to assume that the presence of a bougie will prevent misconstruction of the fundoplication. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2013. All Rights Reserved.)

Figure 3.7 Nissen fundoplication. A: It is advisable to divide the short gastric vessels to facilitate fundoplication and maintain the orientation of the fundus. The orientation and later approximation of the anterior wall (pink) and the posterior wall (blue) should be maintained. B: The fundus is passed posterior to the esophagus to lie on its right. It is critical to maintain the correct orientation of the stomach. Sutures are passed through the greater curve aspect of the rightward lying fundus, then through anterior muscularis propria of the esophagus, and finally through the greater curve aspect of the leftward lying fundus. Usually three sutures are used to construct a 2 cm long (measured anteriorly) fundoplication. The use of a bougie during construction of the fundoplication is discouraged, since it does not guarantee either a loose or floppy fundoplication. In fact, it may foster poor technique by allowing the surgeon to assume that the presence of a bougie will prevent misconstruction of the fundoplication. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2013. All Rights Reserved.)

Components of fundoplication—length, looseness, floppiness, position, and extent of fundoplication—have to be meticulously, precisely, and repeatedly constructed despite variable gastric dimensions and anatomy. The potential for error and post-fundoplication problems is enormous (Fig. 3.8).

Closure of the abdominal wound completes the surgery.
Figure 3.8 Some fundoplication mistakes. A: A tight fundoplication, B: A twisted fundoplication, C: A slipped fundoplication, D: A tight and slipped fundoplication. (Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2013. All Rights Reserved.)
**POSTOPERATIVE MANAGEMENT**

Smooth reversal of the anesthetic and prompt extubation without retching is crucial to avoid early stressing of the repair. An NG tube, although not mandatory, is preferable to avoid gastric distension early in the postoperative course. It may be removed promptly when gastric function is sufficient to avoid distension. With return of bowel function, liquids are started and the patient is advanced to a soft diet prior to discharge, typically on the fourth or fifth postoperative day. The patient is instructed to avoid diaphragmatic stressors, i.e., activities that raise intra-abdominal pressure excessively, such as heavy lifting and straining at stool.\(^5\)

**COMPLICATIONS**

Intraoperative complications specific to dissection at the esophageal hiatus include pneumothorax and injury to the esophagus, stomach and spleen. Immediate intraoperative esophagogastroscopy is imperative to access for any suspected upper gastrointestinal injury. Care must be taken in mobilization of the liver and dissection about the inferior vena cava and aorta. These dissections are more problematic at reoperation. Early postoperative complications include bleeding, early disruption of the repair with recurrent hiatal hernia, leakage from the esophagus or stomach, subphrenic abscess, and pancreatitis. In the past, barium esophagram has been used in early postoperative imaging for investigation of possible complications; however, chest and abdominal CT scans with contrast provide exquisite anatomic display while evaluating for GI and vascular contrast abnormalities. A review of Swedish administrative databases reported that in comparable patients mortality and morbidity were similar between open and laparoscopic surgery.\(^6\)

Dysphagia and gas bloat (post-fundoplication syndrome) are bothersome postoperative complications. Establishing realistic expectations at initial evaluation and preoperative education and preparation will facilitate management of these usually early and transient problems. Rarely will dilatation be necessary in the management of dysphagia and should be avoided if possible. Gas bloat can be more problematic, particularly in patients who have developed the habit of aerophagia and belching as an element of their GERD. This troublesome symptom is the result of loss of the capacitance function of the fundus and the establishment of a substantial antireflux barrier in place of the defective preoperative sphincter mechanism. Persistent gas bloat despite the passage of time and dietary and lifestyle modification may signal a malformed fundoplication. As with all hernia surgery, a repair under tension or persistence of preoperative aggravating factors will produce a recurrent hernia and the need for reoperation.

**RESULTS**

**Randomized Trials**

A randomized controlled study reported by Spechler and colleagues may be dismissed today because it compared open surgery with H2 blocker medical therapy.\(^7\) However, it provides an excellent picture of the results of surgery. Follow-up at a mean of 10.6 years demonstrated that 63% of surgical patients were taking antireflux medication, compared with 92% of medically treated patients. Symptom control on medication was no different between groups; however, symptom control off medication was significantly worse for surgical patients. There was no difference between the groups in grade of esophagitis, frequency of treatment of esophageal stricture, subsequent surgery, quality of life (SF-36 survey), and overall satisfaction with therapy. For the surgical group, 16% required at least
one reoperation and 14% required treatment of esophageal stricture. The authors con-
cluded “antireflux surgery should not be advised with the expectation that the patient
with GERD will no longer need to take antisecretory medication.” Since this study was
conducted in the late 1990s, more effective medical therapy has become available; the
same cannot be said for surgery.

A randomized study comparing open surgery to PPI therapy in GERD was con-
ducted by Lundell and colleagues.8 Treatment failure was the outcome measure. It was
defined as (1) moderate-to-severe heartburn or acid regurgitation in the 7 days prior to
assessment, (2) at least grade II esophagitis, (3) moderate or severe dysphagia or
odynophagia in combination with mild heartburn or regurgitation more than 3 months
after operation, or (4) reoperation or PPI required for more than 8 weeks for symptom
control or consideration or request for surgery by a physician or patient. There were
significantly more treatment failures in the medical group (55% vs. 47%) at 12 years
following randomization. With dose escalation of PPI, this difference still remained
significant. Although GERD control was superior with open surgery, dysphagia, rectal
flatulence, and inability to belch or vomit were significantly more common than in the
medical group. Change in therapeutic strategy was less common in PPI patients (15%
vs. 38%). Quality of life was similar, and within normal range, for both therapies.

Nonrandomized Trials

An interesting query of the VA database identified 5,606 patients who had esophagitis
with ulcers and strictures; 542 had fundoplication.9 At a mean follow-up of 4.2 years,
surgery in the ulcer or stricture patients was better than nonsurgical therapy, with
esophagitis reported in 46% versus 56% (p <0.001), ulcers 33% versus 38% (p <0.05),
and strictures 32% versus 43% (p <0.001), respectively. There was no difference in
number of outpatient visits and procedures between groups. The clinical significance
of these statistically significant improvements is questionable. In 30,119 nonerosive
esophagitis patients, 605 had fundoplication. There was no difference in esophagitis
between surgery and nonsurgical therapy, 24% versus 25%. However, in the surgical
group without strictures or ulcers, there was more dysphagia, 4.6% versus 2.6% (p not
given), more outpatient visits, 40 versus 34 (p <0.05), and more outpatient procedures,
4.3 versus 2.7 (p <0.01). Repeat surgery was required in 2.3% of surgery patients with-
out ulcers and strictures and 5.1% with.

Rantanen and associates10 reported the outcomes of 45 patients in community-based
practices who underwent open GERD surgery and were followed a mean of 78 months.
Eighty-five percent were free of or had mild reflux, 31% reported dysphagia, 67% flatu-
ulence, and 46% bloating. Of 35 who had esophagoscopy, 37% had a defective fundoplica-
tion and 29% erosive esophagitis. Thirteen percent required antireflux medication and 13%
were scheduled for reoperation; two had reoperation in the follow-up period. The frequency
of GERD surgery for six surgeons ranged from 0.08 per year to 1.8 operations per year.

The problem of recurrence after paraesophageal hernia repair was highlighted early in
the laparoscopic experience.11 At this time, laparoscopic repair was associated with triple
the recurrence of open surgery. With acceptance of the principles of hiatal hernia repair,
including addition of esophageal lengthening and attention to crural closure, the rates of
recurrence are now reported to be similar between open and laparoscopic approaches.
However, the reported recurrence in 18% of patients at 12- to 18-month follow-up in the
hands of world-renowned surgeons illustrates the problems with durable paraesophageal
hernia repair. Mesh reinforcement of the hiatal repair is not the answer.2,3

CONCLUSIONS

Reconstruction of the EGJ that includes fundoplication is indicated in the treatment
of GERD and symptomatic paraesophageal hiatal hernia, except in the severely obese
or morbidly obese patient. History and physical examination are essential in patient
selection. Mandatory investigations include EGD and biopsy, barium esophagram,
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high-resolution manometry, and pH monitoring. Repair requires reconstruction of the EGJ. The principles of repair are restoration of the intra-abdominal esophagus, reconstruction of the extrinsic sphincter, and reinforcement of the intrinsic sphincter. Dysphagia and gas bloat are typically transient. Long-term results are good if the above steps are followed. Recurrence is a particularly troublesome problem in the repair of paraesophageal hernias. However, as with all hernia surgery...

"Never do a hernia repair once that you are not prepared to do again."  Anonymous

Recommended References and Readings

Introduction

Thoracic surgeons have demonstrated a consistent interest in the treatment of gastroesophageal reflux disease (GERD) and hiatal hernia and in fact were the pioneers of antireflux surgery. Allison first addressed the challenge, operating through a left thoracotomy with a transthoracic repair of the hiatal hernia that was present in symptomatic patients. His procedure resulted in an anatomically successful herniorrhaphy but did not improve patients’ symptoms as they continued to have both heartburn and endoscopic esophagitis after surgery. This experience led him to the conclusion that the necessary surgical approach would have to rearrange the tissues to restore competence to the cardia and curtail acid reflux, not just address the hernia. The two major contributors to this step were Ronald Belsey and Rudolf Nissen. Belsey in Bristol, England applied principles derived from his clinical experience and thoughtful analysis to a transthoracic approach. After less satisfactory earlier versions, he settled on his Mark IV procedure in the 1950s. Considering publishing of early results anathema, he held off reporting his outcomes until he had accrued an experience with over 1,000 patients with long-term evaluation of nearly all patients in his follow-up clinic. Nissen in 1937 first identified the reflux curtailing effect of a gastric wrap of the distal esophagus when he implanted the esophagus into the stomach with a “gastroplication” following transthoracic resection of the cardia in a young man in Istanbul. Nissen evolved his operation during subsequent stays in the United States and Switzerland into a gastric wrap around the distal esophagus, performed through a thoracotomy or laparotomy and frequently accompanied by a gastropexy attaching the gastric fundus to the anterior abdominal wall.

Both these procedures have documented efficacy over the years, albeit each with its own results and side effects. Ultimately, the Nissen became the more popular operation as it could be performed through a laparotomy, so the patient could avoid the pain and discomfort typically associated with a thoracotomy. The advent of laparoscopic surgery has even further established the abdominal approach and consequently the Nissen procedure as the preferred one for almost all patients. The Nissen operation, with significant modifications from the original description, remains the antireflux operation of choice. Alternative options such as the Hill, Toupet, and Dor procedures have their advocates but have not yet supplanted Nissen’s procedure.
INFORMATION FOR TRANSTHORACIC APPROACH

Consideration of antireflux surgery is appropriate under several circumstances, which are well documented in Chapters 1 and 3. Briefly, operation is reasonable to consider when the patient’s symptoms persist despite medical management, there are reflux complications such as continuing regurgitation, persistent esophagitis or stricture, or repair of a giant hiatal hernia is necessary.

**Absolute Indications**

The majority of patients needing first operations for GERD or giant hiatal hernia can and should be operated with a laparoscopic approach. There are few absolute indications for a thoracic approach. An important instance is when the need to resect the distal esophagus is a distinct possibility. Examples of this scenario include patients with a chronic stricture that is resistant to dilation or who have a distal esophagus anatomically or functionally damaged by prior operations. Preserving a poorly or non-functional esophagus is not a surgical victory. Replacing the diseased esophagus with a healthy and functional alternative such as a colonic or jejunal interposition, while a significant undertaking, is preferable as it gives the patient the best postoperative quality of life. Patients particularly at risk for needing and benefiting from resection and reconstruction with healthy tissue, such as the left colon, are those having a second or even third reoperation (i.e., a third or fourth operation). If resection is required and the surgeon is in the abdomen through a laparotomy, it may not be possible to get cephalad to the damaged esophagus to perform an anastomosis to healthy, functional esophagus through the hiatus. Of course, if the surgeon has performed a left thoracotomy but a resection is not necessary, nothing is lost as an antireflux operation is performed through the left chest with the transthoracic exposure providing the opportunity to generously mobilize the esophagus and add a Collis gastroplasty. Another occasional reason for a thoracic approach, in addition to the concern that a resection will be required, is when a patient has other thoracic pathology requiring attention, such as a lung mass.

**Relative Indications**

Relative indications for choosing a thoracic approach include the uncommon short esophagus associated with chronic reflux and/or stricture or giant hiatal hernia. My experience is that the short esophagus is an acquired condition caused by chronic and uncontrolled reflux producing fibrosis and scarring, rather than being a congenital condition. Although a laparoscopic approach, including performance of a Collis gastroplasty is possible, in this situation a surgeon may feel that the thoracic approach allows helpful access to perform mobilization of the mediastinal esophagus and provides the historically standard approach for performance of a Collis gastroplasty, two steps in ensuring a tension-free reduction of the gastric wrap below the diaphragm, an essential component of a successful antireflux procedure. Another relative indication for choosing to operate through a thoracotomy is a patient having a redo procedure and the surgeon considers a thoracic approach necessary because of improved access to the cardia and the ability to mobilize the thoracic esophagus to obtain sufficient length for a tension-free reduction of the fundoplication below the diaphragm. This is an issue of surgical judgment and experience as reoperation can be carried out by laparotomy or even laparoscopy. The same scenario applies to repair of giant or paraesophageal hiatal hernias, which some surgeons still prefer to repair transthoracically. Finally, significant obesity increases the challenge of the abdominal approach; however, if patients are morbidly obese, they are better served by a bariatric procedure which addresses both the obesity and the reflux. These relative indications for a transthoracic approach are all issues of the judgment and experience of the operating surgeon.
### Chapter 4  Transthoracic Nissen Fundoplication

#### PREOPERATIVE PLANNING

To delineate the anatomy and assess the status of the esophagus and stomach, both upper gastrointestinal x-rays and upper gastrointestinal endoscopy (ideally by the operating surgeon) should be performed. Depending on the preoperative diagnosis, functional studies including pH monitoring and esophageal motility studies are important. If the planned procedure is a reoperation, the operative notes from the earlier operations should be reviewed, so there is knowledge of what and how tissues have been dissected and/or divided and motility evaluation is essential so the surgeon can predict the ability of the esophagus to function sufficiently postoperatively.

#### SURGERY

**Surgical Access**

Thoracic antireflux procedures are performed through a left lateral thoracotomy in the sixth or seventh interspace. A posterior extension is not necessary. If access to the abdomen is required, the lower interspace provides better visibility below the diaphragm and the incision is carried anteriorly to within 5 cm of the costal margin, but not across, as dividing the costal margin is quite painful and not necessary. For adequate exposure of the operative field, I encourage dividing the latissimus dorsi routinely. The serratus is partially divided as necessary for visibility. Resecting a portion of the inferior rib posteriorly, beneath the mobilized erector spinae muscle allows rib spreading without unintended fractures, again minimizing postoperative pain.

The ipsilateral lung is deflated with the use of a double-lumen endotracheal tube, all adhesions from previous operations are lysed, the inferior pulmonary ligament is divided up to the inferior pulmonary vein, and the collapsed lung is packed out of the field with a moist laparotomy pad. The mediastinal pleura is incised, and the esophagus is delivered with finger dissection and held with a Penrose drain. If there is scarring from previous operative dissection, it is best to start the mediastinal dissection cephalad to areas of previous dissection, so the esophagus can be identified and mobilized easily and safely. Both vagus nerves should be surrounded with the Penrose drain and brought with the esophagus as dissection proceeds to free the esophagus from just inferior to the aortic arch to the hiatus.

If this is the patient’s first operation, the cardia can be mobilized through the hiatus. The dissection is begun by incising the phrenoesophageal membrane and peritoneum anteriorly (Fig. 4.1). The surgeon then can control the dissection with the index finger of the left hand and thumb grasping the distal esophagus in the abdomen and controlling the cardia through the incision in the phrenoesophageal membrane (Fig. 4.2). With this control, the hiatus is dissected until the distal esophagus and cardia are completely free. The vagus nerves are protected both by tactile and visual tracking during the mobilization. To construct a Belsey Mark IV fundoplication, no further dissection is usually required. For a Nissen fundoplication, division of enough of the short gastric vessels to allow the fundus to be adequately delivered into the chest is necessary. This is done by exerting gentle traction on the fundus so that these vessels can be sequentially identified, ligated, and divided as they emerge through the hiatus (Fig. 4.3). This sufficiently mobilizes the fundus so that a wrap can be performed. It must be kept in mind that the wrap is being constructed in an artificial location, that is, the chest, but will be returned to and reside in the abdomen, which means truly needing a “floppy” fundus so it can reach up through the hiatus.

In the instance of a reoperation, this complete mobilization at the hiatus and of the fundus cannot be adequately and safely completed through the hiatus because of scarring and adhesions to the hiatus and, intra-abdominally, between the cardia/fundus and the diaphragm, retroperitoneum, and liver. The original gastric wrap is also typically...
Figure 4.1 After fully mobilizing the esophagus, the phrenoesophageal membrane is identified beneath the hiatal muscle rim anteriorly and incised, providing access to the abdomen.

Figure 4.2 With the surgeon’s left index finger passed posterior to the esophagus in the abdomen, the remaining posterior attachments of the cardia to the hiatus are divided. The vagus nerves are protected from harm by being sequestered within the surgeon’s hand.

Figure 4.3 Gentle cephalad traction delivers the fundus through the hiatus. Short gastric vessels are sequentially ligated and divided until a generous amount of fundus has been released and lies easily within the chest.
adhesed to the fundus and terminal esophagus and original sutures are still present, even if the wrap has herniated and/or partially dehisced. To safely attain needed mobilization, dissection within the abdomen is necessary. This access is gained by incising the diaphragm peripherally, 2 to 3 cm from the chest wall attachment, starting anteriorly at the pericardial fat pad and going posteriorly as needed, usually far enough to provide exposure of the gastroplenic ligament and its short gastric vessels (Fig. 4.4). Dissection then proceeds from above and below the hiatus until the distal esophagus, cardia, and proximal fundus are free of adhesions and are mobile. The preexisting wrap, which is typically partially dehisced and/or around the stomach rather than the esophagus, is taken down. This requires cutting the original fundus-to-fundus sutures. At the conclusion of the operation, the diaphragmatic incision is closed with a series of interrupted or near/far–far/near sutures.

**Nissen Fundoplication**

The Nissen procedure entails a 360-degree transversely oriented wrap of fundus around the distal esophagus for a length of approximately 2 cm with subsequent closure of the hiatus. Other than the surgeon’s visual perspective and the need to deliver the fundus sufficiently to construct the wrap in the chest before returning it to its final home below the diaphragm, there are no differences in the steps and final appearance of this operation because of the approach used for it, abdominal or thoracic. When full mobilization of esophagus, cardia, and fundus has been accomplished, the surgeon assesses the ability to reduce without tension, the terminal few centimeters of the esophagus below the hiatus. If this is not possible, a Collis gastroplasty is necessary as described below.

The initial steps are described in the Surgical Access section. Whether the fundus is approached through the hiatus only or through a combined hiatal and transdiaphragmatic dissection, division of all attachments—to the distal mediastinum, the hiatus itself, and upper abdominal structures, including division of several proximal short gastric vessels—is required. These release steps allow the fundus to be drawn into the chest where the wrap will be performed, prior to its return to the abdomen.

After mobilization, the ability to reduce the distal esophagus is determined. If this is the case, stout sutures, such as 0 silk, are placed in the hiatus posterior to the esophagus but not yet tied. The fundus is then rotated in counterclockwise fashion around the

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**Figure 4.4** This illustrates the left upper quadrant exposure after peripheral incision of the diaphragm. Diaphragm function is not impaired as the incision is parallel to and does not transect branches of the phrenic nerve.
distal esophagus where it is secured with three sutures separated by 1 cm, resulting in a 2-cm wrap (Fig. 4.5). The sutures are placed between the anterior and posterior aspects of the fundus while holding the posterior fundus in place with the left hand and incorporating a bite of esophageal muscle with each suture. Typically the surgeon is aware of some vertical tension on the fundus because of the necessity to tug it into the chest; however, once the wrap is reduced to its home below the diaphragm, all tension resolves. The routine placement of an esophageal dilator during the wrap construction is not as helpful as for a laparoscopic Nissen procedure, as the “stretch” of the fundus into the chest results in sufficient looseness of the wrap when returned into the abdomen; however, this step can be added if desired.

When esophageal lengthening is appropriate to achieve a final vertical tension-free placement of the gastric wrap and the surrounded distal esophagus below the diaphragm, a Collis gastroplasty is constructed (Fig. 4.6). The anesthesiologist transorally passes a Maloney bougie, usually size 36 French, which the surgeon guides into the stomach. The mobilized fundus is lifted, and a GIA stapler is pressed firmly against the bougie, which is pressed against the lesser curve of the stomach. When the stapler is fired, a gastric tube is created of the same caliber as the esophagus, effectively producing a “neoesophagus.” The remainder of the operation is as described above with the final gastric wrap surrounding this neoesophagus, resulting in the Collis–Nissen procedure.

The final step, with the wrap lying peacefully in the abdomen and demonstrating no tendency to herniate, is to sequentially tie the previously placed sutures in the hiatus, starting posteriorly and moving anteriorly. The final size of the hiatal opening around the esophagus should be sufficient to accommodate the esophagus and the tip of the surgeon’s index finger but with resistance when the distal interphalangeal joint encounters the hiatal muscle.

POSTOPERATIVE MANAGEMENT

As no lung resection has been performed, patients are typically extubated in the operating room. The chest tube is removed when drainage is acceptable. I leave a
nasogastric tube in place for the first night, or longer if drainage is excessive, to be sure the stomach is emptying satisfactorily to prevent gastric distension, which challenges the wrap and a staple line if a Collis gastroplasty is present. Oral feeding is started with liquids 1 day after nasogastric tube removal and the patient is sent home when taking sufficient amounts of liquids. Subsequently the diet is advanced as tolerated with most patients on an unrestricted diet within 2 weeks.

COMPLICATIONS

In addition to the nonspecific risks, such as deep vein thrombosis and postoperative bleeding, the complications specific to this operation are pulmonary and gastroesophageal. The lung is deflated during the operation, producing some residual atelectasis, and the thoracotomy-induced pain discourages deep breathing and coughing. Consequently, attention to pulmonary toilet is essential. Gastroparesis with delayed gastric emptying can occur if the vagus nerves are contused or divided, distinct possibilities if a reoperation has been performed. Therefore, I leave a nasogastric tube until I am confident the stomach is functioning satisfactorily. If delayed gastric emptying becomes a chronic issue, prokinetic agents are useful as well as Botox injections of the pylorus.

RESULTS

The outcomes of this operation depend in large part on the indications for it. Most frequently, a transthoracic Nissen procedure is performed as a reoperation following one or two failed prior operations for reflux. Experiences show that depending on the number of previous operations, good to excellent results are obtained in between 50% and 85% of patients. The more prior operations, the worse the outcome, stressing the need for the surgeon to carefully balance the desire to “save” the esophagus against the benefits of resection of the nonfunctional esophagus and replacing it with healthy stomach, colon or jejunum.
CONCLUSIONS

- A succinct history of antireflux surgery shows the leadership role of thoracic surgeons.
- Indications for antireflux procedures include recalcitrant GERD and repair of giant (paraesophageal) hiatal hernia.
- An absolute indication for a transthoracic approach is the potential need for an esophageal resection because of stricture or functional or anatomic injury from previous surgery.
- Relative indications for a transthoracic approach are a short esophagus, prior surgery, and obesity.
- Operative principles include a left thoracotomy, generous mobilization of the esophagus and cardia, construction of a loose and short Nissen wrap, and secure closure of the hiatus.
- Postoperative morbidity is reasonable and long-term results vary according to the original surgical indications.

Recommended References and Readings

5 Belsey Mark IV Partial Fundoplication
Arjun Pennathur and Tom R. DeMeester

Introduction

Philip Allison, in 1951, linked the symptoms associated with a sliding hiatal hernia to the reflux of gastric juice into the esophagus and the likelihood of developing esophagitis.1,2 He advocated the repair of the hiatal hernia as a surgical therapy for reflux esophagitis. This required reducing the hernia and repositioning the gastroesophageal junction into its normal intra-abdominal location. During the 1950s, surgeons devised a variety of procedures to more effectively place the gastroesophageal junction in an intra-abdominal position. A posterior gastropexy was devised by Lucious Hill in 1967, which anchored the gastroesophageal junction and its associated phrenoesophageal membrane to the median arcuate ligament of the aortic hiatus.3 The Nissen full fundoplication was introduced by Rudolf Nissen in 1956,4 and the Belsey Mark IV partial fundoplication by David Skinner and Ronald Belsey in 1961.5 The Nissen and Belsey fundoplications were designed to establish an intra-abdominal segment of esophagus surrounded by a cuff of stomach in hopes of forming a functional flap valve. The Belsey Mark IV repair is performed through a thoracic incision; the Hill repair through an abdominal incision; and the Nissen repair through either an abdominal or thoracic incision.

In 1957, Dr John Leigh Collis provided an important contribution to the repair of a hiatal hernia. He introduced a method to manage the shortening of the esophagus that occurred with advanced disease due to reflux-induced intramural fibrosis by describing a technique that adds 3 to 4 cm to the esophageal length by the creation of a short proximal gastric tube along the lesser curvature of the stomach.6 This ingenious technique relieved the tension on a hiatal hernia repair caused by a shortened esophagus and reduced the incidence of reherniation. In 1987, Dr Griffith Pearson modified the procedure to include a Belsey-type partial fundoplication over the gastroplasty tube.7

In the 1990s, the Nissen fundoplication started to be performed using laparoscopic techniques, and today this approach has become commonplace along with the procedure’s reputation of being safe and effective.8 At present, many surgeons are comfortable performing the procedure by the laparoscopic approach, doing a transhiatal mediastinal dissection to mobilize the distal esophagus, and performing a laparoscopic Collis gastroplasty if at least 2 to 3 cm of distal esophagus does not lie comfortably and
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free of tension in the abdomen after the mobilization. Only the most complex multiple redo operations (e.g., a redo operation in a patient with multiple prior antireflux surgeries) require an open operation, which is usually done through a transabdominal incision. Today, open transthoracic Nissen fundoplication (discussed in Chapter 4 by Alex Little) and the Belsey fundoplication (discussed in this chapter) are infrequently performed.

INDICATIONS/CONTRAINDICATIONS

Although the indications for an antireflux repair and the biomechanics of an antireflux repair done by laparoscopic and open approaches are similar, there are some specific situations in which a transthoracic Belsey Mark IV fundoplication or a transthoracic Nissen fundoplication provides an advantage. These include the following.

- A repeat open transthoracic operation can be technically easier in a patient with intrathoracic stomach and a history of multiple failed antireflux repairs.
- A transthoracic fundoplication is a particularly useful approach in patients who require fundoplication but have a “hostile” abdomen due to multiple previous surgeries. It is also of use in patients who have had multiple transabdominal antireflux procedures.
- A transthoracic approach is useful when a partial fundoplication is planned after a transthoracic myotomy for motility disorders such as diffuse esophageal spasm or pulsion diverticula.
- A transthoracic approach is useful for a patient who has extensive shortening of the esophagus. In this situation, the thoracic approach allows for maximum mobilization of the esophagus in order to place the repair, without tension, in the abdomen with or without a gastroplasty to lengthen the esophagus.
- A transthoracic approach is useful for a patient with reflux disease who requires a thoracotomy for another reason, such as pulmonary disease. If the pulmonary disease is on the left side, an open transthoracic approach allows both problems to be addressed through one incision.

The propulsive power of the esophageal body should exceed the resistance to flow through the antireflux repair. Consequently, the choice between a 360-degree fundoplication (Nissen) or partial 240-degree fundoplication (Belsey) is influenced by the strength of the peristaltic contractions. An esophageal body that has normal wave progression and good contraction amplitude will do well with a complete 360-degree fundoplication. When the prevalence of peristaltic wave progression is reduced to <50% or esophageal contraction amplitudes in the distal half of the esophagus are ≤20 mm Hg, a partial 270-degree fundoplication is recommended as this degree of fundoplication has no measurable resistance to esophageal emptying. Inappropriate matching of the body of the esophagus to the resistance imposed by the antireflux procedure can cause a delay in the passage of food through the repair and symptoms of dysphagia. To avoid excessive outflow resistance, the antireflux repair should be performed in such a manner that the postoperative sphincter pressure is not in the hypertensive range and the length of the sphincter measures 3 to 4 cm.

PREOPERATIVE PLANNING

The identification of a patient for an antireflux surgery includes both a complete clinical evaluation consisting of a history, physical examination, and an upper gastrointestinal barium contrast video, and an objective evaluation consisting of an upper gastrointestinal endoscopy, esophageal manometry, and pH testing. If the patient requires a redo antireflux procedure, a more thorough and comprehensive evaluation is done. This requires determining the indication for the initial antireflux surgery, reviewing the patient’s clinical history prior to and after the operation, and thoroughly
studying the operative report. A specific note should be made of the location of the gastroesophageal junction in relation to the location of the fundoplication. The surgeon should also determine if the fat pad was dissected, if the vagi were preserved, and if the crura were closed. The technical details of the construction of the fundoplication itself should be noted. With this information in mind, an endoscopy, upper gastrointestinal barium contrast video, esophageal manometry, pH testing, and a gastric emptying study should be done. Patients who will undergo a transthoracic fundoplication, should also have an assessment of their ability to tolerate a thoracotomy and single-lung anesthesia.

**Surgery**

**Initial Steps and Thoracotomy**

The Belsey operation requires approximately 4 cm of tension-free intra-abdominal esophagus. Consequently, the clinical success of a Belsey repair decreases progressively from 90% in patients who have no esophageal shortening to 50% in those who have significant shortening and a repair under tension. In those patients with shortening, a Collis gastroplasty is added to the repair to gain additional length and alleviate any tension on the repair. A step-by-step description of the Belsey antireflux procedure is detailed below.9,10,11

- An epidural catheter is placed to optimize the patient’s postoperative pain control.
- The patient is intubated with a double-lumen endotracheal tube for anesthesia in the operating room with precautions taken to avoid aspiration. The position of the tube is verified by bronchoscopy. The left lung is selectively deflated. Adequate venous access, a Foley catheter, and an arterial line are placed. An on-table endoscopy is then performed if the surgeon did not perform an endoscopy prior to the surgery to evaluate the hiatal hernia and exclude the existence of Barrett’s esophagus, neoplasm, a stricture, or any other complications of reflux disease.
- Patient is placed in a right lateral decubitus position, the usual position for left posterolateral thoracotomy. The pressure points are padded, and pillow is placed between the lower extremities. A sequential compression device is also placed for deep vein thrombosis prophylaxis.
- The table is flexed above the hip, and the patient is secured to the table with a belt.
- The diaphragmatic hiatus is approached through a left posterolateral thoracotomy in the sixth intercostal space (i.e., along the upper border of the seventh rib).
- For patients who had a previous failed antireflux repair, we prefer to use the seventh intercostal space. This allows better exposure of the abdomen through a peripheral diaphragmatic incision.
- The incision is made circumferentially in the anterolateral portion of the diaphragm, 2 to 3 cm from the chest wall, for a distance of 10 to 15 cm.
- A sufficient fringe of diaphragm must be left along the chest wall to allow for easy closure of the diaphragmatic incision.
- If further abdominal exposure is necessary, the thoracic incision can be extended across the costal margin and diagonally down to the abdominal midline, dividing the fibers of the left rectus abdominis muscle.

**Esophageal Mobilization**

The esophagus is mobilized from the diaphragm to underneath the aortic arch. Care is taken not to injure the vagal nerves. Branches of the vagal plexus going to the left and right lung must be divided to obtain maximal esophageal length. This allows construction, without tension, of a partial fundoplication over a 4-cm segment of abdominal esophagus. Two vessels arise from the proximal descending thoracic aorta just distal to the arch and pass over the esophagus to the left main stem bronchus. They are the left superior and inferior bronchial arteries. Ligation of these arteries is also necessary to
fully mobilize the esophagus. In addition to these arteries, two to three direct esophageal branches come off the distal descending thoracic aorta and pass directly to the esophagus. These are also ligated and divided without concern about ischemic necrosis of the esophagus. There is sufficient blood supply to maintain the integrity of the esophagus through its intrinsic arterial plexus, fed by the inferior thyroid artery in the neck and by branches from the right bronchial artery in the thorax. This degree of mobilization is necessary to place the repair into the abdomen without undue tension. Failure of adequate mobilization is one of the major causes for subsequent breakdown of a repair and the return of symptoms. Therefore, if after adequate mobilization, there is insufficient intra-abdominal length or any tension, a Collis gastroplasty should be added to the repair.

**Mobilization of the Gastroesophageal Junction and Cardia**

Freeing the gastroesophageal junction and gastric cardia from the diaphragmatic hiatus is the most difficult portion of the procedure, but can usually be completed through the esophageal hiatus. It is unnecessary to make a counter incision through the central tendon of the diaphragm or to enlarge the hiatus by an incision through the crura. When there is no hiatal hernia, the rim of the hiatus is grasped with an Allis clamp, and the dissection is started by gaining access to the abdominal cavity with the division of the phrenoesophageal membrane. It can be difficult at times to find the correct tissue plane once the membrane has been divided due to the protrusion of the preperitoneal fat. Persistence and dissection underneath the retracted left crus, away from the gastric vessels, eventually yields entry into the free peritoneal space. Entering the abdominal cavity is easier when a hiatal hernia is present. When a hiatal hernia is present, the hernia sac can be entered near the hiatus. It is again important to be careful to preserve the vagus nerve during the dissection of the sac. In moderate to large hernia, the sac is excised.

The proper stance of the surgeon at the operating table aids in freeing the hiatus. With the patient in the left posterior thoracotomy position, the surgeon should stand adjacent to the patient’s back, facing the head of the table. The left index and middle fingers are placed through the diaphragmatic hiatus into the abdominal cavity, with the palm facing the patient’s feet. The surgeon’s line of vision is down and backward under his or her left axilla. With judicious use of the left thumb, index and middle fingers, the surgeon is able to spread the hiatal tissues and divide them with a scissors controlled by the right hand. In this position, the left hand is also used to retract the esophagus and protect the vagal trunks. Although it sounds somewhat awkward, this stance greatly facilitates the most difficult part of the operation.

All the attachments between the gastric cardia and diaphragmatic hiatus are divided. An inconstant artery (Belsey’s Artery) communicating between the left gastric and the inferior phrenic artery should be divided. This is encountered in the posteromedial dissection, and it is important to control this vessel before division. The short gastric vessels are divided and ligated one by one to allow good mobilization of the fundus. When free, the fundus and part of the body of the stomach are drawn up through the hiatus into the chest (Fig. 5.1). The vascular fat pad, which lies on the anterior and lesser curvature surface of the cardia, is dissected. Care must be taken during this dissection to avoid injury to the vagal nerves. The fundus of the stomach must adhere firmly to the lower esophagus and the dissection of the fat pad facilitates this.

The completely mobilized esophagus is encircled with a Penrose drain and retracted toward the anterior border of the hiatus to give exposure for closure of the posterior hiatus. The right and left crura of the diaphragmatic hiatus are identified and approximated with interrupted figure-eight nonabsorbable 0 sutures (Ethibond), taking generous bites of muscle. Usually there is a decussation of muscle fibers from the right crus that passes anteriorly over the aorta to join muscle fibers from the left crus, but occasionally the aorta lies free within the enlarged hiatus. In either situation, the first crural suture is placed close to the aorta. Traction on this first posterior crural stitch elevates the right crus toward the surgeon and facilitates the placement of subsequent crural
sutures. Occasionally, it is necessary to mobilize the pericardium off the diaphragm to give better exposure of the fascia and muscle making up the right crus. The subsequent crural sutures should incorporate the fascia from the periphery of the central tendon that blends in with the muscle fibers making up the right crus.

On the left side, the sutures are passed through the muscle fibers of the left crus and the firmly adherent overlying pleura. Approximately 3 to 4 figure-eight sutures, placed 1 cm apart, are necessary to approximate the crura and to adequately reduce the size of the hiatus. All sutures are initially placed before tying because it is easier to remove those not needed than to add additional sutures after the hiatus has been closed. These sutures are placed but not tied; tying these crural sutures is the last step in the repair (Fig. 5.2).
Construction of the Fundoplication

The construction of the gastric fundoplication is the keystone of the antireflux repair in that its proper function is responsible for re-establishing the competence of the cardia. In the Belsey Mark IV operation, the fundus of the stomach is plicated around the anterior two-thirds of the lower 4 cm of esophagus. The partial fundoplication is held in place by two rows of three horizontal mattress sutures placed equidistant from each other and into the seromuscular layers of the stomach and the muscular submucosal layers of the esophagus. Number 3-0 silk sutures are used, and each suture obtains a firm grip of the esophageal muscle fibers by passing down to, but not through, the muscularis mucosae. The first row of sutures is placed 1.5 cm above the cardia and is tied only tight enough to obtain tissue apposition without strangulation. It is important to remember that the hiatus is approached surgically from the left lateral position. To construct the fundoplication over the anterolateral two-thirds of the esophagus, it is necessary that the far right suture be placed in the right lateral wall of the esophagus. This is out of the surgeon’s view and requires rotation of the esophagus before placement of the suture. A common mistake is placing this suture too far anteriorly, resulting in an anterolateral fundoplication displaced to the left (Fig. 5.3).

A second row of 3-0 sutures is placed 2 cm above the first row, through the esophagus and the stomach as detailed above, using the position of the previously placed first row of sutures as a guide (Fig. 5.4). In the original description of the Belsey procedure, these sutures were not tied at this juncture, but tied after placement through the diaphragm. We carefully tie the sutures in the second row, so as to give tissue apposition without strangulation. The tails of these sutures are not cut, but are separately retreaded on a large thin Ferguson needle and each of the tails is passed 0.5 cm apart from each other through the diaphragm from the abdominal to the thoracic surface 1 to 1.5 cm from the edge of the hiatus. The three sutures, each with its two tails, are placed at the 4-, 8-, and 12-o’clock positions on a clock face, oriented with the 6-o’clock position at the posterior hiatus between the right and left crura just anterior to the aorta (Fig. 5.5). Again, it is important to place the right lateral, or 4 o’clock, suture properly to avoid the common error of putting this suture too far anteriorly, in the 1- or 2-o’clock position, and constructing an anterolateral fundoplication displaced to the left. These sutures must be carefully placed to avoid injury to the abdominal structures. A spoon retractor has become a popular instrument to aid in placing these sutures without snagging abdominal mesentery or omentum. The needle is guided along the inner surface of a spoon held firmly against the undersurface of the diaphragm before it is passed through the diaphragm.

Figure 5.3 Construction of a Belsey 240-degree partial fundoplication showing placement of the first row of sutures 1.5 to 2 cm above the gastro-esophageal junction. Particular attention must be given to placement of the right lateral suture as detailed in the text.
The partial fundoplication is massaged through the hiatus and into the abdomen. It is not dragged down into the abdomen by pulling on the diaphragmatic sutures, but rather is placed into the abdomen by compressing the fundic ball with the hand and manually maneuvering it through the hiatus. Resistance to placing the repair into the abdomen can result from the shoelace obstruction of the previously placed crural sutures. Opening the crural sutures, as loosening the laces of a shoe, relieves the obstruction and helps in placing the partial fundoplication into the abdomen. Once in the abdomen, the fundoplication should remain there without tension on the holding sutures. A gentle up-and-down hand motion on the diaphragm should not encourage the fundoplication to pop back through the esophageal hiatus. If the repair remains in
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The abdomen unaided, the previously placed crural sutures are tied. The holding sutures are then tied, approximating the knot against the previously tied knot so as to avoid any redundancy in the suture between the repair and the diaphragm (Fig. 5.6). An additional safety factor of the double-knot technique is that if one of the tails of the holding sutures breaks while it is being tied, it is not necessary to take the repair down, pull the stomach back up into the chest, and insert a new suture. Simple anchoring of the single remaining tail to the diaphragm is sufficient to hold the cardia in position. The technique also prevents tying the sutures too tight and causing necrosis of the incorporated esophageal and gastric tissue.

If the fundoplication tends to ride up through the hiatus, the tension on the repair is too great. This is usually caused by inadequate mobilization of the esophagus. If the tendency remains after further mobilization, a Collis gastroplasty is usually necessary.

Belsey Fundoplication with Collis Gastroplasty

In 1957, Dr John Leigh Collis described a technique that adds 3 to 4 cm to the esophageal length by the creation of a short proximal gastric tube along the lesser curvature of the stomach.\(^{10}\) Dr Collis initially introduced the concept of gastroplasty as an antireflux procedure. The concept was modified in 1987 by Dr Griffith Pearson to include a Belsey-type partial fundoplication over the gastroplasty tube.\(^{11}\) The modified Collis procedure was called the Collis–Belsey repair and was typically performed in patients who had gastroesophageal reflux disease (GERD) complicated by esophageal fibrosis and shortening. As a result, many of these patients present with dysphagia in addition to heartburn and regurgitation. The Collis gastroplasty portion of the procedure lengthens the esophagus by constructing a tube along the lesser curve of the stomach to create a “neoesophagus.” A tension-free, Belsey partial fundoplication could then be constructed over the gastric tube. Combining the procedures reduces the risk of subsequent retraction of the fundoplication into the chest. The gastroplasty component of the procedure, in addition to adding esophageal length, provides relatively normal tissue to which the stomach can be sewn in performing the partial fundoplication. The operation improves the competency of the lower esophageal sphincter sufficiently to heal reflux-induced esophagitis, ulceration, and soften the fibrotic strictures. With settling of the inflammation, there can be some restoration of esophageal body compliance and contraction amplitude, but commonly the loss is irreversible.

To perform the Collis gastroplasty procedure, the esophageal and gastric mobilizations are performed as described for the Belsey Mark IV partial fundoplication. The
Collis gastroplasty tube is created along the lesser curvature of the stomach, in continuity with the distal esophagus and for a length of 4 to 5 cm. The tube is constructed over a 48-French Maloney bougie using a single fire of the GIA stapler (Fig. 5.7). To achieve a uniform tube diameter along the lesser curvature, traction is exerted on the greater curvature before the jaws of the stapler are closed adjacent to the bougie (Fig. 5.8). The resultant staple line creates a wedge of fundus that is resected by stapling across the fundus, starting from the greater curvature to the end of the staple line on the gastric tube, in a line perpendicular to the staple line on the gastric tube (Fig. 5.9). The staple line is oversewn with a running absorbable suture. A Belsey partial fundoplication (Figs. 5.10–5.12) is then performed as described previously.

**Final Steps**

- Once the repair is in the abdominal position, the previously placed crural sutures are tied, starting posteriorly at the aortic hiatus and progressing anteriorly until the size of the hiatal opening just allows insertion of the surgeon’s index finger adjacent to the empty esophagus. Any unused sutures are removed (Fig. 5.6). Leaving the hiatus too open encourages reherniation. In the Belsey repair, the closure of the crura provides a posterior buttress against which the intra-abdominal segment of the esophagus is compressed.
- At the completion of the procedure, a nasogastric tube is passed by the surgeon into the stomach to ensure that there has been no angulation of the fundoplication in relationship to the distal esophagus.
- A chest tube for drainage of the pleural cavity is placed and the chest incision is closed.
Figure 5.9 The fundus of the stomach is stapled and cut to form a 5-cm gastric tube along the proximal portion of the lesser curvature. This effectively lengthens the esophagus by approximately 4 to 5 cm. The wedge of the stomach is removed by stapling vertically from the greater curvature down to the horizontal staple line along the dotted line.

Figure 5.10 The staple line is inverted by a running suture and a Belsey 240-degree partial fundoplication is constructed around the gastroplasty tube. The first row of sutures is placed 1.5 cm above the end of the gastroplasty tube. Particular attention must be given to place the right lateral suture far to the right to avoid constructing a partial fundoplication that covers only the left anterior lateral portion of the gastroplasty tube.

Figure 5.11 Continued construction of the Belsey 240-degree partial fundoplication over the gastroplasty tube by placing a second row of sutures 1.5 cm above the first row of sutures and a third row of sutures 1 to 1.5 cm above the previously tied sutures of the second row.
**POSTOPERATIVE MANAGEMENT**

- Antiemetics are given prophylactically to avoid retching or vomiting in the postoperative period. On recovery from anesthesia, the patient usually notes relief from his or her heartburn and regurgitation.

- Nasogastric suction is used to avoid over distention of the stomach during the immediate postoperative period, as excessive gastric distention can cause acute herniation of a Belsey partial fundoplication into the chest. When gastrointestinal function resumes and the nasogastric tube drainage is low, the nasogastric tube is removed.

- A barium swallow is performed to check the repair and the free passage of barium into the stomach. If the findings are acceptable, the patient is started on clear liquids. Patients often experience slight dysphagia when oral intake is resumed, but this usually disappears as the postsurgical edema subsides. Occasionally, intramural gastric hematoma at the site of the fundoplication can cause dysphagia that persists for a longer period. When this occurs, it will generally absorb within 4 to 6 weeks, and the dysphagia subsides. Patients are typically discharged on a soft diet.

- Before discharge, the patient is counseled that until the habit of air swallowing is broken, he or she may experience increased abdominal distention and flatus. Early satiety is common until the patient gains confidence in his swallowing ability and takes fewer swallows to ingest their meal and, as a consequence, ingests in less air with their food.

We have evaluated our patients after surgery with esophageal manometry, 24-hour esophageal pH monitoring, and a questionnaire about their esophageal symptoms and eating habits. Comparison of the results of these studies with results of similar studies obtained from healthy volunteers has helped to objectively evaluate what has been accomplished by the surgical repair. Consequently, the described technique represents a refinement of the method initially published by the originators of the operation. The surgeon must keep in mind that the operation is designed to improve the function of the gastroesophageal barrier and offhanded alterations in technique can cause deleterious on postoperative function. No change in technique should be made unless its effects on function are known.
COMPLICATIONS

In a seminal article published in 1967, Skinner and Belsey reported on over 1,000 patients who received treatment for hiatal hernia including 632 patients who underwent a Belsey partial fundoplication. Operative mortality occurred in 1% of patients who underwent the Belsey procedure. The complications leading to mortality included pulmonary embolism, myocardial infarction, bleeding, and necrosis of lower esophagus. Nonfatal complications during hospitalization occurred in 5% of patients and included thromboembolism or infections in nine, leak in two patients, and distal esophageal necrosis requiring resection in one. Other complications included atrial fibrillation, atelectasis, urinary tract infection, and gastrointestinal bleeding.

Pearson et al. assessed the utility of Belsey fundoplication with a Collis gastroplasty for complicated GERD in 430 patients in a classic 1987 publication. The study population included patients with short esophagus with stricture or esophagitis (n = 215), reoperation (n = 118), stricture or esophagitis associated with motor disorder (n = 37), and giant paraesophageal hernia with intrathoracic stomach (n = 54). The overall mortality was 0.46%. Complications of the thoracotomy included atelectasis, wound infection and pneumonia; esophageal fistula occurred in 1.4% (half of these were in patients who underwent a redo operation), and there was no mortality from these leaks.

RESULTS

Of the 632 patients who underwent Belsey partial fundoplication in Skinner and Belsey’s classical article, long-term follow-up was obtained in 95% of patients, with only 5% of patients lost to follow-up at intervals of 5 years after surgery. In addition, 53% of the 632 patients had a barium esophagogram more than 1 year after surgery. Control of reflux symptoms was excellent. Symptomatic recurrence of a hernia occurred in 5.6% of patients, and an asymptomatic recurrence occurred in 1.2% of patients during long-term follow-up. A poor symptomatic result without a recurrent hernia occurred in 4% of patients. A young age at the time of fundoplication and severe esophagitis leading to esophageal shortening were associated with recurrence. According to the authors the most common cause of recurrence was related to the technique used in placing the sutures in the esophagus when constructing the partial fundoplication and into the crura when closing the posterior hiatus.

In Pearson’s paper assessing the utility of Belsey fundoplication with a Collis gastroplasty in 430 patients with complex GERD, including patients with short esophagus with stricture or esophagitis (215 patients), reoperations (118 patients), giant paraesophageal hernia with intrathoracic stomach (54 patients), and stricture or esophagitis associated with motor disorder (37 patients), the follow-up was complete in 90% of patients at a median time well above 5 years. Remarkably, more than 100 patients were followed for more than 10 years. The clinical results were reported as good in 93% of patients who had a short esophagus with stricture or esophagitis, 91% of patients with giant paraesophageal hernia and intrathoracic stomach, and 80% of patients who had a redo surgery. In contrast to these good results, only 54% of patients with a stricture or esophagitis associated with motor disorder were reported to have a good result. Of particular interest is the landmark publication of Maziak and Pearson on the use of the Collis–Belsey procedure in patients with a giant paraesophageal hernia. The study population consisted of 94 patients. An open transthoracic approach was used in 97% of patients and consisted of a Belsey partial fundoplication in all with the addition of a Collis gastroplasty in 75 patients (80%) who had a short esophagus. The mean follow-up of the study population was 94 months and is one of the longest reported in the literature. Ninety-three percent of the patients were classified as having a good to excellent outcome and 4% with a fair outcome. Two patients had a poor result, and both required reoperation with the addition of gastroplasty for a short esophagus.
CONCLUSIONS

In the current era of minimally invasive surgery, the laparoscopic approach to antireflux surgery has become standard. The transthoracic Belsey partial fundoplication has become an operation of the past; however, it has an important role in some patients with complex esophageal problems, where it can provide a useful alternative approach. In selected patients with complex esophageal problems such as an epiphrenic or midesophageal diverticulum, the rare patients with diffuse esophageal spasm, and patients with complex situations, such as previous multiple transabdominal antireflux repairs or with a “hostile” abdomen from multiple previous operations, a transthoracic approach can become a necessity. The Belsey partial fundoplication, with or without a Collis gastroplasty, is a complex operation, and when done by an experienced surgeon, the results are excellent and have been documented by meticulous studies with long-term follow-up. However, this is a complex operation, and only surgeons with a focused interest in esophageal surgery, trained in thoracic surgery, and who have accumulated extensive experience in the surgical treatment of esophageal disease should consider performing a Belsey partial fundoplication with or without a Collis gastroplasty.

Recommended References and Readings

Introduction

The Collis gastroplasty is a procedure designed to elongate the pathologically foreshortened esophagus, in the setting of long-standing gastroesophageal reflux disease (GERD) by creating a tubular extension of the proximal stomach beyond the anatomic gastro-esophageal junction (GEJ). The laparoscopic Collis gastroplasty employs the same original principles described by Collis in 1957. The “neoesophagus” provides an adequate length of intra-abdominal esophagus to be influenced by the positive pressure environment of the abdomen facilitating the competency of any antireflux mechanism constructed (e.g., fundoplication). The most common circumstances where this esophageal-lengthening procedure may be required are peptic strictures of the esophagus, long-segment Barrett’s, recurrent herniation after fundoplication, and repair of a large hiatal hernia, particularly type III paraesophageal hernias. Selective use of this esophageal-lengthening procedure may be critical for the successful laparoscopic repair of these pathologic conditions.

INDICATIONS

A short esophagus may be suspected by a preoperative barium esophagram or endoscopic measurement of the distance from the upper esophageal sphincter to the lower esophageal sphincter, but is always confirmed intraoperatively. This shortening of the esophagus is thought to be the result of longitudinal esophageal muscular wall scarring secondary to severe chronic GERD. The prevalence of short esophagus is controversial but has been estimated to be present in 1.5% to 19% of patients who undergo surgery for GERD. Esophageal shortening can be defined as an intra-abdominal esophageal length less than 2.5 cm even after extensive mediastinal mobilization. If one encounters a shortened esophagus, the first step is to attempt further esophageal mobilization. However, if after all efforts, the intra-abdominal length of esophagus does not appear adequate for a tension-free, intra-abdominal wrap, then consideration for the Collis gastroplasty esophageal-lengthening procedure should be made.

Horvath et al. defined three types of esophageal shortening: (1) apparent short esophagus; (2) true, reducible short esophagus; and (3) true, nonreducible short esophagus.
Apparent short esophagus is the result of longitudinal compression of the esophagus in the mediastinum, but the esophagus is of normal length. A true, reducible short esophagus is defined as an esophagus that is indeed shortened, but with proper mediastinal mobilization up to and potentially beyond the level of the inferior pulmonary veins (Fig. 6.1), one is able to gain an intra-abdominal length of at least 2.5 cm. A true, nonreducible short esophagus does not allow for an intra-abdominal length of ≥2.5 cm, despite all efforts at esophageal mobilization and mediastinal dissection (Fig. 6.2), and requires a Collis gastroplasty. An esophageal intra-abdominal length of ≥2.5 cm is critical to avoid cephalad traction on the completed antireflux wrap and potential wrap herniation. As with any other hernia repair, recurrence is more common when the repair is done under tension. The successful surgical management of hiatal herniation may be enhanced when this esophageal-lengthening procedure is included with the standard operative repair in the setting of true, nonreducible esophageal shortening.

**CONTRAINDICATIONS**

As long as a patient is considered an appropriate candidate for laparoscopic repair of a hiatal hernia, there are no absolute contraindications to performing a laparoscopic Collis gastroplasty. However, there are number of clinical situations where a Collis gastroplasty may be of concern. For example, in the setting of severe esophageal dysmotility with or...
without stricturing, one would hope to avoid adding a Collis gastroplasty as the dysmotile segment of neoesophagus and a wrap would contribute to postoperative dysphagia. In other cases, where the integrity of the esophagus may be of concern, for example, in difficult hiatal dissections, redo cases, or a difficult giant hernia, significant esophageal trauma may occur with potential myotomies and the safety of adding a Collis staple line may be questionable. Other cases that may be of concern include gastroplasty in compromised, elderly patients with poor tissue integrity or those on steroids where a staple line would preferably be avoided. In any event, we consider the Collis gastroplasty to be a compromise, but one that is necessary if you must do an antireflux procedure and you cannot gain tension-free, intra-abdominal esophagus. These important points emphasize that a Collis gastroplasty should never be used as a substitute to extensive mediastinal mobilization of the esophagus. That is, if you can avoid gastroplasty with good mobilization, then of course do this first. In some patients with a true short esophagus, one may choose to avoid the Collis gastroplasty and the antireflux wrap altogether and perform an esophageal resection with gastric pull-up or a Roux-en-Y esophageojugal reconstruction as the preferred surgical option. In addition, a surgeon who is not properly trained or sufficiently experienced to technically handle a short esophagus should not perform this operation, and referral to clinical centers handling complex esophageal problems on a regular basis should be considered.

PREOPERATIVE PLANNING

The surgeon must consider the possible need for esophageal-lengthening procedure in patients with a large hiatal hernia (>5 cm), a peptic stricture, long-segment Barrett’s esophagus (>3 cm), or a previous failed repair of a hiatal hernia. Because obesity increases intra-abdominal stress on any hernia repair, an esophageal-lengthening procedure should also be considered in obese patients undergoing hiatal hernia surgery.5,13,14

The clinical work-up of a patient being considered for hiatal hernia repair and antireflux surgery should include the following.

- A barium esophagram to assess the size of the hernia and the presence of axial or longitudinal rotation and strictures.
- An upper endoscopy to measure the distance from the GEJ to the crural impression (i.e., hernia size) and to thoroughly examine the mucosa. Any mucosal abnormalities should be biopsied.
- Esophageal manometry to assess motility. In the setting of severe motor dysfunction, we prefer to avoid a Collis if at all possible. This may lead to a decision to perform a partial wrap or in severe cases an esophagectomy or Roux-en-Y.
- 24 hour (or longer) pH study.
- Gastric emptying studies if clinically indicated, for example, redo cases or patients with diabetes.
- A computerized tomography scan can occasionally be helpful but is not routinely required prior to hiatal hernia surgery.

With the clinical information provided by the barium esophagram and endoscopy, the esophageal surgeon should be able to identify those patients at greatest risk for esophageal shortening and, accordingly, be prepared to perform esophageal-lengthening Collis gastroplasty if true esophageal shortening is present.

SURGERY

Positioning

The patient should be in a supine position, on a table capable of steep reverse Trendelenburg, with arms abducted.
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Technique

Our initial surgical technique for laparoscopic gastroplasty, as part of a hiatal hernia repair, was based on the original procedure used by Felix Steichen for open gastroplasties. This was later described laparoscopically by Champion and others for laparoscopic vertical banded gastroplasty. In that procedure, a large esophageal bougie is placed into the upper stomach alongside the lesser curvature, and an EEA stapler is used to create a “doughnut hole” in the upper stomach alongside the margin of the lesser curvature. After successful creation of the “doughnut hole,” a linear endostapler is positioned within the hole, next to the lesser curvature gastric margin and against the intraesophageal bougie. The stapler is fired in a cephalad direction to create the neoesophagus from the lesser curvature stomach tube (Fig. 6.3).

More recently, we have adopted the “wedge” gastroplasty approach (Fig. 6.4) which was used by Champion and described by Hunter and colleagues. This approach is easier to master and in most hands reduces the likelihood of staple-line leakage.

Operative steps for hiatal hernia repair and Collis gastroplasty using the wedge approach include the following:

- Hernia sac reduction and excision.
- Extensive mediastinal esophageal dissection with vagal nerve preservation (Fig. 6.1).
- GEJ fat pad dissection and evaluation of intra-abdominal esophageal length (Fig. 6.2). Intraoperative endoscopy can be of help to define the exact location of the GEJ. The anterior vagus nerve is dissected off the GEJ and proximal stomach. The intra-abdominal esophageal length is best determined after partial closure of the hiatus.
- Placement of a 48-French esophageal dilator along the lesser curvature.
- The tip of the fundus is retracted inferiorly to expose the greater curvature for stapler application (Fig. 6.5).
- The endoscopic GIA stapler is introduced through a left upper quadrant port (Fig. 6.6). The first staple line determines the appropriate level of transection of the greater curvature (Fig. 6.4, panel A and Fig. 6.7). A second and sometimes third staple line is applied to end snugly at the edge of the dilator (Fig. 6.8).
- The wedge is excised with a final staple line from a right upper quadrant port (Fig. 6.4, panel B and Fig. 6.9). This is easier to do with the hiatus partially closed, because it allows the tip of the stapler to enter the mediastinum.
- The Collis segment (neoesophagus) is approximately 2.5 cm in length (Fig. 6.4, panel C and Fig. 6.10).
The crural reapproximation can now be completed.

Nissen fundoplication over a 52- to 54-French dilator. This dilator is placed after removal of the 48-French dilator used earlier in the procedure. The uppermost stitch of the fundoplication should catch the wall of the distal true esophagus, so that the neoesophagus is entirely wrapped within the Nissen fundoplication (Fig. 6.10).

At the end of the procedure, the dilator is removed and a nasogastric tube is placed under direct vision.

Figure 6.4 Collis wedge gastroplasty.

Figure 6.5 Initial set-up for Collis gastroplasty. The arrow indicates the general direction of the 48-French dilator (along lesser curvature), the dashed line shows the greater curvature as it is being retracted inferiorly to allow for stapling. V, vagus nerve.
Figure 6.6 Stapler introduced through the left subcostal port. The arrow indicates the general direction of the 48-French dilator (along lesser curvature), the dashed line shows the greater curvature.

Figure 6.7 First staple line. The arrow indicates the general direction of the 48-French dilator (along lesser curvature), the dashed line shows the greater curvature.

Figure 6.8 Second staple line. The tip of the stapler is in close apposition to the dilator.
POSTOPERATIVE MANAGEMENT

In the immediate postoperative period, gastric decompression with a nasogastric tube should be continued until the first postoperative day. On the first postoperative day, it is prudent to obtain an esophagram to evaluate the integrity of the gastroplasty staple line. Any sign of patient toxicity or staple-line disruption on routine radiographic evaluation (i.e., pneumoperitoneum or pneumothorax) should signal the need for urgent consideration for laparoscopic or open surgical exploration.

Most patients can take sips of clear liquids on the first postoperative day and advance gradually to post-Nissen fundoplication dietary guidelines. Elderly patients with very large hiatal hernia and diabetic patients may develop gastric distension and should be carefully monitored for signs of gastric ileus through serial physical examinations and upright chest x-rays.

No uniform guidelines exist for outpatient follow-up of patients after the repair of a hiatal hernia with or without the use of an esophageal-lengthening procedure. However, it is clear that postoperative symptoms correlate poorly with objective abnormalities,
that recurrences tend to occur within the first 2 years after surgery (but may occur several years after the repair), and mucosal abnormalities such as Barrett’s metaplasia may resolve, persist, or progress on endoscopic and histologic examination.\textsuperscript{2,6,7,12,13} In view of these facts, patients should be followed routinely after the surgical repair of a hiatal hernia; suggested follow-up protocol includes the following.

- Validated symptom review every year for 5 years
- Anatomic evaluation (radiographic or endoscopic) every year for 5 years
- Patients with preoperative esophagitis, stricture, or Barrett’s esophagus should be endoscopically evaluated within a year of surgery
- Persistent or progressive esophageal mucosal abnormalities without anatomic recurrence should be evaluated with a pH study

It is not clear whether every patient with preoperative Barrett’s mucosal changes and a Collis gastroplasty should be treated postoperatively with proton pump inhibitors (PPIs).\textsuperscript{6} Generally, we follow these patients clinically and assess GERD symptoms or dyspepsia and liberally consider the use of a PPI since the gastric mucosa of the neoesophagus has acid secretory potential and the associated lack of motility within this gastric tube may affect refluxed acid clearance from the esophagus. Certainly, any patient with a normal postoperative anatomic evaluation and an abnormal postoperative pH study who is symptomatic or has documented Barrett’s esophageal mucosal changes should be treated with PPIs and followed serially. Radiofrequency ablation of metaplastic/dysplastic Barrett’s mucosa is another consideration when this situation exists.\textsuperscript{26}

**COMPLICATIONS**

The most important complication related to the Collis gastroplasty procedure with a Nissen fundoplication is a gastroplasty staple-line leak. In a large series of laparoscopic hiatal hernia repairs, 88\% of all leaks occurred in patients who had undergone Collis gastroplasty as part of their operative procedure (3.4\% in patients with Collis vs. 0.84\% in patients without Collis).\textsuperscript{8} In addition, dilation of the neoesophageal segment and pseudodiverticula of this adynamic gastric tube have been observed over time in a minority of patients. Placing the uppermost stitch of the fundoplication above the neoesophageal segment line so that it catches the wall of the distal true esophagus may prevent this complication, because the neoesophagus is completely wrapped in the fundoplication (Fig. 6.11).\textsuperscript{19} However, because one has little control over the final length

![Figure 6.11](image-url)  
*Figure 6.11* Correct positioning of a Nissen fundoplication around the neoesophagus. **A:** Appearance of the gastric fundus after wedge gastroplasty. **B:** Placement of fundoplication too low on the neoesophagus. **C:** Improper placement with a portion of the neoesophagus above the fundoplication permits progressive dilation of the neoesophagus over time creating the appearance of a “slipped” Nissen fundoplication. **D:** Correct position of the fundoplication with complete coverage of the gastric staple lines. The superior aspect of the fundoplication is at or above the neoesophagus when placed properly. (From: Van Heve CE, Hunter J, Perry K. Laparoscopic antireflux surgery: Esophageal lengthening procedures. In: Soper NJ, Swanson LL, Eubanks WS, eds. *Mastery of endoscopic and laparoscopic surgery*, 3rd ed. Philadelphia: Lippincott Williams & Wilkins, 2009.)
of the Collis segment, this may or may not be possible. But, again, it highlights the need to perform a complete esophageal mobilization to gain as much tension-free esophageal length as possible to minimize the length of the Collis segment or ideally to avoid a Collis gastroplasty altogether. Following all patients after antireflux surgery is important, but those with a Collis segment are particularly concerning because of the potential for ongoing acid exposure to the distal esophagus from the acid-secreting mucosa of the gastric tube.6,10

**RESULTS**

Results of laparoscopic repair of hiatal hernia with Collis gastroplasty are summarized in Table 6.1. Note that in many earlier series of laparoscopic Collis operations, the EEA approach for creating the Collis gastroplasty was used.3,8,18 The wedge gastroplasty approach has gained popularity and was the primary approach used in the report by Whitson et al.13 The overall incidence of recurrent hiatal hernia following a laparoscopic Collis gastroplasty ranges between 0% and 16%; in our experience, it is about 5% at 2 years. The variation in hernia recurrence between series largely has to do with how closely these patients are followed, the definition of a recurrence and the actual need for reoperation. In comparison, recurrence rates for transthoracic open repair of hiatal hernia with Collis gastroplasty range between 2% and 10%.10,11

**CONCLUSIONS**

Recognition of patients at risk for short esophagus is important for the surgeon considering hiatal hernia repair and fundoplication, particularly in patients with large hiatal hernias, reoperative antireflux surgery, Barrett’s esophagus, or peptic strictures. The important risk factors and preoperative work-up that aid in the identification of these patients have been discussed. The first key step when considering a Collis gastroplasty...
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is careful dissection of the GEJ fat pad to identify the exact location of the GEJ. Objective estimation of the intra-abdominal esophageal length following mediastinal dissection of the esophagus is the next important maneuver. If a foreshortened esophagus is identified, creation of a wedge-type Collis gastroplasty over a 48-French esophageal dilator appears to be a safe, expedient, and effective approach. A fundoplication that covers the Collis staple line and neoesophagus should be performed. Laparoscopic repair of hiatal hernia with Collis gastroplasty can lead to a low-recurrence rate of hiatal hernia and reduce symptomatic GERD. Patient satisfaction with the Collis gastroplasty and fundoplication can be excellent in patients appropriately selected for this procedure.

Recommended References and Readings

7 Open Collis Gastroplasty
Ankit Bharat and Bryan F. Meyers

Introduction
Postoperative hiatal herniation of a fundoplication performed to control medically recalcitrant gastroesophageal reflux disease (GERD) is a common cause of surgical failure and recurrent symptoms following antireflux surgery. It has been recommended that at least 2 to 3 cm of tension-free intra-abdominal esophageal length be obtained during repair of the hiatal hernia. This allows the fundoplication to be performed on tension-free intra-abdominal esophagus and reduce the chances of transdiaphragmatic wrap herniation after antireflux surgery. In most patients, extended mediastinal esophageal mobilization will enable an adequate length of intra-abdominal esophagus to be achieved. However, up to 10% of patients who undergo routine antireflux surgery may not have adequate intra-abdominal esophageal length, despite maximal mediastinal mobilization maneuvers, to create a tension-free intra-abdominal fundoplication.

A solution to this problem of a shortened esophagus was introduced by Leigh Collis in 1957. He described a gastroplasty technique that could lengthen the esophagus by creating a neoesophageal gastric tube. As was the general consensus of that era, Collis’s primary approach to hiatal hernias was limited to reducing the stomach into the abdomen and restoring a normal esophageal hiatal aperture. In the case of true short esophagus, this was not possible, so Collis created the gastroplasty to make a connecting tube that remained in the chest between the intrathoracic gastroesophageal mucosal junction and the body of the stomach, which could now be reduced into the abdomen before repair of the hiatal hernia (Fig. 7.1). A fundoplication was not performed and the esophageal pathology was approached through a left thoracoabdominal exposure.

Although hiatal hernia control was acceptable, medically recalcitrant GERD plagued many of the patients who underwent Collis’s original procedure. Subsequent surgeons reported their experience with the combination of Collis’s esophageal-lengthening procedure and fundoplication that resulted in both acceptable hiatal hernia management and control of GERD. These procedures were primarily performed through a thoracoabdominal or lateral thoracotomy approach. Today, the open approach to Collis gastroplasty can be performed through thoracotomy access or primary abdominal access using the technique for banded gastroplasty with cutting of the vertical staple line and by use of the wedge gastroplasty approach.
The absolute indication for performing a Collis gastroplasty is the presence of obvious esophageal shortening that prohibits reduction of the gastroesophageal junction into the abdomen without tension. This esophageal shortening is usually the result of transmural fibrosis and esophageal stricture related to chronic GERD injury. It is appreciated that at least 2 to 3 cm of distal esophagus within the abdominal cavity below the repair of a hiatal hernia is required to re-establish the normal intra-abdominal esophageal length estimated by radiographic studies and esophageal manometric analysis of normal subjects. Of course, this restoration of normal intra-abdominal length must be accomplished without tension to avoid recurrence of the hiatal hernia. The diaphragm contracts 30,000 times each day for respiration and the esophagus contracts 1,000 times a day for swallowing. Therefore, tension on the repair can lead to wrap herniation or disruption over time, and more importantly, any retching or sudden increase in intra-abdominal pressure can also increase the likelihood of hiatal hernia recurrence.

Standard antireflux procedures in cases of shortened esophagus are unlikely to achieve a sufficient tension-free length of intra-abdominal esophagus and consequently the likelihood of hiatal hernia recurrence, as with any other hernia, is increased. The primary issue is defining the true short esophagus. While some authors recommend the use of a Collis gastroplasty in all cases of reflux stricture due to the inherent tendency for esophageal shortening (Fig. 7.2), others have shown that good results can be obtained with dilation and standard antireflux procedures if the above criteria of 2 to 3 cm of tension-free intra-abdominal esophagus can be achieved. As described by Collis and others, many patients have only moderate esophageal shortening that can be treated by an extended mediastinal dissection and esophageal mobilization. O’Rourke et al. defined an esophageal mediastinal dissection less than 5 cm as type I and an esophageal mediastinal dissection greater than or equal to 5 cm as type II. While such nomenclature might help analyze surgical decision making and guide this discussion,

**INDICATIONS/CONTRAINDICATIONS**

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Relative indications for performing a Collis gastroplasty include situations associated with increased risk of recurrence following antireflux surgery, for example, a large hiatal hernia, a failed prior antireflux procedure, or morbid obesity, which is associated with increased intra-abdominal pressure after hiatal hernia repair. \textsuperscript{18–20} Collis gastroplasty should be avoided in patients with severe inflammatory conditions of the stomach that increase the risk of staple-line failure and leak.

**PREOPERATIVE PLANNING**

Preoperative assessment of esophageal shortening can be challenging. Conditions in which esophageal shortening is likely to occur include fibrotic strictures, ulceration with dense periesophageal fibrosis, large or fixed hiatal hernias with dense adhesions around the sac and following failed prior antireflux procedures, particularly where there is proximal migration of the gastroesophageal junction into the chest. The presence of a large paraesophageal hiatal hernia is also considered by some to be highly predictive of the presence of short esophagus. \textsuperscript{20–22} Urbach et al. reported a 4.5-fold increased use of gastroplasty in their experience when the surgery was performed for paraesophageal hernia, 4.3-fold increase in the setting of Barrett’s esophagus, and 11.6-fold likelihood of gastroplasty during “redo” surgery. \textsuperscript{23} Of course, this is not necessarily the experience of other skilled esophageal surgeons. However, Urbach’s work does give us some direction as to which patients may have anatomic changes suggestive of esophageal shortening where gastroplasty may be considered. It is also important to realize that no preoperative assessment can provide information about the degree of elasticity or fibrosis of the esophagus. Therefore, the decision to perform a gastroplasty is an intraoperative decision based on all the factors mentioned above and ultimately,
the intraoperative estimate of an adequate length of intra-abdominal distal esophagus for tension-free hiatal hernia repair and fundoplication.\textsuperscript{23}

The preoperative modalities available to assess the likelihood that esophageal shortening will require a Collis gastroplasty include barium contrast studies, endoscopy, manometry, and cross-sectional radiographic imaging. The following findings have been associated with the presence of short esophagus.

- Larger (>5 cm) nonreducing hiatal hernia indicates long-standing disease with associated mediastinal scarring and shortened esophagus. This can be assessed on contrast swallow or cross-sectional radiographic imaging.
- Esophageal stricture that suggests transmural inflammation and mediastinal scarring. Strictures can be diagnosed on contrast swallow as well as upper endoscopy.
- Barrett's esophagus is most commonly associated with a hiatal hernia and is a marker of long-standing GERD. Although this is not an independent factor associated with esophageal shortening, the presence of Barrett's esophagus is commonly seen in the large hiatal hernia (>5 cm length) and peptic stricture setting.
- Lower esophageal sphincter (LES) at 35 cm or less from the incisors as assessed using upper endoscopy or manometry in an adult male of average height. The normal esophageal (LES) location is around 40 cm from the upper incisors.
- The LES is normally seen within the positive pressure swings with respiration seen with an intra-abdominal location of the LES. If the LES is noted in a negative pressure swing environment of the thoracic cavity on manometric evaluation, this suggests that the LES is in a shortened circumstance. Of course, these manometric findings must be correlated with barium esophagram and endoscopic findings suggestive of hiatal hernia.

### Transabdominal Collis Gastroplasty

Collis gastroplasty is performed as one component of the primary procedure used to correct a hiatal hernia and control of gastroesophageal reflux. Occasionally, an open gastroplasty via an abdominal approach is required. This is relatively rare and is done when the primary esophageal procedure is being approached through laparotomy, for example, in patients who have had multiple prior laparotomies, multiple prior antireflux procedures, or who are undergoing another unrelated open abdominal procedure.

Intraoperative endoscopy following esophageal mobilization is strongly advised for the assessment of shortened esophagus.\textsuperscript{5,24} After completing the hiatal and mediastinal dissections, we routinely perform endoscopy to assess adequate intra-abdominal length of the esophagus. The gastric folds provide a good anatomic landmark of the GE junction as they are normally located at or a few millimeters below the Z-line.\textsuperscript{24} After the endoscope is passed into the gastric fundus, the point of passage between the tubular esophagus and the stomach is recognized by means of transillumination or by palpating the tip of the scope. The distance between the hiatus and GE junction is estimated. A stitch is placed on the GE junction to mark it and to facilitate subsequent Collis gastroplasty and antireflux wrap calibrations.

If a diagnosis of shortened esophagus is made after adequate transhiatal mediastinal mobilization, we will make the decision to perform the Collis gastroplasty. The orogastric tube is removed, and a 48- to 52-French bougie is advanced down the esophagus into the stomach carefully with manual assistance by the surgeon. We always perform the gastroplasty after placing a bougie to avoid esophageal narrowing. Open gastroplasty can be performed using the technique of EEA circular stapler or wedge gastroplasty, although we prefer to use wedge gastroplasty due to the complications associated with the EEA technique.

To accomplish the wedge gastroplasty, an angulating linear stapler with a thick tissue load is introduced. The assistant retracts the fundus of the stomach inferiorly and slightly...
to the patient’s left, thereby pulling the lesser curve against the bougie. The stapler is directed perpendicular to the long axis of the planned neoesophageal segment, aiming the tip of the stapler to the planned distal end of the gastroplasty (Fig. 7.3). The assistant retracting the stomach should manipulate the top edge of the greater curve into the stapler jaw, and then retract the stomach inferiorly thereby withdrawing as much of the greater curve out of the stapler to avoid excessive resection of the fundus. It is important that the greater curvature be the portion of the stomach most deeply into the jaws of the stapler. It is easy to create an oblique bite of the stomach if careful attention is not paid to this point. The tip of the stapler is carefully advanced to fit snugly against the intraluminal bougie and fired to create a transverse stapled resection line. It is important that the bougie is reached with the final firing, and this is assured when the dilator is pushed away when closing the stapler. The second staple line is completed longitudinally with the stapler aimed toward the mediastinum while applied firmly against the bougie. It is crucial that the assistant place gentle lateral traction on the wedge of stomach to be removed during the second staple-line firing. The stapler is fired once or twice to produce a stapled wedge of stomach. The two stapled resection lines result in a small triangular wedge resection of the stomach at the angle of His, effectively lengthening the intra-abdominal esophagus by length of the upward directed staple line. Since the neoesophagus is aperistaltic, it is advisable to limit this length as much as possible. The bougie is then removed and an orogastric tube can be passed back so that the tip is in the proximal stomach.

Some authors have suggested that the distal esophagus and proximal stomach can be filled with 250 mL dilute methylene blue to test the staple line and establish that there is no leak. We skip this step and have not regretted doing so. The senior author of this chapter is aware of two leaks after Collis gastroplasty procedures in 15 years: Both were associated with necrosis of the Collis segment and neither would have likely demonstrated any leakage immediately after their creation.

As previously mentioned, gastroplasty using the circular stapler has fallen out of use completely at our center as well as most other centers. We only use the wedge gastroplasty technique to perform esophageal lengthening due to the reasons described before. After the Collis gastroplasty, we complete the operation by reconstructing the esophageal hiatus and creating the antireflux wrap. The details of the subsequent crural closure and antireflux wrap are covered by other authors in this text.

**Transthoracic Collis Gastroplasty**

The transthoracic approach to Collis gastroplasty was commonly performed until the advent of laparoscopic fundoplication. There are still several circumstances when an open

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**Figure 7.3** Wedge Gastroplasty A: Surgeon’s left hand lifts the gastric cardia with a grasper and the assistant grasps the greater curvature and gives a downward and lateral traction. A linear stapler is placed so that it approximates the bougie in the esophagus. B: After the initial firing of the stapler, the wedge gastroplasty is completed by one or two additionalfirings parallel to the bougie. B indicates location of the bougie in the esophagus. (A laparoscopic Collis gastroplasty is depicted; the same principles apply when performing open transabdominal Collis gastroplasty).
Thoracotomy approach for hernia repair, Collis gastroplasty, and fundoplication is a reasonable surgical option. For example, after a prior transabdominal antireflux surgery, the herniated portion of stomach may not be accessible via an abdominal approach due to adhesions. In other patients, the transthoracic approach may be preferred for improved visualization of the esophageal pathology due to excessive obesity. Similarly, some esophageal surgeons prefer the transthoracic approach for the correction of large paraesophageal hernias. In any case, the transthoracic approach to Collis gastroplasty can be more straightforward than the transabdominal and laparoscopic approaches for the procedure.

- The thoracotomy incision is usually at the seventh interspace with the eighth rib shingled posteriorly to increase the rib mobility during retraction to achieve intrathoracic exposure of the esophageal pathology.
- The inferior pulmonary ligament is incised which allows visualization of the hiatal hernia contents and distal esophagus in the posterior mediastinum.
- The hernia sac is opened and the stomach and esophagus mobilized to identify the shortened GE junction. The gastroesophageal fat pad is dissected off the stomach with care taken to preserve the vagus nerves.
- A 48- to 54-French bougie is passed through the esophagus, the GE junction and verified manually within the intra-abdominal esophagus (Fig. 7.4A).
- With the bougie in place, a linear stapler is placed adjacent to the bougie while the bougie is firmly pressed against the lesser curvature of the stomach (Fig. 7.4B). The stapler is fired, typically creating a staple line of 3 to 5 cm in length. No resection of tissue is required as the wedge gastroplasty described in the abdominal procedure is merely a method to allow the gastroplasty to be created toward the angle of His as opposed to away from it.
- Once the staple line is completed, an antireflux wrap is formed and the chest closed. Some authors advocate oversewing the staple line with absorbable suture (Fig. 7.4C) but we have not had problems with staple-line leaks and do not perform this step routinely.

**Type of Fundoplication Performed with the Collis Gastroplasty**

The Collis gastroplasty has been combined with many fundoplication procedures. Typically a standard 360-degree, Nissen fundoplication or a 270-degree, partial, Toupet fundoplication is constructed when the procedure is approached through the abdomen, as described in Chapter 3. The Belsey partial fundoplication (described in Chapter 5) or the standard Nissen fundoplication (described in Chapter 4) is constructed when using a thoracotomy approach (Fig. 7.5). One controversial point is that a complete 360-degree Nissen wrap over the aperistaltic neoesophagus may be prone to cause postoperative dysphagia, especially since many of these patients may already have had esophageal dysmotility disorders. The partial, 270-degree, Toupet wrap, on the other hand, may be less effective in controlling reflux symptoms. There are no good clinical trials comparing complete and partial wraps after Collis gastroplasty.

**POSTOPERATIVE MANAGEMENT**

The immediate postoperative management is influenced by the surgical approach, namely, abdominal or chest. We obtain a contrast swallow on the first postoperative day and then feed a full liquid diet if the study is normal. The information that we seek from the swallow evaluation includes the integrity of the wrap, whether there is edema leading to contrast retention in the esophagus, gastric transit time that might be delayed in case of vagus nerve injury and any evidence of leak. The patients are typically discharged on a full liquid diet for 3 to 4 weeks, after which we expect the swelling at the wrap site to have resolved and the patients to better tolerate solid food. If the hiatal dissection was tedious or if there was some other reason for not feeding...
Figure 7.4 Transthoracic Collis Gastroplasty. A: The esophagus is encircled and a bougie inserted. The gastric fundus is retracted superiorly using atraumatic clamps. B: Neoesophagus is created using a stapler, making sure that the stapler is parallel to the bougie. C: The suture can be oversewn using absorbable suture material.

Figure 7.5 The combined Collis-Nissen as described by Orringer. Placement of the gastric fundus around the gastroplasty tube and construction of the fundoplication. Inset A shows the 3-cm long fundoplication. Inset B shows the fundoplication reduced beneath the diaphragm. (From: Stirling MC, Orringer MB. The combined Collis-Nissen operation for esophageal reflux strictures. Ann Thorac Surg 1988;45(2):148–157, with permission).
the patient, for example, tenuous respiratory status, we occasionally delay the swallow evaluation until the patient is deemed ready for oral feeding.

**COMPLICATIONS**

Collis gastroplasty allows a more durable hiatal hernia repair and antireflux procedure by eliminating tension in the setting of short esophagus and also allows for the performance of the fundoplication around a healthy segment of neoesophagus that accepts fundoplication sutures more readily than an inflamed or a fibrosed esophagus. However, the more liberal extension of Collis gastroplasty to patients with less complicated forms of GERD needs to be considered very cautiously, weighing the potential complications of the procedure.\(^25,26\) Complications include the suture-line leaks, suture-line fistula, and consequences associated with the gastric mucosa of the neoesophagus. The construction of the neoesophagus leads to a relatively adynamic distal segment that may result in dysphagia. This can be more profound in patients with considerable esophageal dysmotility, those with a longer than average gastroplasty and those given a full Nissen wrap. Second, because the neoesophagus contains gastric mucosa, in effect it produces an iatrogenic Barrett’s columnar-lined esophagus that may result in acid production inside the esophagus. This may be relevant to the incidence of postoperative esophageal inflammation. Lin et al. reported that recurrent erosive esophagitis due to pathologic acid exposure was found in over 80% of patients who underwent Collis gastroplasty. Nevertheless, 65% of patients with recurrent hiatal hernias reported significant symptomatic improvement after Collis gastroplasty and repair of the hernia. It is therefore advised that patients undergo subsequent follow-up with objective testing and be placed on proton pump inhibitors if there is an abnormal acid exposure. For these reasons, some experts advocate the use of a Collis gastroplasty only when absolutely indicated for significant esophageal shortening consequent to severe forms of reflux stricture or ulceration with peri-esophageal fibrosis.

**RESULTS**

Large original series of Collis gastroplasty with antireflux procedures have been published by Pearson and Henderson,\(^19\) Stirling and Orringer,\(^18\) and Henderson.\(^27\) The series published by Pearson included 430 patients who underwent Collis gastroplasty in conjunction with a Belsey antireflux wrap. In this series about 50% of the patients had dilatable stricture treated surgically. The remaining subjects included patients with severe ulcerative esophagitis, failed prior antireflux procedures, large, fixed hiatal hernias and patients with severe esophageal dysmotility. Overall, satisfactory results were obtained in over 80% of the patients. Patients with a stricture but with neither a motility disorder nor previous surgery did better than those who had either or both of these complicating conditions. Five patients developed adenocarcinoma up to 7 years after surgery. Stirling and Orringer,\(^18\) and Henderson,\(^27\) both reported a high recurrent reflux rate of 30% following the Collis–Belsey procedure and advocated the use of Nissen fundoplication in combination with Collis gastroplasty. In the series of 353 Collis–Nissen procedures reported by Stirling and Orringer,\(^18\) patients with reflux strictures comprised 20% of the patients, and a majority of the patients were believed to be at high risk for recurrence due to the presence of a hiatal hernia, dysmotility, marked obesity, or having undergone a previous unsuccessful hiatal hernia repair. This series demonstrated good symptomatic and objective improvement in 90% of cases. In this series, 10% of patients required revisional surgery for recurrent reflux and 17% required dilation for dysphagia. The Henderson series included 601 Collis–Nissen procedures, 250 of which were performed transabdominally in patients who had not undergone previous surgery.\(^27\) Patients with reflux strictures comprised 10% of the series and half of these patients had esophageal shortening. Overall, good symptomatic results were shown in 93%
of patients while 88% of patients with strictures had good results. Avoidance of post-thoracotomy pain proved to be an advantage of performing the procedures transabdominally.

**CONCLUSIONS**

Collis gastroplasty remains a useful technique augmenting hiatal hernia repair and antireflux surgery in patients with shortened esophagus. The addition of the esophageal-lengthening Collis gastroplasty may improve the durability of the repair by reducing tension in the surgical repair and fundoplication. Several modifications have been proposed following the original description and presently the technique of stapled wedge gastroplasty through the laparoscopic approach has become the most popular. Collis gastroplasty is not without long-term sequelae and therefore it should be carefully selected on a case by case basis and careful attention should be paid to the technical details of this procedure.

**Recommended References and Readings**

Reoperative Antireflux Surgery
Omar Awais, Arjun Pennathur, and James D. Luketich

Introduction

The majority of patients with gastroesophageal reflux disease (GERD) are managed medically; however, in a subset of patients, antireflux surgery is necessary for intractable GERD. Since the first laparoscopic Nissen fundoplication was performed in 1991, minimally invasive antireflux surgery has been widely accepted as the “gold standard” operation for intractable GERD. Prior to laparoscopic operations, open operations were the standard for these patients and the reported failure rates for open fundoplication ranged from 9% to 30%.1–3 Laparoscopic failure rates have been similar and range from 2% to 17%.4,5 Although some patients with recurrent symptoms after antireflux surgery can be managed medically, it is estimated that 3% to 6% of post-Nissen patients will require reoperative antireflux surgery.6 In experienced centers, many claim that first-time antireflux surgery is successful in over 90% of patients.7 While the exact success rate varies from center to center and surgeon to surgeon, all agree that the success rates for reoperative antireflux surgery performed either open or laparoscopically do not measure up to that of the first-time operation. Historically, with open antireflux surgery, satisfactory results have been reported in 84% of patients who have undergone reoperative antireflux surgery and in only 42% of patients who have undergone three or more antireflux operations.1 It is clear that in some patients, especially those that have undergone multiple redo operations on the esophagus and remain markedly symptomatic, an esophagectomy may be the only viable option; however, in the majority of patients with benign esophageal disease, the first goal is esophageal preservation. There are several options for the patient who remains symptomatic after antireflux surgery including redo fundoplication (partial or complete), the addition of a Collis gastroplasty, Roux-en-Y (RNY) near esophagojejunostomy, which is particularly applicable in obese patients, jejunal or colon interposition, and finally esophagectomy. After seeing many different approaches to redo antireflux surgery, it is clear to us that the redo procedure is unlikely to be a simple operation that can be successful by removing one or two sutures, or simply “tightening up the wrap.”
Reoperative antireflux surgery is a complex operation, and the success of the operation is strongly correlated with the surgeon’s experience, the patient’s symptom complex, and the findings of detailed objective tests. Performance of the surgery by an inexperienced surgeon will increase the chances of a suboptimal result and the best shot at successful redo antireflux surgery is a first redo in experienced hands. Another important consideration is poor correlation between objective tests and clinical symptoms, which should raise concern when considering redo surgery. For example, if the original indications for surgery were unclear, such as a cough in the setting of a normal pH study and no evidence of a hiatal hernia, additional workup may be needed before considering a redo operation. However, obvious symptoms, such as dysphagia, dumping syndrome, excessive nausea, and chest pain, that were not present prior to the original antireflux operation and are now recalcitrant to medical therapy will frequently need reoperation, depending on the severity.

Failure of antireflux surgery can have numerous etiologies including misdiagnosis prior to the initial operation. Thus, one of the first steps when evaluating these patients is a thorough review of the history and testing performed prior to the original operation. If these considerations are in order, a failure of the original antireflux operation can be due to technical problems during the first operation, or later breakdown of the wrap. A hiatal hernia after antireflux surgery may be due to poor hiatal closure, delayed reherniation, or placement of the wrap on the tubularized cardia due to an unrecognized short esophagus. The cause of symptoms such as recurrent heartburn, regurgitation, and dysphagia should be thoroughly investigated with a barium esophagogram and esophageal physiology testing. Factors such as the type of symptoms (heartburn vs. dysphagia), the status of esophageal motor function, the number of prior antireflux operations, and the patient’s body mass index (BMI) should be strongly considered when counseling patients regarding the options when symptomatic after initial antireflux surgery.

For example, a patient with recurrent or persistent heartburn who has failed optimal medical therapy and with a positive DeMeester score, a barium swallow that demonstrates a recurrent or persistent hiatal hernia, reasonable peristalsis, a normal-range BMI, and a single prior antireflux operation should be considered an ideal patient for a redo fundoplication by an experienced esophageal surgeon. In our experience, many of these redo fundoplications can be performed laparoscopically. Again, it is important to stress that these cases should be performed by an experienced esophageal surgeon who is comfortable with advanced minimally invasive procedures.

Reoperation may be more complex in patients with some of the following characteristics.

- Morbid obesity
- Esophageal dysmotility
- Multiple prior antireflux procedures

In the setting of morbid obesity and the comorbidities of obesity, a patient with a failed antireflux surgery may be the ideal patient for an RNY. If an RNY is determined to be a reasonable option, then a full workup for bariatric surgery should be pursued. This might include nutritional counseling, psychiatric evaluation, attendance at a support group meeting, and review of all the implications regarding quality of life (QOL) and the range of potential complications. If the RNY is decided upon, the surgeon should be experienced in both advanced laparoscopic antireflux surgery and gastric bypass techniques. In some cases, this might be best accomplished by consultation with an established esophageal surgeon working with an experienced bariatric surgeon to deliver the best care for these complicated patients. Sound judgment is needed for all patients who undergo reoperative antireflux surgery and the more complex the case, the more experience is needed. In patients with a severely diseased esophagus, such as severe dysmotility, nondilatable strictures, multiple prior operations, and significant gastroparesis, an esophagectomy may be the best option.
In summary, the following two general groups of patients should be considered for reoperative antireflux surgery.

1. Those with intractable recurrent or persistent GERD symptoms after prior antireflux surgery.
2. Those with intractable symptoms (e.g., dysphagia, nausea, gas bloat, or pain) that began after the initial antireflux operation, persisted, and did not respond to conservative measures.

### PREOPERATIVE PLANNING

The workup of a patient who presents with recurrent symptoms after a prior antireflux surgery is initiated with a detailed history of the evolution of symptoms. It is important to evaluate the original symptoms prior to the first operation, the response to medical therapy, and the findings of prior testing. This may identify an esophageal motility disorder that may have been missed or an incorrect indication for the original operation. You may also identify a number of potential warning signs that may have been overlooked and present serious obstacles to successful antireflux surgery including the following.

- The presence of severe constipation that has not been resolved
- Chronic opiate usage, medically controlled or otherwise
- Atypical GERD symptoms with poor correlation with objective tests, such as a chronic cough with a normal DeMeester study
- Poor esophageal motility
- Morbid obesity with comorbidities
- Irritable bowel syndromes

The presence of any one of these clinical entities may limit the success of what appears to be a technically sound antireflux operation. Of course, failure can occur in any setting if the technical approach was initially poor, or has changed in an unfavorable way since the initial operation, due to reherniation, crural breakdown, etc.

A detailed review of the original operative report focusing on esophageal mobilization, vagal preservation, division of the short gastric vessels, and crural repair (primarily or with mesh) should give further insight into the technical causes of failure of the prior antireflux operation. Symptomatic improvement or lack of relief after the original repair should be carefully assessed. In addition, it is important to determine if there was a change in the patient’s symptoms (e.g., heartburn before the operation but dysphagia afterward) and the exact timing of the return of symptoms.

In addition to a detailed history, a detailed physical examination, and a careful review of the prior operative notes, it is essential to obtain a barium esophagogram as one of the first steps in the workup of the symptomatic patient after antireflux surgery. This simple and inexpensive test is universally available and is extremely useful in defining the anatomy, and identifying the presence of a persistent or recurrent hiatal hernia, a paraesophageal hernia, a tight or twisted wrap with or without herniation, or a specific pattern of failure of the prior fundoplication. In some cases, the barium swallow may be all you need prior to reoperative surgery. In some cases, the esophagastroduodenoscopy (EGD) may allow the surgeon to define one of the classic patterns of failure. There are many ways that a prior antireflux operation can fail; these have been summarized previously and include crural disruption, transdiaphragmatic herniation of the fundoplication, breakdown of the fundoplication, slipped or misplaced Nissen, misdiagnosis of achalasia, loose fundoplication, or tight fundoplication.

Upper endoscopy permits direct visualization of the mucosa with complete evaluation of the esophagus, stomach, duodenum, and the fundoplication. The finding of esophagitis or esophageal stricture may contribute to the evaluation. Biopsies can be performed to evaluate for cancer and/or Barrett’s esophagus. Detailed evaluation of the...
fundoplication and hiatal anatomy will further give insight into the likely cause of failure. Frequently, one can identify subtle recurrent hiatal hernias, failure of the classic “stack of coins” on retroflex view, or a wrap that is simply too tight or too loose.

Repeat pH monitoring is helpful when primary symptoms are heartburn-related; however, it is clear that some patients may have a normal pH study and still have marked symptoms from a twisted wrap, too tight of a wrap, or a completely herniated and partially obstructing wrap. A repeat manometry is important in the workup of the patient with a failed Nissen, even if the prior manometry was normal, but is especially helpful in patients with predominant symptoms of dysphagia. Intractable bloating or gastroparesis may indicate vagal nerve compromise and gastric emptying studies may help in planning the best approach. All of these studies are very valuable in identifying the cause of the patient’s symptoms and help the surgeon tailor the best redo operation for the patient.11,14,15 After completion of all comprehensive testing, the surgeon and the patient discuss the findings and determine the best course of action, which may include continuation of medical therapy, redo fundoplication, conversion to an RNY, or esophagectomy or colon interposition. Factors to consider in determining the best course of action will depend on the dominant clinical symptoms (i.e., heartburn or dysphagia), baseline esophageal function on physiology testing, number and success of the prior antireflux operations, evidence of gastroparesis, and the patient’s BMI. A number of warning signs were listed earlier and must be considered prior to reoperation.

One example of a warning sign that may have been overlooked and may present serious obstacles to successful antireflux surgery is chronic constipation due to bowel abnormalities or simply due to chronic opiate usage. In this setting, one can anticipate extremes of gas bloating and recurrent GERD due to extremely poor downstream peristalsis. In some cases, simply resolving the chronic constipation can go a long way to improving symptoms of bloat, gas, and in some cases even typical GERD symptoms. Thus, in all patients with constipation, we first work on a bowel regimen that normalizes bowel movements. Consultation with an experienced gastroenterologist is essential to resolve these issues prior to surgery. We consider chronic opiate usage a very serious warning sign that a simple Nissen may be technically adequate but postoperatively, the patient may be troubled by excessive gas, bloat, abdominal cramps, nausea, and failure to reach a satisfactory resolution of GERD symptoms. In this setting, we give strong consideration to the possibility of first working on a satisfactory bowel regimen, then reassessing the patient to see if indeed some of the GERD symptoms have resolved. We have seen many cases where a patient troubled by GERD and on chronic opiates with severe constipation is managed with a successful bowel regimen, and the GERD symptoms markedly improve. This is becoming an increasingly familiar clinical problem, and the Drug Enforcement Agency (DEA) has noted a clear epidemic of the legal use and abuse of prescription narcotics and has estimated that the prescribing of narcotics in the United States has increased over 600% in the past decade.16 In some of these patients, aggressive proton pump inhibitor (PPI) use, bowel regimens to control constipation, or working with the patient and the pain clinic to lower or completely eliminate the opiates, if possible, may resolve the GERD symptoms.

In summary, assessment of patients with failed fundoplication contains the following steps.
- A detailed history and physical examination with review of all prior testing and records.
- A comprehensive evaluation that includes an endoscopy and a barium esophagram, and frequently manometry, pH testing, and gastric emptying studies.
- Establishing a correlation between clinical symptoms and objective testing to tailor an appropriate redo operation.

Esophageal-preserving surgical options for redo antireflux surgery include redo fundoplication (partial or complete) and RNY. To provide the best outcome, an individualized approach based on the cause of fundoplication failure, the overall esophageal motility, and
the patient’s BMI is necessary. As a last resort, an esophagectomy or a colon interposition may be the only viable option. Operative technique for redo fundoplication and RNY will be discussed.

Key factors to consider when selecting the type of operative approach include the following.

- Redo fundoplication is ideal for a first-time redo in patients who have preserved esophageal function, an obvious anatomic wrap failure, objective evidence of recurrent reflux, and who are not obese.
- RNY should be considered in obese patients with recurrent symptoms and multiple comorbidities.
- For very complex settings, such as patients with multiple failed redo operations, poor esophageal motility, and associated gastroparesis, going straight to minimally invasive esophagectomy with a high intrathoracic anastomosis and narrow gastric tube may be considered.

Positioning

Once the patient is under general anesthesia, an arterial line, a Foley catheter, and adequate intravenous access are placed. The patient is placed supine in reverse Trendelenburg position with his or her arms out. In anticipation for a long operative case, all pressure points need to be padded.

Operative Technique for Redo Fundoplication

The principles of reoperative antireflux surgery, whether minimally invasive or open, are the same. The focus should be on first carefully assessing the existing anatomy, reestablishing the normal anatomy (step by step), preserving vagal integrity, preserving crural integrity if possible, looking for and recognizing a short esophagus and performing an esophageal-lengthening procedure when necessary, identifying the need for crural reinforcement, and properly constructing the fundoplication. The operation should be performed at a center with extensive experience in reoperative esophageal surgery.

- On-table endoscopy is performed to evaluate the esophagus, the stomach, and the fundoplication. An assessment of the mucosa is essential to rule out the presence of Barrett’s esophagus or neoplasm that might change the operative plan.
- The abdomen is prepped and draped, and the initial port is placed away from prior incisions via a cut-down technique to allow safe entry into the abdomen. In most cases, we are able to perform laparoscopic lysis of adhesions to allow the remaining ports to be placed under direct visualization. However, the surgeon should not hesitate to open the abdomen, if needed, at any time.
- The upper abdomen is explored and additional lysis of adhesions is performed to free the liver from the prior fundoplication. The caudate lobe of the liver is identified, which will allow the surgeon to recognize the right crus. Right and left crural mobilization is performed from the liver and the spleen, respectively, paying particular attention to preserving the integrity of the crus.
- Frequently, it is necessary to go from side to side, moving from areas of recognizable anatomy, and into more difficult areas carefully. We frequently first work a little lower on the crus muscle and identify normal planes and carefully move up the crus.
- Once the crura have been identified, we attempt to remove crural sutures and open the posterior mediastinum.
- Next, we carefully work along the crural planes laterally into the mediastinum, attempting to avoid injury to the vagus nerves, and avoid entering the pleura. Early entry into the pleura may necessitate placing a pigtail catheter into the respective pleural space. As we move into the mediastinum, we can frequently see the esophagus and vagus nerves proximally. We carefully continue this plane of dissection and then begin to move anteriorly.
As one moves either anteriorly or posteriorly, care must be taken to preserve vagal integrity. We avoid going directly between the two limbs of the wrap in the initial phases of the reoperation as the vagus nerves are particularly at risk early in the reoperation before the anatomy is identified.

- Sharp dissection with the ultrasonic shears or other device will provide a relatively bloodless field allowing safe recognition of important structures.

- At any point in the operation, where progress is not safe, we will move to another area and reassess there. For example, assessing slightly lower on the greater curvature of the stomach and taking down the short gastric vessels and dissecting up toward the left crus from below can be a rewarding plane in some cases.

- As we work on the right or left crus, knowledge of the operative steps during the initial operation(s) is essential. Knowing if the vagal nerves were left inside the wrap (as in most cases) or outside the wrap or if mentioned at all can be helpful.

- If the wrap was tacked to the right and left crus, it is very easy to inadvertently enter the stomach. Again, we frequently go back and forth from the right crus to the left, looking for areas of safe progress. Once we have some identification of the stomach and wrap limbs, we generally start on the left limb of the wrap and gently work inside of this, sweeping any fat or tissue centrally, assuming the anterior vagus is between the suture limbs of the wrap. As this is done, removal of fundoplication sutures can safely be done from just on the undersurface of the wrap on the left, thereby preserving the anterior vagal trunk. Once this is done, one can frequently pick up the right limb of the wrap, sweep inside of this, and gently clear the esophageal side of the wrap until both limbs of the gastric wrap are mobilized.

- Once both limbs are mobilized completely, the wrap is freed completely from the right and posterior crus and tucked back under the esophagus into its normal anatomical location.

- If we can pick up the fundic tip and it lifts easily and completely, then we consider that near-normal anatomy is reestablished. At this point, we completely remove the fat pad, starting from the angle of His and moving from the left crus side toward the right. We avoid the anterior vagus and identify the true esophageal wall as it meets the stomach.

- Next, we completely mobilize the esophagus into the mediastinum and assess the esophageal length to determine if it is adequate. Ideally, 2.5 to 3 cm of tension-free intra-abdominal esophageal length should be established. If we do not have this length, we first attempt to mobilize the esophagus more proximally to gain additional length. If the esophagus is still short, a Collis gastroplasty should be strongly considered. Collis gastroplasty can be performed with a bougie in the esophagus, using a circular end-to-end anastomotic (EEA) technique (Fig. 8.1), but is more commonly performed with a wedge gastroplasty (Fig. 8.2).

- An on-table endoscopy is again performed to evaluate any inadvertent esophageal or gastric perforations. It is very easy to miss a small gastric enterotomy, and these injuries should be repaired before performing a fundoplication. If there is extensive damage to the gastroesophageal junction or the fundus, such that repair or a safe fundoplication cannot be constructed, a different surgical option, such as RNY or esophagectomy, should be considered. We always discuss these extreme situations with the redo patient before operation and the consent indicates these other options as “possible.”

- If performing a complete wrap, we do a floppy, two-stitch fundoplication on the esophagus over a 52 to 56 F bougie or on the neoesophagus if a Collis gastroplasty was performed. (Fig. 8.3). It is essential to deliver the fundus with proper orientation in an untwisted, nonspiraled fashion, as assessed by the “shoe-shine” maneuver.

- For patients with severe dysmotility or significant dysphagia, a partial wrap (Dor or Toupet) may be considered. In rare circumstances, in the setting of a very tight wrap that led to long-standing dysphagia, manometry testing may suggest pseudoachalasia. In these unusual cases, a distal myotomy may be needed in addition to converting the wrap to a partial fundoplication.

- The crural repair completes the operation. The crura are approximated posteriorly with permanent suture. It is important to completely mobilize the right and left crura of the liver and the splenic attachments to allow tension-free primary closure. If the
Figure 8.1 Collis gastroplasty performed with a transgastric EEA followed by a linear stapler. **A–C:** Anvil positioning of the EEA stapler. **D:** Creation of the neoesophagus with an Endo GIA stapler.
integrity of the crura is compromised or a tension-free closure cannot be achieved despite all efforts (e.g., inducing a left-side pneumothorax or lowering intra-abdominal pressure during laparoscopy), a biologic mesh should be used to reinforce the crural repair. Nonabsorbable mesh should be avoided at all costs due to the concern of delayed erosion into the esophagus.

The operation is concluded with the placement of nasogastric tube and closure of all incisions.

Figure 8.2 Collis wedge gastroplasty.

Figure 8.3 Completed Nissen fundoplication. The wrap is tension-free and subdiaphragmatic with proper orientation.
Operative Technique for Roux-en-Y Near Esophagojejunostomy

- RNY can be performed either laparoscopically\(^{10}\) or via an open technique. For laparoscopic RNY, the initial port placement, lysis of adhesions and dissection to establish normal anatomy is the identical to that described above for redo fundoplication.
- Once normal anatomy has been established, a small gastric pouch is constructed with linear stapling devices from the cardia just beyond the GE junction.
- We have used two options for laparoscopic gastrojejunostomy. One is to perform an end-of-stomach pouch to the side of the jejunum anastomosis. To accomplish this, we insert a 25- or 28-mm anvil into the pouch of stomach and secure with a purse-string stitch.
- Next, the crus is approximated posteriorly, as noted above, to close the diaphragmatic hiatus.
- Attention is directed toward the ligament of Treitz and we divide the jejunum approximately 40 cm from the ligament of Treitz, using care to first ensure that we have chosen a relatively mobile area of the jejunal mesentery. We then measure down 75 to 100 cm on the distal side of the divided jejunum to create a Roux limb. This limb is delivered in a retrocolic and retrogastric manner and an end-to-side gastrojejunostomy is performed with the EEA.
- Alternatively, one may use a side-to-side stapled gastrojejunostomy. We use an endo-GIA to perform this and then close the opening with an inverting Connell stitch. An on-table endoscopy is performed to test for a leak.
- Intestinal continuity is reestablished by constructing a jejunoojejunostomy between the proximal ends of the divided jejunum at the 40-cm mark from the ligament of Treitz and performing a side-to-side jejunostomy between the proximal jejunum and 75 to 100 cm down the Roux limb using a 60-mm linear stapler. Again, we close the enterostomy with a running Connell stitch. This is followed by closure of all potential mesenteric defects created to prevent internal herniation (Fig. 8.4).

![Figure 8.4 A Roux-en-Y near esophagojejunostomy. This is typically performed with a laparoscopic approach in a retrocolic and retrogastric fashion. A gastrostomy tube is placed to drain the remaining stomach. Inset shows esophagojejunostomy performed with an EEA stapler.](image-url)
A 10 F flat Jackson-Pratt (JP) drain is routinely placed behind the proximal anastomosis. This allows for control of an anastomotic leak if a leak was to develop in the postoperative period.

A feeding gastrostomy is placed in the partitioned gastric remnant in select patients. In general, the more trauma and gastric serosal tears present, the more likely we will choose to add a decompressing gastrostomy.

All incisions are approximated.

**POSTOPERATIVE MANAGEMENT**

The care of the patients in the immediate postoperative period is similar for patients who have undergone a redo fundoplication and patients who have undergone an RNY. All patients are extubated in the operating room and, after a short period in the recovery room, are transferred to a monitored bed. Nutritional and respiratory services are consulted to help with dietary education and pulmonary toilet, respectively. Patients are started on patient-controlled analgesia until they can start oral intake. Early ambulation is encouraged.

In our experience, the median length of stay after redo fundoplication is 2 to 3 days. A barium contrast study is performed, usually on postoperative day 2, and if there is no leak and gastric emptying is acceptable, patients are started on a post-Nissen diet and transitioned to oral medications. During the first postoperative office visit, patients are transitioned to a regular diet. Long-term follow-up depends on the symptoms and individual case, but in general we follow with an annual clinic visit and barium contrast imaging.

In patients who underwent conversion to RNY, the barium contrast study is delayed to postoperative day 3 if the patient’s clinical status permits. The drainage character and output from the JP drain are evaluated on a daily basis to identify a leak. After the barium contrast study is performed and looks good, patients are started on a phase 1 diet (clear liquids limited to a few ounces at a time). Patients are started on oral medication and are discharged when tolerating adequate oral diet usually by postoperative day 3 or 4. Prior to discharge, the JP drain is advanced slightly and resutured. During the patient’s first follow-up visit, 10 to 14 days after discharge, if the JP drainage has appropriate character and the drain has appropriate output, it is removed and patients are transitioned to a pureed diet. If there is any question of a subclinical leak or if the drainage from the JP drain has changed, we obtain another contrast study. Over the next 3 to 4 weeks, the patient is advanced to a regular diet. Lifelong daily multivitamins and monthly B12 shots are required. We also recommend a dose of a PPI or H2 blocker at bedtime. The patient’s weight and clinical symptoms are followed very closely every 3 months for the first year then annually, thereafter.

**COMPLICATIONS**

In a literature review of 81 studies examining reoperation for failed antireflux surgery by Furnée et al., the overall mortality was 0.9%. The authors concluded that the morbidity and mortality was higher with reoperative surgery than after primary antireflux surgery. In our recently published analysis of outcomes of over 270 patients who underwent reoperative antireflux surgery, overall perioperative morbidity (pneumonia, pulmonary embolism, leaks, etc.) was 10%, and there was no mortality. The most significant complication, a postoperative gastroesophageal leak, after a redo fundoplication was noted in 3% of patients in our experience. Similarly, the reported leak rate after conversion of a prior failed Nissen to an RNY ranges from 0% to 8%; the reported morbidity ranges from 0% to 32%, and the mortality is less than 1% in most series.
RESULTS

First-time antireflux operations have reliably demonstrated successfully outcomes in terms of symptomatic control in over 90% of patients. In contrast, the successful outcomes drop to ~80% or less after reoperative antireflux surgery. In our recent analysis of outcomes in 275 patients with reoperative antireflux surgery using specific, established tools to measure QoL (GERD-Health related QoL; SF-36 physical and mental scores), excellent to satisfactory outcomes were noted in over 80% of patients. These findings are seen when reoperative antireflux surgery is performed at high-volume centers of excellence. The improvement of GERD symptoms after conversion to RNY ranges from 78% to 90% with the added benefit of weight loss.

The need for surgical intervention after a primary antireflux procedure is reported to be 3% to 6%. In carefully selected patients with a failed initial antireflux surgery, the success rate in terms of improvement in GERD symptoms and overall satisfaction scores approached 90% after reoperation in our experience. One can conclude that not only is the morbidity and mortality higher after redo antireflux surgery compared with the primary operation, but also there is a greater likelihood of recurrent GERD symptoms or symptoms due to the repeated surgeries, such as dumping and dysphagia, and the need for possible additional surgical intervention.

CONCLUSIONS

- Redo antireflux surgery is a complex operation and should be performed at centers with extensive experience.
- A detailed history and physical examination are necessary to document the evolution of the patient’s symptoms. The clinical symptoms should be verified with thorough comprehensive testing that includes upper endoscopy, barium esophagogram, pH testing, manometry, and gastric emptying studies.
- Patients with recurrent intractable symptoms that correlate with the findings of objective tests should be considered for reoperative antireflux surgery.
- Surgical options that allow esophageal preservation include a redo fundoplication (complete or partial) and RNY near esophagojejunostomy.
- Important steps of a redo fundoplication include complete takedown of the fundoplication and esophageal mobilization to restore normal anatomy, vagal and crural preservation, identification of a short esophagus, esophageal lengthening when indicated, careful crural closure with consideration of crural reinforcement when the crural integrity is destroyed or when tension-free repair cannot be achieved, and construction of a “floppy” wrap.
- If during the performance of a complex reoperation, the normal anatomy cannot be reestablished and it appears likely that the antireflux procedure will fail symptomatically or will leak, the surgeon should consider esophagectomy, using a minimally invasive approach if possible.
- RNY is an attractive option in obese patients who require redo antireflux surgery. A small gastric pouch constructed of gastric cardia and a roux limb of 75 to 100 cm are necessary to divert the acid and bile from the esophagus.
- A postoperative barium contrast study is necessary to rule out leak before starting oral intake.
- Redo antireflux surgery has a higher morbidity and mortality and a greater need for surgical reintervention than primary antireflux surgery.
- Successful outcomes in terms of reflux control can be achieved in over 80% of patients who undergo reoperative antireflux surgery at centers of excellence.
Recommended References and Readings

Gastric Bypass
Brian R. Smith and Ninh T. Nguyen

Introduction

Over the past 40 years, use of the Roux-en-Y gastric bypass has increased to become the most commonly performed bariatric operation for the treatment of morbid obesity. It has also undergone evolution from an open operation to a predominately laparoscopic one. Multiple benefits of the laparoscopic approach have been observed. These benefits include decreased risk for incisional hernia, decreased rate of wound infection, shorter length of hospital stay, faster recovery, and shorter convalescence. Furthermore, the field of bariatric surgery has emerged with an understanding of the metabolic benefits that accompany surgical weight loss, which now carries importance equal to that of actual weight loss. This chapter discusses the indications, technique, and outcomes of laparoscopic gastric bypass in the modern era.

INDICATIONS/CONTRAINDICATIONS

In 1991, the National Institutes of Health Consensus Development Conference established the current indications for bariatric surgery, which have remained in effect since that time. These guidelines recommend bariatric surgery for patients

- with acceptable operative risks
- who are well informed and motivated
- evaluated by a multidisciplinary team
- with failure of established weight control programs
- with body mass index (BMI) ≥40, or ≥35 with at least one high risk, obesity-related comorbid condition

The prominent obesity-related comorbid conditions include hypertension, type 2 diabetes, dyslipidemia, obstructive sleep apnea, cardiomyopathy, and pseudotumor cerebri.1,2 Other common obesity-related comorbidities include gastroesophageal reflux, osteoarthritis, infertility, cholelithiasis, venous stasis, and urinary stress incontinence.3 With a large body of evidence supporting the efficacy of bariatric surgery in ameliorating the above comorbidities, debate over the role of bariatric surgery specifically to treat these conditions, more than the obesity, has begun.4,5

Relative contraindications to bariatric surgery include the following.
Part I  Surgical Treatment of Gastroesophageal Reflux and Paraesophageal Hernia

- Alcohol or drug dependence
- Ongoing smoking
- Uncontrolled psychiatric disorders such as depression or schizophrenia
- Inability to comprehend the requirements for postoperative nutritional and behavioral changes
- Unacceptable cardiorespiratory risk (American Society of Anesthesiologists [ASA] class IV)
- End-stage hepatic disease

PREOPERATIVE PLANNING

Patients preparing for gastric bypass require both preoperative medical evaluation and optimization of medical comorbidities prior to surgery. Medical clearance requires a comprehensive and thorough review of the patient’s medical history, specifically looking for factors which can predict an adverse outcome. Independent predictors of surgical morbidity and mortality include age ≥ 45 years, male gender, BMI ≥ 50 kg/m², risk for pulmonary embolism, and hypertension. Collectively, these clinical findings can be used to calculate an Obesity Surgery Mortality Risk Score (OS-MRS), which has been validated at multiple institutions. Patients with 0 or 1 comorbidity are considered low risk or class A with a 0.2% risk of mortality. Those in class B have 2 or 3 comorbidities and are at intermediate risk of 1.2%. Class C patients are highest risk and have 4 or 5 comorbidities with a corresponding mortality of 2.4%. BMI ≥ 50 kg/m² and cigarette smoking have also been shown to be associated with higher postoperative surgical morbidities. Preoperative workup should include the following:

- Comprehensive history and physical examination
- 12-lead EKG
- Basic blood chemistries, lipid profile, and nutritional panel
- Chest radiograph

The choice of operation for a particular patient must take into account several issues including the surgeon’s expertise and the patient’s preference, BMI, metabolic conditions, and other associated comorbidities. While gastric bypass is largely considered the most effective procedure in achieving long-term weight loss, it is also the most effective in reducing the metabolic derangements of obesity, including diabetes, hypertension, and dyslipidemia. However, these benefits come with a slightly higher overall mortality rate. For gastric bypass, an average 30-day mortality is 0.16% compared with that of laparoscopic adjustable gastric band placement at 0.06%. For this reason, high-risk patients may at times be counseled away from the more definitive gastric bypass and toward the safer, albeit less effective, laparoscopic gastric banding.

The benefit of preoperative weight loss prior to gastric bypass has been debated. A recent randomized trial demonstrated that patients who achieve ≥ 5% excess body weight loss prior to surgery had significantly lower weight and BMI and a higher excess body weight loss 1 year after surgery. The success of this and other trials is felt to predict those patients with the discipline and willingness to follow healthy lifestyles that will ultimately translate to successful and sustained long-term weight loss. As a result, many surgeons will place patients on one of many available forms of preoperative weight loss diet for 2 to 4 weeks prior to surgery, with a goal of 10% excess body weight loss. Many forms of commercial dietary programs are available for these purposes, often consisting of a high-protein, low-fat, low-carbohydrate, predominately liquid diet. An additional benefit of this preoperative liquid diet is decreased liver size and density that makes manipulation of the left lobe of the liver easier during surgery.

SURGERY

All patients should receive routine deep venous thrombosis (DVT) chemoprophylaxis immediately prior to arrival in the operating room, as initial development of DVT is felt to occur intraoperatively in this high-risk population. In addition, routine preoperative
antibiotic prophylaxis is also indicated. A second generation cephalosporin is adequate, but typically requires increased dosing in morbidly obese patients.

**Patient Positioning**

Patient positioning is often dictated by the surgeon’s preference. Some surgeons prefer the French or lithotomy position. The main advantage of this position is access in between the patient’s legs and the inline trajectory of one’s laparoscopic instruments. This centers the surgeon over the operative field and improves the posture while minimizing shoulder fatigue. However, this position can be difficult and time consuming and places patients at risk for nerve injury if not positioned properly. Most surgeons have evolved their procedure to a completely supine position with arms outstretched on and secured to arm boards. A footboard is recommended to minimize patient slippage inferiorly during reverse Trendelenburg positioning, as is an upper thigh strap to minimize lateral slippage during rotation of the patient. All bolsters placed behind the patient’s neck and/or shoulders during anesthesia to facilitate endotracheal intubation should be removed prior to initiation of surgery. A Foley catheter is optional. Routine cardiac noninvasive monitoring is essential. Invasive monitoring, including arterial and central venous catheters, is not routinely indicated and is only utilized in selected cases where such additional monitoring is necessary.

**Technique**

Standard technique includes a 5-trocar configuration (Fig. 9.1). Initial cannulation of the abdominal cavity with a Veress needle is typically through the camera port, located in the left supraumbilical region. Upon insufflation to 15 mm Hg, the Veress needle is removed and a 12-mm trocar is inserted followed by camera confirmation of no visceral injury from entry. Subsequent 5-mm trocars are placed in the far left and right subcostal margins just above the viscera, along with a right epigastric (12-mm) and right upper quadrant (5-mm) trocars. The far right subcostal trocar secures a serpentine liver retractor for anterior retraction of the left lobe of the liver. Alternatively, the subxiphoid 5-mm trocar site can be used to accommodate a Nathanson liver retractor. The operating surgeon utilizes the epigastric and right upper quadrant trocars while the assistant utilizes the left subcostal trocar and the laparoscope.

Creation of the gastric pouch and gastrojejunostomy begins with division of the gastrohepatic ligament (Fig. 9.2). The vasculature of the lesser curve of the stomach should be divided with a vascular stapler. Creation of the gastric pouch then proceeds with transverse division of the proximal stomach approximately 4 cm distal to the gastroesophageal
Figure 9.2 Construction of lesser curve-based gastric pouch. The staple line should start horizontally and then turn perpendicularly, directly up toward the angle of His in an effort to create a rectangular pouch.

junction. The transection is made approximately 3 cm wide and then proceeds superiorly toward the lateral aspect of the angle of His. Once the pouch is constructed, the gastrojejunostomy can be formed. The small bowel and its mesentery are divided approximately 30 cm distal to the ligament of Treitz, and the distal (Roux) limb is brought up to the gastric pouch (Fig. 9.3). Great care must be taken to divide the mesentery carefully so as to avoid significant devascularization of the Roux limb. The greater omentum can be divided in the middle to permit easier approximation of and less tension on an antecolic gastrojejunostomy.

Figure 9.3 Division of jejunum and its mesentery 30 cm distal to the ligament of Treitz.
The jejunojejunostomy, while the lower risk of the two anastomoses, is often the most technically challenging. The biliopancreatic limb should line up against the left side of the Roux limb approximately 150 cm distal to the proximal end (Fig. 9.4). A stay suture is placed between the two limbs and an enterotomy is created in each limb. A single, linear, 60-mm gastrointestinal anastomosis (GIA) stapler with 2.5-mm staples (white load) is introduced and the anastomosis is constructed (Fig. 9.5). The common enterotomy is then closed in either a handsewn fashion or with a linear stapler, taking great care to ensure the lumen is not narrowed and that the completed anastomosis lies comfortably without kinking or twisting. An antiobstruction suture is placed to discourage kinking of the common channel. The mesenteric defect between the two limbs is then closed with several interrupted sutures.

The gastrojejunal anastomosis can be created in one of several ways, including circular stapled, linear stapled, or handsewn. For circular stapled, the stapler anvil can be placed within the pouch either transorally on a preloaded orogastric tube or by creating a small gastrotomy on the pouch, placing the anvil through the anterior or posterior wall and then closing the gastrotomy with a linear stapler. The stapler is then inserted into the open end of the Roux limb and coupled to the anvil through the antimesenteric border of the Roux limb. The open end of the Roux limb (sometimes referred to as the “candy cane”) is then closed with a linear stapler. For a linear stapled anastomosis, an enterotomy is created in the Roux limb and a gastrotomy in the gastric
pouch, and one jaw of the laparoscopic linear stapler is inserted into each segment of the bowel and fired to create an anastomosis (Fig. 9.6). The common enterotomy is then closed in a handsewn fashion. For an entirely handsewn anastomosis, posterior stay sutures are placed between the pouch and Roux limb, followed by the creation of an enterotomy and gastrotomy. A running absorbable suture then approximates the anastomosis. A final anterior layer is placed to reinforce the anastomosis. Several stay sutures can be placed between the pouch and Roux limb at the discretion of the surgeon, depending on the perceived tension on the anastomosis (Fig. 9.7). Although some surgeons utilize drains around the proximal anastomosis, especially in the setting of gastric bypass or a redo esophageal procedure, we do not routinely use drains at any anastomosis for gastric bypass surgery.

A leak test at the completion of the final anastomosis is routinely performed by most surgeons. This test can be carried out in one of three ways. The first is instillation of methylene blue down a nasogastric tube into the gastric pouch, with laparoscopic observation for leak of dye. The second option is placement of a nasogastric or Ewald tube by the anesthesiologist, with air instillation while the anastomosis is submerged, looking for bubbles from the anastomosis. The final option is intraoperative endoscopy, where the gastrojejunalostomy is visualized with an endoscope and intraluminal insufflation while the anastomosis is submerged under peritoneal irrigation, again looking for bubbling of air from the anastomosis. This technique has been shown to decrease both the incidence and the seriousness of anastomotic leaks postoperatively.14
Routine patients without significant cardiac issues can be transferred to a ward bed. Cases where continuous monitoring may be indicated postoperatively include a significant cardiac history, any intraoperative cardiorespiratory issue, or severe obstructive sleep apnea. Nasogastric tube decompression is not indicated and there is risk for pouch perforation if not inserted by experienced personnel. A postoperative upper gastrointestinal study on the first postoperative day should be performed, particularly during the surgeon’s learning curve. Patients begin a diet of sugar-free clear liquids on the first postoperative morning and are continued on DVT chemoprophylaxis until discharge. Ambulation can begin as early as the evening of surgery and is essential by the first postoperative day. Medication adjustments are vital, particularly in diabetic patients, and must take place immediately postoperatively. While each patient must be considered individually, often utilizing half of the patient’s preoperative dose of diabetic medications serves as an appropriate starting point after surgery.

Diet may be advanced to sugar-free full liquids on the second postoperative day and most patients will be ready for discharge by this time. Full liquids, including protein shake supplements, continue until 2 weeks postoperatively. Patients are then
transitioned to a pureed diet, soft foods, and finally a modified regular diet over the ensuing 6 weeks. Postoperatively, patients are counseled regarding appropriate behavioral and dietary changes. Overall dietary guidelines include routine low-calorie, low-fat, and low-sugar food intake. Patients are encouraged to take in three small meals per day with healthy snacks in between and to eat slowly, stopping at the first sign of feeling full. Specific efforts at protein intake during each meal are encouraged. Patients are counseled to take eight 8-ounce cups of water daily and should avoid taking beverages concurrently with meals. Carbonated beverages result in gas expansion of the small gastric pouch, which leads to significant discomfort, and hence should be avoided. Vitamin and mineral supplementation is essential to avoid deficiencies in vitamins A, D, B1, B6, B12, calcium, and folate.\textsuperscript{15} Alcoholic beverages undergo rapid absorption through the small intestine, resulting in accelerated intoxication. Patients must be counseled regarding these changes in their intestinal absorption. Routine daily physical activity is encouraged and participation in monthly bariatric support groups has been shown to result in significantly improved and sustained weight loss.\textsuperscript{16,17} Postoperative follow-up typically occurs 1 week, 1, 3, 6, 9, and 12 months postoperatively, and then every 4 months thereafter. Evaluation for late complications, behavioral counseling, and monitoring for nutritional deficiencies are the main goals of these routine visits.
Significant effort has been put forth to improve the safety of gastric bypass since the inception of the laparoscopic approach in the late 1990s. Complications can be classified as those occurring early (<30 days) and those occurring beyond this perioperative period (Table 9.1).

Of the early complications, pulmonary embolus remains the most common cause of mortality in bariatric patients, with an overall incidence of 0.1% to 2%. Anastomotic leak occurs most commonly at the gastrojejunostomy, followed in decreasing frequency by the gastric remnant, the jejunojejunostomy, the gastric pouch, and the stapled end of the Roux limb. The overall incidence of all leaks after laparoscopic gastric bypass ranges from 1% to 5.6%. Prompt identification of the source of the leak and control of peritoneal contamination are crucial in minimizing sepsis. In addition, the presentation of anastomotic leak is highly heterogeneous and as a result, early operative intervention as a diagnostic and therapeutic tool is highly encouraged. Of the clinical symptoms that are suggestive of leak, tachycardia, fever, and abdominal pain are the most common. Early postoperative gastrointestinal hemorrhage typically occurs along the gastrointestinal staple line and can occur intraluminally or intraperitoneally.

Small bowel obstruction is the most frequent late complication following laparoscopic gastric bypass. Early small bowel obstruction (first few months postoperatively) is more common in laparoscopic gastric bypass than open gastric bypass, as are internal hernias. The most common causes of small bowel obstruction after laparoscopic gastric bypass include internal hernia, jejunojejunostomy complications, adhesions, and port-site herniation. Internal hernias can occur through either small bowel mesenteric defects or more commonly through Petersen’s space (beneath the Roux limb). Findings of a mesenteric “swirl” sign on the computed tomography scan are the single best predictor of internal herniation and should prompt urgent surgical intervention. Leaks predispose patients to anastomotic strictures, as do ischemia, tension, technical errors, and marginal ulceration. Strictures often require endoscopic balloon dilation to maintain an anastomotic diameter greater than 10 mm. Rates of marginal ulceration vary widely from 1% to 16%, depending on the study. Gallstone formation is a common occurrence after significant weight loss, with a frequency up to 30% following gastric bypass.

**Table 9.1 Early (<30 days) and Late (>30 days) Complications After Laparoscopic Gastric Bypass**

<table>
<thead>
<tr>
<th>Complications</th>
<th>Rate of Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>7%</td>
</tr>
<tr>
<td>Early</td>
<td></td>
</tr>
<tr>
<td>Hemorrhage</td>
<td>2–3.5%</td>
</tr>
<tr>
<td>Wound Infection</td>
<td>1.8%</td>
</tr>
<tr>
<td>Bowel Obstruction</td>
<td>1.7%</td>
</tr>
<tr>
<td>Anastomotic Leak</td>
<td>1–5.6%</td>
</tr>
<tr>
<td>Venous Thromboembolism (VTE)</td>
<td>0.1–2%</td>
</tr>
<tr>
<td>Late</td>
<td></td>
</tr>
<tr>
<td>Symptomatic Gallstones</td>
<td>22–71%</td>
</tr>
<tr>
<td>Gastrogastric Fistula</td>
<td>3%</td>
</tr>
<tr>
<td>Marginal Ulceration</td>
<td>1–16%</td>
</tr>
<tr>
<td>Anastomotic Stricture</td>
<td>1–9%</td>
</tr>
<tr>
<td>Small Bowel Obstruction</td>
<td>3.2%</td>
</tr>
<tr>
<td>Nutrient Deficiency (Unmonitored)</td>
<td>1% (30%)</td>
</tr>
</tbody>
</table>
RESULTS

Bariatric surgery has been shown repeatedly to be the most definitive and successful treatment for severe obesity, compared with conventional medical therapy. Nearly 80% of patients who undergo gastric bypass experience an excess body weight loss of 60% to 80%. Lifetime risk of death from extreme obesity is decreased by 35% in individuals who undergo bariatric surgery, compared with control individuals. However, the safety of bariatric surgery has come under increasing scrutiny since the early part of this century. Bariatric Centers of Excellence were developed by the American College of Surgeons and the American Society of Metabolic and Bariatric Surgery and many insurance carriers have followed by only covering bariatric surgery performed at these centers. The Leapfrog Group has added bariatric surgery to the growing list of procedures with improved mortality when performed at high-volume centers (>125 annual cases).

The most comprehensive meta-analysis to date evaluated more than 85,000 patients and found the overall mortality for laparoscopic gastric bypass to be 0.16%. Outcomes of gastric bypass on metabolic derangements are equally impressive. Pories et al. were the first to describe long-term glucose control in 83% of noninsulin-dependent diabetics and 99% of patients with glucose impairment. Since that time, numerous studies have validated gastric bypass as the most effective operation for the treatment of type 2 diabetes, both as early as 1 week postoperatively and with sustained results at 2 years. Metabolic syndrome is composed of the triad of diabetes, dyslipidemia, and hypertension. Collectively, this triad increases the risk of coronary artery disease. Metabolic syndrome is cured in 96% of patients who undergo bariatric surgery and no other medical treatment has come close to the success rates of bariatric surgery. More recently, similar results have also been shown in diabetic patients with lower BMI (30 to 35), who do not meet traditional bariatric surgical criteria. Finally, adverse maternal and neonatal outcomes are lower in patients who become pregnant after undergoing bariatric surgery for morbid obesity.

CONCLUSIONS

Gastric bypass remains the gold standard operation for significant, sustained weight loss in morbidly obese patients. It is also the most effective means of treating metabolic syndrome, type 2 diabetes, and other obesity-related medical comorbidities, such as uncontrolled GERD or the need for a redo antireflux operation. Significant progress has been made in the overall safety of gastric bypass and it is considered as safe as other commonly performed general surgical operations such as laparoscopic cholecystectomy. Patients must be monitored for long-term complications, including vitamin and nutrient deficiencies, small bowel obstruction, anastomotic stricture, and marginal ulceration.

Recommended References and Readings


Introduction

Gastroesophageal reflux disease (GERD) represents a serious health concern in Western countries with nearly half of Americans reporting symptoms at least monthly, and up to 10% experiencing daily reflux symptoms. Proton pump inhibitors (PPI) provide effective symptom control for many GERD patients, but this approach requires lifelong medical treatment, and up to 20% of patients experience breakthrough heartburn and regurgitation. Laparoscopic antireflux surgery provides excellent reflux control and high patient satisfaction rates; however, the invasiveness, high costs and risks associated with surgery are significant factors that deter some potential patients.

These hurdles have led physicians to pursue minimally invasive, effective and durable treatment alternatives that directly address the pathophysiologic mechanisms of reflux. Over the past two decades, several endoluminal approaches to GERD management have been developed as an intermediate between medical management and invasive surgical fundoplication. Transoral incisionless fundoplication (TIF) using the EsophyX device (Endogastric Solutions Inc., Redmond, WA) allows creation of a robust gastroesophageal plication via the transoral route and is detailed in this chapter.

Another intermediate between medical management and surgical fundoplication is the LINX system (Torax Medical, St Paul, MN), which augments lower esophageal sphincter function using a ring of magnetic beads placed laparoscopically at the gastroesophageal junction. For reflux to occur, the intragastric pressure must overcome both the patient’s native lower esophageal sphincter pressure and the force of the magnetic beads; however, the magnetic beads separate sufficiently to allow passage of a food bolus, belching, or vomiting. Initial clinical trials of the LINX system indicate that it is effective at decreasing esophageal acid exposure, reducing GERD symptoms, reducing PPI dependence, and improving the patient’s quality of life, and that it can be removed without damaging the esophagus. An update on this new technology will be forthcoming.
As with other endoscopic reflux therapies, the ideal patients for TIF are those with minimal anatomic change at the gastroesophageal junction (GEJ) and moderate-to-severe GERD symptoms that are responsive to PPI therapy. TIF should not be performed in patients with significant hiatal hernias, severe esophagitis, esophageal dysmotility, or in the setting of esophageal varices. Also, TIF is not recommended for acid control in patients with Barrett’s esophagus because normalization of esophageal pH has not been consistently demonstrated.

**Indications**
- PPI-dependent patients with objective evidence of GERD
- Good response to PPI therapy
- Medically fit for general anesthesia

**Contraindications**
- Age <18 years
- BMI >35 kg/m²
- Hiatal hernia >2 cm
- Esophageal varices
- Barrett’s esophagus
- Severe esophagitis (LA class C or greater)
- Severe esophageal dysmotility

**PREOPERATIVE PLANNING**

Patients with GERD may present with typical or atypical symptoms. Most often, GERD presents with heartburn and regurgitation and may progress to dysphagia and chest pain. Less commonly, patients may present with supraesophageal symptoms including chronic nausea, aspiration, asthma exacerbation, cough, hoarseness, and globus sensation, with or without typical GERD symptoms. Patients who have undergone a period of medical treatment with improvement of their symptoms with acid suppression may be candidates for TIF; however, further objective evaluation is required.

The preoperative evaluation prior to TIF centers on establishing objective evidence of acid reflux and assessing patient suitability for the procedure. At a minimum, patients should undergo an upper endoscopy to assess for the presence of hiatal hernia and esophagitis, and esophageal manometry should be performed to demonstrate adequate peristalsis. Ambulatory pH testing is useful for establishing the diagnosis of GERD in patients who do not have erosive esophagitis and those with atypical symptoms. Contrast radiography can assess the presence and size of hiatal hernia and a video esophagram can be used in lieu of manometry to establish evidence of normal esophageal motility.

Routine preoperative upper endoscopy with a rigorous assessment of the GEJ anatomy performed by the operating surgeon can improve patient selection for TIF. This allows for identification of reflux-related complications including severe esophagitis, strictures, and Barrett’s esophagus that may exclude TIF as a treatment option. Also, a detailed examination of the GEJ in the retroflexed view should be performed with the stomach sufficiently distended to produce effacement of the rugal folds. In this view, the crura can be seen impinging on the GEJ, and the transverse dimensions of the hiatus should be evaluated (Fig. 10.1). TIF should only be considered for patients in whom this measurement is less than twice the diameter of the endoscope because when the transverse hiatal diameter exceeds this threshold, the plication may fail due to a tendency to herniate into the thorax.
Device

The EsophyX device (Endogastric solutions, Inc., Redmond, WA) is a gastroesophageal plicating device that is introduced into the stomach transorally over a standard endoscope (Fig. 10.2). This enables approximation of gastric and esophageal tissue in the region of the GEJ, and plicates these tissues together using placement of H-shaped full-thickness polypropylene fasteners.

The device consists of a handle (Fig. 10.3) where the device controls are located, a shaft that is 18 mm in diameter, and an articulating arm (the tissue mold) that approximates tissue and deploys tissue fasteners. When the tissue mold is placed in the retroflexion position, a tissue retractor with a helical screw at the tip can be advanced to engage and manipulate the mucosa at the GEJ (Fig. 10.4). A deployable stylet is located on either side of the helical retractor, and these serve to guide the deployment of the tissue fasteners (Fig. 10.5). The stylets are deployed through the esophageal and gastric walls and the H fasteners are deployed over the stylet so that the leading leg of the fastener engages in the gastric lumen, while the trailing leg remains within the esophageal lumen (Fig. 10.6).

Pertinent Anatomy

When describing the location of the fastener placements, it is useful to orient the retroflexion view of the GEJ as a clock face. The 12-o’clock position is defined as the location of the lesser curvature, with the 3-o’clock position on the anterior surface of the stomach and the 9-o’clock position on the posterior gastric wall. Six o’clock refers to the valve position that faces the greater curvature of the stomach (Fig. 10.7).
Figure 10.3 EsophyX device handle. (© 2014 EndoGastric Solutions, Inc.)

Figure 10.4 Partially closed tissue mold with deployed helical retractor. (© 2014 EndoGastric Solutions, Inc.)

Figure 10.5 Fully closed tissue mold with deployed stylet and polypropylene H fastener. (© 2014 EndoGastric Solutions, Inc.)

Figure 10.6 Schematic representation of tissue apposition and fastener deployment during TIF. **Left:** the helical retractor engages the mucosa at the level of the gastroesophageal junction. **Middle:** The tissue mold is closed to appose the esophagus and stomach while transmural fasteners are placed to recreate the angle of His. **Right:** Proper fastener position with leading and trailing limbs positioned within the stomach and esophagus, respectively.
Technical Evolution

TIF is an endoscopic procedure that aims to create a gastroesophageal reflux valve through the creation of a full-thickness gastroesophageal plication. The technique used to create the plication has evolved since the introduction of the EsophyX device in 2007. The initial TIF-1 technique aimed to create the plication at the level of the GEJ, creating a partially circumferential gastrogastric fundoplication. The second iteration (TIF-2) involved creating a more robust gastroesophageal fundoplication by adding rotary and longitudinal elements and deploying fasteners 3 to 4 cm above the GEJ. This approach has proven capable of producing a 270-degree plication over a length of 3 to 4 cm. The most recent evolution of the TIF-2 procedure described here emphasizes the rotational elements of the gastroesophageal plication and achieving a valve of adequate length without including crural tissue in the plication.

Patient Positioning and Preparation

The patient is nasotracheally intubated and placed under general anesthesia. Nasotracheal intubation minimizes the space occupied within the oropharynx and facilitates passage of the EsophyX device into the esophagus. Sequential compression devices are placed, and preoperative antibiotics are administered due to the full thickness, transluminal application of the polypropylene fasteners. The patient is then placed in a semi-recumbent position with the left side elevated approximately 45 degrees. A preprocedure endoscopy is then performed to evaluate the GEJ anatomy and identify anatomical landmarks. Following this endoscopy, the hypopharynx and esophagus are dilated via placement of a 56-French Maloney dilator. Early in our experience, we did not use bougie dilation, but have since found that this greatly reduces the difficulties encountered with device insertion.

Technique

The device is generously lubricated and placed over a standard endoscope, and a bite block is placed over the device and between the patient’s teeth. The endoscope-device...
complex is inserted into the stomach transorally. A jaw-lift maneuver often facilitates easy passage of the device through the hypopharynx. Care must be taken during device insertion as hypopharyngeal perforations were reported during the early experience with this procedure. The endoscope is advanced into the stomach, a retroflexed view of the GEJ is obtained, and the stomach is insufflated with carbon dioxide to a pressure of 15 mm Hg using a standard high-flow laparoscopic insufflator. The device is advanced until the entire articulating arm is visualized within the gastric lumen (Fig. 10.8A). The endoscope is then backed up into the device (Fig. 10.8B) and the tissue mold is placed into the retroflexion position. Following this, the endoscope is advanced into the gastric lumen and retroflexed to view the GEJ and tissue mold (Fig. 10.9).

The gastroesophageal plication is created by placing pairs of full-thickness fasteners at strategic locations. The initial steps create the rotary portion of the plication, whereas the final steps increase its length. The steps involved in creating the valve include the following.

- Placement of fasteners in the anterior corner of the plication
- Fastener placement in the posterior corner
- Deep plication along the greater curvature
Placement of Anterior Plication Sets
The closed tissue mold is rotated to the 12-o’clock position, and the helical retractor engages the mucosa at the GEJ (Fig. 10.10). The tissue mold is opened and rotated back to the 6-o’clock position to prepare for performing the initial anterior plication. While traction is placed on the helical retractor, the tissue mold is partially closed and rotated anteriorly toward the 1-o’clock position (Fig. 10.11). Simultaneously, the stomach is desufflated to allow maximal rotation into the anterior corner and the device is closed against the tissue, apposing the gastric and esophageal walls. Once this is achieved, the suction is applied and the stomach is insufflated to visualize the articulating arm of the device and permit the safe engagement of the stylets and deployment of a pair of fasteners (Fig. 10.12). This process is repeated twice at slightly different depths relative to the GEJ so that six fasteners have been deployed to create the anterior corner of the gastroesophageal plication.

Placement of Posterior Plication Sets
While maintaining the helical retractor at the 12-o’clock position on the lesser curve, the tissue mold is opened and rotated through the lesser curve in the counterclockwise direction and returned to the 6-o’clock position. Traction is placed on the helical retractor while the stomach is desufflated. The tissue mold is partially closed and rotated in the clockwise direction into the posterior corner toward the 11-o’clock position (Fig. 10.13).
When maximal rotation is achieved, the tissue mold is closed and the suction applied. The stomach is then insufflated to allow visualization of the back of the tissue mold. The device is gradually rotated back out of the corner to allow safe deployment of the stylets and fasteners. Two more fastener sets are deployed in the posterior corner at different depths to complete this portion of the plication.

**Greater Curve Longitudinal Plication**

When the anterior and posterior corners of the plication are complete, attention is turned to the placement of deep plicating fasteners closer to the greater curvature of the stomach to increase the valve length. The helical retractor is disengaged from the mucosa at the 12-o’clock position, and may be replaced at the 6-o’clock position (Fig. 10.14). These fasteners may also be placed without using the helical retractor. The tissue mold is opened slightly and positioned at the 5-o’clock position. The device is withdrawn slightly from the mouth and the tissue mold is closed to create a gastroesophageal plication 2 to 4 cm above the GEJ (Fig. 10.15). Care should be taken not to close the device over the crus, incorporating diaphragmatic tissue into the plication, as the fasteners are not designed to traverse this thick tissue. Including excess tissue in the plication may cause the fasteners to pull through and lead to areas of esophageal perforation. Two fastener sets are deployed at different depths at the 5-o’clock and 7-o’clock positions to complete the esophageal plication.
Device Removal
When the plication is complete, the device is advanced until the hinge can be clearly visualized within the stomach. The helical retractor is disengaged and the endoscope is withdrawn into the shaft of the device. The tissue mold is straightened and withdrawn under direct vision. Care must be taken during device removal to avoid esophageal mucosal lacerations. If this occurs, the mucosal injury may be closed with endoclips.

Completion Endoscopy
Immediately after the procedure, endoscopy is performed to assess the esophageal mucosa, completeness of the fundoplication, and adequacy of hemostasis. When visualized in the retroflexed view, the TIF valve exhibits the classic omega-shaped appearance associated with Nissen fundoplication (Fig. 10.16).

POSTOPERATIVE MANAGEMENT
Following completion endoscopy, patients are given intravenous ondansetron to prevent retching, which may disrupt the T fasteners and lead to early procedure failure.

Figure 10.14 Engaged helical retractor at the 6-o’clock position applies traction during longitudinal plication at the greater curve positions.

Figure 10.15 The tissue mold is closed at the 5-o’clock position to create a longitudinal gastroesophageal plication above the GEJ.
Patients are admitted for overnight observation and receive scheduled intravenous antiemetic medications during their hospital stay. Patients often experience sore throat and chest or shoulder pain during the first 3 to 4 days and may require narcotic pain medication. We do not routinely employ contrast swallow evaluation following TIF, but pain that is persistent or out of proportion with expectations should raise concern for complications including esophageal perforation or mediastinal abscess.

Patients are permitted sips of clear liquids following the procedure, and in the absence of dysphagia, diet is advanced to thick liquids prior to hospital discharge on postoperative day 1. A full liquid diet is maintained for 5 days and then advanced to a soft food diet for the next 2 to 4 weeks. Liberal use of oral antiemetics and consumption of small frequent meals are encouraged to limit retching and gastric distension during the early postoperative period.

**COMPLICATIONS**

Although rare, complications of cervical esophageal perforation, postoperative hemorrhage, mediastinal abscess, and early procedure failure have been reported. In an early multicenter European trial, two patients suffered cervical esophageal injuries during TIF. As with any over-the-scope device, care must be exercised during the insertion of the EsophyX. Insertion of these large devices in patients with limited working space due to body habitus or limited neck mobility is particularly difficult, and care must be taken when selecting patients for these procedures. Along with careful patient selection and adequate lubrication of the device, predilation of the esophagus with a 56- to 60-French bougie may facilitate the delivery of this system and reduce complications.

Postprocedure hemorrhage requiring blood transfusion or endoscopic intervention has been reported in several series. This may occur at the site of helical retractor placement or if fasteners are deployed too close to the lesser curvature of the stomach. In our experience, two patients have required blood transfusions following TIF. Repeat
endoscopy did not reveal an active site of bleeding in either case. Careful placement and removal of the helical retractor, awareness of the lesser curve location, and examination of all surgical sites during completion endoscopy may help reduce the incidence of postprocedure bleeding.

Finally, gastric leak, mediastinal abscess, and early procedure failure have been reported following TIF. Each of these complications likely relate to fasteners pulling through the gastric or esophageal wall during the early postoperative period. During TIF, care should be taken to ensure that the diaphragmatic crura are not included in the plication, as the fasteners are not designed to pass through and plicate that much tissue. Postoperatively, aggressive use of antiemetic medications should be employed to prevent retching, and small meals should be encouraged to reduce the amount of gastric distension during the early postoperative period.

## RESULTS

Early cohort studies examining the clinical efficacy of TIF have been promising. Cadiere et al. reported an initial experience of 86 patients with 6-month follow-up in 81 patients. GERD Health-Related Quality of Life (GERD-HRQL) scores improved in 80% of patients and PPI use was eliminated in 81%. Postoperative pH studies demonstrated normal esophageal acid exposure in 40%. We reported the initial US experience in a relatively unselected population referred for surgical GERD treatment. After 10 months, 53% of patients showed reduced medication usage and symptom improvement. Bell demonstrated significant symptom improvement in patients with both typical (70%) and atypical (64%) GERD symptoms with no reported dysphagia, bloating, or flatulence after TIF. Several other small cohort series have demonstrated similar improvements in heartburn scores, PPI use, and esophageal acid exposure; however, controlled trials and long-term follow-up studies are lacking. Further studies are required to identify the subset of GERD patients most likely to benefit from TIF.

In addition, some centers have abandoned this procedure despite early enthusiasm due to recurrence of GERD symptoms and generally dissatisfaction with the overall results. For example, Hoppo et al. reported the outcomes of 19 patients who underwent the EsophyX procedure at three institutions over a 16-month period. During a short follow-up (median 10.8 months), most patients experienced symptom recurrence (13/19, 68%) and over half (10/19, 53%) required surgical reintervention. In Furnee’s series of 88 patients who underwent an EsophyX antireflux procedure, 11 patients (12.5%) required laparoscopic Nissen fundoplication as a redo surgery for recurrent symptoms. Median time between procedures was 8.1 months. Similarly, Romario et al. reported outcomes in nine patients who underwent laparoscopic Nissen fundoplication a median of 13.3 months after the EsophyX procedure. Both surgeons noted an increased risk of dysphagia after fundoplication performed as a redo surgery for a failed EsophyX procedure, as dysphagia occurred in 22% to 27% of patients who underwent a revision fundoplication. While Romario et al. reported no intraoperative complications during laparoscopic Nissen fundoplication as a result of the EsophyX procedure, Furnee reported intraoperative gastric perforation in two patients and a postoperative subphrenic abscess in one. The risk of gastric damage caused by the EsophyX fasteners (27% of patients in Furnee’s series) was higher than that typically seen during primary or redo antireflux surgery. Other surgeons have also noted significant difficulty in removing the H fasteners and restoring normal anatomy. The H fasteners tend to produce minute fistulous tracts that are noted following laparoscopic removal, and leaks may be evident during endoscopic insufflation during the redo procedure (J. Luketich, personal communications). Thus, it is imperative that surgeons performing redo antireflux surgery on patients who have had an EsophyX antireflux procedure be aware of these issues and prepared to deal with these technical problems.
The EsophyX device and TIF technique have improved over time, and show potential for the treatment of patients with GERD. Multiple studies have demonstrated that TIF can be accomplished in most patients with a low risk of complications. Following TIF, symptoms and quality-of-life scores are significantly improved, as is esophageal acid exposure. However, a high failure rate and significant complications during subsequent antireflux surgeries have been seen in other studies. Prospective controlled trials and long-term registry studies are currently underway and will continue to define the role for TIF in the management of GERD.

**Recommended References and Readings**

Introduction

Hiatal hernias are generally classified into four types (Fig. 11.1) with Type I being a sliding hiatal hernia, with a simple sliding of the gastroesophageal junction into the chest (Fig. 11.1A). Paraesophageal hernia (PEH) occurs when part or all of the stomach translocates from the abdomen through the esophageal hiatus and into the posterior mediastinum. When the gastroesophageal junction remains in the normal intra-abdominal position, the PEH is a “true” PEH as the fundus of the stomach herniates through an anterolateral weakening of the phrenoesophageal ligament and lies next to the esophagus in the mediastinum. This type of PEH is known as a Type II PEH, which we and others have found to be rare (Fig. 11.1B). More commonly, the gastroesophageal junction has migrated cephalad, likely as a result of long-standing gastroesophageal reflux and fibrotic changes to the esophagus causing foreshortening of the esophageal longitudinal muscles and, subsequently, the esophagus itself. Over time, this foreshortening pulls the gastroesophageal junction into the posterior mediastinum, along with the proximal stomach, lengthens the phrenoesophageal ligament and widening the crural aperture. Eventually, the gastroesophageal junction becomes fixed within the posterior mediastinum with varying degrees of gastric herniation and is known as a Type III PEH (Fig. 11.1C). Patients with large, symptomatic PEH usually present with symptoms suggestive of obstruction, including chest pain, postprandial bloating, or dysphagia. Anemia and shortness of breath are also common symptoms that are often attributed to other causes. Type III PEH account for approximately 5% to 10% of all hiatal hernias. When other abdominal organs follow the stomach into the chest, such as omentum, colon, spleen and or portions of the pancreas, they are referred to as Type IV PEH (Fig. 11.1D).

Over the past decade, the laparoscopic approach for PEH repair has become a standard approach, enabling PEH to be repaired with less pain, faster recovery, and reduced morbidity particularly when performed by experienced surgeons with significant open and minimally invasive esophageal surgery experience. When performed in centers of excellence, the outcomes of laparoscopic repair compare favorably with the outcomes of open repair. To optimize repair durability and to ensure long-term symptom resolution, PEH repair requires strict attention to several key elements: (1) Complete dissection and tension-free reduction of the hernia sac, stomach, and any other contents
Repair is recommended for all symptomatic patients. The management of asymptomatic hernia remains the subject of debate, however, and warrants further discussion. The incidence of a truly asymptomatic giant PEH is uncommon in our experience, and more commonly, significant symptoms exist, but they have occurred so insidiously and have been present so long, that patients have learned to live with these significantly troublesome symptoms. Some studies have estimated that the risk of life-threatening complications from a PEH is lower than the risk of undergoing repair.\textsuperscript{6,7} When analyzing the findings of these studies, however, it is important to make note of the definition of minimally symptomatic or asymptomatic used; in the paper by Stylopoulos, minimal symptoms were defined as “heartburn that did not affect patient quality of life.” In our experience, the vast majority of patients with radiographic findings of large PEH will have obstructive symptoms, including dysphagia, postprandial bloating, and chest pain. On occasion, elderly patients in our clinics may deny difficulty swallowing and other symptoms, but will report significant and unintentional weight loss over the previous 5 to 10 years and, when questioned further, report substantial changes to their diet to avoid hard, and sometimes even soft solids, because the “food would not go down.”
When these hernias progress to requiring semi-urgent, nonelective repair, we and other surgeons have found that they are associated with a significantly increased risk of perioperative morbidity and mortality. In our series of 662 patients who underwent laparoscopic repair of giant PEH, patients admitted electively for laparoscopic repair had a postoperative mortality rate of 0.5% compared with 7.5% for patients who underwent urgent repair. This can be markedly higher when patients present with gastric necrosis, massive hemorrhage or severe aspiration pneumonia, albeit these more life threatening situations are less common. Thus, when evaluating patients who may be minimally symptomatic it is important to keep this data in mind. The risk of perioperative mortality and/or morbidity with elective and nonelective operation can be estimated to some degree by the size of the PEH, the patient’s functional status, the presence of comorbid conditions, and the patient’s symptom complex. We have recently shown that in patients with age-adjusted Charlson Comorbidity Index (CCI) scores of 5 or less, perioperative morbidity and mortality with elective laparoscopic repair is low and increases dramatically when performed urgently. We also showed that patients with very large PEH were much more likely to have obstructive symptoms, and to present urgently when compared with patients with smaller (<75% gastric herniation) PEH. Many of these urgent presentations occurred in patients who were over 80 years of age and in whom the presence of the PEH was known at an earlier age, even decades earlier, and not repaired. As such, we recommend elective surgical repair for most patients who have minimal symptoms and very large PEH because of the higher risk of mortality or complications after emergency surgery.

Relative contraindications to laparoscopic PEH repair include conditions that might preclude or increase the risk of all laparoscopic surgery, such as portal hypertension, dense abdominal adhesions preventing progress in the case, and significant hematologic clotting disorders, and contraindications to any surgery, such as inadequate cardiovascular function or the inability to tolerate general anesthesia. Age greater than 80 years is not a contraindication for laparoscopic PEH repair if these relative contraindications are manageable. Obesity is not a contraindication, but in the appropriate patient, a hernia repair along with a Roux-en-Y near-esophagojejunostomy may be a better option, especially in patients with comorbidities of obesity and a very high body mass index (BMI). It has also been noted that the risk for recurrent herniation with PEH repair in the morbidly obese patient may be increased and might be lowered by combining a hernia repair with a Roux-en-Y.

### PREOPERATIVE PLANNING

Careful preoperative evaluation is essential. Careful symptom history includes: assessment of typical symptoms of gastroesophageal reflux disease (GERD) (heartburn, regurgitation), obstructive symptoms (dysphagia), chest or epigastric pain, postprandial pain, postprandial vomiting, and atypical symptoms (recurrent aspiration with or without associated pneumonia, cough, shortness of breath, and dyspnea on exertion). In patients with gastric volvulus in association with a PEH, which may be exacerbated in patients with a narrow crural opening, overt or occult bleeding can occur due to compromised blood supply to the herniated portion of the stomach. Even when overt strangulation or volvulus is not apparent, some patients with large PEH will experience varying degrees of gastritis. In some cases, ulceration and bleeding, occurs and patients present with hematemesis or melena but more often the presentation of bleeding is with a chronic anemia. In our experience, iron-deficiency anemia was diagnosed in a number of patients prior to surgical referral, but the relationship to the PEH went unrecognized; this association, when overlooked, can result in multiple blood transfusions, often over many years, before the patient is finally referred for surgical PEH repair. Following repair, the anemia resolves in the majority of patients. As such, assessment in patients with radiographic findings of PEH must include assessment for bleeding or chronic iron-deficiency anemia.
Additional preoperative evaluation includes the following.

- **Blood work.** Hemoglobin to assess anemia; serum albumin to evaluate nutritional status.

- **Radiographic evaluation.** Prior to operative intervention, all patients have radiographic evaluation of the PEH. The most common study is a barium esophagram, and this is currently standard for all of our elective cases unless the patient is unable to participate in the study. Computed tomography provides complementary information to the barium esophagram, such as identification of Type IV PEH, and can be used as a substitute for barium esophagram in urgent situations or for those patients unable to tolerate the barium esophagram. The barium esophagram and computed tomography scan provide an assessment of the location of the gastroesophageal junction, esophageal length, the amount of stomach herniated into the chest, if other organs may also be herniated, and whether a volvulus of the stomach is present. The barium esophagram may suggest that esophageal shortening is present, although, the absolute finding of a shortened esophagus can only be made at the time of surgery when the gastroesophageal junction cannot be delivered tension free into a subdiaphragmatic location. In addition, the barium esophagram can provide information about abnormal esophageal motility and associated abnormalities such as esophageal lesions, strictures or diverticula. A preoperative chest radiograph is obtained in all patients as well to identify other pulmonary pathology that might be present and assess for signs of either chronic lung injury or acute pneumonia secondary to aspiration.

- **Flexible endoscopy.** Preoperative or intraoperative endoscopy is always performed by the operating surgeon to evaluate gastric and esophageal viability, identify associated abnormalities, such as Barrett’s esophagus or esophageal malignancy, identify the location of the gastroesophageal junction, and assess and estimate esophageal length, which may have been difficult to evaluate due to the anatomic distortion created by the PEH. It is critical for the surgeon to perform their own endoscopy and not rely on the findings on endoscopy reported by others as the anatomy of the esophagus and stomach are often distorted and can be difficult to evaluate when unaccustomed to evaluation of PEH.

- **Pulmonary function testing.** We do not routinely obtain pulmonary function testing (PFT) for elective repair of a large PEH; however, when shortness of breath or dyspnea on exertion is present, PFTs may offer important information and risk assessment. This can be due to the space-occupying effects of the gastric herniation into the posterior mediastinum, with local effects on both the heart and the adjacent lung, but may also be due to chronic aspiration and in some cases repeated pneumonias. In cases of complete intrathoracic stomach, the herniation may occupy as much as 40% to 50% of the volume of the right or left hemithorax. In these extremes, PFTs may be useful for assessing the degree of pulmonary impairment but it may be difficult to determine how much of this is due to the hernia versus coexisting lung disease.

- **Esophageal physiology testing.** For large PEH, particularly in patients with primarily obstructive symptoms, pH studies are not routinely performed because the primary indication for repair is related to the mechanical obstruction of the esophagus and stomach rather than sphincter incompetence and reflux disease. A negative pH study would not change the need for operative repair. Manometry can be useful in some patients in whom an esophageal motility disorder is suspected, but should be undertaken with caution as the placement of the catheter can result in perforation of the esophagus or stomach when the anatomic derangements due to the herniation are not recognized. However, if simple manometric assessment of the esophageal body and motor function are being performed, this is generally well tolerated and may help in determining the type of fundoplication used during repair of the PEH.

**SURGERY**

It is important that in the preoperative setting a thorough discussion of the risks and benefits of the operation, including the risk for perioperative death or other adverse
Chapter 11 Laparoscopic Paraesophageal Hernia Repair

outcomes, recurrent hernia, and potential need for reoperation is undertaken. After repair, patients are followed in our clinics long term to monitor for recurrent symptoms or hernia. This close attention to long-term outcomes facilitates early recognition of recurrent symptoms, including dysphagia, and appropriate interventions to assist with patient comfort and satisfaction with quality of life. It is important for the surgeon to remain engaged in this process as the patient’s primary care physicians and even their gastroenterologists may incorrectly attribute symptoms to the PEH repair or fail to recognize correctible problems that are related to the PEH repair.

Once the patient agrees to proceed, final preparations for surgery are made. All patients have a preoperative electrocardiogram, chest radiograph, type and screen and received modified bowel prep with 1 L of polyethylene glycol electrolyte solution. We have found this to be helpful, especially in elderly patients or in patients prone to constipation. Any patients with risk factors for coronary heart disease, including age, hypertension, history of smoking or prior history of coronary disease also undergo cardiac evaluation with a minimum of an exercise or persantine-thallium stress test to determine whether significant coronary disease is present. If the stress test is positive, cardiology consultation is obtained prior to operative intervention, except in emergency cases.

On the day of surgery, patients receive 5,000 units of heparin subcutaneously prior to induction of anesthesia, preferably in the preoperative holding area. In the operating room, general endotracheal anesthesia is induced and flexible endoscopy performed by the surgeon. Care is taken to minimize air insufflation during the endoscopic evaluation. The esophagus is inspected and the stomach is decompressed as much as possible, given the anatomy of the patient. The patient is then positioned for laparoscopy. Our preferred approach for positioning of the patient is supine with the surgeon on the patient’s right side and the assistant on the left. A subhepatic liver retractor is used, so the patient is placed to the far right of the operating room table. A foot stop is placed to facilitate reverse Trendelenburg positioning. Sequential compression devices are placed on the legs bilaterally. A Foley catheter is placed. The patient’s arms are rotated away from the patient, secured to an arm board at a 45-degree angle from the bed and carefully padded. This angle provides adequate access to the operating table and minimizes the risk of stretch injury to the brachial plexus. The abdomen is then prepped and draped and intravenous antibiotics administered for wound infection prophylaxis.

Proper port placement is the key to successful execution of the operation. Because of the extensive mediastinal dissection required to reduce the hernia sac and to fully mobilize the esophagus, placement of the ports in the upper aspect of the abdomen is critical. To accomplish this, we identify the midline from the xiphoid to the umbilicus.

Figure 11.2 Surgeon and port position. Port placement and instrument positions are shown. In a nonobese patient, the ports are positioned one-third of the distance from the xiphoid to the umbilicus. In obese patients, this measure is often inaccurate because of the increased abdominal circumference. In this situation, the patient’s bony anatomy can be used to determine appropriate placement with an imaginary line across the abdomen at top of the anterior superior iliac spines serving as a marker for the normal distance to the umbilicus.
and use a skin marker to divide the distance into thirds (Fig. 11.2). In morbidly obese patients, attention to the distance from the costal margins to the pelvis using the bony anatomy will assist with gauging proper port placement. In the majority of patients, five ports are used. Using the open, blunt port cut down technique, a 10-mm Hassan port, is placed in the right paramedian line approximately one-third of the way from the xiphoid to the umbilicus, taking care to avoid dissection into the falciform ligament. Insufflation pressures are set at between 12 and 15 mm Hg, depending on the patient’s hemodynamics and intraoperative visibility. In compromised patients with poor cardiopulmonary risk, we have found that many can be repaired with insufflation pressure ranging from 8 to 10 mm Hg routinely. Once we have confirmed proper positioning of the Hassan port within the peritoneal cavity, full insufflation is achieved. Port placement then proceeds under direct vision. The assistant’s ports are positioned to the left of the midline. The assistant’s left hand holds the camera, which is passed via a 5- or 10-mm port in the left paramedian line at approximately the same level or slightly lower than the Hassan port in the right paramedian line. The assistant’s right hand is directly below the costal margin in the midclavicular line and is used for retraction. The surgeon’s ports include the Hassan port, through which an energy device is passed for use in sharp dissection. A 5-mm port for the surgeon’s left hand is placed in the right midclavicular line directly below the costal margin. It is critical that the subcostal ports on either side be at least a hands breath (9 to 10 cm) from the paramedian ports as closer positioning creates the potential for interference between the instruments during the procedure. Liver retraction can be accomplished either using a subxiphoid position or through a 5-mm port in the far right lateral subcostal position, depending upon the type of liver retractor to be used.

Reducing the Hernia Sac

Following port placement and liver retraction, the operating room table is placed in steep reverse Trendelenburg to facilitate visualization of the hiatus. Because the patient may be dehydrated due to having nothing by mouth for at least 8 hours, we often begin slowly and incrementally increasing the angle as soon as the operation begins, which allows time for the anesthesiologist to respond to hemodynamic changes and volume requirements. Steep reverse Trendelenburg is helpful to fully expose the hiatus and shift the upper abdominal contents toward the patient’s pelvis and away from the hiatus. Reduction of herniated contents, such as omentum and bowel, is performed upon initial assessment of the hiatus. We do not, however, place traction on the stomach itself, as this causes unnecessary trauma. Rather than placing retraction on the stomach, the surgeon focuses on dissection and reduction of the sac back into the abdomen, which will, by default, also reduce the stomach because the hernia sac also includes the peritoneal lining of the cardia of the stomach. To accomplish sac reduction, the surgeon and assistant grasp the hernia sac just inside the hiatus at or near the 12-o’clock position using the surgeon’s left hand and the assistant’s right hand (Fig. 11.3). By everting this sac, the surgeon can then use hemostatic energy devices such as the harmonic scalpel (Ethicon, Cincinnati, OH) or the ultrasonic shears (US Surgical/Covidien, Mansfield, MA) to proceed. The sac is opened at the junction between the attenuated phrenoesophageal ligament and the peritoneal reflection. The posterior mediastinum is entered through this anterior opening in the hernia sac, exposing the areolar attachments of the hernia sac to the mediastinal structures. To minimize even modest bleeding, the areolar attachments are divided using the energy source, rather than with blunt dissection.

During dissection of the sac, the pleural reflection is identified early in the procedure to minimize risk of intraoperative pneumothorax. Injury to the pleura allows the insufflated CO₂ to enter the hemithorax and can result in hemodynamic instability or ventilation difficulties related to a pneumothorax. The pleural reflection, particularly on the left, can often be identified crossing the midline over the esophagus and can be easily injured during the dissection if intentional and early identification is not routinely performed. Mediastinal dissection is continued until the entire hernia sac is
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Laparoscopic Paraesophageal Hernia Repair

Figure 11.3 Reduction of the hernia sac without retraction on the stomach. The operation begins with the surgeon and the assistant everting the hernia sac just inside the hiatus. The sac is incised, allowing entry into the mediastinum. Dissection proceeds using an energy device and coagulation of the fine areolar attachments of the hernia sac to the surrounding mediastinal structures (inset). During this dissection, care is taken to maintain the integrity of the crural lining and avoid damage to the crural muscle, vagus nerves, or pleura. Note, the stomach is not being retracted during this dissection.

Figure 11.4 Establishment of an intraperitoneal stomach after complete reduction of the hernia sac. Complete reduction of the sac and esophageal mobilization may require 1 to 2 hours of dissection within the mediastinum, but is critical for the long-term success of the operation.

dissected and subsequently reduced, taking care to avoid injury to the pleura, and the anterior and posterior vagus nerves (Fig. 11.4).

After the sac has been reduced from the mediastinum, it is completely separated from the crura. With the sac fully reduced back into the abdomen, the stomach will be noted to lie within the subdiaphragmatic location and frequently completely returned to its anatomic position without the potential for injury that can be caused by retraction on the stomach itself when using the hand-over-hand technique. When separating the sac from the crura, great care is taken to avoid injury to the peritoneal lining covering the crura so to preserve the integrity of the crura and this is a key component to a successful
primary closure (Fig. 11.5). If the crural integrity is not preserved, the integrity is markedly compromised and will not hold sutures securely to prevent dehiscence of the crural repair. If the integrity of the crural lining is maintained and the attachments between the diaphragm and the stomach, spleen, and other retroperitoneal structures are completely divided, a tension-free closure of the crura can be achieved in more than 85% of patients without requiring mesh cruroplasty. We have found that if crural tension is still present after complete mobilization of the hernia and sac, inducing a left-sided pneumothorax may indeed yield a “floppy diaphragm sign,” making tension-free primary repair much easier. Subsequently, the surgeon can then place a small pigtail catheter and eliminate the pneumothorax. This catheter can be removed very early in the postoperative course. It is important to communicate with the anesthesiologist when inducing a pneumothorax.

Re-establishing Adequate Intra-abdominal Esophageal Length

The next step in the PEH repair is to re-establish adequate intra-abdominal esophageal length. If this is not achieved, the esophagus and stomach continue to exert axial forces on the crural closure and a recurrence is likely to result. Extensive, circumferential mobilization of the esophagus is performed high into the mediastinum. The dissection can be carried as high as the inferior pulmonary veins without difficulty. In extreme cases, the dissection can be carried significantly higher, if needed, to gain additional esophageal length. In order to accurately assess the location of the true gastroesophageal junction, we routinely mobilize the gastric fat pad off the stomach and the distal esophagus, similar to the procedure to expose the gastroesophageal junction for a Heller myotomy. This allows clear visualization of the junction of the longitudinal muscle fibers of the esophagus and the serosa of the stomach. We continue the fat pad dissection around the GEJ to create a posterior window between the esophagus and posterior vagus nerve through which to perform the fundoplication (Fig. 11.6). As with the sac reduction, awareness of the anterior and posterior vagus nerves is critical to avoid injury to these vital structures. If there is significant esophageal shortening, which is common with Type III PEH, extensive esophageal mobilization is required and the surgeon should be prepared to perform a Collis gastroplasty if necessary to achieve adequate intra-abdominal esophageal length. We have found over the years, that with more experience, and better esophageal mobilization, the need for a Collis gastroplasty can be reduced, and when it is needed, the length of the gastroplasty can be kept to a smaller distance. We consider adequate esophageal length to be 2 to 3 cm distance from the crura to the gastroesophageal junction with the stomach in a relaxed position within
the abdomen. If tension on the gastroesophageal junction is needed to create this amount of intra-abdominal esophagus, further dissection or gastroplasty is required. Currently our preferred technique for Collis gastroplasty is the wedged technique that we and others have previously described (Fig. 11.7).14

**Re-establishing the Antireflux Barrier**

While gastroesophageal reflux is present in only approximately 50% of patients at the time of PEH repair, the reduction of the mediastinal sac and dissection of the esophagus, by necessity, disrupt the phrenoesophageal ligament and the integrity of the lower
esophageal antireflux barrier and create the potential for symptomatic reflux disease postoperatively. As such, we generally perform an antireflux procedure in the majority of patients. Surgeon preference and preoperative findings on manometry regarding esophageal motility, may help determine the type of fundoplication to be performed: a circumferential “floppy” fundoplication (2-stitch Nissen over a 54 or 56 bougie)\(^\text{15}\) (Fig. 11.8) or a partial fundoplication.\(^\text{16,17}\) In the past, we routinely performed the circumferential “floppy” Nissen fundoplication but more recently, have moved on to a partial fundoplication or “near” Nissen to minimize side effects such as dysphagia, gas bloat, and flatulence. Before performing the fundoplication, the surgeon passes the bougie, which we find preferable due to varying experience in doing this by the anesthesiologist. We then go on to crural closure. In the past, we performed a fundoplication of some type on the vast majority of patients. However, more recently, we have noted that some patients clearly do well with this step omitted but only if the other steps are completely performed, including sac dissection, complete stomach mobilization, and careful crural closure followed by gastropexy. While you may leave some patients with reflux, the side effects of a wrap in elderly patients are not inconsequential. However, we acknowledge, that most patients will tolerate a partial wrap or a floppy Nissen.

In rare situations, such as when the surgeon is concerned about patient stability in the operating room or the viability of the stomach, in very elderly patients (age ≥80 years), in patients with significant multiple comorbidities, or in patients with a significant esophageal motility disorder, salvage procedures, such as gastropexy only, have been recommended. We try to avoid gastropexy only. If pressed for time, we will try to at least perform the sac mobilization and obtain tension-free intra-abdominal stomach. It is rare that with we cannot get this done safely and then add the gastropexy. In our experience, this is much more likely to prevent marked recurrence of the intrathoracic stomach along with symptoms. If esophageal or gastric necrosis is present, esophagogastrectomy may be required. Partial resections and diversion may be necessary in emergency situations with compromised patients, and we would then do a delayed reconstruction when the patient is more stable. For the occasional patient in whom the

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Figure 11.8 Creation of “floppy, two-stitch” Collis–Nissen fundoplication. Maintenance of a proper orientation of the wrap as it passes through the retroesophageal space is critically important for the successful creation of a new antireflux barrier. The Nissen fundoplication is performed after placement of a bougie (usually 54-French) into the esophagus under direct vision.
surgeon decides not to perform fundoplication, the stomach should at least be mobilized, sac dissected and then the stomach secured in an intra-abdominal position using an extended gastropexy technique. Others have described gastropexy as a single point of fixation using suture or the placement of a gastrostomy tube. In contrast, we perform a gastropexy with multiple serial interrupted horizontal mattress heavy sutures (0-gauge) between the stomach and the diaphragm and along the anterior abdominal wall. Beginning at the gastroesophageal junction with a pexy of the stomach to the left crura, sutures are placed approximately 2 cm apart over a distance of 10- to 14-cm. Using this approach, multiple points of fixation are created between the stomach and the diaphragm and abdominal wall to minimize the risk of large hernia recurrence.

**Repairing the Hiatus**

After complete reduction of the hernia sac and extensive esophageal mobilization to restore adequate intra-abdominal length, the third critical element of PEH repair is the crural closure. With meticulous attention to preservation of crural integrity and complete untethering of the crura by dividing the phrenogastric, phrenosplenic and retrogastric attachments, a tension-free, primary suture closure of the hiatus can be achieved in the majority of patients (~85%). To ensure crural integrity, the lining of the crura is identified and preserved early in the procedure. The fully mobilized crura are reaproximated, without tension, using heavy suture (0-gauge) (Fig. 11.9). We prefer to perform crural closure with the bougie removed. After completion of the fundoplication, the bougie is removed and the hiatal opening is inspected. The closure is performed with 2 or 3 interrupted sutures placed posteriorly with the esophagus lying in a neutral, tension-free position within the hiatus. We typically do not place more than 2 stitches posteriorly as additional sutures create an artificial angulation of the esophagus as it passes through the hiatus and may be a source of postoperative dysphagia. After placing the sutures posteriorly, the hiatus is reevaluated. If the anterior space continues to be patulous, that is, more than a centimeter of space between the crura and esophagus with introduction of a grasper through the opening, additional interrupted horizontal sutures are placed anteriorly, on the upper aspect of the crura. If tension is present to any degree, at this point, we induce an intentional pneumothorax to create a “floppy diaphragm sign” which allows the crura to be repaired with essentially no tension. At the completion of the closure, a grasper
should be easily introduced through the hiatus with approximately 1 cm of space surrounding the esophagus circumferentially. In those situations where the crural muscles are attenuated or the overlying peritoneum was demounded during dissection or the crural muscles remain tethered and unable to be reapproximated without tension, the induced pneumothorax may allow viable, good integrity diaphragm to be pulled into place. If this is absolutely not possible, cruroplasty can be performed with bioprosthetic mesh to reinforce the closure. Cruroplasty with other forms of mesh have been reported over the years, by others and by us, but all have some propensity to erode into the esophagus. Thus, we try to avoid synthetic mesh if at all possible in this location, but there will be times when mesh must be considered to avoid leaving an obvious large defect. While biomesh does appear to nicely buttress a somewhat weakened primary repair, spanning distances of crura space with biomesh alone, will likely fail in the long run. A nasogastric (NG) tube is then placed by the anesthesiologist or the surgeon while carefully watching the tube as it is advanced into the stomach with the laparoscope. It is critical that the surgeon and anesthesiologist approach this placement with care as the obstruction created by the wrap and the closure can easily cause resistance to passage of an NG tube and subsequent esophageal perforation during placement if the nasogastric tube is pushed forcefully through the repair.

### POSTOPERATIVE MANAGEMENT

The majority of patients are extubated in the operating room, transferred to the recovery room, and then admitted to the hospital ward for postoperative recovery. However, it is not uncommon to make the decision to admit the patient to the intensive care unit (ICU) for postoperative observation due to age and comorbidities. This decision takes into account intraoperative concerns, the length and urgency of the operation (elective vs. nonelective), and the patient’s underlying comorbid diseases. We also consider ICU admission for the first postoperative night in patients with marked sleep apnea for careful observation. In our series of more than 650 patients, we placed 32% of our patients in the ICU postoperatively for observation. In contrast, ICU admission after antireflux procedures for small hiatal hernias and GERD is extremely rare. Median ICU stay for this subset of patients was 2 days (interquartile range 1 to 3 days). We routinely restrict oral intake to nothing by mouth until after a barium esophagram is performed. In the majority of patients as determined by clinical condition, the barium study is performed on postoperative day number 1 (fundoplication or gastropexy alone) or postoperative day number 2 (Collis gastroplasty plus fundoplication). The barium esophagram in the immediate postoperative setting documents subdiaphragmatic positioning of the fundoplication wrap and assesses for unrecognized esophageal or gastric injury or staple-line leak (in patients who received an esophageal lengthening [Collis] procedure). Given the documented reports of a significant incidence of recurrent hiatal hernias in this population, we perform this test as our first baseline assessment and it serves as a comparison for future studies and as a critique of our surgical repair. In rare patients, the barium esophagram has identified immediate postoperative recurrence and facilitated reoperation in the same hospital setting. After a barium esophagram confirms the adequacy of the repair and an intact esophagus and stomach, oral intake is initiated with clear liquids (~120 mL/hour). Patients are then discharged to home after a median hospital length of stay of 3 days (IQR 2 to 5), although, it is clear that many patients under the age of 80, with minimal comorbidities can be discharged on postoperative day 1 or 2. At discharge, they are instructed to progress to full liquid intake after 3 days and then soft solids after another 3 days. Patients are instructed to eat smaller, frequent meals up to six to eight times daily in small quantities and to avoid hard solids, such as chicken, steak or doughy breads, for at least 6 weeks to allow swelling from the procedure to resolve and to minimize the risk of gas bloat, and dysphagia.
Laparoscopic repair by experienced, laparoscopic, esophageal surgeons is associated with a significant decrease in postoperative morbidity as compared with most series of open repair (~25% of patients experience complications after laparoscopic repair as compared with ~60% after open repair), although no randomized comparative studies have been performed. In our series of over 650 patients who underwent laparoscopic giant PEH repair from 1997 to 2006, the largest series to date, major adverse outcomes included pneumonia (4%), pulmonary embolism (3.4%), congestive heart failure (2.6%), need for reintubation (2.6%), and postoperative leak (2.5%).

Older patients and patients with significant comorbidities (CCI ≥3) had an increase in perioperative morbidity. All postoperative deaths occurred in patients who were older than 70 years, were obese, or had significant comorbid conditions. The majority of postoperative leaks in the series occurred in patients who received Collis gastroplasty (12/14). Obesity was also correlated with the risk of a postoperative leak. When we examined predictors of adverse outcome in a subsequent analysis of 980 patients, a prediction model incorporating patient age (<80 vs. age 80 years or more), elective versus nonelective urgency of operation, and two CCI variables (congestive heart failure and pulmonary disease) provided discriminatory accuracy of 88% for postoperative mortality. Similarly, the discriminatory accuracy of a prediction model for major postoperative morbidity that incorporated sex (male vs. female), age by decade, urgency of operation, the presence of congestive heart failure, and pulmonary disease was 68% (Table 11.1).

While further refinement is needed, patient-specific risk prediction can contribute substantially to decision making regarding operative intervention in this disease process as it will enable the surgeon and patient to weigh the benefits of repair against the potential risk of the operation, taking into account the individual patient’s comorbid conditions along with their symptoms and the size of the hernia.

### Table 11.1

<table>
<thead>
<tr>
<th>Variables in Each Model</th>
<th>Points</th>
<th>Comparison</th>
<th>p-value</th>
<th>Adjusted OR*</th>
<th>95% CI</th>
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</thead>
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<tr>
<td><strong>Mortality</strong></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>Congestive heart failure</td>
<td>5</td>
<td>present vs. absent</td>
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<td>4.740</td>
<td>1.481, 15.172</td>
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<td>present vs. absent</td>
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<td>3.342</td>
<td>1.345, 8.306</td>
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<tr>
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<td>3.165</td>
<td>1.193, 8.397</td>
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<td>Age ≥80 (years)</td>
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<td></td>
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<tr>
<td>Sex</td>
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<td>male vs. female</td>
<td>0.122</td>
<td>1.328</td>
<td>0.927, 1.901</td>
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<tr>
<td>Congestive heart failure</td>
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<td>present vs. absent</td>
<td>&lt;0.001</td>
<td>4.267</td>
<td>2.083, 8.737</td>
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<tr>
<td>Pulmonary disease</td>
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<td>present vs. absent</td>
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<td>1.515</td>
<td>1.083, 2.121</td>
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<td>2.142</td>
<td>1.466, 3.128</td>
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<tr>
<td>Age group (years)</td>
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<td>≥80 vs. &lt;50</td>
<td>&lt;0.001</td>
<td>2.689</td>
<td>1.123, 6.441</td>
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OR, Odds ratio; CI, confidence interval.
*Adjusted for all other factors in the model.
*History of each comorbid disease as defined in the CCI.
*Nonelective surgery includes urgent and emergency surgery as defined by the Society of Thoracic Surgeons.

From reference 8; used with permission.
POSTOPERATIVE FOLLOW-UP

Postoperatively, we follow patients according to our clinical pathway at 2 weeks and then again 1 year after surgery. In the absence of any symptoms, patients are then followed every 2 years with routine barium esophagram and symptom assessment. We have found routine barium esophagram to be extremely useful for determining whether the repair is intact and for understanding the etiology of any symptoms that may develop over time. For example, approximately 15% of patients in our series had a radiographic evidence for small recurrent hernia during postoperative assessment. The majority of these recurrences were associated with minimal symptoms that were managed nonoperatively. If a patient is known to have a minimally symptomatic small recurrence but subsequently presents with worsening symptoms, a repeat barium esophagram can be compared with prior studies when fewer symptoms were present. If the barium esophagram remains unchanged, operative repair of the recurrence may not improve the patient’s symptoms. In contrast, a patient who previously had an intact repair, with worsening or recurrent symptoms associated with a new recurrence would be a candidate for reoperation after confirmatory testing. Symptom assessment is also routine and standardized, including the use of validated measures for GERD health-related quality of life (GERD-HRQL)19 and overall quality of life (SF-36).20 Common postoperative complaints include dysphagia, heartburn, gas bloat, and diarrhea. When significant symptoms are identified during routine, pathway-driven clinical follow-up, appropriate therapy and/or intervention can be performed based on the degree of symptoms, including resumption of medical therapy, endoscopy and dilation, or reoperation, as needed.

RESULTS

In our experience, laparoscopic PEH repair, resulted in good-to-excellent results in up to 90% of patients in both intermediate (median 30 months) and long-term (median 44 months) follow-up. Small radiographic recurrences identified by barium esophagram were seen in ~16%; less than 5% of patients underwent reoperation for recurrent symptoms or symptomatic hernia recurrence.4,5 We have also shown that symptomatic outcomes after laparoscopic fundoplication with Collis gastroplasty are excellent and comparable with those of fundoplication alone. The use of Collis gastroplasty was associated with a higher rate of postoperative leaks (2.7% vs. 0.6%, respectively); however, patients who required Collis gastroplasty in this series had significantly larger PEHs.18

CONCLUSIONS

- There are several key elements to laparoscopic repair of PEH, and these include: (1) complete reduction of the hernia sac and contents; (2) careful preservation of the anterior and posterior vagus nerve; (3) mobilization of the gastroesophageal fat pad and identification of the gastroesophageal junction; (4) recognition and management of a shortened esophagus (extensive mediastinal mobilization and performance of a Collis gastroplasty when necessary); (5) preservation of crural integrity and closure of the hiatal defect without tension; selective use of mesh reinforcement only when a tension-free repair is not possible; and (6) performance of an antireflux procedure.
- Laparoscopic repair of PEH provides excellent patient satisfaction and symptom resolution.
- When performed by surgeons with extensive experience in minimally invasive and open esophageal surgery, the reoperation rates with a minimally invasive approach are comparable with the best open series.5,21
Recommended References and Readings

Open Paraesophageal Hernia: Transthoracic Approach
Gail E. Darling and F. Griffith Pearson

INDICATIONS/CONTRAINDICATIONS

The primary indication for the repair of a paraesophageal hernia is a symptomatic hernia. The most common symptoms are postprandial pain (59%), vomiting (31%), and dysphagia (30%), but may include postprandial dyspnea, acid reflux, iron deficiency anemia, or symptoms of volvulus, acute incarceration or ischemia with severe retrosternal chest pain mimicking myocardial ischemia. Repair of asymptomatic paraesophageal hernia may be considered in patients who are fit for surgery, given that these hernias enlarge over time, often becoming symptomatic, although catastrophic complications, such as gastric strangulation, are rare occurring in only about 3%. A transthoracic approach may be used for repair of any paraesophageal hernia but is particularly appropriate for Type III or IV hernias and should be considered for reoperative repairs, obese patients, and those with acquired esophageal shortening. A transthoracic approach facilitates the assessment of acquired esophageal shortening, which may be difficult to appreciate through a transabdominal approach.

Contraindications for transthoracic repair include impaired cardiopulmonary reserve or the inability to tolerate single-lung anesthesia. Previous left-sided thoracotomy or pulmonary sepsis, wherein one may anticipate difficulty in exposure of the hernia due to extensive adhesions, may be taken into consideration.

PREOPERATIVE PLANNING

Preoperative assessment should include an assessment of the foregut anatomy, noting particularly the location of the gastroesophageal junction, with barium swallow and upper endoscopy. Prolonged exposure to acid reflux may lead to transmural inflammation and acquired esophageal shortening. In such cases, an esophageal-lengthening procedure is required for a successful durable repair. Factors that may be predictive of acquired...
esophageal shortening include an incarcerated hiatus hernia, a large hiatus hernia (greater than 5 cm), Type III hernia, peptic stricture, and Barrett’s esophagus. Assessment of esophageal length is ultimately determined at the time of repair after mobilization of the esophagus, but preoperative endoscopy, barium swallow, and the distance between upper cervical and lower esophageal sphincters on esophageal manometry provide useful insights that may advise intraoperative decision making.

Esophageal manometry should be included in the preoperative assessment if one is considering performing a total or 360-degree fundoplication. This assessment is less critical if one is planning a partial fundoplication. A 24-hour pH study is not required but may be included in the preoperative assessment if the primary indication for repair is acid reflux.

Other important components of the preoperative assessment include assessment of cardiopulmonary reserve. The patient must have adequate pulmonary reserve to tolerate single-lung anesthesia and maintain postoperative pulmonary toilet. Active esophagitis should be treated with proton-pump inhibitors before proceeding with repair. Further, any active pulmonary infection, for example, secondary to aspiration, should also be treated prior to surgery. Active smokers should avoid smoking for a minimum of 2 weeks prior to surgery.

Surgery

The principles of repair are as follows:

- Tension-free reduction of the hernia contents back into the abdomen
- Removal of the hernia sac from the chest
- Closure of the defect by tension-free closure of the crura
- Anchor the stomach in abdomen through performance of fundoplication and crural pexing sutures

The steps include the following:

1. Mobilization of the esophagus
2. Protection of the vagus nerves
3. Mobilization and resection of the hernia sac
4. Assessment of esophageal length and Collis gastroplasty, if required
5. Fundoplication
6. Crural closure

Anesthetic Considerations

Single-lung anesthesia is required using either a double-lumen endotracheal tube or bronchial blocker. A thoracic epidural may be beneficial for postoperative pain control; alternatively, a paravertebral catheter or intercostal nerve blocks may be placed at the time of thoracotomy.

Positioning

The patient should be positioned in full right lateral decubitus position with an axillary role in place and all pressure points well padded. The operative table may be slightly flexed or “broken” at its midpoint to open up the intercostal spaces.

Incision

A posterolateral thoracotomy incision is performed preserving the serratus anterior muscle, entering the chest through the sixth intercostal space. The dome of the diaphragm will interfere with the exposure of the hiatus if the seventh intercostal space is used. Some surgeons resect a segment of the sixth rib to facilitate exposure.
Technique

After entering the chest, the left lung is deflated by the anesthesiologist, and the inferior pulmonary ligament is divided using an electrocautery. Using a malleable retractor and one or more sponges, the lung may be packed out of the way superiorly and anteriorly.

The mediastinal pleura is then opened over the esophagus just anterior to the descending aorta beginning at approximately the level of the inferior pulmonary vein or higher, if necessary, to get above the hernia and at a level where the vagus nerves are still identifiable adherent to the esophagus. Dissection may be accomplished using scissors, electrocautery, or ultrasonic device. The esophagus is mobilized and encircled with a Penrose drain or umbilical tape taking care to keep both vagus nerves with the esophagus. The esophagus is mobilized proximally as far as the aortic arch if necessary and distally to the hiatus. When mobilizing distally, the middle esophageal artery will be divided. This artery must be controlled or troublesome bleeding will result. Traction on the Penrose drain will facilitate both proximal and distal dissection of the intrathoracic esophagus.

The esophagus and hernia sac are mobilized from the mediastinum and pericardium and from the right chest and the contralateral pleura. Ideally, one should avoid entering the contralateral pleural space to avoid unrecognized accumulation of blood into the dependent hemithorax. This dissection may be completed using both sharp dissection and gentle blunt dissection with a pledget or a sponge stick. When mobilizing the esophagus and hernia sac away from the pericardium, care must be taken to avoid excessive pressure on the heart to prevent hypotension or arrhythmia. Gentle traction on the pericardium with an Allison lung retractor or sponge stick will facilitate this dissection. Grasping the pericardium risks injury to the underlying heart and may cause pericardial irritation leading to pericardial effusion or even cardiac tamponade and should be undertaken with great care. The hernia sac is mobilized circumferentially down to the diaphragmatic hiatus. This dissection can be quite challenging when addressing very large paraesophageal hernias.

Once the hernia is completely mobilized, the sac is opened anteriorly (Fig. 12.1). The hernia “sac” (which is actually the attenuated and greatly expanded transversalis fascia draped over the herniated intrathoracic abdominal viscera) is divided circumferentially at the level of the hiatus from the short gastric vessels posteriorly around to the pericardium anteriorly and then continuing posteriorly until joining the original plane of dissection. As stated earlier, care must be taken to avoid injury to the vagus nerves, particularly during this critical phase of the operation where orientation of the transposed abdominal viscera and the esophagus can be challenging. Once this dissection of the hernia sac is complete, the margins of the hiatus, the right and left crura,
and the caudate lobe of the liver can be visualized. The cardia of the stomach will have then been completely mobilized.

The “sac” is then dissected off the stomach. When resecting the sac off the gastroesophageal junction, care should be taken to identify and preserve both vagus nerves. After removing the anterior component of the sac, the stomach and esophagus are retracted anteriorly, and the posterior component of the sac is identified and removed. This dissection can be quite tedious as the sac is very thickened and vascular. Meticulous hemostasis is required to prevent excessive intraoperative blood loss. Once the sac has been removed, the gastroesophageal fat pad is removed, beginning anterior to the right vagus nerve and continuing across to the left, mobilizing the left vagus off of the stomach to clearly identify the gastroesophageal junction (Fig. 12.2).

At this point, the diaphragmatic hiatus should be clearly exposed circumferentially, the lower half of the intrathoracic esophagus fully mobilized, and the gastroesophageal junction clearly identified. To completely mobilize the proximal stomach, the upper portion of the lesser omentum should be divided. This may contain an artery termed “Belsey’s artery,” which is a branch from the left gastric artery that anastomoses with a branch of the inferior phrenic artery. It should be carefully controlled or it may retract into the abdomen. At this point, the cardia should be freely mobile and easily delivered into the chest. This should be adequate for a Belsey Mark IV repair. If a Nissen fundoplication is planned, further mobilization of the fundus may be necessary and can be accomplished by the division of one or two short gastric arteries.

The next step is to determine the need for an esophageal-lengthening procedure. The stomach is reduced into the abdomen. The gastroesophageal junction should lie comfortably in the abdomen with at least 2 cm of intra-abdominal esophagus sitting below the level of the diaphragmatic hiatus without tension. If the stomach or gastroesophageal junction tends to pull up into the chest or there is insufficient intra-abdominal esophageal length, a Collis gastropasty should be strongly considered to ensure an adequate intra-abdominal length of esophagus.
If a Collis gastroplasty is to be performed, a 48- or 52-French Maloney bougie is inserted so that its tip is well within the stomach. The esophagus, gastroesophageal junction, and proximal stomach are delivered into the chest. The greater curvature of the stomach is grasped with two atraumatic graspers and a 60-mm linear stapler with 3.5-mm staples is applied tightly against the bougie so that the bougie is tight against the lesser curve of the stomach (Fig. 12.3). Upward traction on the Penrose drain will facilitate the placement of the stapler. An endoscopic or open stapler may be used. Generally a 5-cm gastroplasty is created. After firing the stapler, the cut edge is oversewn with a running 3-0 absorbable suture.

If a gastroplasty is not required or once the gastroplasty has been completed, the crural sutures are placed (Fig. 12.4). Babcock clamps are used to grasp and elevate each pillar of the right and the left crus, placing them on slight tension. The stomach and gastroesophageal junction are retracted to the right using an Allison lung retractor or a sponge stick. Crural sutures of #1 silk or other heavy nonabsorbable suture are placed 0.5 cm apart beginning posteriorly. The distance between the sutures on the left pillar is slightly longer than on the right. Crural sutures should incorporate some of the tendinous portion of the diaphragm anteriorly taking care to avoid the inferior vena cava on the right. If the hiatus is very large, some sutures may be placed in the anterior hiatus in front of the esophagus to avoid significant angulation of the esophagus as it passes through the hiatus, which may contribute to postoperative dysphagia. The crural sutures are tagged and left untied until the fundoplication has been completed.

**Belsey Fundoplication**

A Belsey fundoplication is accomplished by placing two tiers of three horizontal mattress sutures. If a Collis gastroplasty has been performed, a third tier of three horizontal mattress sutures is added. These sutures roll the fundus up over the distal esophagus for a total distance of 3 or 4 cm creating a 270-degree fundoplication. Key steps to this repair are removing the gastroesophageal fat pad so that the gastroesophageal junction is clearly identified and mobilization of the vagus nerves at the level of the distal esophagus and gastroesophageal junction so that they are not incorporated into the fundoplication.

Using double-armed 2-0 silk with an atraumatic needle, the first suture is placed quite posteriorly, just anterior to the mobilized right vagus. The suture is placed longitudinally in the esophageal muscle for a distance of 0.5 cm approximately 1.5 cm above the gastroesophageal junction and then passed through the seromuscular layer of the fundus 1.5 cm distal to the gastroesophageal junction (Figs. 12.4 and 12.5). The second arm of the suture is placed in similar fashion 0.5 cm away from the first. The second
Figure 12.4 The gastroplasty staple line is then oversewn with a running absorbable 3-0 suture, taking care to reinforce the apex of the staple line. Then, using a heavy nonabsorbable suture such as #1 silk, the crural sutures are placed beginning posteriorly. An atraumatic grasper is applied to each crural pillar and gentle traction applied. The sutures are placed about 0.5 cm apart with slightly wider spacing on the left pillar. The more anterior sutures should include some of the tendinous diaphragm. The fundoplication is begun by placing the first tier of horizontal mattress sutures using double-armed 2-0 silk. The first arm of the suture is placed longitudinally in the esophageal muscle for a distance of 0.5 cm approximately 1.5 cm above the gastroesophageal junction. A seromuscular suture is then placed in the stomach 1.5 cm below the gastroesophageal junction in line with the esophageal suture. The second arm is placed adjacent to the first approximately 0.5 cm medially, placed 1.5 cm above the gastroesophageal junction, and carried longitudinally in the esophageal muscle for a distance of 0.5 cm. A seromuscular suture in the stomach 1.5 cm below the gastroesophageal junction completes the first stitch. The two arms of the suture are tagged. The first suture is placed quite posteriorly pushing the right vagus posteriorly. The second suture is placed in similar fashion, 135 degrees from the first. The middle suture should be aligned with the gastroplasty staple line. The third suture is placed in similar fashion, 135 degrees from the second, pushing the left vagus posteriorly. After placing all three sutures, they are tied down in sequence.

Figure 12.5 The second tier of sutures is placed in similar fashion, 1.5 cm above the first. If a Collis gastroplasty has been performed (as is illustrated), three tiers of horizontal mattress sutures are used. They are placed in similar fashion 1 to 1.5 cm above and below the new “gastroesophageal junction.” Each tier of sutures successively rolls the fundus up over the distal esophagus. It is important that the spacing of the suture on the fundus is similar to the spacing on the esophagus so that the fundus does not bunch up around the esophagus. When completed, the fundus envelopes the distal esophagus for about 270 degrees of its circumference, with the most lateral sutures lying about 1 cm apart with the vagi lying between them.
Chapter 12  Open Paraesophageal Hernia: Transthoracic Approach

The needles should be left attached after placing the second tier. The stomach and gastroesophageal junction with fundoplication is reduced into the abdomen by applying gentle pressure from above and pulling up the second tier sutures while doing so to remove the slack on the sutures. Once the fundoplication is reduced into the abdomen, it is anchored to the diaphragmatic hiatus by passing the needles through the diaphragm from the abdominal side to the thoracic side (Fig. 12.6). It is important to protect the underlying abdominal viscera (using a spoon or a similar device) when passing the anchoring sutures to prevent incorporating these structures into the fundoplication. The sutures in the diaphragm should line up with the corresponding suture in the esophagus and should be the same distance apart as those in the esophagus. Once all the sutures have been placed, they are tied down snugly in sequence, ensuring that there is no slack or redundancy in the sutures but that the tissues are not strangulated.

If a Collis gastroplasty has been performed, three tiers of sutures are placed rather than two with approximately 1.5 cm between each tier (Figs. 12.4 to 12.6). In this situation, the third or final tier of sutures is used to anchor the fundoplication to the diaphragmatic hiatus.

Following completion of the fundoplication, the crural sutures are tied down sequentially beginning from the most posterior. Upon completion of the crural closure, the hiatus should allow a fingertip to pass easily between the esophagus and the adjacent crus with the bougie in place (Fig. 12.7).
Upon completion of the repair, clips are applied at the upper and the lower end of the gastroplasty (if used) or at the top of the fundoplication, and two clips are placed on the apex of the hiatus. These serve as markers for follow-up on subsequent chest x-rays allowing the surgeon to easily determine if there has been an anatomic recurrence. An intercostal drain is placed through a separate stab wound and positioned in the paravertebral gutter, and the chest is closed. Prior to closure, it is important to ensure complete reinflation of the left lung and to evaluate the integrity of the contralateral pleura and if not intact, to evacuate the contralateral pleural space.

**POSTOPERATIVE MANAGEMENT**

Perioperative prophylactic antibiotics (usually cefazolin) are given with one dose preoperatively and one dose postoperatively. Good postoperative pain control, using intravenous narcotics administered using patient-controlled analgesia or a thoracic epidural with continuous infusion of narcotics and local anesthetic supplemented by intermittent boluses controlled by the patient, is essential to prevent inadequate cough and complications such as pneumonia. Nonsteroidal anti-inflammatory drugs are also useful.

A nasogastric tube may be used for the first 12 to 24 hours or longer if there is evidence of gastric stasis or distension. Barium swallow may be performed on the first postoperative day (or later) to rule out leak and confirm the position of the repair. The chest tube and nasogastric tube (if used) remain in situ until the absence of a leak has been confirmed by a contrast study.

**COMPLICATIONS**

Complications in the early postoperative period include atelectasis (5%) and pneumonia (2%). These are prevented through adequate pain control and chest physiotherapy.

The other potential complications that may occur in the early postoperative phase include leak of gastrointestinal contents from either an injury to the stomach or the esophagus in the course of mobilization of the hernia and sac or from a Collis gastroplasty. The risk of these complications is 0% to 4%. Very large paraesophageal hernias tend
to have quite mature adhesions to both pleurae, and mobilization can be difficult and tedious. The adhesions can be quite vascular as can the hernia sac itself. Meticulous hemostasis is required during the dissection to prevent postoperative hemorrhage (<1%). There is a small risk of injury to the spleen or short gastric vessels that is prevented by avoiding excessive traction on the stomach.

Vagal nerve injury may occur most commonly on the left. With very large paraesophageal hernia, the vagus nerves become attenuated and displaced from the esophagus and may be difficult to identify particularly on the left. The risk of vagal nerve injury is higher in reoperative surgery. The consequence of vagal nerve injury may be unnoticeable or may result in delayed gastric emptying or diarrhea. Even in the absence of vagal nerve injury, delayed gastric emptying may occur as a consequence of prolonged incarceration of the stomach in the chest. For this reason, prolonged nasogastric drainage may be required in some patients.

Failure of the crural sutures may occur in the immediate postoperative period with acute herniation of the stomach into the chest requiring urgent reoperation. This may occur when the patient wakes abruptly from anesthesia or has severe retching. This has not been reported in the literature after a transthoracic Belsey approach but has been reported in 1.6% of transthoracic Nissen repairs. Crural sutures may fail over time leading to late herniation in up to 8%. Re-repair is indicated if the patient is symptomatic, but small recurrent hernias are rarely symptomatic. Symptoms associated with recurrence are rarely those of the original presentation and are most commonly related to acid reflux. Symptoms of acid reflux are generally managed medically, but re-repair may be considered.

Obstructive symptoms or postprandial pain may result from inadequate mobilization of the fundus and cardia, failure to correct gastric volvulus, recurrent hernia, or incarceration of the fundoplication in the hiatus. Early dysphagia occurs in 10% of patients and acute gastric dilation in 2% to 5%.

RESULTS

The operative mortality for transthoracic repair is 0% to 5.5%. In laparoscopic repairs, operative morbidity and mortality increases beyond 80 years of age. Although this question has not been specifically addressed for transthoracic repair, it is reasonable to assume the same would be true for open transthoracic repairs. Postoperative complications occur in 19% to 26% of patients although most are not life-threatening. The major drawback of this approach relates to postoperative pain from the thoracotomy. The hospital length of stay reported in the literature is approximately 10 days but may be shorter in the modern era. Anatomic recurrence rate, determined when routine barium swallow is performed in follow-up, is 8%. The rate of symptomatic recurrence is lower at 1% to 3%. The transthoracic repair is durable with low rates of anatomic recurrence and with 18-year follow-up of the Belsey Mark IV procedure, good control of reflux in 84% of patients and the ability to belch and swallow comfortably.

CONCLUSIONS

Transthoracic repair of paraesophageal hernia provides a durable repair with excellent functional results. The transthoracic approach facilitates adequate mobilization of the esophagus, dissection and removal of the hernia sac, meticulous hemostasis, and accurate assessment of esophageal length. It is very useful for reoperations, obese patients, and complex hernias. This repair has stood the test of time but is performed less frequently as laparoscopic repairs are being performed more often with satisfactory and durable results reported.
Recommended References and Readings

13 Open Paraesophageal Hernia and Hill Repair: Open Abdominal Approach

Philip W. Carrott, Jr. and Donald E. Low

INDICATIONS/CONTRAINDICATIONS

Paraesophageal hiatal hernias (PEH) are a rare surgical problem that afflicts older adults, more commonly women. The relatively occult location of the hernia, a historic impression of minimal or vague symptoms, and an incomplete understanding by most physicians of the differing presentation and significance of PEH and sliding hiatus hernias often leads to a delay in diagnosis. Patients often present with a long history of symptomatic “hiatal hernia” and radiographic findings similar to the chest x-ray shown in Figure 13.1. This patient has >50% of her stomach intrathoracic and thus has a “giant” paraesophageal hernia, most likely type III. This picture of a large air space in the lower mediastinum with an air–fluid level will typically be a PEH, but will be labeled as a “hiatal hernia” by many physicians and radiologists. The symptoms in these patients can be subtle and the symptoms experienced by these patients are quite different from those found in patients with standard GERD or a type I or sliding hernia. Type I hernias are the “sliding” type, often producing symptoms of reflux or regurgitation, with only the gastroesophageal junction (GEJ) herniating into the chest. Type II hernias have the fundus of the stomach, but not the GEJ, herniating into the chest; these are relatively uncommon. The most common PEH is type III, which is where both the GEJ and the fundus or body of the stomach is herniated. The larger type IV hernia encompasses both the stomach and other intra-abdominal viscera such as the colon, small bowel, pancreas or spleen.

The PEH patient will typically describe symptoms that slowly evolved over years. Early satiety, anemia, chest pain, and dyspnea are typical in a patient with a large intrathoracic stomach. When the entire array of symptoms associated with PEH is understood, we believe that patients are rarely asymptomatic at diagnosis. In addition, following repair, the vast majority of patients demonstrate measurable improvements in symptoms and quality of life. Reviews from experienced centers have shown that results of repair have improved, with reports of good or excellent subjective outcomes in 83% to 98% of patients.¹
Initial case series suggested that a significant proportion of patients with PEH presented as a surgical emergency with incarceration and/or ischemia of the stomach. Older series showed rates of incarceration and strangulation of 30%, with a mortality of 7%. Modern series and population analyses show that urgent or emergent presentations account for 5% to 15% of operative cases and up to 50% of admissions for PEH, although surgical management is required at the time of acute presentation only a third of the time. In cases of urgent presentation with incarceration and obstruction or ongoing pain, decompression with endoscopy and subsequent nasogastric (NG) tube placement (which may need to be placed with endoscopic guidance) typically relieves acute symptoms and allows for more thorough preoperative preparation. In a review of 5 years of data from New York state, Polomsky et al. found that as more operations were being done, the number of emergent presentations decreased. However, a population-based study of a cohort of octogenarians showed that 43% of these patients had urgent surgery, with a mortality of 15% in the urgent group.

Dyspnea may be related to the hernia as a space-occupying lesion in the chest or an effect on the diaphragmatic function, although effects of the hernia on respiratory function are likely more complex. We have previously demonstrated a measurable improvement in pulmonary function tests (PFTs) for most patients following repair; thus, borderline PFTs should not disqualify a patient from consideration of elective repair. We currently advocate that fit, symptomatic patients presenting with giant PEH should meet with a surgeon to discuss elective repair to improve current quality of life and avoid additional symptoms as these hernias continue to grow. The only contraindications to repair would be medically unfit patients.

Paraesophageal Hernia Repair Indications
- Increasing symptoms or signs associated with giant PEH, which include heartburn, regurgitation, dysphagia, early satiety, dyspnea, upper gastrointestinal (UGI) blood loss
anemia, chest and abdominal pain following meals, as well as eating or lifestyle modification as a result of ongoing early satiety or regurgitation.

- Semi-elective repair in patients presenting with acute nonischemic incarceration treated with NG tube or endoscopic decompression.
- Urgent repair in the setting of unremitting chest or abdominal pain, UGI obstruction, active gastrointestinal bleeding from Cameron lesions/ulcer disease or evidence of ischemia on upper endoscopy.

### PREOPERATIVE PLANNING

Patients presenting with PEH should undergo a barium swallow to confirm the anatomic conformation of the hernia, with an assessment of the esophageal and gastric emptying as well as the degree of esophageal shortening. When possible, being present for the barium swallow gives the surgeon the best information regarding esophagogastric anatomy and motility of the esophagus and whether the hernia is fixed or mobile. If this is not feasible, a video recording of the swallow is a good alternative. Upper endoscopy is utilized to assess the degree of esophageal shortening, document esophagitis or Barrett’s esophagus, and assess the grade of the flap valve, as well as evaluate for Cameron lesions or erosions in the stomach at the diaphragmatic hiatus (see Fig. 13.2). We recommend esophageal manometry routinely to evaluate the lower esophageal sphincter (LES) pressure and assess esophageal motility pattern. Inserting the current high-resolution catheters is often difficult in large PEHs; therefore, we routinely combine manometry with upper endoscopy and insert the catheter over a wire. Nonspecific motility disorders are common in older patients with PEH, although motility pattern will often improve following repair. The approach to repair may have to be modified in patients with esophageal dysmotility (poor peristaltic progression) or hypomotility (mean wave amplitude <30 mm Hg). We do not routinely perform gastric emptying or 24-hour pH-impedance studies in this population. We do, however, routinely have patients perform PFTs before and after surgery, as many will have measurable improvements following repair.

Figure 13.2 UGI and EGD Passage: A: EGD view of the hiatal narrowing from above. B: UGI showing a near 100% intrathoracic stomach.
Preoperative Assessment

- Barium swallow
- Upper endoscopy, with or without wire-guided manometry
- Esophageal manometry
- PFTs, medical or cardiac clearance as necessary

Surgery

The open Hill repair is performed via a limited upper abdominal midline incision. We currently utilize the laparoscopic approach in virtually all patients with type II hernia and many patients with type III and type IV hernias whose GEJ is seen to be mobile on UGI fluoroscopy study. The open Hill repair is our preferred approach in patients with large type III and type IV hernias involving 75% to 100% of the stomach and significant esophageal shortening, which either does not reduce or only minimally reduces during witnessed preoperative barium studies. The advantages of this approach include the fact that a primary closure of the diaphragm is virtually always possible. The Hill repair is based on anchoring of the GEJ to reliable intra-abdominal structures posteriorly and therefore avoids the need to utilize the Collis gastroplasty, thereby maintaining normal anatomy. Originally, Dr. Hill used the median arcuate ligament to anchor the repair. Most surgeons find the dissection of the celiac axis daunting which is one of the reasons that the Hill repair is not more commonly utilized. We advocate utilizing the base of the crura and the pre-aortic fascia for anchoring the repair. The Hill operation has distinct advantages over other methods, as it firmly anchors the GEJ in the abdomen, re-establishing the normal length of intra-abdominal esophagus.

Once the hernia sac is completely reduced and excised, the esophagus can undergo extensive transhiatal mobilization, often up to the carina, to allow the GEJ to be reduced into the abdominal cavity with little or no tension. The esophagus becomes foreshortened and dysfunctional when elevated as in a type III or type IV PEH, and once it is secured to its standard length, its normal contraction pattern is often restored. Esophageal shortening is more prevalent when the patient has a history of esophagitis, esophageal stricture, or Barrett’s esophagus. One of the biggest controversies in PEH repair is that of recurrence. The diaphragmatic hiatus must be closed securely, but not to a point that results in postoperative dysphagia. Many have supported the use of various synthetic or biologic meshes to augment the hiatal closure. We have found that with appropriate mobilization of the right and left crura, closure can almost invariably be done primarily. Secure fixation, as performed in the Hill repair, produces a low recurrence rate that is similar to a Collis–Nissen fundoplication.

Historically, the three options for dealing with clinically significant esophageal shortening were a thoracic approach with extensive esophageal mobilization, an esophageal-lengthening procedure (such as the Collis gastroplasty), or the Hill repair.

Keys to the Operation

- Adequate esophageal mobilization and mediastinal dissection, to establish 3 to 4 cm of intra-abdominal esophagus should be the goal.
- Excision of the hernia sac
- Firmly anchoring repair sutures to reliable intra-abdominal structures to avoid recurrence
-Accentuating the angle of His and recreating the gastroesophageal flap valve to produce a viable antireflux mechanism.

Positioning

The patient is placed supine with the right arm tucked and left arm out at 90 degrees. We use the “upper hand” retractor system (V. Mueller, Allegiance, Deerfield, IL) as well as a stationary liver retractor to retract the left lobe of the liver. The “upper hand” retractor...
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blades are placed under the right and left costal margins, retracting each superiorly and laterally. This works to verticalize the diaphragm and allow for good exposure of the esophageal hiatus. A Balfour retractor is used for the lower portion of the incision (see Figure 13.3).

**Technique**

The Hill operation is predicated on using the natural attachments of the esophagogastric junction, specifically, the phrenoesophageal membranes to anchor the repair firmly in the abdominal cavity to the condensation of the crura and the preaortic fascia, thereby accentuating the angle of His and recreating a functional gastroesophageal flap valve.

- The operation is done through a limited upper midline incision between the tip of the xiphisternum and 4 to 5 cm above the umbilicus. The xiphisternum is often excised and an upper hand retraction device is used to elevate the costal margin and verticalize the diaphragm to allow unobstructed access to the esophagogastric junction.

- Exposure is further improved by mobilizing the left lobe of the liver by taking down the triangular ligament. The liver is then retracted to the patient’s right with a deep Harrington retractor held in place with an upper arm or a retracting device (Figs. 13.3 and 13.4).

**Figure 13.3**
- Martin’s Arm and upper hand retractors in place. Current incision limited to half the distance from xiphoid to umbilicus.
- Retractor setup for exposing the abdominal esophagus. The upper hand retractor verticalizes the diaphragm.
- Following mobilization of left lobe of liver, it is retracted with a Harrington retractor held in place with a Martin’s Arm retractor (See Figure 13.4).

**Figure 13.4** The hernia sac is freed from mediastinal attachments and reduced into the abdomen.
The intrathoracic stomach is reduced into the abdominal cavity as much as possible. The dissection begins along the medial border of the right crus taking down the peritoneal reflection. There are often two sacs associated with paraesophageal hernias. The one along the right crus is typically smaller, although in rare circumstances, it can go for an extensive distance into the mediastinum and right chest. Dissection is continued outside of the sac, but inside the right crus. There are typically extensive attachments to the right pleura, which can be easily separated from the hernial sac, and then the dissection is continued up over the anterior aspect of the hiatus where the raphe between the right and left sacs is regularly encountered (Fig. 13.5).

Dissection is continued around the anterior edge of the hiatus and down onto the left crus, once again separating the peritoneal reflection. The peritoneum in this area can often be profoundly thickened due to the chronic nature of the hernia, and then once again working outside of the sac, dissection is continued up into the mediastinum. The pleura is inevitably attached to the outside of the sac and once again needs to be separated. Most of this dissection can be done without sharp or cautery dissection. Mobilization of the peritoneal reflection is then continued down onto the midportion of the left crus. At this point, there is usually easy access to the mediastinum and the esophagus can be encircled first manually and then encircled with a Penrose drain (Fig. 13.4). In many cases, the posterior vagus nerve will be geographically separate from the posterior aspect of the esophagus and should be included in this dissection to avoid injuring it with the additional posterior dissection.

With the esophagus encircled, it can be retracted inferiorly and the remainder of the peritoneal reflection on the inferior aspect of the left crus is easily taken behind the esophagus (Fig. 13.6). It should be noted that every effort should be made to preserve the peritoneal coverings of both the right and left crura. The outside aspect of the left crus is then mobilized to make this structure as mobile as possible. In older patients, the left crus will often be seen to be smaller and, therefore, complete mobilization is important. One of the advantages of the Hill procedure is the fact that the short gastrics do not need to be mobilized to carry out the operation.
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Working up through the esophageal hiatus, the esophagus should be circumferentially mobilized. Taking note of the pathway and location of the anterior and posterior vagus nerves, this dissection can be easily done for 10 or 12 cm and, depending on the body habitus of the patient, often up to the subcarinal space to facilitate as tension free a reduction of the GEJ into the abdominal cavity as possible.

With the esophagogastric junction completely reduced, the preaortic fascia can be palpated as a rim over the surface of the aorta through the inferior aspect of the hiatus. In many older patients, this tissue will either be attenuated or absent and, in this case, the base of the left and right crura should be grasped with a large Babcock clamp, and then the condensation of the crus is lifted away from the underlying aorta and two 0-silk sutures with pledgets are placed above and below the Babcock clamp and tied to initiate closure of the hiatus and also to act as retraction sutures to anchor the repair (Fig. 13.7).

Figure 13.6 The posterior vagus nerve (highlighted by the forcep) with the dissected right and left crura immediately posterior.

Figure 13.7 A: The condensation of the crura are approximated with a Babcock clamp. There is a sponge in the hiatus and the esophagus is retracted to the left. B: First crural sutures (held within the clamp) are left long to use as a retractor to elevate the crura away from the aorta when the repair sutures are placed.
The hiatus is then closed with interrupted simple 0-silk sutures with pledgets placed posterior to the esophagus. These are placed approximately 1 cm apart and, often due to the size of these hernias, the hiatus can be selectively further plicated with 0 silk sutures placed at 10- and 2-o’clock positions to close the hiatus and minimize the anterior deviation of the esophagogastric (EG) junction.

The hernia sac is then trimmed away from the esophagogastric junction, carefully identifying the anterior vagus nerve, which can often run across the anterior aspect of the sac.

The posterior phrenoesophageal bundle is identified and grasped by palpating the posterior vagus nerve with the left hand placed behind the EG junction and using the right hand to rotate the fundus, utilizing the posterior vagus as a fulcrum, and identify the phrenoesophageal bundle and underlying serosa immediately posterior to the posterior nerve (Fig. 13.8).

The anterior phrenoesophageal bundle is identified at the base of the angle of His anteriorly; depending on the patient’s body habitus, it can have a generous amount of fatty tissue associated with it and it is important to grab the tissue right at the base of the angle of His and include some underlying serosa of the fundus. Once this tissue is grasped, it can be rotated down to the base of the crural approximation to get an impression of the ultimate alignment of the repair (Fig. 13.8).

The repair is carried out with four 0 silk sutures that are placed lateral to medial on the anterior bundle, superior to inferior on the posterior bundle and through the condensation of the crus (Fig. 13.9). Each suture is placed through the anterior
bundle to the posterior bundle and then through the condensation of the crural fibers, lifting them away from the underlying aorta with the retraction sutures (Figs. 13.10 and 13.11).

- Once these sutures are placed, the first two sutures are tied down to the condensation of the crus with a single throw and clamped (Fig. 13.12). This provides the opportunity to measure intraoperative manometric pressures. The targeted goal in an open
procedure is between 25 and 55 mm Hg, and if pressures exceed this level, the sutures can be loosened and pressure measurements repeated (Fig. 13.13).

- Once suitable pressures are obtained, all four sutures are permanently tied and a final manometric reading is obtained and recorded.
- The flap valve is then accentuated with two 0 silk sutures placed anteriorly and laterally from the fundus to the esophageal muscularis and the rim of the esophageal hiatus. This closes off the anterior hiatus and accentuates the valve (Fig. 13.14).
- The manometric catheter is removed and replaced with an NG tube and at this point, palpation through the anterior stomach will reveal a well-formed and functional flap-valve apparatus. In very large hernias, where recurrence or postoperative nausea and vomiting are a concern, the selective placement of a gastrostomy tube can be considered to anchor the anterior body of the stomach and allow gastric decompression should nausea occur in the 3 to 4 weeks following surgery. Addition of a pexy to the diaphragm can also aid in preventing a recurrence (Fig. 13.15).
- Retractors are removed and closure is done in the standard fashion. Blood loss should be <50 ml under normal circumstances. These operations are done with an epidural catheter and the patient is typically mobilized on the day of surgery and the NG tube is removed the following day.

Figure 13.12 The first two repair sutures are tied with a single knot and held in place with clamps. This allows adjustment depending on manometric findings.

Figure 13.13 With the first two repair sutures clamped, manometric pressures are obtained to ensure the repair is not too tight. Pressures should be between 25 and 55 for patients with normal esophageal function.
Postoperative management is similar to that for any other antireflux surgery. We give antiemetic agents before the patient emerges from anesthesia, in most cases droperidol, dexamethasone, and ondansetron. We do leave an NG tube overnight in most patients following an open repair and aggressively treat nausea to minimize retching. Mobilization, ideally, is started the day of surgery and continued throughout the hospital stay. The NG tube is typically removed the next day and diet is advanced to clear liquids.
on the second postoperative day. Patients are typically discharged on postoperative day 3 or 4 on a pureed diet. We maintain patients on pureed and selective soft food for about 2 weeks postoperatively, beginning on postoperative day 2 or 3. Following this, a modified soft diet is used for another 2 weeks, limiting the amount of bread and meat.

### COMPLICATIONS

The most commonly encountered complications in the older population include atrial fibrillation, delirium, wound complications, and incisional hernias.\(^{12}\) We have utilized permanent suture to reinforce the inferior portion of the wound to minimize the incidence of incisional hernia. The vast majority of complications in the immediate postoperative period, however, are minor. Early dysphagia to solid food can occur, but is typically not an issue when the patient adheres to the postoperative dietary protocol.

### RESULTS

Patients are typically extremely satisfied following repair. In our series, over the last 10 years, we have no operative mortalities and no recurrences requiring reoperation in 270 consecutive patients.\(^1\) Over 90% of those complaining of heartburn or regurgitation were improved following repair. A substantial majority were also improved with regard to their preoperative early satiety and dyspnea. We routinely obtain 3-month postoperative barium swallows and PFTs. Repeat endoscopy is done in patients who have persistent dysphagia or a history of Barrett’s esophagus. In our published series, a recurrence was seen in 25 of 170 postoperative barium studies. Of these, 23/25 were described as “small sliding hernias” or between 1 and 3 cm. These results are similar to the largest laparoscopic series by Luketich et al., which demonstrated a 15% radiographic recurrence, although Collis procedures were used 53% to 86% of the time and crural mesh reinforcement 12% to 17% of the time.\(^{11}\) The vast majority of radiographic recurrences are small and rarely clinically significant.

### CONCLUSIONS

The incidence of giant paraesophageal hernias is increasing in the United States.\(^3\) The open Hill repair has specific benefits in this patient population in that the operation involves firmly anchoring the repair in the abdominal cavity, which makes it unique compared with other antireflux procedures. This firm anchoring, combined with an extensive transabdominal mobilization, produces a reliable, functional repair without the need for a thoracic approach or a Collis procedure. It can be done safely with a low recurrence rate and significantly impacts patients’ preoperative symptoms.

- The symptomatic impact of PEH is underappreciated and typical and atypical symptoms routinely improve following repair.
- Symptomatic patients who are surgical candidates should meet with an experienced surgeon to review the pros and cons of elective repair.
- Thorough preoperative workup should include UGI, EGD, and manometry. Nonspecific esophageal motility diseases typically improve following repair.
- The Hill repair provides an excellent transabdominal alternative, especially in patients with giant hernias and a potential for esophageal shortening.
- The Hill repair can be typically accomplished without the need for esophageal-lengthening procedures (Collis) or mesh reinforcement of the hiatal closure.
- The Hill repair can be done safely with very low morbidity and mortality and a low incidence of recurrence.
Recommended References and Readings

Achalasia is the most common esophageal motor disorder with an incidence of 0.03 to 1 case per 1,00,000 people per year. The underlying motor dysfunction includes aperistalsis of the esophageal body and a failure of the lower esophageal sphincter (LES) to relax. Approximately 50% of patients with achalasia have increased resting pressure of the LES. Dysphagia is the most common symptom of achalasia, and its onset is usually insidious. Most patients complain of dysphagia to both solids and liquids with the progression of disease. Other symptoms include regurgitation of undigested food, aspiration, and chest pain.

Histologic analysis using tissue specimens from autopsy and surgical myotomy in patients with achalasia have demonstrated that the primary region of damage is the esophageal myenteric (Auerbach’s) plexus, which exhibits loss of the inhibitory innervation of the esophageal body and LES. Histologic characteristics of the myenteric plexus include a prominent but patchy inflammatory response consisting of predominantly CD3- and CD8-positive cytotoxic T lymphocytes, variable numbers of eosinophils and mast cells, loss of ganglion cells, and some degree of myenteric neurofibrosis. In the early stage of the disease, an inflammatory reaction is more prominent and the ganglion cells appear to be preserved; however, with the progression of disease, the ganglion cells are completely lost and replaced by myenteric fibrosis. Although previous studies have suggested a familial predisposition to the development of the disease, degenerative, autoimmune, and infectious factors are also listed as possible causes of the inflammatory process that leads to the expression of the disease.

**INDICATIONS/CONTRAINDICATIONS**

Because none of the available treatments can correct the underlying disease in patients with achalasia, the foundation of therapy is palliative and centers on relieving esophageal outlet obstruction while minimizing postmyotomy gastroesophageal reflux. Pneumatic dilation and surgical myotomy are the procedures most commonly performed for achalasia. In current practice, pharmacologic therapies, such as botulinum toxin and
smooth muscle relaxants, while minimizing the side effects of surgery, are reserved for patients who are unable or unwilling to undergo surgical treatment or pneumatic dilation. A recent meta-analysis suggested that surgical myotomy is superior to pneumatic dilation in achieving long-term therapeutic success, although the included studies were inadequately powered and exhibited a large degree of heterogeneity in study design and likely in surgical techniques. The most recent European multicenter, randomized controlled study to compare pneumatic dilation with laparoscopic myotomy demonstrated that the short-term therapeutic success rate (up to 2 years) was equivalent between the groups. In this study, the dilation was initially performed using a 35-mm balloon and esophageal perforation occurred in 30% of patients. Subsequently, the protocol was modified and the primary dilation was performed using a 30-mm balloon. The esophageal perforation rate in the dilation group was 4% compared with 12% in the myotomy group. Due to recurrent symptoms, 24% of the dilation group required additional dilations or surgical myotomy, whereas only 14% of the myotomy group required dilation. Up to 20% of the myotomy group had evidence of postmyotomy gastroesophageal reflux. These findings suggest that the treatment algorithm for achalasia requires further modification and individualization in order to improve the outcomes, regardless of which procedure is employed. Although pneumatic dilation is the most effective nonsurgical option to treat achalasia, it is a process requiring several interventions that result in submucosal microhemorrhage and fibrosis, and in our most recent review, we noted an increased risk of mucosal perforation during surgical myotomy. In addition, younger patients (<40 years) tend to require more dilations for recurrent symptoms, thus we prefer to manage younger patients preferentially with surgical myotomy.

The Heller myotomy was first described as two parallel myotomies in 1913 and was subsequently revised to a single anterior myotomy in 1923. With the advancement of minimally invasive surgical techniques over the last two decades, laparoscopic myotomy has become the first-line treatment option at most centers in the United States. Prior interventions (such as dilation or botulinum toxin injections), the presence of a sigmoid esophagus, long duration of symptoms, and a low resting LES pressure may be associated with an increased risk of failure with laparoscopic myotomy. In addition, preexisting daily chest pain is a predictor of therapeutic failure and likely indicates vigorous achalasia with simultaneous esophageal contractions as a cause contributing to the symptom complex.

Since Richards et al. demonstrated a significant benefit with the addition of a partial fundoplication to reduce postmyotomy gastroesophageal reflux symptoms, the majority of surgeons have incorporated a Dor or a Toupet partial fundoplication as an integral component of the procedure. In this chapter, the technique of the laparoscopic Heller myotomy combined with laparoscopic partial fundoplication (Dor or Toupet) is described.

**Sigmoid Esophagus**

Sigmoid esophagus is a dramatically dilated and tortuous thoracic esophagus that reflects long-standing achalasia and chronic obstruction. Although somewhat controversial, several authors have demonstrated good outcomes in patients with achalasia and a sigmoid esophagus who had undergone myotomy and a partial fundoplication. Others recommend esophagectomy for these patients.

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**DIAGNOSIS AND PREOPERATIVE PLANNING**

Achalasia should be suspected for any patient with dysphagia and regurgitation of undigested food and saliva. The diagnosis is based on clinical symptoms, barium esophagram, and esophageal manometry. During the workup, it is crucial to exclude any organic lesions, such as esophageal cancer, that may cause pseudoachalasia. Patients with pseudoachalasia may be older and have a quickly progressing dysphagia and remarkable weight loss. If pseudoachalasia is still suspected after a meticulous workup, endoscopic ultrasound and/or CT scan should be performed to rule out external compression or an intramural neoplastic process. It should be noted that pseudoachalasia can follow...
long-standing dysphagia from an excessively tight anti-reflux wrap or can occur as a component of a paraneoplastic syndrome, and the treatment of the primary tumor (i.e., colon cancer) can improve the symptoms of achalasia.

In patients with achalasia, a barium esophagram typically demonstrates a dilated esophagus with a smooth distal tapering, and this finding is frequently described as a "bird’s beak" narrowing at the gastroesophageal junction (GEJ). It should be noted that esophageal dilation may not be present in the early stages of achalasia. Upper endoscopy may show a dilated esophagus with undigested, retained food. A feeling of a “pop” will often be experienced by the endoscopist when traversing the GEJ with the endoscope, which further supports the diagnosis. Endoscopy is also important to rule out the presence of esophageal malignancy and/or Barrett’s esophagus and to remove the retained fluid and the debris from the esophagus prior to surgery.

Esophageal manometry is the gold standard in making the diagnosis of achalasia, typically demonstrating absent or incomplete relaxation of LES and an aperistaltic esophageal body. The LES resting pressure is often elevated from baseline; however, many patients have relatively normal LES resting pressure but do not demonstrate complete relaxation upon deglutition. The aperistalsis may be characterized by low-amplitude (<30 mm Hg), simultaneous mirror image (isobaric) waves due to a common cavity phenomenon. Vigorous achalasia is a rare variant of achalasia, which is characterized by repetitive simultaneous contractions with no relaxation of the LES and can be associated with chest pain. Because the interpretation of manometry is sometimes difficult in patients with a dilated or a food-filled esophagus, the data should be interpreted as a component of the entire clinical picture. Recently, Pandolfino et al. categorized patients with achalasia into three groups based on the findings exhibited on high-resolution manometry (HRM): Achalasia without esophageal pressurization (type I, classic), achalasia with esophageal compression or compartmentalization in the distal esophagus >30 mm Hg (type II), and achalasia with spastic contractions (type III) (Fig. 14.1). Logistic regression analysis demonstrated that a type II pattern on HRM is a predictor of positive treatment response, whereas type III is associated with negative treatment response, suggesting that this classification system may be useful in predicting the outcomes and tailoring therapeutic options.
Prior to surgery, the possibility of the need for subsequent interventions due to primary treatment failure should be explained, especially in patients with preexisting chest pain, prior dilations or botulinum toxin injections, a sigmoid esophagus, and long duration of symptoms. Preoperatively, the patient should be maintained on a liquid diet for 3 days to reduce the amount of undigested food in the esophagus. Rapid sequence intubation with cricoid pressure (Sellick’s maneuver) should be uniformly employed to minimize the risk of aspiration.

**SURGERY**

**Positioning**
- The operation is performed under a general anesthesia in a split-legged position. Sequential compression devices are routinely applied to prevent deep venous thrombosis. The patient’s knees are supported and a footboard is placed to prevent patient sliding when the table is placed in a steep reverse Trendelenburg position. The surgeon stands in between the patient’s legs, and the assistant stands on the left side. Alternatively, the surgery can be performed with the patient in a supine position and the surgeon standing on the right side of the table.
- Upper endoscopy is performed. Care is taken not to insufflate too much air and to decompress the stomach thoroughly after the endoscopic examination. The endoscope can be maintained in the proximal esophagus for evaluation following myotomy.

**Port Placement**
- We first create pneumoperitoneum by inserting a blunt port using a cut-down technique; others describe inserting a Veress needle in the left upper abdomen close to the costal margin. A 5-mm port is subsequently placed in the left paramedian location 3 to 5 cm above the umbilicus and the pneumoperitoneum is maintained at 15 mm Hg. This 5-mm port is used for the camera which is controlled by the assistant’s left hand. A 5-mm 30-degree laparoscope is introduced through this port, and exploratory laparoscopy is performed (Fig. 14.2A). We use VersaStep bladeless trocars for all ports (Covidien Surgical, Mansfield, MA).
- The second port (10 mm) is placed in the left midclavicular line, 2 cm below the left costal margin under direct visualization. This access is used for the surgeon’s right hand. The third port (5 mm) is then placed within the left anterior axillary line along the left costal margin and is used for the assistant’s right hand. The fourth port

![Figure 14.2 A: Port placement. Five-port technique is used. B: Placement of Nathanson liver retractor. The left lateral segment of liver is retracted superiorly to expose the diaphragmatic hiatus.](image-url)
(5 mm) is placed immediately to the left of the xiphoid process. A Nathanson liver retractor (Cook Medical, Bloomington, IN) is inserted through this port and secured with a table-mounted holder to retract the left lateral segment of liver superiorly, exposing the diaphragmatic hiatus (Fig. 14.2B). The last port (5 mm) is placed 2 to 3 cm below the right costal margin, immediately to the anatomic right position of the falciform ligament and is used for the surgeon’s left hand.

**Dissection**

- The operation is started by dividing the gastrohepatic ligament using harmonic shears (Ethicon Endo-Surgery, Inc., Cincinnati, OH). Other energy devices can be used for this and the subsequent dissection. Once the right crus of the diaphragm is identified, it is separated from the esophagus, keeping its peritoneal covering intact. The dissection is continued anteriorly to the esophagus along the phrenoesophageal membrane moving toward the left crus. Care should be taken to identify and preserve the anterior vagus nerve trunk during this maneuver.
- The dissection is carried onto the left crus separating it from the esophagus. Again, the peritoneal lining of the crus should be preserved. The acute angle of His and gastric fundus are mobilized by dividing the gastrophrenic attachments and the highest short gastric vessels with harmonic energy. If no hiatal hernia is identified, posterior dissection is unnecessary and the posterior attachments of the phrenoesophageal membrane and the esophageal hiatus are preserved.
- To clearly define the GEJ, the gastroesophageal fat pad is mobilized from left to the right side starting along the cardia (Fig. 14.3). The anterior and the posterior vagus nerve trunks are identified and preserved throughout the procedure. The fat pad and the nerves are reflected to the right to expose the entire area of anterior wall of the esophagus, GEJ, and proximal stomach for myotomy.

**Myotomy**

- The myotomy can be performed in several different ways—using blunt dissection, hook electrocautery, or other energy devices. We start by bluntly separating the longitudinal muscle fibers with atraumatic graspers immediately proximal to the GEJ on
the anterior wall of the esophagus until the circular muscle fibers are encountered. The circular muscle fibers are then divided bluntly until the submucosal plane is identified (Fig. 14.4A). Subsequently, the myotomy is extended proximally 5 cm from the GEJ and distally 2 to 3 cm onto the gastric cardia (Fig. 14.4B). The muscle edges are further separated from the underlying mucosa on both sides, leading to a distinctive view of the bulging mucosa of the distal esophagus. In order to completely divide the remaining muscle fibers, a 52-French dilator is carefully placed under laparoscopic visualization, thus highlighting the remaining muscle fibers. These fibers are individually divided sharply and bluntly. A sponge with dilute epinephrine solution can be used to stop oozing at the myotomy site, should the surgeon wish to avoid all forms of energy near to the exposed submucosa.

At the completion of myotomy, upper endoscopy is performed to confirm a widely patent GEJ and the absence of leak. If a perforation has occurred, it is repaired with an interrupted absorbable suture.

**Fundoplication**

We prefer to perform a Dor fundoplication to reduce postoperative reflux symptoms while covering the myotomy site with the gastric serosa. To reconstruct the acute angle of His, the gastric fundus 2 cm distal to the anatomic GEJ along the greater curvature is sutured to the left crus at the 4-o’clock position, incorporating the left side of the myotomy with a 2-0 nonabsorbable suture (Fig. 14.5A, B). Then, the anterior surface of gastric fundus is folded toward the patient’s right side, covering the myotomy site with the posterior gastric wall facing the anterior abdominal wall. An interrupted greater curvature of fundus-to-myotomy-to-crura suture (2-0 nonabsorbable) is placed at the 2-o’clock position to start the fundoplication (Fig 14.5C). An additional three to four sutures are placed to secure the fundus to the right crura (7- to 8-o’clock) and to the apex of the esophageal hiatus (11- to 1-o’clock). The stitches along the right crura may include the right edge of the myotomy to keep it from closing (Fig. 14.5D). The appearance of a groove over the posterior gastric fundus, which indicates a “tight” fundoplication, should be avoided. Care should be taken to avoid any injury to the myotomy site when sutures are placed, and this can be avoided by mobilizing the muscle away from the submucosa after longitudinal myotomy.

A Toupet fundoplication is an option if circumferential esophageal mobilization is performed. The gastric fundus is passed through the retroesophageal space to the right side of the esophagus without redundancy or twisting, and two or three sutures
Figure 14.5 Dor fundoplication. A, B: The first suture is placed between the proximal gastric fundus, left crus, and the left edge of the myotomy to recreate the angle of His. C, D: The gastric fundus is sutured to diaphragmatic opening, covering the myotomy site.

are then placed between the posterior aspect of the gastric fundus and the right crus. Additional sutures are placed between the left gastric fundus and the left crus to align the fundoplication with the esophagus. Both the right and left sides of the gastric fundus are then sewn to both edges of muscular layers along the myotomy site with four or five interrupted sutures on each side (Fig. 14.6).

**Sigmoid Esophagus**

- Patients with sigmoid esophagus should undergo circumferential mobilization of the distal thoracic esophagus and the GEJ. This maneuver helps to straighten the esophageal axis, which may help with better postmyotomy emptying.

**Closure**

- After complete hemostasis is achieved, the liver retractor is removed under laparoscopic visualization. The skin incisions are closed with absorbable suture.
The patient is extubated in the operating room. A chest radiograph is obtained in the recovery room to ensure there are no acute pulmonary issues such as atelectasis or pneumothorax. The urinary catheter is removed in the recovery room or the following morning. Prophylactic anticoagulation, in conjunction with sequential compression stockings, is routinely employed to decrease risk of deep venous thrombosis and pulmonary embolism. The nursing staff is instructed not to place a nasogastric tube at any
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Chapter 14  Laparoscopic Heller Myotomy and Fundoplication for Achalasia

Point in the setting of nausea or emesis to avoid iatrogenic perforation along the myotomy. If the patient develops persistent nausea or has significant abdominal distension, we perform an upper endoscopy and place a nasogastric tube under direct visualization. The patient is admitted to the surgical ward and encouraged to ambulate and use the incentive spirometer to maximize physical and pulmonary function, thus preventing cardiopulmonary complications. Usually, a patient-controlled analgesic pump is used to provide adequate pain relief for the first 24 hours. In the absence of nausea, abdominal distension, or a large gastric bubble on chest x-ray, a barium esophagram is performed on postprocedure day 1 to rule out a leak. If appropriate, a liquid diet is started. A dietary consultation is routinely performed prior to discharge to counsel and educate the patient on a postfundoplication diet. Most patients are discharged on a liquid diet by the second postoperative day. Soft diet can be initiated after a week and a regular diet by 4 weeks. Patients are instructed to avoid heavy lifting (greater than 10 kg) for 6 weeks and to crush their pills or switch to a liquid form, if possible.

COMPLICATIONS

In a meta-analysis comparing various endoscopic and surgical modalities for the treatment of achalasia, Campos et al. reviewed 39 papers involving 3,086 patients who had undergone laparoscopic myotomy with a mean follow-up of 35.4 months. Complications were reported in 6.3% of patients, and mortality was 0.1%. Intraoperative perforation was seen in 182 patients (6.9%). Postoperative clinical manifestation of perforation requiring additional therapy was observed in 19 patients (0.7%). With the laparoscopic technique, the incidence of wound infection or port site hernia is extremely low. Despite performing antireflux surgery, postoperative gastroesophageal reflux can occur in up to 10% of patients, and reflux symptoms can be controlled with medical therapy. Postoperative dysphagia can be caused by incomplete myotomy (especially on the gastric side), submucosal fibrosis, a tight fundoplication, anatomic obstruction secondary to megaesophagus, or gastroesophageal reflux-related mucosal injury such as esophagitis and peptic stricture.

RESULTS

The controversies as they relate to surgical myotomy include approach, whether or not to use a fundoplication, type of fundoplication, length of myotomy, and therapeutic approach to sigmoid esophagus.

Surgical Approach

In the meta-analysis by Campos et al., laparoscopic myotomy provided better symptom relief (89.3%; median follow-up, 35.4 months) compared with open abdominal myotomy (84.5%; median follow-up, 87.4 months), transthoracic myotomy (83.3%; median follow-up, 102 months), or thoracoscopic myotomy (77.6%; median follow-up, 36.4 months). The incidence of postmyotomy gastroesophageal reflux was lower with the addition of a fundoplication after laparoscopic myotomy than without (8.8% vs. 31.5%, respectively, \( p = 0.003 \)). It is generally accepted that the laparoscopic Heller myotomy is the optimal operative approach for patients with achalasia.

Sigmoid Esophagus

Several authors have described good long-term results with a laparoscopic myotomy in patients with sigmoid esophagus. Mineo et al. showed significant improvement in dysphagia score and quality of life in 14 patients with sigmoid esophagus treated with open and laparoscopic myotomy at a median follow-up of 85 months. Schuchert et al. showed 37.5% failure rate of myotomy in 24 patients with sigmoid esophagus. Age and symptom
duration were associated with higher risk of myotomy failure. In a study by Sweet et al., 12 patients with sigmoid-shaped esophagus and esophageal diameter greater than 6 cm were treated with laparoscopic Heller myotomy. Excellent-to-good results were seen in 91% of these patients. At a median follow-up of 45 months, 33% of patients had persistent or recurrent dysphagia that improved significantly with esophageal dilation. In a retrospective review, Faccani et al. showed improved outcomes in 18 patients who had sigmoid esophagus who underwent myotomy and a “pull-down” technique. These patients had 360-degree mobilization of the GEJ along with the application of U stitches on the right of the lower esophagus to rotate the GEJ to the right and straighten the distal esophagus. In light of these reports, Heller myotomy can be considered as a first-choice treatment in selected patients with a sigmoidal esophagus and achalasia before undertaking an esophagectomy.

**Need for Fundoplication**

In a double-blind randomized study by Richards et al., 43 patients were divided into two groups—21 with myotomy alone and 22 with myotomy and a Dor fundoplication. Postoperative LES pressures and symptom improvement were similar at 6-month follow-up. Based on 24-hour pH monitoring, the myotomy alone group had significantly higher incidence of pathologic reflux compared with the myotomy plus Dor group (47.6% vs. 9.9%; \( p = 0.005 \)). Median distal esophageal acid exposure time was lower in the myotomy plus Dor group (0.4%; range, 0 to 16.7) compared with the myotomy group (4.9%; range, 0.1 to 43.6; \( p = 0.001 \)). In a retrospective study of 149 patients, Rice et al. demonstrated that although postmyotomy resting and residual LES pressures were higher in patients with the addition of Dor fundoplication, it did not impair esophageal emptying and significantly reduced reflux symptoms. It is generally accepted that partial fundoplication should be included with laparoscopic Heller myotomy.

**Dor versus Toupet Fundoplication**

In a retrospective study comparing Dor (n = 41) with Toupet fundoplication (n = 23) following Heller myotomy, Arain et al. demonstrated no differences between Dor and Toupet fundoplication with regard to dysphagia resolution and the postoperative use of proton pump inhibitors. Recently, a multicenter, randomized controlled trial to compare laparoscopic Dor (n = 36) with Toupet fundoplication (n = 24) following Heller myotomy demonstrated that there were no significant differences in efficacy to improve dysphagia and regurgitation symptoms based on the type of partial fundoplication. The Dor group was more likely to have abnormal pH testing compared with the Toupet group (41.7% vs. 21.1%, respectively), although this difference was not significant (\( p = 0.152 \)). A Dor or a Toupet partial fundoplication can be used interchangeably with equivalent reflux control in patients with achalasia who undergo laparoscopic Heller myotomy.

**Dor Versus Nissen Fundoplication**

A randomized controlled trial to compare Dor (n = 71) with Nissen fundoplication (n = 67) following Heller myotomy demonstrated no significant difference in reflux symptoms, but dysphagia rates were significantly higher in the Nissen fundoplication group at a mean follow-up period of 125 months (15% vs. 2.8%; \( p < 0.001 \)). Nissen fundoplication should not be used as an antireflux procedure in patients with achalasia who undergo laparoscopic Heller myotomy.

**Extension of Myotomy**

In a retrospective study to evaluate the outcomes of 102 patients who had undergone laparoscopic Heller myotomy (7 cm myotomy including 1.5 cm onto the gastric wall) with Dor fundoplication, Patti et al. suggested that an inadequate myotomy onto the gastric cardia is an avoidable cause of postoperative persistent dysphagia. Oelschlager
et al. reported the outcomes of patients who had undergone extended myotomy (3 cm onto the cardia) with a Toupet fundoplication (n = 63), and compared the results with those who had undergone standard myotomy (1.5 cm onto cardia) with a Dor fundoplication (n = 52). Nine patients (17%) with standard myotomy required repeat intervention due to postoperative dysphagia, including four who required a redo myotomy, whereas three patients (5%) with extended myotomy required reintervention (endoscopic dilation) with no need for redo operations (p < 0.005). An extended gastric myotomy (2.5 cm) should be performed in all patients with achalasia who undergo laparoscopic Heller myotomy.

**CONCLUSIONS**

Treatment of achalasia aims to release of esophageal outlet obstruction at the GEJ, while minimizing gastroesophageal reflux. Laparoscopic Heller myotomy with a partial fundoplication is a reasonable option to treat achalasia and can be performed with minimal morbidity and almost zero mortality when patients are appropriately selected. Extension of the myotomy onto the gastric cardia for at least 2 to 3 cm is essential to achieve excellent symptomatic improvement. It should be noted that none of the treatments for achalasia can restore the impaired function of LES and esophageal body, so the ultimate goal of the surgeon is to direct patients to the optimal initial treatment option, most likely to achieve long-term symptom control rather than just initial symptomatic improvement.

**Recommended References and Readings**


15 Transthoracic Approach for Achalasia
Richard F. Heitmiller and Lynne A. Skaryak

Introduction
Open transthoracic surgery for achalasia is nearly 100 years old. Heller is credited with the first description of an open transthoracic surgery for achalasia in 1913. This involved dual distal esophagomyotomies, one on each side of the esophagus. In 1918, De Brune Groenveldt showed that a single myotomy was equally effective and this is the approach that is used today. At first, this method was not universally accepted. Up until the 1950s, many surgeons believed that the region of narrowing in achalasia was hypoplastic, and therefore proposed methods commonly used for open pyloroplasty to relieve the lower esophageal obstruction. While these methods did relieve obstruction, they also resulted in profound and unacceptable rates of reflux. After increasing reports came out to this effect the technique of esophagomyotomy won the day. More recently, the effectiveness of myotomy has not been questioned but the length and extent of myotomy have been debated. In 1967, Ellis et al. described an open surgery that restricted the esophagomyotomy to the distal esophagus, thus striking a balance between releasing the muscular obstruction yet avoiding reflux. Others advocate a longer myotomy, onto the stomach, with an added fundoplication. Both methods have their supporters and good results. This chapter will describe the methods of open transthoracic surgery for patients with achalasia.

INDICATIONS/CONTRAINDICATIONS
The age distribution of patients with achalasia is a bell-shaped curve ranging from the very young to those of advanced age. The peak age for clinical presentation is 30 to 40 years. There is no cure for achalasia, and there are limited treatment options. The first principle of care, therefore, is to ensure that any treatment for patients with achalasia fits into a lifelong plan for their care. This is especially true for patients presenting at a younger age.

The indications for management of patients with achalasia include dysphagia leading to weight loss, prominent regurgitation especially with associated aspiration pneumonia, and pain from spasm. In general, despite its effectiveness, open surgery is no longer considered the best first-line therapy for achalasia. Treatment plans should proceed from less to more invasive methods. Laparoscopic esophagomyotomy has emerged...
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as the leading primary treatment, especially in younger patients. Still, there is a role for open surgery.

Indications for open myotomy include the following.

- Failure of prior laparoscopic esophagomyotomy, especially if the results were initially favorable
- Failure of medical therapy such as botulinum toxin injections or pneumostatic dilatation
- Patients whose esophagus has been perforated during nonopen treatment methods
- Patients who are not candidates for laparoscopic methods due to adhesions or prior surgeries
- Associated intrathoracic or esophageal pathology such as diverticular disease or associated ipsilateral lung pathology requiring surgery
- Vigorous achalasia
- An irreparable esophagus secondary to size, tortuosity, or injury

Contraindications for open surgery include the following.

- Patient is not a candidate for open surgery due to the risk of surgery from comorbidities
- Young patients who have not been evaluated for laparoscopic esophagomyotomy

Indications for esophageal replacement include the following.

- Failed prior surgeries for esophagomyotomy with scarring, stricture, and adhesions
- Markedly dilated esophagus (>6 cm diameter), also referred to as megaesophagus, especially when associated with tortuosity

PREOPERATIVE PLANNING

Preoperative preparation involves confirming the diagnosis of achalasia, ruling out or identifying any associated conditions, assessing overall gastrointestinal motility, and assessing the patient's risk for thoracotomy.

Manometry remains the gold standard for diagnosing achalasia. If this is not available or not tolerated by the patient, video esophagography by an experienced radiologist serves well to confirm the clinical suspicion of achalasia. A standard contrast swallow is less accurate but is sometimes clear in cases of dilated esophagus with a classic bird's beak narrowing of the lower esophagus at the esophagogastric junction.

Associated esophageal conditions that should be looked for include evidence for spasm, as seen with vigorous achalasia, or diverticular disease. Flexible esophagogastroscopy should be performed to rule out an occult esophageal malignancy presenting as pseudoachalasia. Finally, any other intrathoracic pathology that might need to be managed or evaluated at thoracotomy should be identified before surgery. Computed tomography, though not needed routinely before transthoracic esophagomyotomy, will best define any ipsilateral thoracic pathology if it is suspected.

Rarely a patient is suspected of having achalasia clinically, who in fact has global, severe, gastrointestinal hypomotility. The patient's dysphagia and regurgitation, a product of pan-gastrointestinal lack of inertia, are falsely interpreted as a primary esophageal disorder. Proceeding with esophagomyotomy in these patients does not solve their clinical problem.

Patients should undergo standard preoperative workup for thoracotomy. The need for a more detailed evaluation of cardiorespiratory status, including detailed cardiac or pulmonary function, depends on a patient's clinical history and physical findings.

SURGERY

The objectives of transthoracic esophagomyotomy are to relieve lower esophageal obstruction by myotomy, address any associated esophageal pathology if present, and prevent or minimize postoperative gastroesophageal reflux. The following procedures
will be discussed: (1) esophagomyotomy (Heller procedure), (2) esophagomyotomy with partial fundoplication (“modified Heller procedure”), (3) extended esophagomyotomy for vigorous achalasia, (4) reoperative esophagomyotomy, and (5) esophageal replacement.

**Transthoracic Esophagomyotomy**

Double-lumen general endotracheal anesthesia is used. Special attention must be directed toward protection against aspiration during intubation, given the potential for regurgitation of retained esophageal contents in achalasia patients. A nasogastric tube is placed prior to patient positioning to empty the esophagus, facilitate esophageal mobilization, and for postoperative esophagogastric decompression if needed. Patients are then positioned in the right lateral decubitus position. A left lateral thoracotomy through the sixth, seventh, or eighth intercostal space is used. The specific interspace should be individually selected based on the level of the left side of the diaphragm so that optimal exposure of the lower esophagus is obtained. If the incision is too low, the left hemidiaphragm obstructs the operative field. If it is too high, it is extremely difficult to see or reach the lower chest to complete the surgery. The ideal interspace should open just over the dome of the ipsilateral hemidiaphragm (Fig. 15.1). Ellis et al.3,5 are credited with championing the method of esophagomyotomy that is limited to the distal esophagus. The distal esophagus is circumferentially mobilized taking care not to injure the vagus nerves or to disrupt the esophageal hiatal attachments. An encircling 0.25-inch Penrose drain works well to lift the lower esophagus up from the mediastinum. A longitudinal myotomy is performed down to the mucosa that characteristically pouts out (Fig. 15.2). The myotomy extends distally just across the esophagogastric junction onto the stomach for a length of 1 cm or less. Proximally, it is continued for a 5 to 7 cm total length. The cut edges of the muscle are further dissected back to widely free the mucosal lumen and to prevent rehealing of the cut muscle (Fig. 15.3). Adding additional procedures, such as vagotomy, gastric drainage, or fundoplication, according to Ellis,6 “merely complicates an otherwise simple operation.”

The technique of open myotomy that we prefer uses blunt-tipped Metzenbaum scissors to divide the muscle down to the mucosa. This yields a very controlled myotomy with easy muscle layer identification and a minimal chance of mucosal damage. Once the mucosa is identified the myotomy is easily and rapidly extended in either direction. Other methods include using a straight or hooked cauter, or a long-handed knife to divide the muscle. If a knife is used, passing a midsized bougie into the esophagus first can serve as an “anvil” upon which to cut with greater control.

Thoracotomy closure with chest tube drainage is routine.
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Figure 15.2  Esophagomyotomy is performed with scissor dissection exposing the underlying mucosal surface.

Figure 15.3  Two methods of myotomy are shown. In (A), the myotomy extends well onto the stomach. A partial fundoplication is then added. In (B), the myotomy extends just onto the stomach. No fundoplication is added. Dissection of the divided muscle on either side minimizes rehealing of the cut edges (inset).
Modified Heller Esophagomyotomy

Esophagomyotomy plus antireflux fundoplication is referred to as a modified Heller myotomy. The rationale for combining these procedures is based on the fact that many surgeons find it difficult to determine just how far to extend the myotomy onto the stomach. By extending the myotomy well onto the stomach, the chance of leaving persistent, obstructing lower esophageal sphincter (LES) muscle fibers is minimized, and reflux is then managed by means of fundoplication.

Double-lumen endotracheal anesthesia is used. A nasogastric tube is placed after induction and before positioning. Patients are placed in the right lateral decubitus position and a left sixth to eighth interspace incision is used. The pulmonary ligament is divided, the ipsilateral lung deflated, and the lower esophagus circumferentially mobilized. Care is taken to avoid vagal nerve injury. In contrast to myotomy alone, the esophageal hiatus is opened and the peritoneum entered. The gastroesophageal (GE) junction is identified and delivered into the chest. The GE junction fat pad is split in the midline. Each half, along with the vagus, is reflected to either side of the esophagus. A myotomy is made on the lower 5 to 7 cm of esophagus and extended for approximately 2 cm onto the stomach. Again, the cut edge of the myotomy is dissected back to minimize reapproximation with healing. The hiatus is narrowed by interrupted non-absorbable sutures placed in the crus laterally that displace the esophagus medially and anteriorly. These sutures are placed but not tied as yet. A two-stitch “Belsey type” partial fundoplication is performed (Fig. 15.4). A double-armed nonabsorbable suture is ideal for this. No pledgets are used. The two-stitch fundal wrap, in addition to its antireflux role, is ideal at helping to keep the cut edges of the myotomy separated. Once the fundoplication is completed and the GE junction returned to the abdomen, the lateral crural sutures are tied and cut (Fig. 15.5). The hiatus should be tightened to where it just accommodates the tip of a finger alongside the esophagus posteriorly.

Thoracotomy closure and chest drainage proceed in routine fashion.

Extended Myotomy For Vigorous Achalasia

In some patients with achalasia, esophageal spasm pain is especially prominent. This entity is termed vigorous achalasia, and it should be screened for as part of the preoperative workup for open achalasia surgery.

Treatment options for this variant of achalasia are similar to those described above. However, for vigorous achalasia patients, the myotomy is extended proximally to include the region of esophagus identified preoperatively to produce high-amplitude,
nonperistaltic waves. If a specific site cannot be identified, a myotomy that extends to the level of the aortic arch is used (Fig. 15.6). The chest incision is closed per routine.

**Reoperative Transthoracic Esophagomyotomy**

Reoperative surgery after a previous failed esophagomyotomy can be a challenge. For reoperative chest surgery, it helps to have either a nasogastric tube or an esophageal bougie in the esophagus to assist with esophageal remobilization. Another maneuver to consider is to open the hemidiaphragm through its central tendon to assist with mobilization of the esophagogastric junction from below.

**Esophageal Resection and Replacement**

Either a transthoracic or transhiatal esophagectomy method may be considered for esophageal resection and gastric pull-up. If there has been no previous intrathoracic surgery with adhesions, a transhiatal approach with gastric pull-up and cervical esophagogastric anastomosis has been reported. The steps for transhiatal esophagectomy are standard (see Chapter 20) and will not be detailed in this chapter focusing on transthoracic methods. If this approach is used, extra care must be taken during the mediastinal dissection to avoid esophageal injury with spillage, injury of mediastinal structures,
and bleeding because of the enlarged size, tortuosity, and hypervascular nature of the “end-stage” achalasia esophagus.

We prefer a three-incision approach to esophagectomy for achalasia patients who need esophageal replacement for controlled, direct visualization during transthoracic esophageal mobilization (Fig. 15.7). General double-lumen endotracheal anesthesia is used. A nasogastric tube is placed after induction. Again, care must be taken to avoid aspiration during induction, intubation, and positioning. Patients are placed in the left lateral decubitus position and a right fifth or sixth intercostal space lateral thoracotomy incision is employed sparing the anterior serratus muscle. The ipsilateral lung is deflated and retracted medially. The mediastinal pleura is opened just distal to the azygos vein arch and the esophagus encircled with a 0.25-inch Penrose drain. The esophagus is mobilized distally toward the hiatus. Generous use of the electrocautery is recommended. The chance of injury to mediastinal structures is minimized by progressively lifting the esophagus out of its bed. Proximally, it is best to leave the azygos arch and the superior mediastinal pleura intact (Fig. 15.8). This serves to isolate the proposed cervical esophagogastric anastomosis from the chest. Apical dissection is completed using a transhiatal method. The thoracic duct is routinely suture-ligated in the lower right chest, a chest tube placed, the lung expanded, and the chest closed. The patient is then returned to the supine position, reintubated with a single-lumen tube, and positioned as for a transhiatal esophagectomy. The remainder of the procedure is identical to a transhiatal esophagectomy except that the intrathoracic esophageal mobilization has already been completed. Modified left collar and midline abdominal incisions are employed. In the neck, the previously mobilized esophagus is encircled. The stomach is mobilized preserving the right gastroepiploic vascular arcade. A greater curvature-based gastric tube is created using a linear stapler. The staple line is secondarily closed with an absorbable running suture. The esophagus and the gastric cardia are then withdrawn out through the neck incision, and the stomach tube passed through the esophageal bed into the neck using a technique previously reported (Fig. 15.9). A two-layered,
Figure 15.8 Preservation of the azygos vein arch and upper mediastinal pleura separates the upper gastric tube and anastomosis from the right chest. The location of the thoracic duct is shown (inset).

Figure 15.9 The completed gastric pull-up is shown.
handsewn, end-to-side esophagogastric anastomosis is used as previously described. A jejunostomy is placed in a fashion that permits percutaneous replacement later on.

POSTOPERATIVE MANAGEMENT

Myotomy

Following esophagomyotomy alone, the target discharge will be after 2 to 3 days. The limiting factors are pain control and chest drain management. Nasogastric tube placement is not routine. A contrast esophagogram is not mandatory before resuming oral feedings; however, a “baseline” postsurgery study is helpful to document the anatomy in the event that the patient presents with recurrent symptoms in the future.

Following modified Heller procedure, the target discharge will be after 3 to 4 days. A nasogastric tube may be used to prevent retching and disruption of the partial fundal wrap. The chest drain is managed as per usual. Again, a contrast study is helpful as a baseline but not needed before resuming oral intake.

Esophagectomy

Management of postesophagectomy achalasia patients is the same as for patients undergoing surgery for esophageal cancer. Our patient care pathway targets a discharge on postoperative day 6 or 7. Patients are kept intubated overnight after surgery to protect against aspiration pneumonia, then extubated per routine criteria. Nasogastric drainage continues for 3 or 4 days. Low-rate tube feedings (10 to 30 mL maximum) begin on day 3. Contrast esophagography is performed on day 5 and oral feedings then resumed in a graded fashion prior to discharge.

COMPLICATIONS AND OUTCOMES

Operative mortality is 0% to 1%. Vigorous pulmonary toilet and adequate pain control are crucial to prevent pulmonary complications postoperatively. Early results demonstrate good-to-excellent symptom improvement in 83% to 98% of patients. Although symptom relief may be durable, most series document a steady decline in swallowing quality as symptoms recur. In a series involving 159 patients, Liu et al. demonstrated favorable symptom relied in 97% to 98% of patients early on, that fell to 53% to 55% depending on whether myotomy alone versus myotomy plus Belsey antireflux wrap was used. Late dysphagia is independent of whether fundoplication is performed. Gastroesophageal reflux symptoms occur in 13% to 24% of patients. Gaisser et al. noted that early postoperative dysphagia was an indicator of early failure but that sigmoid esophagus was not.

Esophageal resection for failed achalasia is a complex undertaking because of the invariable previous surgeries. Miller et al. presented their series with 37 patients. Indication for surgery was recurrent obstruction (81%), cancer (8%), bleeding (5.5%), or perforation (5.5%). Operative mortality was 5.4% and good-to-excellent long-term results were achieved in 91.4% of patients.

CONCLUSIONS

Transthoracic surgery for patients with achalasia, primarily esophagomyotomy with or without fundoplication, has a proven track record as it approaches its 100th year anniversary. It is a safe and an effective treatment for symptomatic patients, and it must be considered the gold standard against which to measure all new competing treatment surgeries.
Recommended References and Readings

Introduction

Epiphrenic diverticula are outpouchings in the distal 1/3 of the esophagus due to herniation of the esophageal mucosa and submucosa through the muscular layers of the esophageal wall. Most patients with an epiphrenic diverticulum (>75%) have abnormal esophageal motility. Therefore, epiphrenic diverticula are typically treated with diverticulectomy to correct the outpouching and myotomy to address the underlying motor disorder.

Dysphagia, food regurgitation, and chest pain are the presentation symptoms recorded in patients with epiphrenic diverticula. The main reason for suggesting a surgical approach is the regular and progressing discomfort resulting from the underlying motor dysfunction. The condition is usually present in high-strung individuals and proper physiologic and psychological investigation is indicated. Up to one-third of all patients with an epiphrenic diverticulum are asymptomatic. These patients can be treated conservatively but kept under observation as 20% will show an increase in size of the diverticulum. Inflammation, bleeding, fistulisation, and cancer formation are complications that may result from an intrathoracic epiphrenic diverticulum.

**INDICATIONS/CONTRAINDICATIONS**

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<th>Indications</th>
<th>Contraindications</th>
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<td>• Severity of symptoms associated with the diverticulum</td>
<td>• Asymptomatic patient</td>
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<td>• Complications related to the diverticulum</td>
<td>• Associated medical condition</td>
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<td>• Progression in size of the diverticulum</td>
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PREOPERATIVE PLANNING

Symptom evaluation is important as symptom frequency, duration, and severity represent the main indicators to proceed with surgery.

Radiologic evaluation of the esophagus is essential to document the anatomy and exact location of the diverticulum. Epiphrenic diverticula are found on the distal 10 cm of the esophagus above the cardia (Fig. 16.1). They usually develop on the right posterolateral side of the esophageal wall and are frequently associated with a small sliding hiatal hernia.

Manometric evaluation of esophageal function is essential as a majority of the patients will be documented with a primary idiopathic motor disorder of the spastic or achalasic variety. Dysfunction of the lower esophageal sphincter (LES) may be recorded intermittently but is still a significant abnormality that probably plays a major role in the functional obstruction of the distal esophagus and the eventual appearance of hyper pressures and diverticular herniation through the esophageal wall. Endoscopy is essential to document location and orientation of the diverticulum but mostly to rule out associated benign or malignant esophageal lesions.

Essential evaluation

- Symptoms
- Esophagram
- Motor function evaluation
- Endoscopy

Figure 16.1 Barium esophagram of an epiphrenic diverticulum.
The patient is positioned in a right lateral decubitus and a left thoracotomy above the eighth rib is completed. The rib is sectioned at the anterior and posterior extremities. Ventilation is via a double-lumen endotracheal tube, allowing the exclusion of the left lung. The inferior pulmonary ligament is divided and the lobe is retracted anteriorly and superiorly (Fig. 16.2).

The mediastinal pleura is opened along the anterior border of the thoracic aorta, along the left crus of the diaphragm and then following the posterior pericardial reflection. The esophagus is mobilized progressively with careful separation of the contralateral pleura from mediastinal tissues. The integrity of both vagi nerves is protected.

The diverticulum location has been determined by radiologic and endoscopic investigation and Penrose drains are placed around the esophagus proximally at the level of the inferior pulmonary vein and distally at the level of the cardia (Fig. 16.3).

Most of the epiphrenic diverticula will look toward the right pleural cavity. Thus, the esophagus and the diverticulum are freed progressively from fascia and vascular tissues of the mediastinum. Inflammation can be significant around the diverticulum, and frequently there are adhesions between the diverticulum and surrounding structures (Fig. 16.4).
The esophagus is freed between the inferior pulmonary vein and the diaphragm. A small hiatal hernia is frequently present, and we free all anterolateral hiatal attachments to mobilize the gastric fundus from the gastroplenic vessels. The whole gastroesophageal junction is delivered into the chest through the hiatus.

With the esophagus and proximal stomach completely mobilized, the esophagus and the diverticulum can be rotated easily to allow easy access for dissection of the diverticulum by the surgeon. With a Duval clamp holding the diverticulum, the fibromuscular tissue covering its neck or collar is freed progressively and the defect in the esophageal muscularis is identified (Fig. 16.5). A large, weighted bougie (50 to 56 French) is passed into the stomach and helps to free the esophageal mucosa above and below the collar of the diverticulum.

The diverticulum generally develops due to the presence of a motor dysfunction of the esophagus. Depending on its position in the esophageal circumference, the diverticulum may be part of the myotomy that needs to be completed or may need to be treated separately.
A large-mouthed diverticulum developed toward the left chest may be managed with a long myotomy surrounding the collar of the diverticulum and extending proximally to its upper limit. The diverticulum, if shallow, can then be suspended to the rim of the divided muscularis in order to eliminate any dependency of the sac.

Usually, the diverticulum will be oriented toward the right chest and will need to be resected (Fig. 16.6).

Special care must then be taken to protect the integrity of the esophageal lumen by ensuring the presence and correct positioning of the large endoesophageal bougie (Fig. 16.7A).

Figure 16.6 Typical orientation of an epiphrenic diverticulum.

Figure 16.7 A: Large bougie placed in the esophagus. B: Esophagus after resection of the epiphrenic diverticulum.
Part II  Surgical Treatment of Esophageal Motility Disorders—Achalasia and Esophageal Diverticula

The resection is at the level of the collar with the bougie offering protection against excess mucosal resection. The resection is completed either with an open handmade repair or using a stapler technique (Fig. 16.7B).

Traction sutures are placed on the proximal and distal borders of the diverticulum collar, and the diverticulum is resected (Fig. 16.8A).

The esophagotomy is closed as for a standard handmade anastomosis; inverted total layers sutures are used for the extremities, and the closure is completed by single sutures tied externally (Fig. 16.8B).

Using the same precautions for protection of the esophageal lumen integrity, a linear 5- or 6-cm stapler can be used to close the neck of the diverticulum. A 1-cm rim of mucosa is left distal to the stapling line and a second row of suture integrates that rim of mucosa with closure of the muscularis over the resection line (Fig. 16.9).

The esophagus resumes its normal position following resection of the diverticulum.

A posterolateral long esophageal myotomy is planned contralaterally, from a level above the upper border of the diverticulum collar and extending distally 2 to 3 cm

Figure 16.8  A: Placement of traction sutures and resection of the diverticulum. B: Suture closure of the esophagomyotomy.

Figure 16.9  Stapled closure of the esophagomyotomy.
on the stomach wall. The myotomy is planned as an inverted T where distal lateral transection will allow suture eversion of the gastric muscularis. The spastic motor abnormality present in these patients motivates this type of myotomy, and the LES effects must be removed as well as it is also dysfunctional (Fig. 16.10).

When myotomy is performed, many surgeons also do a partial fundoplication. The incidence of gastroesophageal reflux disease (GERD) in patients who have undergone a myotomy after resection or suspension of an epiphrenic diverticulum is unknown. However, GERD occurs in ~50% of patients who have undergone myotomy for achalasia.

**POSTOPERATIVE MANAGEMENT**

- At the completion of the operation, the patient has:
  1. An epidural catheter for the control of pain during the first 3 to 4 postoperative days
  2. A thoracic-drainage catheter in the left side of the chest
  3. A nasogastric tube to decompress the stomach
  4. Many surgeons also leave a small drain near the esophageal suture line in case of a postoperative leak
- Prophylactic antibiotics to cover aerobes and anaerobes are used preoperatively and for the first day after the operation if the diverticulum has been resected. The nasogastric tube is removed as soon as proper peristaltic activity has been identified.
- The chest tube is removed when no air leak has been documented for 48 hours and when less than 200 mL of chest drainage is recorded for the last 24 hours.
- A barium swallow is obtained when all drainage catheters have been removed, to ascertain the integrity of the diverticulum transection line. A soft-food diet is started the same day.
- The patient is usually discharged the 5th or 6th day and with follow-up ensured at the outpatient clinic a few weeks later.
COMPLICATIONS

In our series of 23 patients who underwent transthoracic diverticulectomy and myotomy, morbidity was observed in 2 patients. The morbidity was related to pulmonary atelectasis in one patient and to pulmonary embolism in another. There was no mortality. In other series, morbidity ranged from 0% to 33% and mortality ranged from 0% to 9%. In a systematic review of 13 studies, morbidity occurred in 18% of patients (41/224) and mortality in 4% (9/224).

Reported complications can be related to the operative technique, for example, narrowing of the lumen at the diverticulectomy site when insufficient protection of the esophageal lumen integrity has been offered. Leakage at the diverticulum transection line is the most feared complication as it can result in severe sepsis and death. Leakage is usually associated with not performing an esophagomyotomy that includes the LES after resecting the diverticulum. Reflux disease may result over time after the myotomy, despite the partial fundoplication usually offered to prevent it. Proper follow-up and medication may prevent this.

RESULTS

- Significant improvement of dysphagia and chest pain.
- In Benacci’s series of 33 patients who underwent transthoracic surgical repair of epiphrenic diverticula, 29 of 30 postoperative survivors were followed for up to 15 years (median 6.9 years, range 4 months to 15 years). Excellent long-term results were seen in 14 patients (48%) who were symptom-free and able to eat normally; 8 patients (28%) reported minimal symptoms; 5 (17%) had improved symptoms but required either antireflux medication or esophageal dilation; and 2 (7%) had no improvement in their preoperative symptoms.
- In Varghese’s series of 35 patients who underwent transthoracic surgical repair of epiphrenic diverticula, all patients were satisfied with the results of the operation during follow-up (median follow-up: 33 months). The surgery completely resolved the preoperative symptoms in 76% of patients; 21% had mild dysphagia requiring intermittent esophageal dilation. One patient had a poor outcome and required regular esophageal dilations to relieve dysphagia.
- Widening of the esophageal lumen.
- Weakening of LES.
- Frequent reflux disease over time.

CONCLUSIONS

- Basic investigation of the epiphrenic diverticulum should include symptom assessment with radiologic–endoscopic and esophageal motor function evaluation.
- A symptomatic diverticulum is the main indication for operation.
- The essential aspect of the operation is the esophageal myotomy that must include the LES and extend to the proximal neck of the diverticulum.
- One of the most feared complications is a postoperative leak near the esophageal staple line; therefore, many surgeons choose to leave a drain near this area.
- The diverticulum itself should be seen as the complication of the dysfunction. It is either resected or suspended.
Recommended References and Readings

17 Minimally Invasive Approach to Resection of Thoracic and Epiphrenic Diverticula

Virginia R. Litle, James D. Luketich, and Hiran C. Fernando

Introduction

Esophageal diverticula of the mid- and distal esophagus are rare lesions with an estimated prevalence of less than 0.1% of the United States population. They are classified by location and extent of esophageal wall involvement. Midesophageal “true” diverticula are typically traction diverticula involving all layers of the esophageal wall and associated with mediastinal inflammation. In the majority of patients, midesophageal diverticula are small and frequently asymptomatic. Occasionally, especially individuals from regions where histoplasmosis is endemic, traction-type diverticulum of the mid-esophagus may enlarge and take on the appearance of epiphrenic diverticula without any associated apparent distal luminal obstruction or motor disorder. Distal esophageal diverticula are typically “false” or pulsion diverticula that are most commonly present in the epiphrenic location due to esophageal motility disorders including achalasia. With advances in minimally invasive approaches to treat esophageal pathology over the past two decades, thoracoscopic and laparoscopic techniques are available to surgically resect symptomatic or large diverticula.

INDICATIONS/CONTRAINDICATIONS

Indications for surgical intervention for esophageal diverticula include symptoms, large diverticula size, bleeding, and rarely cancer of the diverticulum (Avisar, 2000). Symptoms commonly include chest pain, dysphagia, and regurgitation of food or pills. Some patients are treated primarily for an achalasia pattern of symptoms and likely will need resection of the diverticulum and myotomy. Most patients seen by a surgeon are referred for symptoms, and the decision to operate is fairly straightforward, but in some cases, we have
operated on asymptomatic patients depending on the size of the diverticulum and the degree of motor dysfunction that is revealed on workup. If the decision is made not to operate due to absent or minimal symptoms, we recommend follow-up, as it is likely that the epiphrenic diverticulum will enlarge and become symptomatic over time.

Our treatment of choice for diverticula in an epiphrenic location, associated with achalasia, hypertensive lower esophageal sphincter, or other motility disorders with abnormal manometry isolated to the distal esophagus is a right thoracoscopic diverticulectomy and a distal myotomy down onto the stomach. While some surgeons have advocated a laparoscopic approach, it can be quite difficult to retract the diverticulum at a right angle to the esophagus, expose the narrow neck, dissect this away from the musculature, and completely resect the diverticulum at its base laparoscopically. The laparoscopic approach does make the distal portion of the myotomy easier and also facilitates the creation of a partial fundoplication. However, we have seen several patients, both who have been treated exclusively by our practice and who have had a diverticulectomy performed elsewhere and then been referred to us, over the years with incompletely resected epiphrenic diverticula performed laparoscopically. Regardless of the approach, it is essential that a careful myotomy be performed distal and to some degree proximal to the diverticulum to allow adequate exposure of the neck. The larger the diverticulum is, and if there is an extension into the chest, the more compelling the argument to perform these cases via a video-assisted thoracoscopic (VATS) approach. If the VATS approach does not afford the view or access for a complete myotomy onto the stomach, one can always perform a laparoscopy at the end of the VATS portion of the case, complete the myotomy, and perform the anterior fundoplication.

**Indications for Diverticulectomy**

- Dysphagia.
- Regurgitation.
- Cancer or dysplastic degeneration within the diverticulum.
- Weight loss.
- Aspiration.
- Large diverticula with minimal to no symptoms in low-risk surgical patients.

**Considerations for Observation**

- No symptoms.
- Small diverticula (<5 cm) with minimal to no symptoms.
- Significant mediastinal adenopathy in patients with midesophageal diverticula. An open approach should be considered. This may have to be determined intraoperatively.
- Elderly, high-risk surgical patients with minimal symptoms.

**PREOPERATIVE PLANNING**

For midthoracic and epiphrenic diverticula, a barium swallow and an upper endoscopy should be performed preoperatively (Fig. 17.1). At some point, the surgeon should also perform his or her own flexible upper endoscopic examination of the patient prior to the procedure to identify the location of the diverticulum and to assess other potential-associated esophagogastric pathology. Ideally, manometry should be performed to assess the degree of esophageal motor dysfunction. This can generally be performed by an experienced esophageal testing center; it may require fluoroscopic or endoscopic guidance.

Patients with epiphrenic diverticula should have a clear liquid diet instituted at least 2 to 3 days before surgery to reduce risk of aspiration related to uncleared/retained esophageal and diverticular debris. This is especially important in patients with large diverticula and when a large diameter esophagus is present in the setting of achalasia. If significant debris is present at the time of the on-table endoscopy, careful clearance of all esophageal contents should also be performed. These interventions and perioperative risks should be discussed with the patient prior to surgery.
In the operating room, the patient is maintained in a supine position, and rapid sequence induction of general anesthesia is performed to minimize aspiration risk. The surgical team should be present at this time to assist with a Sellick maneuver and to alert the entire team to the risk of aspiration.

An esophagogastroduodenoscopy (EGD) should be performed at the start of the procedure to ensure that the esophagus and diverticula are clear of food debris. Esophagoscopy should also be performed after completion of the diverticulectomy during the surgical intervention, regardless of whether a myotomy was performed, to ensure that the mucosa and muscular wall of the esophagus at the area of the diverticulectomy are intact, and that no leak is present.

VATS Approach

The patient is placed in lateral decubitus position after double-lumen endotracheal intubation has been successfully accomplished to establish contralateral single-lung ventilation during the thoracic procedure. Proper endotracheal tube position is assured with bronchoscopic examination.

A right VATS approach can be used for epiphrenic and midesophageal diverticulum with the surgeon standing on the right side of the table (posterior aspect of the patient). In some cases, some surgeons will prefer a left VATS approach to the epiphrenic diverticulum as it may make easier to carry the myotomy down onto the stomach.

In our practice, we have successfully used the right VATS approach for virtually any mid- to distal esophageal diverticulum. In this setting, we place a retraction suture on the diaphragm to gain lower exposure, and put the patient in a moderate reverse Trendelenburg position to allow gravity to facilitate better exposure of the lower esophagus.

A 10-mm port is placed in the seventh or eighth intercostal space (Fig. 17.2) anteriorly for the initial thorascopic exploration and direction of subsequent intercostal access sites. Placing the port as low as possible has advantages for exposure of the...
distal esophagus and, frequently, we place this port right at the costophrenic angle. Posteriorly, we place another 10-mm port near the eighth intercostal space; again, keeping this port lower will facilitate the dissection angles. A 5-mm access site is established near the posterior scapular tip. During resection of true epiphrenic diverticulum, it may be wise to lower this port one interspace, especially in tall patients. Next, another 5-mm port is placed two to three interspaces above the camera port and just medial (toward the sternum) to allow a suction irrigator to keep the plane of dissection bloodless. The final 10-mm port is placed higher, medial to the anterior axillary line, to allow placement of a fan-type lung retractor.

- The presence of a first and second assistant allows the operation to flow more expeditiously as the first assistant holds the camera and the suction device and the second assistant retracts the lung. Alternately, a self-retaining retractor can be used for the lung retraction.

- Division of the azygos vein with a vascular endoscopic stapler is often required to gain clear access/dissection for midesophageal dissection.

- The esophagus is mobilized above and below the diverticulum with sharp dissection using autosonic shears, a harmonic scalpel, or similar device.

- The diverticulum is identified and completely mobilized, and its neck/base is exposed for subsequent resection (Fig. 17.3). The epiphrenic and the larger midesophageal diverticula are commonly “false diverticula” and the delineation of the submucosa of the diverticulum neck will be evident during the course of this dissection.
The start of this dissection should be away from the true esophageal lumen until the dissection planes are well established. Care should be taken to retract upward on the diverticulum itself as this portion will be later resected and frequently is quite fibrous even though it is primarily made up of only esophageal mucosa.

It is important during the initial phases of the operation to identify the course of the right vagus nerve from the right VATS approach. Sometimes this is best accomplished by first opening the mediastinal pleura above and below the diverticulum and starting the myotomy; care must be taken as the myotomy extends down near the junction of the native esophageal lumen with the diverticulum.

The lateral separation of the longitudinal muscle layers and the remaining circular fibers at the neck of the diverticulum, both proximal and distal, is critical to allow a clear stapling plane to the diverticulum. Failure to precisely visualize the narrow neck, compared with the broad body of the diverticulum, will lead the inexperienced surgeon to staple early and incompletely remove the diverticulum. It is essential that the lateral muscle wall is free from the neck of the diverticulum in a 360-degree fashion before preparing to staple off the diverticulum.

At any point during the dissection, placement of a soft-tipped bougie will facilitate stabilization of the esophageal lumen and allow the surgeon to concentrate on the plane between the mucosa and the muscle walls. We use a 50- to 54-French bougie. This also will lower the risk of narrowing the native lumen of the esophagus excessively during stapling of the diverticulum.

An endoscopic gastrointestinal stapler (typically a rotating and articulated 45-mm stapler with a 3.5-mm staple cartridge) is placed across the neck/base of the diverticulum delineated by the line of defect in the longitudinal musculature of the esophagus, and the diverticulum is stapled and excised with the bougie in place within the esophagus (Fig. 17.4).

We prefer to use an articulating head on the stapler to gain an angle of 45 degrees or more. If the stapler is inserted from the lowest anterior port possible, one can generally get a satisfactory angle of the stapler relative to the bougie. This is critical to get the staple flush on the neck of the diverticulum to avoid leaving a residual diverticulum.

Prior to resection of the diverticulum, we generally use the diverticulum as a handle to some degree to facilitate the distal myotomy down onto the stomach. The surgeon can open the pleura at this level and visualize the crus and deliver a small amount of gastric cardia into the chest. If this can be accomplished via the VATS procedure, then the myotomy can be extended distally onto the stomach (Fig. 17.5). The completeness of the myotomy is best assessed by removing the bougie and endoscopically evaluating the esophagus to (1) rule out any staple line leaks, (2) make sure all of the diverticulum is resected, and (3) make sure all of the distal muscle ring is opened up to allow easy passage of the endoscope into the stomach.

At this point, the surgeon must decide if a partial fundoplication is needed. In the past, using a left VATS approach we performed a small series of these diverticulum repair with a VATS Belsey but were not satisfied with the technical outcome. Therefore, we prefer to do these using a right VATS approach with selective laparoscopy to complete the distal myotomy if needed, or to add a partial wrap laparoscopically. In some cases, we discuss with the patient that the latter part of the operation may be via a staged approach. That is if the myotomy and diverticulectomy lead to a satisfactory outcome, then no further surgery would be indicated. If however, significant reflux develops, a second stage of performing a laparoscopic partial fundoplication may be indicated.

Of note, we have performed over 40 thoracoscopic diverticulectomies with this selective approach, and less than 10% of patients developed any significant reflux after a careful myotomy and diverticulectomy using the right VATS approach. If there is manometric evidence of achalasia, we would consider adding the laparoscopic portion.

After diverticulectomy, we prefer to reapproximate the muscle layers in a running or interrupted fashion and end this closure at the start of the distal esophageal myotomy as it extends onto the stomach. We then lay a Jackson-Pratt (JP) drain near the
Figure 17.4  
A: A bougie is placed in the esophagus and the endoscopic stapler is used to excise the diverticulum.  
B: Stapler on the neck of the diverticulum.  
C: Excision of the diverticulum with the stapler.

Figure 17.5  
A myotomy is made with ultrasonic shears or hook cautery.
staple-line repair, but not directly on it, and close the mediastinal pleura over this drain.
- A 28-French chest tube is placed outside of the reapproximated mediastinal pleura.

**Laparoscopic Approach**

Generally, a laparoscopic approach is considered as the first operation when there is obvious concurrent achalasia necessitating not only a myotomy extending onto the stomach but also a partial fundoplication. The biggest problem we have seen with the laparoscopy only approach is that there can be significant difficulty in retracting the diverticulum at a right angle to the native esophagus. If this is not done, it can be very difficult to dissect out the epiphrenic diverticulum, which can be quite large. Difficulty in retracting the diverticulum can also lead to significant retraction against the right crus leading to damage to these muscles. We use a laparoscopic approach primarily for smaller epiphrenic diverticulum with clear manometric evidence of achalasia. Following the esophagomyotomy, a concurrent antireflux procedure is performed. A partial fundoplication (Dor or Toupet) is routinely utilized in these circumstances. Similar to the VATS approach, if the surgeon is not happy with the conduct of the laparoscopic resection of the diverticulum, it may be necessary to complete the myotomy, and the partial wrap and then do a right VATS to complete the resection of the diverticulum.

**General Considerations for Laparoscopy**

- The patient is placed in the supine position, slightly to the right side of the table to facilitate placement of a lateral port for a liver retractor.
- A footboard is used, so as to prevent patient sliding when the patient is in the reverse Trendelenburg position during the operation.
- The surgeon stands on the patient’s right side, the first assistant surgeon stands on the patient’s left.
- Five laparoscopic ports are used with one 10-mm port and four 5-mm ports (Fig. 17.6).
- Our preference is to use ultrasonic coagulating shears for the major portion of the dissection.
- The gastrohepatic ligament is opened using the ultrasonic shears.

![Figure 17.6 Port placement for laparoscopic repair.](Image)
The right crus is identified and the esophagus dissected away from this with care taken to preserve the peritoneal lining over the crus.

The proximal two or three short gastric vessels are ligated and divided using the ultrasonic shears. This will allow for tension-free mobilization of the fundus for future partial fundoplication.

The anterior gastric fat pad is dissected from the gastroesophageal junction. This is performed from left to right taking care to protect and mobilize the anterior vagus nerve with the fat pad. The posterior vagus nerve is also carefully protected. This dissection allows the surgeon to clearly identify the gastroesophageal junction and determine the optimal length and location of the myotomy.

The distal esophagus is dissected at the hiatus into the mediastinum, and the epiphrenic diverticulum is identified.

The epiphrenic diverticulum is then dissected with careful exposure of the entire neck of the diverticulum in relation to the longitudinal musculature of the esophagus.

A 54-French bougie is placed in the esophagus.

The epiphrenic diverticulum is resected with an endoscopic gastrointestinal stapler (typically a rotating and articulated 45- or 60-mm stapler with a 3.5-mm staple cartridge).

Following resection of the epiphrenic diverticulum, the overlying esophageal muscle layer is closed using the surgeon’s preferred laparoscopic suturing technique with interrupted 2-0 permanent suture.

Attention is then turned to the contralateral esophageal wall for the long esophagogastric myotomy. Epinephrine (1 mL of 1:1,000 in 19 mL normal saline) is injected into the muscular layers of the anterior wall of the distal esophagus, the gastroesophageal junction and the proximal stomach on the opposite side of the stapled diverticulum. This improves hemostasis during the myotomy and also elevates the submuscular–submucosal plane for the myotomy dissection.

The myotomy is then performed on the opposite side of the diverticulum extending from the level of the diverticulum down onto the first 2 to 3 cm of the stomach. The myotomy is performed using a combination of sharp dissection with ultrasonic shears or a hook cautery and blunt dissection with endopeanut dissectors.

Esophagogastrosopy is performed upon completion of the myotomy by the operating surgeon to assess for mucosal violation and potential leak. If a mucosal injury is identified, laparoscopic suture repair is performed with coverage of this area with the anterior partial Dor fundoplication.

If performing the procedure entirely by laparoscopy, we would position a JP drain off to the side of the diverticulectomy.

We routinely include a partial fundoplication (an anterior modified Dor (Fig. 17.7) or a posterior Toupet) with the laparoscopic approach. Sutures are placed between

Figure 17.7 A partial anterior fundoplication (Dor) is done after completion of the long esophagogastric myotomy.
the fundus and the myotomized esophageal muscle to help keep the myotomy open when a posterior fundoplication is performed.

- We strongly prefer not to use a nasogastric tube due to concerns about traumatizing the myotomized esophagus. If placement of a nasogastric tube is the surgeon’s preference, the nasogastric tube should be placed carefully, and it should be made clear in the postoperative orders that no one should manipulate the tube and that suction should be intermittent or with very low vacuum to avoid injury to the esophageal mucosa.

**POSTOPERATIVE MANAGEMENT**

**VATS or Laparoscopy**

- If a nasogastric tube has been used, it is typically removed on the first postoperative day; a postoperative ileus is uncommon with either VATS or laparoscopy.
- We recommend obtaining a barium swallow on postoperative day 1 or 2 before initiating an oral diet. This study is used to assess esophageal leak and to get a good baseline examination to confirm complete diverticulectomy (Fig. 17.8).

**VATS**

- The chest tube is removed on the day of the barium swallow, if negative.
- The JP drain is generally moved slightly after a negative swallow but left in place. We remove the JP drain on the first postoperative visit, which is about the twelfth postoperative day.
- Routine pain management is administered with patient-controlled analgesia, and then oral liquid pain medication.

*Figure 17.8 Barium esophagram of the esophagus after repair of the large epiphrenic diverticulum shown in Figure 17.1.*
COMPLICATIONS

Perioperative complications occur in 0% to 45% of patients and include the following.

- Intraoperative perforation risk is low (<2%), and perforations should be repaired carefully with interrupted sutures.
- Postoperative esophageal leak ranges from 0% to 23% in larger series, which provides the indication for the JP drain in all cases.
- Leak is minimized by a careful dissection between the sac and the diverticular neck, closure of the muscle layer over the mucosal staple line, and performing an adequate myotomy onto the gastric cardia.
- Pneumothorax from invasion of the mediastinal pleura during laparoscopic dissection of the diverticulum is common and should be recognized intraoperatively. If needed, a pigtail thoracostomy can be placed intraoperatively.
- Aspiration pneumonia can be minimized by attention to the preoperative bowel preparation and by assuming there is a full esophagus during intubation.
- Empyema generally occurs only if there is an undrained leak or unrecognized leak.
- Mortality is less than 1% in most published series.

RESULTS

In published series with small numbers of patients treated with minimally invasive approaches, recurrence rates are low (10%) as identified on barium swallows done for symptoms. Symptomatic relief of the chest pain, dysphagia, and regurgitation is seen in over 90% of patients in most series. The need for reoperation for a symptomatic recurrent diverticulum should be low if both the myotomy and diverticulectomy are complete (Fernando, 2005; Kilic, 2009).

CONCLUSIONS

Esophageal diverticula are rare benign esophageal lesions that can be treated minimally invasively when symptomatic or large. Approach via VATS or laparoscopy is determined by the location of the diverticulum within the esophagus and the skill set of the surgeon. An underlying motility disorder must be suspected in patients with epiphrenic diverticula, and a myotomy should be performed. The addition of a partial wrap should be considered in cases where a manometric diagnosis of achalasia is confirmed. In many cases, a VATS diverticulectomy and myotomy can be performed onto the gastric cardia. If only a nonspecific motor disorder is present, this generally leads to a very good postoperative relief of symptoms with minimal reflux. The esophageal leak rate after diverticulectomy and myotomy using a minimally invasive approach can reach 20%, as reported in larger series, and therefore most surgeons leave a drain and obtain a routine barium swallow. The perioperative mortality has been less than 1% in most series.

Recommended References and Readings

Open Cricopharyngeal Myotomy and Correction of Zenker's Diverticulum

André Duranceau

Introduction

Zenker's diverticula are outpouchings of the pharyngeal mucosa through the posterior pharynx (Fig. 18.1). Zenker's diverticula arise in the posterior midline of the esophagus in Killian's triangle, between the thyropharyngeus muscle and the cricopharyngeus muscle. High hypopharyngeal pressure during swallowing, due to a dysfunctional upper esophageal sphincter (UES), is thought to cause a pulsion diverticulum.

Open myotomy of the cricopharyngeal muscle at the pharyngoesophageal junction is the operation of choice in patients with hypertonicity of the UES resulting in significant oropharyngeal dysphagia. Neurologic damage, striated muscle disease, iatrogenic damage to the junction, and idiopathic disorders are the known causes that explain the dysphagia. Cricopharyngeal (Zenker's) diverticulum is classified within the idiopathic disorders where sphincter dysfunction has been explained by the presence of a constrictive pathology with muscle atrophy, chronic inflammation, and fibrous and fatty infiltration. The etiology of this muscle pathology remains unknown.

INDICATIONS/CONTRAINDICATIONS

Open cricopharyngeal myotomy is indicated in any patient in whom significant oropharyngeal dysphagia is documented. Aspiration, regurgitation, and weight loss are also common presenting symptoms. As the difficulty in swallowing is at the confluence of the esophageal opening and the tracheobronchial tree, the surgeon needs to be ready to manage persistent aspiration by laryngeal exclusion or excision. Relative contraindications to the operation are dictated by the medical condition of the patient. Recently, some surgeons have advocated transoral stapling in patients with significant medical comorbidities.
Part II  Surgical Treatment of Esophageal Motility Disorders—Achalasia and Esophageal Diverticula

**Figure 18.1** Radiographic image of a Zenker's diverticulum.

**Etiology**
- Neurologic
- Myogenic
- Iatrogenic
- Idiopathic
- UES dysfunction alone
- UES dysfunction with pharyngoesophageal diverticulum

**PREOPERATIVE PLANNING**
- Clinical assessment of symptoms. Assessment of clinical symptoms is essential as they are the main reason for the intervention. Quantification of the symptoms by a scoring system or by the patient on a numerical scale is seen as an objective index of symptom severity with the advantage of allowing post-treatment assessment.
- Videoradiology of the pharyngoesophageal junction. Videoradiology is an important method of investigation, as it describes the very rapid events that occur with swallowing. The documentation of abnormal sphincter opening, of laryngeal competence, and of the type and size of the herniated pouch is important for planning the type of operation to be offered. Distal esophageal pathology must be ruled out.
- Radionuclide quantification of emptying. Radionuclide scintigrams are used to quantify bolus retention before surgery and the improved clearance after treatment. Manometric studies help to understand the pathophysiology of the condition. They require strict interpretation criteria. The presence of symptoms without any evidence of abnormality on investigation must raise doubts regarding the indication for surgical treatment.
Chapter 18  Open Cricopharyngeal Myotomy and Correction of Zenker’s Diverticulum

General Principles
- Myotomy is the essential part of treatment to remove the restrictive dysfunction.
- Treatment of the diverticulum is seen as managing the complication of the dysfunction.
- Minute diverticula disappear with the myotomy.
- 1- to 3-cm diverticula are suspended.
- Diverticula larger than 4 cm are resected.

Surgical Technique
- The patient lies supine with a pillow under the shoulders. The head is in hyperextension, rotated toward the right. The incision follows the anterior border of the left sternomastoid muscle and extends from the sternal notch to a few centimetres from the ear lobe (Fig. 18.2).
- The plane of access to the pharyngoesophageal junction must be developed anterior to the carotid artery and the deep jugular vein, just lateral and posterior to the thyroid gland (Fig. 18.3).
Subcutaneous tissues and platysma are divided first. A branch of the cervical cutaneous nerve traverses the incision, often in its middle or proximal part, and must be divided for proper exposure; submandibular cutaneous anaesthesia results. The sternomastoid muscle is dissected free and the omohyoid and the prethyroid muscles are exposed. They are divided along the incision line, freeing the thyroid gland (Fig. 18.4).

Traction is exerted on the thyroid gland by the assistant. The middle thyroid vein is located and ligated. The deep cervical fascia is then under tension, and it is opened and divided progressively along the line of the incision. The inferior thyroid artery is identified and ligated just under the fascia (Fig. 18.5). Occasionally, the vascular supply to the superior pole of the thyroid must be ligated for proper exposure of the pharynx and hypopharynx.

The cellular plane between the buccopharyngeal fascia and the prevertebral fascia is freed progressively and the whole pharyngoesophageal junction can be lifted and everted toward the surgeon. The pharyngoesophageal diverticulum develops between the cricopharyngeus, the cervical esophagus muscularis, and the buccopharyngeal fascia. The buccopharyngeal fascia must be divided, usually with the use of diathermy, to free the diverticulum (Fig. 18.6).
Once the pharyngoesophageal diverticulum is freed from the muscularis and the cricopharyngeus, it is uplifted and a 36-French bougie is passed through the mouth and directed manually into the esophagus. The bougie will serve as a stent during the cricopharyngeal myotomy and will protect the integrity of the pharyngoesophageal lumen, if the diverticulum needs to be resected. The myotomy is then planned, using low-powered diathermy, starting 2 cm on the right side of the cervical esophagus, extending 2 more centimetres along the right collar of the diverticulum and then 2 more centimetres on the hypopharynx (Fig. 18.7).

The myotomy is then transected laterally at its proximal and distal extremities, and the muscular flap resulting is unwrapped from around the collar of the diverticulum. It is resected along the left esophageal line for histologic analysis.

The diverticulum itself must be seen as the complication of the muscle dysfunction. If it is very small, it will disappear within the mucosa of the myectomized area. If larger (usually 1 to 4 cm), it is usually uplifted, and its tip is fixed to the transected muscle of the pharyngeal wall using four or five 3-0 silk stitches (Fig. 18.8). Full-thickness bites of the diverticulum tip may lead to soiling the operation field with bacteria from the diverticular pouch.

When the diverticulum is at 4 cm or larger, it is usually resected. With the intraesophageal bougie secured, a 3-cm linear stapler is placed transversely, at the collar of the diverticulum, which is then resected, leaving a 1-cm rim of mucosa distal to the stapled line (Fig. 18.9). This will allow uplifting of the collar to eliminate any dependency of the remaining mucosal sac.
Figure 18.8 Tip of the diverticula is fixed to the transected muscle of the pharyngeal wall using four or five stitches.

Figure 18.9 Resection of a large diverticulum via transverse application of a linear stapler.

Figure 18.10 Fixing the transected collar of the diverticulum to the hypopharyngeal musculature.
The transected mucosa of the collar of the diverticulum is fixed on the muscularis of the hypopharyngeal musculature. The myectomized area below the diverticulectomy site is left wide open (Fig. 18.10).

The intraesophageal bougie is removed and meticulous hemostasis is ensured. Integrity of the mucosa at the resection and myectomy sites is verified by injecting air through a nasogastric tube while the pharyngoesophageal junction is submerged (Fig. 18.11). The nasogastric tube is then directed toward the stomach. Gastric decompression is ensured for the initial 12 hours. Two small Penrose drains are left along the myotomy area.

**POSTOPERATIVE MANAGEMENT**

- Many surgeons obtain a postoperative barium esophagram to assess a satisfactory myotomy and rule out leaks.
- The nasogastric tube installed during the operation is removed the next morning, and a soft food diet started that same day. The Penrose drains are removed the second day, and the patient is usually discharged home with oral pain medicine.
- Antibiotics are used prophylactically to protect against aerobic and anaerobic infections. The patient is seen at the outpatient clinic 1 week after the operation to rule out any infection or retropharyngeal collection.

**COMPLICATIONS**

In published series, complications have occurred in 4% to 24% of patients and include fistula, hematoma, and leaks. Temporary recurrent laryngeal nerve palsy is reported in 2% to 15% of patients, but permanent recurrent laryngeal nerve paralysis is rare. Typical complications of open myotomy with or without diverticulum resection are described in Table 18.1.

**RESULTS**

- Results of Zenker’s diverticulum treatment are uniformly good.
- Resolution of symptoms in >90% of patients.
- For diverticula <3 cm, open cricopharyngeal myotomy, with or without diverticulectomy, was associated with improved symptom outcomes as compared with transoral diverticulectomy.
In a study with up to 10 years of patient follow-up by Bonavina et al., 98% (30/31) of patients who underwent open diverticulectomy and cricopharyngeal myotomy were asymptomatic 5 years after surgery and 84.2% (16/19) were asymptomatic 10 years after surgery.

Mortality after open diverticulectomy or diverticulopexy and cricopharyngeal myotomy is rare, and many published series report no perioperative deaths.

### CONCLUSIONS

- Cricopharyngeal myotomy removes the obstructive effects of the UES when it is affected by disease or dysfunction.
- The indications for cricopharyngeal myotomy include the following.
  - Neurologic disease
  - Muscular disease of striated muscle
  - Idiopathic dysfunction of the UES
  - Iatrogenic effects of operations in the neck and the oropharyngeal area
- Objective documentation of the dysfunction is essential.
- The cervical approach along the anterior border of the sternocleidomastoid muscle provides the best exposure to the pharyngooesophageal function.

### Recommended References and Readings

Introduction

Zenker's diverticula are a form of pulsion diverticulum, also referred to as “false” diverticula as they do not include all layers of the esophageal wall. Zenker's diverticula occur in an area of muscular weakness (Killian’s triangle) located posterolaterally between the inferior constrictor and cricopharyngeal muscles. The condition was first described by Ludlow in 1764 and subsequently, Zenker published a series of 23 cases in 1877. Some surgeons hypothesize that dysfunction of the lower esophageal sphincter leads to gastroesophageal reflux, thereby stimulating a high tonicity of the upper sphincter. Years of unabated reflux may lead to a Zenker's diverticulum essentially as a physiologic, protective response to long-standing failure of the lower esophageal sphincter. In fact, personal communication between Antoon Lerut and James Luketich revealed that over 50% of Lerut’s patients with Zenker’s diverticula had pathologic acid reflux and over 80% of the patients with Zenker's diverticulum in our series had a coexisting hiatal hernia or history of significant reflux (Luketich JD, personal communication).

Symptoms of Zenker's diverticula include dysphagia, regurgitation of undigested food, globus sensation, halitosis, and aspiration pneumonia. Surgical intervention via an open neck incision has been recognized as the only effective treatment and improves symptoms and quality of life with little morbidity. Recently, transoral endoscopic repair of Zenker's diverticulum has been described and is gaining popularity.

INDICATIONS/CONTRAINDICATIONS

Because many patients with Zenker's diverticula are elderly, an endoscopic approach offers potential advantages by avoiding neck incision. However, several technical points need to be emphasized. It is important to divide the cricopharyngeus muscle completely, and the diverticulum should be at least 3 cm in size if considering the transoral approach to allow for entrance of the stapler and a complete cricopharyngeal myotomy. Significantly larger diverticula (>6 cm) are also a relative contraindication when considering a
transoral approach, particularly when the diverticulum deviates markedly to one side, or when there are bilateral pouches, as this approach may leave a considerable residual diverticulum. Other relative contraindications include the presence of prominent upper incisors, limited mouth opening, and the inability to adequately extend the neck; these anatomic features make an endoscopic repair technically difficult.

**PREOPERATIVE PLANNING**

All patients should be evaluated by a barium swallow and upper gastrointestinal esophagoscopy. The Zenker’s diverticulum should be at least 3 cm in size to allow a complete transoral cricopharyngeal myotomy. In addition, patients should be evaluated for limited mouth opening and inability to adequately extend the neck, which can make placement of the Weerda laryngoscope difficult. An esophagogastroduodenoscopy (EGD) should be performed at the time of the procedure by the operating surgeon (even if it has been done preoperatively) to evaluate the diverticulum, remove any debris from the diverticulum, and examine the esophagus for any other pathology. During flexible endoscopy, the anatomy and entry into the native esophagus can be challenging. If there is difficulty in identifying the normal anatomy, we place a flexible guidewire into the native esophageal lumen and advance this into the stomach. This facilitates identifying the anatomy when inserting the Weerdascope.

**SURGERY**

Necessary equipment for a transoral Zenker’s diverticulectomy includes the following.

- Weerda laryngoscope (Karl Storz, Tutlingen, Germany)
- Low-profile endostapler to allow stapling and cutting of the sphincter muscle to the end of the stapler (Fig. 19.1)
- 5-mm 30-degree laparoscope to allow for additional visualization
- 0.035 flexible guidewire

**Positioning**

Patient is placed supine on the operating table with the head positioned at the top of the operating table. General anesthesia is established using a small diameter (7 mm) endotracheal tube. Arms are typically tucked at the patient’s sides. The operating table should be rotated so that the anesthesia team is to the left.

**Technique**

With the patient adequately anesthetized, flexible esophagoscopy is performed to assess the diverticulum and also to suction any retained material from the diverticulum. At this time, we sometimes place a guidewire in to the native esophagus to help us place the Weerdascope properly.

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**Figure 19.1** Stapler with anvil.
Rigid esophagoscopy is performed using the Weerda laryngoscope (Karl Storz, Tuttingen, Germany). This scope has two jaws (Figs. 19.2 and 19.3). The upper jaw, which is longer, is placed into the native esophageal lumen and the second is placed in the diverticulum. The jaws are then expanded which allows clear visualization of the diverticulum and the common septum formed by the cricopharyngeus muscle and the esophagus.

The placement of a 5-mm 30-degree laparoscope alongside the Weerda laryngoscope can further enable visualization of the distal anatomy during stapler placement and firing.

A traction suture (US Surgical Endostitch, Norwalk, Connecticut) is placed in the common septum (Fig. 19.4). The traction suture helps to expose the septum and facilitates a complete cricopharyngeal myotomy.

Using the suture to provide proximal traction on the common septum, the stapler is placed across the septum and fired (Fig. 19.5). When positioning the stapler, the flat part of the stapler is placed within the diverticulum, and the disposable cartridge is placed within the esophageal lumen. Further firings of the stapler are performed as needed to ensure the common septum is divided to the base of the diverticulum. Occasionally, the traction stitch is replaced after a firing of the stapler to further expose any residual septum.

It is essential to realistically evaluate the progress of the procedure, and to abandon the transoral approach if it becomes unusually difficult. It is far safer for the patient to have a well-performed open operation than a complication of an endoscopic procedure.
A nasogastric tube is not inserted. A barium swallow is obtained on the first postoperative day. If the barium swallow demonstrates satisfactory results and no leaks, a liquid diet is initiated and slowly advanced over several weeks. A small residual diverticulum is often noted at the inferior aspect of the divided cricopharyngeus. If it is small, and the cricopharyngeal septum has been completely divided, the residual diverticulum has minimal clinical significance.

**COMPLICATIONS**

A leak from the staple line is extremely uncommon and can typically be handled conservatively with antibiotic therapy and prohibiting oral intake (nothing by mouth). If cervical crepitus, erythema, and tenderness develop, drainage may be indicated. Dental injuries from the placement of the laryngoscope are more commonly reported.

**RESULTS**

The first report of an endoscopic approach was by Mosher in 1917, where a knife blade was used to divide the common wall. Because of complications, little attention was paid to endoscopic approaches until Dohlman and Mattsson reported endoscopic division of the common septum using a diathermy knife. Other subsequent reports have involved use of a laser to divide the common septum. A disadvantage of the above endoscopic methods is that a mucosal closure is not performed, leaving the possibility of contamination and infection of the adjacent cervical space. Collard revolutionized the endoscopic treatment of Zenker’s diverticulum by the introduction of an endoscopic...
stapler to divide the common septum. The stapler completely divides the common septum, and applies three rows of staples on each side of the section line which provide excellent closure and hemostasis of the mucosal edges. A study from Gutschow et al. compared open surgical intervention with endoscopic repair by either endoscopic stapling or endoscopic laser division. They noted that in larger diverticulum (3 cm or larger), there was no difference between the endoscopic and open procedures when examining patients who were either asymptomatic or who had mild occasional symptoms. We compared open repair with endoscopic stapling and found no difference in preoperative and postoperative dysphagia scores with equivalent length of stay and complications.

CONCLUSIONS

- Transoral repair requires general anesthesia.
- Small diverticula are contraindicated for transoral repair. The diverticulum needs to be greater than 3 cm to allow for entrance of the stapler and a complete cricopharyngeal myotomy. Significantly larger diverticula (>6 cm) are also a concern when considering a transoral approach as they may leave a significant residual diverticulum, which may lead to symptoms.
- Introduction of scope and stapler is limited in some patients due to limited mouth opening or neck flexion. This is much less of a problem in the edentulous patient with a generous mouth opening, which can be assessed preoperatively.
- The stapler chosen should have a low-profile tip to allow stapling and cutting to the base of the diverticulum.
- A traction stitch in the common septum greatly facilitates exposure and stapling of the diverticulum and minimizes the tendency for the thick septum to be pushed away by the stapler instead of being completely divided. A 5-mm 30-degree laparoscope can also assist with visualization when placed alongside a Weerda laryngoscope.
- A residual distal diverticulum is often present on postoperative barium swallow but has minimal clinical significance if it is small and if the septum has been completely divided.

Recommended References and Readings

Transhiatal esophagectomy (THE) is a safe, expeditious, and effective technique for resection of benign and malignant diseases of the esophagus. It has several potential advantages over transthoracic esophagectomy (TTE) and minimally invasive esophagectomy (MIE). It is less costly than MIE and avoids thoracotomy and intrathoracic anastomosis associated with TTE. THE allows access to all of the abdominal gastrointestinal conduits that may be necessary for reconstruction. This chapter discusses the principles, indications, diagnostic evaluation, operative techniques, postoperative course, and potential complications for THE. Our experience is also reviewed.

History

The first blunt transmediastinal esophagectomy without thoracotomy was reported by Denk in 1913 using a vein stripper to avulse the esophagus in cadavers. In 1933, the British surgeon Turner performed the first successful THE for carcinoma. In that operation, he re-established gastrointestinal continuity with an anterior thoracic skin tube at a second procedure.

Ong and Lee (1960) and Le Quesne and Ranger (1966) reported the first successful, primary pharyngogastric anastomosis after laryngopharyngectomy and total esophagectomy. In 1975, Orringer and Sloan described the use of substernal gastric bypass and thoracic esophageal exclusion for palliation of dysphagia for incurable esophageal carcinoma. These results demonstrated that with proper mobilization the stomach is able to reach above the level of the clavicles for cervical esophagogastric anastomosis. If they occur, cervical anastomotic leaks are usually less severe than disruption of an intrathoracic anastomosis. Based on these principles, Orringer and Sloan reported a series in 1978 of 28 patients who underwent THE. The experience at the University of Michigan now includes over 2,000 patients who have undergone THE over the past 3 decades with 96% of those utilizing stomach as an esophageal substitute. This experience has confirmed, in their opinion, that few patients who undergo esophagectomy for benign or malignant disease require a thoracotomy.

Principles and Justification

In all patients with resectable carcinoma of the esophagus, surgery remains the mainstay of treatment in conjunction with neoadjuvant chemoradiotherapy. Multiple studies have
concluded that chemotherapy and radiotherapy followed by surgery improves survival in patients with potentially resectable carcinoma over surgery alone.\textsuperscript{7,8} Although very few randomized, prospective trials have demonstrated a benefit,\textsuperscript{8,9} a recent meta-analysis lends further credence to the survival advantage provided by neoadjuvant therapy for esophageal cancer.\textsuperscript{10} This analysis comparing neoadjuvant chemoradiation and surgery versus surgery alone in over 1,200 patients showed a statistically significant survival advantage for patients receiving induction therapy followed by surgery. Orringer reported 583 patients who received neoadjuvant chemoradiation. One hundred twenty-five patients (21%) were complete responders (T0N0 tumors). These patients had a 2- and 5-year survival of 80% and 58%, respectively.\textsuperscript{6}

The main causes of morbidity and mortality after standard TTE are pulmonary complications and mediastinitis. Resecting the entire thoracic esophagus via THE virtually eliminates mediastinitis and empyema. It also provides maximal proximal resection margins. Significant gastroesophageal reflux after THE is also uncommon.\textsuperscript{5} Mediastinitis follows disruption of an intrathoracic anastomosis and is associated with an average mortality of 50%. The technique of THE reduces the physiologic insult to the patient by avoiding the need for a thoracotomy. A leak after THE is often managed by simple drainage and establishment of a salivary fistula. When compared with MIE, THE avoids the prolonged operative time and high costs of performing esophageal resection. With MIE, the learning curve is exceedingly high and usually requires two surgeons to perform.

THE has been criticized for ignoring several key surgical principles—exposure, hemostasis, and inability to perform a complete oncologic resection. From an oncologic standpoint, lower esophageal lymph nodes are easily resected as are celiac nodes. Because the overall survival of patients after THE for carcinoma is similar to that reported after transthoracic resections, it is difficult to argue that the method of esophageal resection determines survival in patients with carcinoma.\textsuperscript{5}

### INDICATIONS/CONTRAINDICATIONS

Regardless of which technique of esophageal resection is used, it is very important that the operation be well tolerated by the patient with low morbidity and complication rates. It should offer a reasonable expectation to resect all evident tumors without the cost or risk being prohibitive. Treatment is usually palliative, and an outcome that leads to a long drawn-out hospitalization is to be avoided.

Orringer et al.\textsuperscript{5} have stated that all patients being evaluated for an esophagectomy for benign or malignant disease should be considered potential candidates for THE. We reserve THE for those patients with lower third esophageal malignancies or benign disease. Middle third esophageal cancers are treated by an Ivor Lewis approach or a three-incision technique including laparotomy, thoracotomy, and cervical incision with anastomosis performed in the neck.

Patients who have positive subcarinal lymph nodes picked up either by positron emission tomography (PET) or endoscopic ultrasound (EUS) are not offered THE. Those patients are offered Ivor Lewis or three-field dissection. In cases of gastroesophageal junction tumors, if the bulk of the mass is on the gastric side of the GE junction, this is treated as gastric carcinoma with preoperative chemotherapy and esophagogastrectomy by a left thoracoabdominal approach.

At our institution, contraindications to performing THE include middle and upper third lesions, patients with stage IV cancer, and patients who have bronchoscopic evidence of tracheobronchial invasion.

THE can also be performed in patients with periesophageal fibrosis from previous surgeries, corrosive injuries, or radiation therapy. If significant adhesions are encountered during surgery via palpation through the hiatus, the surgeon should be prepared to convert to a transthoracic approach.
PREOPERATIVE PLANNING

The initial history and physical examination of patients with esophageal carcinoma is vital. The presence of palpable adenopathy, stigmata of liver disease, and evidence of malnutrition could indicate unresectability or high operative risk, respectively. A barium swallow is routinely obtained on all our patients.

PET scan has become an integral tool in the preoperative staging of esophageal cancer. It can detect metastatic disease which may preclude resection. PET scan can also be used to determine response to neoadjuvant chemoradiation therapy. EUS is now also used routinely to define the depth of tumor invasion and presence of mediastinal, paraesophageal, and celiac axis nodal metatases. All patients at our institution are evaluated with EUS and PET scans. All patients with T3 or greater tumors or patients who have nodal involvement undergo neoadjuvant chemoradiation therapy.

Patients should undergo pulmonary function testing and smoking cessation for at least 2 weeks before THE. All patients receive a cardiology evaluation. When patients have exhibited severe weight loss and dehydration, percutaneous gastrostomy or jejunostomy feeding tubes can be placed. All patients undergo bowel preparation preoperatively in the unlikely event that a colon interposition is needed.

SURGERY

Anesthetic Management
We routinely place an arterial line, triple-lumen catheter, and epidural in all patients. The epidural is vital for postoperative pain control, which then leads to improved pulmonary function. A Foley catheter is inserted at the start of the case. A dose of IV cefazolin and metronidazole is given prior to incision. A standard endotracheal tube is used. During the mediastinal dissection, close cooperation and communication between the surgeon and the anesthesiologist are required as episodes of hypotension can occur during the transhiatal dissection. All patients are given volume expansion with albumin before starting the transhiatal dissection as it appears to prevent hypotension during this stage of the operation. Patients are started on low dose (2.5 mg) of IV dopamine to improve splanchnic blood flow. Both the epidural and IV dopamine are continued for 5 days postoperatively.

Positioning
The patient is positioned supine with the head turned toward the right (Fig. 20.1). The neck is extended by placing a gel pad behind the shoulders. The operative field extends from the mandibles to the suprapubic area and anterior to both midaxillary lines. The arms are padded and tucked at the sides. A self-retaining, table-mounted upper abdominal retractor (upper hand retractor) is used to facilitate exposure of the upper abdomen and hiatus (J. Hugh Knight Instrument Co., Slidell, Louisiana). THE is performed in four separate phases—abdominal, transhiatal, cervical, and anastomotic.

Abdominal Phase
The procedure is performed through an upper midline incision (Fig. 20.2). The falciform ligament is divided. The upper hand retractor is put into place (Fig. 20.3). Assessment of the liver, hiatus, and peritoneal cavity is performed to determine resectability. The triangular ligament is divided and the liver is retracted laterally. Our dissection begins at the pars flaccida where gastrohepatic attachments and lesser omentum are taken down as we proceed superiorly on the lesser curve. These attachments are taken down sharply with electrocautery or the Ligasure Impact device (Valley Lab, Covidien,
Mansfield, Massachusetts). The right gastric artery is preserved as the dissection is continued along the lesser curve. The right crus is dissected. The left crus and the angle of His are mobilized with electrocautery. The hiatus is opened (Fig. 20.4) and the tumor palpated in the mediastinum to ensure mobility and hence respectability (Fig. 20.5).

The lower esophagus including the periesophageal fat, nodes, and vagus nerves are encircled with a Penrose drain. At this point, the course of the right gastroepiploic artery is identified from the pyloroduodenal area to the middle of the greater curvature, where it generally terminates as it enters the stomach or divides into smaller branches that anastomose with the left gastroepiploic artery. This vessel will serve as the main blood supply of the gastric conduit.

Starting at the esophagogastric junction proceeding inferiorly on the greater curve, the left gastroepiploic and short gastric vessels are ligated with the Ligasure. As the dissection proceeds down the greater curvature and the omentum is separated from the...
stomach, care is taken to apply the Ligasure device at least 2 cm below the right gastroepiploic artery. Dissection proceeds down to the pylorus. With gentle upward traction of the stomach, the filmy posterior attachments on the stomach are sharply divided. The left gastric artery is identified and transected at its origin usually with a linear vascular stapler. Lymphadenectomy at the celiac axis at this point is also performed (Figs. 20.6 and 20.7).
Figure 20.5 Tumor is palpated to ensure resectability. (© 2014 Wm. B. Westwood, CMI.)

Figure 20.6 Short gastric arteries divided by the Ligasure Impact device (Valley Lab, Covidien, Mansfield, Massachusetts). (© 2014 Wm. B. Westwood, CMI.)
Chapter 20  Transhiatal Esophagectomy

The mobility of the esophageal tumor is once again assessed to ensure that it is not fixed to the prevertebral fascia, aorta, or surrounding mediastinal structures. The diaphragm is incised up to the pericardium to open the hiatus. Retractors can be placed into the hiatus to allow ligation of the periesophageal tissues to the level of the carina under direct vision. The value of the Ligasure for this part of the procedure cannot be overstated. At least 10 cm of the distal esophagus can be mobilized under direct vision. For this maneuver to be effective, the esophagus should be retracted from one side to the other in the lower mediastinum to create tension on the tissues on the opposite side and facilitate their division (Fig. 20.8). Then, with downward traction on the esophagus, the surgeon’s hand is inserted into the hiatus and further blunt, gentle mobilization of the esophagus, to at least the level of the carina, is carried out. Mobility of the esophagus within the posterior mediastinum is assessed. If the esophagus is not fixed and transhiatal resection is possible, the mediastinal dissection is completed for now. Throughout the gastric and esophageal mobilization process, the utmost care in handling the stomach is required.

Figure 20.7 Celiac lymph nodes are excised with the Ligasure Impact device (Valley Lab, Covidien, Mansfield, Massachusetts). (© 2014 Wm. B. Westwood, CMI.)

Figure 20.8 Division of the periesophageal attachments are divided with the Ligasure Impact device (Valley Lab, Covidien, Mansfield, Massachusetts). (© 2014 Wm. B. Westwood, CMI.)
After gastric mobilization has been completed, a generous Kocher maneuver is performed (Fig. 20.9) to allow mobilization of the pylorus to the level of the hiatus. A 20-French jejunostomy tube is placed before proceeding with the cervical phase. This is usually placed 40 to 45 cm distal to the ligament of Treitz in a Stamm fashion.

**Cervical Phase**

An oblique incision is made along the anterior border of the left sternocleidomastoid muscle (Fig. 20.10). The incision is centered on the cricoid cartilage and extends inferiorly to the suprasternal notch. Dissection is taken down medially to the carotid sheath. The omohyoid muscle is divided. Two Gelpi retractors are placed for soft tissue retraction. The middle thyroid vein and the inferior thyroid artery are ligated. The recurrent

![Figure 20.9](image.png)  
A Kocher maneuver is depicted. (© 2014 Wm. B. Westwood, CMI.)

Figure 20.9 A Kocher maneuver is depicted. (© 2014 Wm. B. Westwood, CMI.)

![Figure 20.10](image.png)  
A neck incision is made anterior to the sternocleidomastoid muscle. (© 2014 Wm. B. Westwood, CMI.)

Figure 20.10 A neck incision is made anterior to the sternocleidomastoid muscle. (© 2014 Wm. B. Westwood, CMI.)
laryngeal nerve is identified and protected. At no time should metal come into contact with the recurrent laryngeal nerve (Fig. 20.11).

After dissecting to the prevertebral fascia, blunt finger dissection is continued into the superior mediastinum. The plane between the trachea and esophagus is developed by sharp dissection; the dissection is kept as posterior to the tracheoesophageal groove as possible to avoid injury to the recurrent laryngeal nerve. The cervical esophagus is bluntly mobilized from adjacent tissues circumferentially with attention not to injure the posterior membranous portion of the trachea. The esophagus is encircled with a Harkin clamp and is encircled with a small Penrose drain. The upper thoracic esophagus is mobilized almost to the level of the carina using blunt dissection and keeping the fingers directly against the esophagus. When sufficient mobilization has been accomplished, the nasogastric tube is removed and the Sweet scissors (an angled instrument) are used to transect the esophagus, at the level of the thoracic inlet. It is important to preserve as much cervical esophagus as possible provided that the blood supply and the resection margin are adequate (Fig. 20.12).

Transhiatal Phase

Attention is now focused on transhiatal dissection of the esophagus. Esophageal mobilization is begun in an orderly fashion. One hand is inserted through the diaphragmatic...
hiatus, posterior to the esophagus, dissecting periesophageal tissue (Fig. 20.13). The blood pressure is carefully monitored to prevent hypotension. Anterior mobilization of the esophagus is done with the fingers directly against the anterior esophagus avoiding injury to the posterior membranous portion of the trachea. The esophagus is then held in the superior mediastinum, between the index and the middle fingers of the hand inserted through the hiatus, and the remaining attachments are lysed with a downward motion. Subcarinal or subaortic attachments can be finger fractured. The esophagus is then delivered out of the hiatus. Retractors through the hiatus are placed to inspect for hemostasis. The posterior mediastinum can be packed to tamponade minor bleeding.

The stomach is separated from the esophagus with multiple loads of a GIA (gastrointestinal anastomosis) stapler along the lesser curve. Each time the stapler is removed,
traction is applied to the fundus to allow the stomach to be straightened progressively so that its most cephalad portion is reached. We do not typically tubularize the stomach as some have advocated. We like to leave a rather broad conduit (about 6 cm wide) to try and preserve collateral circulation to the fundus (Fig. 20.14). We do not oversew the staple line. The specimen is now passed off the field.

At this point, a 28-French chest tube is passed through the cervical incision down through the mediastinum and out the hiatus. We suture the chest tube to the tip of the stomach using a heavy silk stitch (Fig. 20.15). The chest tube is then pulled up through the incision, and the stomach is then gently grasped with fingers and pulled out through the cervical incision. While the stomach is passing through the hiatus, we assure proper orientation so that the gastric staple line is facing the right side of the patient. The stomach can be palpated through the hiatus to ensure that there is no torsion. Once the fundus of the stomach can be seen in the neck, it is grasped with a Babcock clamp and gently brought up further into the operative field. The suture holding the chest tube is cut, and we are now prepared for esophagogastric anastomosis.

**Cervical Esophagogastric Anastomosis**

Over the years, our technique for cervical esophagogastric anastomosis has come full circle. Techniques used have included one-layer handsewn, modified Orringer, and end-to-end (EEA) anastomoses. Of all our techniques, we have come to favor the end-to-side (functional end-to-end) handsewn technique. Our incidence of leaks and need for dilations have lessened since switching to a one-layer, full-thickness, 2-0 vicryl (Ethicon, Inc., Somerville, NJ), handsewn anastomosis.

A gastrotomy is made using a cautery away from the gastric staple line. Immediately, succus entericus is drained out of the stomach using a pool suction. Two stay sutures are placed on the esophagus marking the lateral edges and keeping proper orientation (Fig. 20.16). Interrupted full-thickness 2-0 vicryl sutures are placed completing the back wall first (Fig. 20.17). The knots are on the inside on the back wall. The
Figure 20.15 A 28-French chest tube has been passed down from the cervical incision through the hiatus and is sutured to the fundus with a heavy silk suture. (© 2014 Wm. B. Westwood, CMI.)

Figure 20.16 Two stay sutures are placed on the esophagus marking the lateral edges and keeping proper orientation. (© 2014 Wm. B. Westwood, CMI.)

Figure 20.17 The back wall of the anastomosis is completed first with interrupted full-thickness 2-0 vicryl sutures. (© 2014 Wm. B. Westwood, CMI.)
Figure 20.18 The anterior wall of the anastomosis is now completed using interrupted full-thickness 2-0 vicryl sutures. (© 2014 Wm. B. Westwood, CMI.)

Figure 20.19 Anatomy of the completed procedure depicted after the stomach has been pulled down from the hiatus straightening it. The anastomosis is at the level of the thoracic inlet, and the gastrectomy staple line is properly oriented. (© 2014 Wm. B. Westwood, CMI.)
anterior portion is completed in a similar fashion except the knots are on the outside. When suturing, it is vital to keep mucosal to mucosal apposition (Fig. 20.18). The stomach is then pulled down from the hiatus to straighten the anastomosis making a linear relationship of the remnant esophagus and stomach. At the end of the procedure, the anastomosis is found at the thoracic inlet (Fig. 20.19). Upon completion of the anastomosis, a nasogastric tube is gently passed. A small Penrose drain is placed at the level of the anastomosis and brought out through a separate stab incision. The cervical wound is then closed in two layers after proper irrigation.

Closure

A pyloromyotomy is performed (Fig. 20.20). We start by scoring the proposed incision with cautery, then we cut the muscle fibers with straight Mayo scissors. Any bleeding from the pyloromyotomy site is controlled with topical hemostatic agents. Cautery is to be avoided. After the pyloromyotomy, the gastric conduit is sutured to the hiatus as it passes into the mediastinum with two to three 3-0 silk sutures. This is done to prevent herniation of bowel into the mediastinum. Bilateral 28-French chest tubes are placed via anterior thoracostomy incisions. The abdomen is then irrigated and the closure is performed with running no. 1-looped PDS (polydioxanone) suture.

POSTOPERATIVE MANAGEMENT

We prefer to keep the patient intubated overnight. A chest radiograph is obtained in the recovery room to evaluate for hemothorax, pneumothorax, or mediastinal widening suggestive of postoperative hemorrhage. Patients are admitted to the ICU after a short recovery room stay. They are extubated on postoperative day 1 and are transferred to our thoracic surgery unit. Ambulation begins on the first postoperative day. Incentive spirometry and aggressive pulmonary toilet are emphasized throughout the remainder of the patient’s hospitalization. Thoracic epidural anesthesia, intravenous low dose dopamine, and Foley catheter drainage are continued for 5 days postoperatively. Antibiotic coverage is continued for 24 hours postoperatively. Jejunostomy tube feedings are begun at 10 mL per hour on postoperative day 2 and are advanced as tolerated until nutritional goals are reached. The nasogastric tube is removed on postoperative day 5,
and an esophagram is typically performed on postoperative day 5 or 6. Once confirmation of an intact anastomosis and gastric emptying is obtained, the patient is given a clear liquid diet and is advanced to a soft mechanical diet by postoperative day 7. The patient is then discharged on the same day. The cervical Penrose drain is also removed after the patient has passed their swallow examination. If oral intake is poor, nocturnal supplements are given by jejunostomy tube; however, in most cases, patients are eating well and the jejunostomy tube is removed 2 weeks postoperatively.

### COMPLICATIONS

Intraoperative complications include pneumothorax, hemorrhage, and tracheal tear. Early complications that can occur within 10 days include hoarseness or difficulty swallowing due to recurrent laryngeal nerve injury, disruption of the anastomosis, arrhythmias, chylothorax, and sympathetic pleural effusion. Late complications are relatively uncommon and include diaphragmatic hernia and cervical anastomotic stricture.

#### Hemorrhage

Aortic esophageal arteries are small branches and generally thrombose if avulsed during esophagectomy. The average intraoperative blood loss is less than 300 mL if patients are properly selected. Patients who have tumors fixed to the aorta or periesophageal tissues should undergo TTE. If intraoperative hemorrhage occurs, retractors are placed into the hiatus, a sump catheter is placed, and the bleeding is identified and controlled. If the point of bleeding cannot be identified, the mediastinum is packed for 5 to 10 minutes with volume resuscitation. If the bleeding continues, the procedure is converted to thoracotomy.

#### Tracheal Tear

Tracheal tears are rare, are generally small and linear, and generally involve the membranous portion of the trachea. Upon identifying a tracheal tear, the surgeon should guide the endotracheal tube distal to the tear. If possible, the esophagectomy should be completed to achieve better exposure before repair. A partial upper sternotomy provides direct visualization of the upper trachea, if necessary. Extensive tears involving the carina or main stem bronchi may require posterolateral thoracotomy. In these cases, the abdominal and cervical wounds are closed, and the patient is repositioned for a right thoracotomy. After repair, the patient is again placed supine, and the THE is completed.

#### Recurrent Laryngeal Nerve Injury

Injury to the recurrent laryngeal nerve can result in hoarseness as well as cervical dysphagia and potentially serious aspiration pneumonia. This complication is preventable by avoiding the placement of retractors in the tracheoesophageal groove. Cautery is also avoided. Recurrent laryngeal nerve injury has not occurred at the author’s institution in the last 17 years.

#### Anastomotic Leak

If the patient develops a fever of 101°F or more 48 hours after THE, this is assumed to be the result of an anastomotic leak until proven otherwise. A dilute barium study is obtained. Assurance is made that no distal obstruction is present. If a leak is confirmed, the patient is allowed to drink water for good mechanical wound cleansing out into the Penrose drain. Most cervical anastomotic leaks heal within 1 week. Tube feeds are continued until the leak has stopped.
Part III  Techniques and Approaches for Esophageal Resection

**Postoperative Chylothorax**

If chylothorax is suspected, the chest tube effluent is sent for assessment of triglyceride levels for confirmation. Treatment at our institution consists of a transthoracic approach to the thoracic duct with direct identification and suturing of the leak facilitated by cream administration through the jejunostomy tube. We prefer this over prolonged chest tube drainage and parenteral administration.

**Anastomotic Stricture**

Dysphagia secondary to anastomotic stricture formation occurs in about 50% of all patients who have undergone THE. With early dilation with Savary and Maloney dilators under anesthesia, the need for subsequent dilations is often greatly reduced or eliminated completely. Comfortable swallowing is achieved if a 46-French Maloney or 15-mm Savary dilator can be passed.

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**RESULTS**

The largest reported single institution series of 2,007 patients treated over 30 years was published by Orringer et al.\(^6\) Seventy-six percent (1,525 patients) were treated for carcinoma. THE was technically possible in >98% of cases. Twenty-two patients required thoracotomy for hemorrhage or esophageal fixation. Stomach was used for reconstruction in 97% (1,942 patients). In a previous series of more than 1,000 THEs, Orringer concluded that the stomach is the preferred conduit for esophageal replacement because it is well vascularized, usually has sufficient length to reach the neck, and is prone to the redundancy that occurs with intestinal substances.\(^11\) It is also relatively easy to mobilize and requires only a single anastomosis. In Orringer’s earlier series, intraoperative blood loss averaged 652 mL in patients who had carcinoma.\(^11\) With increasing experience in performing more of the esophageal dissection under direct vision, the intraoperative blood loss was reduced to 368 mL for 739 patients who underwent THE for carcinoma between 1998 and 2006.\(^6\) Injury to the membranous trachea occurred in 8 patients and splenectomy was performed in 2% due to intraoperative injury. Less than 1% of patients (24 patients) had persistent laryngeal nerve injury. Thoracic duct injury occurred in 1% (25 patients). Cervical anastomotic leak occurred in 12% (232 patients) and was more common after retrosternal placement, radiation therapy, and prior operation at the gastroesophageal junction. The cervical side-to-side stapled anastomosis has significantly decreased the anastomotic leak rate.\(^12\) Orringer et al. reported a hospital mortality rate of 3% (51 deaths) in 2,007 patients. There were four intraoperative deaths due to uncontrollable hemorrhage.\(^6\)

Katariya and colleagues\(^13\) evaluated 23 series with a total of 1,353 patients (99% esophageal cancer) published between 1981 and 1992. Complications included anastomotic leak (15.1%), recurrent laryngeal nerve injury (11.3%), cardiac complications (11.9%), splenectomy (2.6%), chylothorax (0.7%), and tracheal injuries (0.67%). Although pulmonary complications occurred in 50% of patients, a wide variety of complications were included, such as pneumothorax, pneumonia, and pleural effusions. Conversion to thoracotomy occurred in 1.3% of cases for hemorrhage, and 30-day mortality was 7.1%; however, 69.5% of the series included fewer than 50 patients and may not reflect the results of more experienced surgeons.

At our institution, 319 THEs were performed from January 1992 to December 2009. Complications included anastomotic leak (9.4%), recurrent laryngeal nerve injury (0%), cardiac arrhythmia (12.5%), splenectomy (0%), chylothorax (0%), and tracheobronchial injuries (0%). Conversion to thoracotomy because of hemorrhage occurred in 2/319 patients (0.63%). Mean operative time was 158 minutes. Our mean length of stay was 10.9 days (4 to 55 days). Thirty-day mortality was 1.9%. Twenty-six out of 30 patients (86.6%) who had a postoperative anastomotic leak did receive neoadjuvant chemoradiation therapy. Since converting back to the handsewn, one-layer, interrupted 2-0 vicryl anastomosis, we have had no anastomotic leaks in the last 50 patients.
Controversy still remains regarding the appropriateness of THE as a cancer operation. Critics argue that without an en bloc mediastinal lymphadenectomy, THE does not provide accurate staging or the potential for a curative procedure.\(^4\) \(^5\) \(^6\) Orringer et al. reported that the Kaplan–Meier actuarial survival of 1,525 patients who underwent THE for carcinoma was similar to that reported after TTE; the overall 2-year survival was 51% and the 5-year survival was 29%.\(^8\) In addition, several authors have reported survival after THE is similar to that reported after TTE\(^17\) \(^18\) as well as after radical esophagectomy with mediastinal lymphadenectomy.\(^19\) The most important determinants of survival appear to be the biologic behavior of the tumor and the stage at the time of resection rather than the operative approach, and esophageal carcinoma will likely require systemic therapy for a cure.

CONCLUSIONS

The optimal technique to esophagectomy remains controversial. Perhaps more important than the approach to esophageal resection; however, is the case volume and the experience of the centers that perform the operation. Operative mortality rates ranged from 12.2% in low volume centers to 3% in high volume centers.\(^21\) At our center, 30-day mortality was 1.9%.

THE is a technique that we use in the resection of benign and lower third esophageal malignancies. It has several potential advantages over TTE including significantly decreased respiratory complications and mediastinitis due to avoidance of thoracotomy and intrathoracic anastomosis. Advantages over MIE include decreased cost and shorter operative time. With experience, THE is safe, well tolerated, and can be performed with low morbidity and mortality rates in properly selected patients.

Recommended References and Readings

21  Ivor Lewis Esophagectomy  
Christopher J. Mutrie, Christopher R. Morse, and Douglas J. Mathisen

Introduction

Treatment of esophageal carcinoma is aimed at cure of the neoplasm. However, relief of dysphagia is an important secondary concern. An operation that removes the entire tumor, with adequate margins, as well as the lymph node drainage offers the best chance for cure. Studies have shown that neoadjuvant therapy may improve survival for patients with squamous carcinoma of the esophagus and possibly adenocarcinoma of the esophagus.1,5,25,34,36,39,41 As preoperative adjuvant therapy for carcinoma of the esophagus increases in popularity, operative approaches that provide as much biologic and staging information as possible allow better evaluation of the results of such treatment.

Location of the tumor, preference of the surgeon, body habitus, prior operations, condition of the patient, and choice of esophageal substitute are all factors influencing the choice of operation for carcinoma of the esophagus. Prior irradiation and irradiation for other diseases are important considerations. The risk of complications after esophagectomy is greatly increased if the dose of irradiation exceeded 50 Gy and was given more than 1 year before the contemplated surgery. If this is the case, an anastomosis outside the irradiated field so that one end of the anastomosis has not been irradiated should be performed. Buttressing the anastomosis with additional tissue, such as omentum or pedicled muscle, aids with healing and minimizes leaks.

The choice of incision is influenced by the ease of anastomosis and the ability to mobilize the stomach and resect the esophagus. Tumors located in the middle third of the esophagus have traditionally been removed by a combined laparotomy and right thoracotomy—the Ivor Lewis approach.16

INDICATIONS

- The most common indication for an Ivor Lewis esophagectomy is middle-third esophageal squamous or adenocarcinoma
- Esophageal disorders requiring removal of most of the esophagus
- Distal esophageal tumors with proximal extension above 35 cm
- High-grade dysplasia in Barrett’s esophagus with proximal extension above 35 cm
Failed myotomy for achalasia with sigmoid esophagus requiring near-total esophagectomy

**CONTRAINDICATIONS**

Contraindications to an Ivor Lewis esophagectomy are relative and in some cases may include prior thoracotomy, especially for inflammatory disease on the right side. Factors to be considered include the nature of esophageal disease (benign vs. malignant), the need for adequate longitudinal and radial margins, surgeon preference, patient factors, and neoadjuvant treatment.

**PREOPERATIVE PLANNING**

Careful evaluation of each patient is essential. Patients must be in reasonable medical condition and must have adequate pulmonary function. Patients with forced expiratory volume in 1 second of less than 1 L are probably not suitable candidates for this approach. Smoking should be stopped, and aggressive measures to treat underlying obstructive lung disease should be instituted. Careful evaluation for underlying cardiac disease should be done in elderly and high-risk patients.

**Radiologic Evaluation**

Standard preoperative evaluation includes the following.

- Barium esophagography
- Computed tomography (CT) of the chest and upper abdomen
- For malignant esophageal tumors, esophagoscopy with endoscopic ultrasound to assess depth of invasion and presence of enlarged lymph nodes

**Endoscopic Evaluation**

Histologic diagnosis and determination of the true proximal and distal extent of the tumor is best achieved through endoscopic evaluation. Direct visualization also allows for checking of the presence of Barrett’s mucosa proximal to adenocarcinomas. The proximal extent of the tumor and abnormal mucosa is critical in determining surgical approach.

Endoscopy should be performed by the surgeon in all cases. It is particularly helpful in determining proximal extent of tumor. A 5-cm surgical margin is desirable for carcinoma. Distal tumors with proximal involvement above 35 cm may be technically difficult to resect from the left side. Tumor involvement of the esophagus between 30 and 35 cm can be approached from either the left side, utilizing a supra-aortic anastomosis, or the more traditional Ivor Lewis approach.

In patients with adenocarcinoma arising in Barrett’s mucosa, it is important to resect the tumor, with a 5-cm proximal margin and all of the Barrett’s mucosa. It is helpful to identify the proximal extent of Barrett’s mucosa by endoscopically placing the nasogastric tube just above the squamocolumnar junction or by performing endoscopy intraoperatively to identify the location. Tumors extending above 30 cm may involve either the left main stem bronchus or the trachea and should be evaluated with bronchoscopy by the surgeon.

A combined thoracoscopy–laparoscopy, where peritoneal or pleural seeding, lymph node involvement, and local extent of tumor can all be assessed offers the potential for minimally invasive surgical staging of esophageal cancer and is an adjunct similar to that associated with mediastinoscopy for lung cancer. Pretreatment staging is necessary to better evaluate response to neoadjuvant therapy and should include esophageal ultrasound, CT scan, PET scan, and brain MRI.
Open Ivor Lewis Esophagectomy

Surgery

Abdominal Phase

Positioning
With the patient in the supine position, an upper midline abdominal incision is made (Fig. 21.1). The abdomen is explored. If liver metastases or unresectable retroperitoneal nodes are found, resection should be abandoned, and palliation of dysphagia should be achieved by other means. Endoscopically placed covered esophageal stents or irradiation have successfully been used.8,32

Technique
- If the tumor is resectable, the left triangular ligament of the liver is divided.
- The lesser sac is entered through the greater omentum, preserving the gastroepiploic artery.
- The omentum is separated from the transverse colon, and care taken to preserve the gastroepiploic artery. If possible, omentum along the greater curvature is saved for later use to cover the anastomosis. Excess bulk of omentum can be removed to facilitate transport into the chest. By elevating the greater curvature of the stomach, while preserving the gastroepiploic artery, the surgeon can easily divide the short gastric vessels (Fig. 21.2).
- The gastrohepatic ligament is divided taking care to preserve the right gastric artery.
- The left gastric artery and vein are isolated and doubly suture-ligated at their origin with lymph nodes taken from this area with the specimen.
- The hiatus and distal esophagus are dissected. Enlarging the hiatus from the right chest is difficult and more easily achieved through the laparotomy incision.

Figure 21.1 Standard incisions for an Ivor Lewis esophagectomy. An upper midline abdominal incision is used to mobilize the stomach. A right thoracotomy is used to resect the esophagus and do the esophagogastric anastomosis.
Maximal mobility of the stomach can be achieved with a Kocher maneuver.

A pyloroplasty or pyloromyotomy is often done at the surgeon’s discretion.

It is helpful to identify the point of transection of the stomach and clear the greater and lesser curvature in the abdomen. At this point, the final diameter of the new conduit must be determined; there are arguments in favor of a wider conduit and in favor of a narrow conduit. No objective data exist in terms of the ideal diameter of the new conduit. One argument in favor of a narrow conduit (3 to 4 cm in diameter) is that it may lead to less acid reflux.

A feeding jejunostomy is inserted in most patients, especially high-risk or nutritionally depleted patients.

It is helpful to accomplish as much dissection of the lower esophagus as possible from the abdomen. This dissection facilitates the intrathoracic dissection of the lower esophagus, which can be difficult through a high right thoracotomy. An attempt should be made to advance the stomach and omentum into the posterior omentum before closing the abdomen to facilitate retrieval of the conduit from the chest.

**Thoracic Phase**

**Positioning**

The patient is then placed in the left lateral decubitus position. A double-lumen endotracheal tube is used allowing the lung to collapse and exposing the esophagus for dissection and anastomosis.

**Technique**

A standard posterolateral right thoracotomy is performed. The serratus muscle is spared, and the chest is entered through the fourth or the fifth interspace. After the lung is examined for abnormalities, it is deflated and retracted anteriorly.

- The azygos vein is divided.
- The esophagus is dissected from the vertebral body to the pericardium. All paraesophageal nodes, including subcarinal nodes, are included in the specimen. Dissection is continued to the apex of the chest.
The stomach is then pulled into the chest and divided. It is done only after all of the intrathoracic dissection has been completed to avoid any confusion about orientation of the stomach.

- Care must be taken to avoid pulling too much of the stomach into the chest. Redundant gastric conduit above the diaphragm will fall into the costophrenic gutter, creating an S-loop and cause delayed emptying of the stomach.
- Pulling the stomach too tightly into the chest may also lead to impingement of the stomach at the level of the hiatus and cause delayed emptying as well as compression of the gastroepiploic vessels.
- It is best to grasp the omentum near the stomach to avoid tearing the gastroepiploic vessels.

Anastomotic Technique

Sweet published his initial experience with surgical management of carcinoma of the esophagus in 141 patients in 1947. Operating in an era without sophisticated postoperative monitoring devices, mechanical ventilation, or broad-spectrum antibiotics, his results were remarkable: An operative mortality of 15%, anastomotic leaks in 1.4% of patients, and overall 5-year survival of 11%. These results served as a standard for many years. The low incidence of leaks and operative mortality was related to the attention to detail and the reliability of the anastomotic technique.

- Churchill and Sweet warned of factors predisposing to anastomotic leak—namely the lack of an esophageal serosal layer and the segmental blood supply of the esophagus.
- Churchill and Sweet emphasized the importance of preserving the esophageal and gastric blood supply; gentle handling of the tissues, interrupted sutures, avoiding crushing clamps, cutting with a knife or other sharp instrument, and firm but gentle tying of sutures to avoid cutting tissues.

The traditional anastomotic technique is as follows.

- A 2-cm diameter circle is scored on the surface of the stomach (Fig. 21.3A). The defect created should be 2 cm away from the stapled edge of the stomach to avoid a compromised blood supply.
- Submucosal vessels are identified and individually ligated with fine silk sutures.
- Interrupted mattress sutures of fine suture (4-0 silk) are used to construct the back row of the anastomosis (Fig. 21.3B). Corner stitches are placed first, with the remaining sutures placed evenly between them. The sutures on the stomach include the seromuscular layers. The esophageal sutures should be deep enough to include both the longitudinal and circular muscular layers of the esophagus.
- The esophagus is opened sharply from one corner stitch to the other. The circular button of the stomach is removed (Fig. 21.3B).
- The inner layer is completed with simple sutures, including just the mucosa of the esophagus and all layers of the stomach (Fig. 21.3C).
- The knots are on the inside, allowing inversion or turning in of mucosa of both the stomach and the esophagus. This step is accomplished for the entire circumference of the anastomosis (Fig. 21.3D).
- A nasogastric tube is passed into the stomach under direct vision before a single Connell stitch is placed for closure of the final opening. Healing of the inverted mucosa is important in preventing leakage, and the location of the knots on the luminal side minimizes foreign-body reaction with the actual tissues of the anastomosis.
- The outer row is completed using horizontal mattress sutures as described for the back row of the outer layer (Fig. 21.3E).
- The omentum, mobilized with the stomach, is placed over the anastomosis anteriorly to provide an additional layer of coverage. In order to avoid tension on the anastomosis when the patient is upright, several sutures are placed between the stomach and the mediastinal pleura.
- Sutures are also placed between the stomach and the diaphragmatic hiatus to prevent herniation of abdominal contents.
In accordance with Dr. Churchill and Sweet's teachings, trauma to the tissues is avoided as much as possible. Once the first stitch is placed and tied, traction on it permits placement of the next without the need of instrumental grasping of the mucosa. The surgeon ties the sutures by positioning the index finger cephalad to the anastomosis and lifting the stomach to the esophagus. This avoids pulling down on the fixed and more fragile esophagus.

A nasogastric tube passed through the anastomosis for a short time decompresses the stomach and avoids distention of the suture line. Gentle, periodic irrigation of the tube ensures its patency. Temporary gastric decompression more than compensates for any potentially deleterious effect of the intraluminal foreign body lying against the suture line for a short period.

### COMPLICATIONS

Experience with this technique from the Massachusetts General Hospital in a consecutive series of 104 patients was reported. There were three postoperative deaths (2.9%), all attributable to pneumonia and respiratory failure. Five patients developed anastomotic stricture requiring dilation 3 to 6 weeks postoperatively. Dysphagia resolved after one to three dilations. Delayed anastomotic stricture was not present in this group of patients. All patients underwent a postoperative barium swallow. There were no
anastomotic leaks, even of the localized type. The reliability of this precise, two-layer anastomotic technique has been reported by others as well.\(^7\)

**Anastomotic Leaks**

Aggressive management of anastomotic leaks is required if fatalities are to be avoided.

- If the leak is small and contained or well drained by the chest tube, the patient should take nothing by mouth; antibiotic therapy and nutritional support should be continued, and the contrast study should be repeated 1 week later.
- CT is performed to identify any undrained collections.
- Small, undrained collections can be drained by percutaneous ultrasound-guided catheters.

The presence of a massive leak warrants urgent intervention. If the leak is related to necrosis of the stomach, the stomach should be resected to viable tissue, returned to the abdomen, and a cervical esophagostomy should be done. Reconstruction of the gastrointestinal tract can be performed at a later date. Local repair in the presence of gross contamination of the pleural cavity can be expected to fail in most cases.

- If local repair is attempted, devitalized tissue should be debrided and the repair should be buttressed with healthy tissue. Omentum, chest wall muscles (serratus, pectoralis), or pedicled intercostal muscle can all be used.
- The lung should be decorticated, and wide drainage of the pleural cavity should be provided.
- Cervical esophagostomy may be appropriate if concern exists about the repair. The esophagostomy can be constructed in such a way that reanastomosis can be done between the divided ends of the esophagus in the neck, avoiding more complicated reconstructive methods.\(^10\)
- Alternatively if preservation of the conduit is desired and the anastomosis is otherwise intact, a long T-tube can be placed through the defect, brought out through the chest wall with pedicled muscle wrapped around the T-tube fistula. Drains should be placed in close proximity to T-tube.

**Delayed Gastric Emptying**

The two main reasons for delayed gastric emptying after an Ivor Lewis esophagectomy are the following.

- Obstruction at the hiatus
- Redundant intrathoracic stomach lying in the posterior costophrenic gutter

These problems are best avoided by an adequate drainage procedure at the time of operation, with the surgeon enlarging the hiatus, not pulling the stomach too tightly into the chest, and avoiding excess stomach in the chest.

Pyloric obstruction may also cause delayed gastric emptying. When a drainage procedure has been done, pyloric obstruction usually resolves with time. Metoclopramide may be useful. Endoscopy and cautious balloon dilation of the pylorus can be tried. Failure of conservative management requires reoperation and an adequate drainage procedure. Obstruction at the level of the hiatus usually demands reexploration and enlargement of the hiatus. This procedure is often difficult, and great care must be taken to avoid injury to the blood supply of the stomach.

**Mortality**

Advances in anesthesia, perioperative care, monitoring, and enteral and parenteral nutrition have resulted in a dramatic decrease of 50% over 10 years in overall postoperative mortality. In addition, there was a significantly lower hospital mortality rate for resections performed with curative intent versus those with palliative intent (mean, 11% vs. 19%, respectively).\(^24\) The hospital mortality rate was nearly identical whether or not the anastomosis was located in the neck if the procedure involved a thoracotomy of
any type. Many institutions have reported operative mortality rates near or below 5% for either transthoracic or transhiatal resection.3,29,37,38

**Survival**

Despite the theoretical advantages of an en bloc dissection and full lymphadenectomy, studies comparing these procedures with transhiatal esophagectomy show no difference in overall survival between these two approaches for esophageal carcinoma. Shahian et al.31 demonstrated no statistically significant difference in survival for all patients who underwent transthoracic versus extrathoracic esophagectomy for carcinoma (median, 14.1 vs. 12.6 months; \( p = 0.48 \)), regardless of whether patients had stage I or stage III disease. In the review by Müller, only tumor stage at time of operation was a significant determinant of long-term survival. There was no significant difference in survival according to extent of surgery or type of resection.

**RESULTS**

The greatest immediate concern is the fate of the intrathoracic anastomosis. It is undoubtedly this concern that has led to the popularity of the transhiatal esophagectomy, which places the anastomosis in the cervical area.28 We and others have shown that attention to technical details of the anastomosis leads to a very low incidence of leaks and subsequent mortality, stressing the importance of how the anastomosis is done rather than where it is done.

Transhiatal esophagectomy has become the popular alternative to Ivor Lewis esophagectomy. No direct randomized series have compared the two procedures. Müller et al.24 reviewed all published reports of surgical therapy of esophageal carcinoma from 1980 to 1988 (a summary of 59 published reports) and drew some conclusions about the two procedures. Others have compared the two procedures in a retrospective fashion within a single institution and provide some important insights into the relative merits of the two procedures.3,17

In most reports, the risk of anastomotic leak from a cervical anastomosis is higher than that reported for an intrathoracic anastomosis.24 In patients experiencing leaks, however, morbidity and mortality related to the leak itself are lower if the anastomosis is in the neck rather than in the chest. This finding is borne out in the Müller review. The anastomotic leak rate was 11% for intrathoracic anastomosis compared with 19% for cervical anastomosis. However, the mortality rate for an intrathoracic anastomotic leak was three times higher than that for a cervical anastomotic leak (69% vs. 29%, respectively).

Cervical anastomotic leak rates for transhiatal esophagectomy without thoracotomy have been reported to be as low as 6% to 8% for operations performed for carcinoma of the intrathoracic esophagus,28 and leak rates from 0% to 2% have been reported for intrathoracic anastomosis.9,22,38 Even within the same institution and with the same surgeons, cervical anastomosis is associated with a higher incidence of leaks. This finding is confirmed by a report from the Lahey Clinic, with 15.4% leak for cervical anastomosis but 1.8% for intrathoracic anastomosis.31

Respiratory insufficiency and atelectasis occur more commonly after transthoracic esophagectomy, but the incidence of pneumonia is similar. Transhiatal esophagectomy is associated with a high incidence of recurrent nerve paresis or palsy (6% to 24%), but this is very uncommon after transthoracic esophagectomy. Chylothorax, posterior membranous tracheal tears, and increased blood loss are all more frequent after transhiatal esophagectomy. Most reports have not demonstrated the superiority of one surgery over another and view the procedures as alternative choices.17,31

In a recent presentation at the American Surgical Association annual meeting, a national database of over 15,000 esophagectomies was evaluated. The primary comparison was between patients having an intrathoracic anastomosis versus a cervical anastomosis. The interesting findings of this study were that the patients with the intrathoracic anastomosis fared markedly better in terms of length of stay, mortality, and hospital charges. Another interesting finding was that the leak rate was about 10% in
each group, but overall morbidity and mortality still favored the intrathoracic anastomosis group. This data compare favorably with the recent series by Luketich et al. where they compared ~500 consecutive neck anastomosis to ~500 intrathoracic anastomosis and found better outcomes with the intrathoracic anastomosis as well. So, it does appear that over the last decade or so, we are seeing an increasing number of surgeons choose the Ivor Lewis approach with morbidity that is quite favorable compared with cervical anastomosis reports.

**Late Functional Results**

Although little information has been reported about late functional results after an Ivor Lewis esophagectomy, the Mayo clinic did report early and late functional results in 100 patients. A pyloromyotomy (39 patients) or pyloroplasty (56 patients) was done in 95 patients. Early functional results were excellent, with development of dysphagia and gastroesophageal reflux in only 3% and 1% of patients, respectively. The mean follow-up of patients was 2.3 years. Late dysphagia occurred in 40 patients; in 5 patients it was related to anastomotic recurrence and in 35 to benign anastomotic narrowing, requiring dilation. Dilation (range, 1 to 22 dilations; mean, 3.4 dilations) relieved symptoms in all 35 patients with benign stenosis. Delayed presentation of reflux occurred in 14% of patients and dumping in 5%. All patients with reflux or dumping were treated successfully by standard medical therapy. Postoperative weight loss (median, 15.7 kg) occurred in 62% of patients. The authors believed that weight loss was multifactorial and not necessarily related to the procedure itself.

**CONCLUSION**

Ivor Lewis esophagectomy remains an excellent procedure for resection of the middle third of the esophagus with good long-term functional results. Proper patient selection, adequate preoperative preparation of the patient, attention to technical details of the operation, and diligent postoperative care allow this procedure to be performed safely with acceptable morbidity and mortality rates. A reliable anastomotic technique should be implemented to avoid intrathoracic anastomotic leaks, the source of greatest morbidity and mortality. Ivor Lewis esophagectomy offers potential advantages of wider, more complete resection for better staging information, lower local recurrence rates, and possibly improved survival as compared with transhiatal esophagectomy.

**Minimally Invasive Esophageal Resection**

More recently, in an effort to limit the physiologic stress and possibly reduce the morbidity associated with open esophagectomy, minimally invasive surgical approaches to esophagectomy have been developed. The dramatic improvement in laparoscopic technology since its introduction in 1991 has witnessed an associated evolution in the complexity of laparoscopic technology. Complex esophageal disorders, including achalasia and giant paraesophageal hernia, are being successfully treated laparoscopically. Watson et al. reported a minimally invasive Ivor Lewis technique in 1999 with their description of a laparoscopically constructed gastric conduit followed by thoracoscopic esophagectomy with construction of an intrathoracic esophagogastric anastomosis.

Concerns in minimally invasive esophagectomy include the amount of nodal clearance achieved, the complexity of the procedure, and the ability to achieve a measurable impact on mortality. Early data reporting the outcomes of minimally invasive esophagectomy challenge these concerns. Recent studies have shown that minimally invasive esophagectomy is associated with outcomes comparable with open surgery. The minimally invasive Ivor Lewis esophagectomy is also described in detail in chapter 24.
Minimally Invasive Ivor Lewis Esophagectomy

Abdominal Phase

Positioning
The patient is positioned supine and a double-lumen tube is placed for eventual lung isolation. As with the open technique, on table esophagoscopy is performed to determine the location and extent of tumor involvement as well as to assess the stomach for suitability as a gastric conduit.

- Five ports are placed in the abdomen for gastric mobilization (Fig. 21.4).
- The liver and peritoneal surfaces are inspected to rule out metastatic disease.
- The celiac and left gastric artery and vein lymph nodes are identified. Any suspicious nodes are removed and sent for frozen section analysis.

Technique
Dissection begins with mobilization of the right crus and the lateral aspect of the esophagus. The dissection is carried anteriorly and superiority over the esophagus toward the left crus. Division of the phrenoesophageal ligament is spared until the end of the case in order to maintain pneumoperitoneum. A retroesophageal window is created through dissection of the inferior aspect of the right crus.

- The lesser sac is then entered through cephalad retraction of the antrum of the stomach taking care to preserve the right gastroepiploic artery.

Using ultrasonic shears (Autosonix, Covidien, Mansfield, MA; Harmonic Scalpel, Johnson and Johnson, Piscataway, NJ) and the Ligasure device (Ligasure, Valleylab,
Chapter 21  Ivor Lewis Esophagectomy

Boulder, CO), dissection is carried along the greater curvature of the stomach to the end of the gastroepiploic arcade with division of the short gastric vessels. Once mobilization of the greater curvature of the stomach is achieved, the retrogastric attachments are exposed by lifting the fundus of the stomach toward the patient’s right shoulder.

- The fundus of the stomach is completely mobilized and the retrohepatic attachments are divided sparing the left gastric artery and vein. Care must be taken when mobilizing the pyloroantral region of the stomach to avoid the gastroepiploic arcade or the gastroduodenal artery.
- When the pylorus is able to reach the right crus of the diaphragm under no tension, the pylorus is adequately mobilized.
- The left gastric artery and vein are divided with a vascular Endo GIA stapler (Autosuture, Covidien, Mansfield, MA) through the lesser curve.

The gastric tube is then created. The first staple line is placed on the lesser curve with a vascular Endo GIA stapler through a midclavicular port. Care is taken to avoid the gastric antrum. To aid in this step, the assistant grasps the tip of the fundus through a left upper quadrant port and stretches it toward the spleen with a second grasper placing downward retraction on the antral area. The staple line parallels the gastroepiploic arcade. The stomach is then divided across the antrum with 4.8-mm Endo GIA stapler loads aiming for the conduit to be 5 cm wide (Fig. 21.5).

- Holding sutures are placed on the superior and inferior aspects of the pylorus to hold the pylorus on tension. Ultrasonic shears are used to open the pylorus.
- The pyloroplasty is then closed in Heineke-Mikulicz fashion using interrupted sutures and covered with omentum.

A feeding jejunostomy is placed using a needle catheter kit (5-French needle catheter, Compat Biosystems, Minneapolis, MN) in the left lower quadrant (Fig. 21.6).

- The ligament of Treitz is identified with cephalad retraction on the transverse colon and a loop of jejunum is tacked to the abdominal wall 30 to 40 cm from the ligament of Treitz using an Endo Stitch device.
- A needle and guidewire are placed into the jejunum under laparoscopic vision and placement is confirmed with air insufflation and visible jejunal distention. The jejunum is then tacked to the abdominal wall using an endostitch device.

Lastly, the most superior portion of the gastric tube is stitched to the specimen. This stitch maintains correct orientation of the gastric conduit as it is delivered into the chest.

- The final step of the laparoscopic portion of the surgery is to divide the phrenoesophageal membrane.

![Figure 21.5 Creation of the gastric tube. Care is taken to avoid the gastric antrum. The assistant grasps the tip of the fundus through a right lower quadrant port and stretches it toward the spleen with a second grasper placing downward retraction on the antral area. The staple line parallels the gastroepiploic arcade.](image)
Thoracic Phase

Positioning
The patient is then placed in the left lateral decubitus position for esophageal mobilization and creation of the anastomosis. The primary surgeon stands facing the patient’s back. As in the abdomen, five ports are used (Fig. 21.7).

- A 10-mm port is placed in the seventh intercostal space anterior to the midaxillary line.
- A 10-mm port is placed at the eighth intercostal space, posterior to the posterior axillary line as the working port.
- A 10-mm port is placed in the anterior axillary line at the fourth intercostal space allowing for retraction of the lung with a fan retractor to expose the esophagus.
- A 5-mm port is placed anterior to the tip of the scapula, used as a retraction port for the surgeon.
- A final port is placed at the sixth rib, at the anterior axillary line for suction and for creation of the anastomosis.

Technique
The gastroesophageal junction is exposed by placement of a retraction stitch placed through the chest wall at the level of the diaphragm insertion and passed through the central tendon of the diaphragm.
The inferior pulmonary ligament is divided and the inferior pulmonary vein is retracted anteriorly allowing the dissection to be carried along the pericardium exposing the subcarinal lymph node packet. Care must be taken during mobilization of the subcarinal nodes to avoid the posterior membranous wall of the right main stem bronchus.

- Both the right and left main stem bronchi should be clearly identified with complete dissection of the subcarinal space.
- The mediastinal pleura is then opened along the hilum to the level of the azygos vein and above the azygos vein.
- The azygos is then divided with a vascular load of the Endo GIA stapler.
- The pleura overlying the esophagus is opened carefully, avoiding injury to the thoracic duct and underlying aorta. Any tissue suspicious for branches of the thoracic duct is clipped prior to division.
- The lateral dissection is carried from the azygos vein to the gastroesophageal junction. The deep margin is the contralateral pleura.

With complete esophageal mobilization, the specimen is brought into the chest with the attached gastric conduit. As with the traditional Ivor Lewis approach, care must be taken to avoid bringing redundant gastric conduit into the chest. Redundant conduit in the chest is a source of poor gastric emptying owing to the fold of conduit created. Similarly, spiraling of the conduit should be avoided as the conduit is brought into the chest. As dissection progresses above the azygos vein, it is important to stay on the wall of the esophagus to avoid injury to the recurrent laryngeal nerve. Once the esophagus is completely mobilized in the thoracic cavity, it is brought out through enlarging the inferior lateral port to 3 cm. A wound protector is used during removal of the tumor and assists in retraction of the wound. The esophagus is transected with Endo Shears (Fig. 21.8). The anastomosis is performed as follows.

- The anvil of a 28-mm EEA stapler is placed in the proximal esophagus and two purse-string sutures are placed and tied to secure the anvil in position and pull in any mucosal defects.
- The gastric conduit is then pulled to the apex of the chest and ultrasonic shears are used to open the tip of the gastric conduit along the staple line.
- The EEA stapler is placed through the posteroinferior port and positioned in the conduit.
- The stapler is brought out through the greater curve of the gastric conduit to join the anvil.
- Once it is determined that there is no redundant conduit within the chest and there is no twisting of the conduit, the tip of the stapler and anvil are docked and the stapler fired at approximately the level of the azygos vein (Fig. 21.9).
The excess gastric conduit, through which the gastrostomy for the EEA stapler was made, is trimmed with a linear stapler.

A 28-French chest tube and Jackson-Pratt drain are placed near the anastomosis and the space between the conduit and the right crus of the diaphragm is closed with a single stitch.

**RESULTS**

In the literature, two case series and several case reports characterize the results of this innovative procedure. One of the first large series came from the University of Pittsburgh.² With 50 patients, the reported median ICU stay was 1 day and the median hospital stay was 7 days. The mortality rate was 6% and an anastomotic leak occurred in 6%. The initial oncologic outcomes regarding negative surgical margins and lymph node clearance were comparable to most open series. In a larger series update from the University of Pittsburgh, Luketich reported on over 1,000 minimally invasive esophagectomies. Within this group, they compared ~500 cases performed with a neck anastomosis (McKeown approach²) to ~500 cases performed with an intrathoracic anastomosis (Ivor Lewis approach). In this series, the Ivor Lewis group fared better in terms of lower mortality, had fewer anastomotic leaks, and had a 1% incidence of recurrent nerve injuries. Therefore, the Ivor Lewis approach has become their favored approach for routine gastroesophageal junction carcinomas.¹⁸ Kunisaki et al.,¹³ in a smaller series of 15 patients, observed an elevated leak rate of 13.3% with a long hospital stay of 30 days.²,¹³,²⁶,⁴⁰

**CONCLUSION**

The minimally invasive Ivor Lewis esophagectomy avoids a neck dissection and the associated risk of recurrent laryngeal nerve injury and microaspiration seen in transhiatal esophagectomy. Minimally invasive esophageal resection is technically feasible and can be performed as safely as conventional esophagectomy. However, minimally invasive
esophageal surgery should be performed in centers with significant experience in open esophagectomy and esophageal surgery and by surgeons who have experience in both open esophagectomy and advanced laparoscopic and thoracoscopic procedures.

Recommended References and Readings


En Bloc Esophagectomy

Simon Law

Introduction

The concept of “en bloc” resection involves resecting the esophagus, together with its fascial envelope to ensure a negative circumferential margin, as well as sufficient axial margins proximally and distally. This envelope contains the lymphatics of potential spread which are also removed. The propensity of esophageal cancer to spread submucosally along the length of the esophagus dictates the removal of a long length of esophagus; for squamous cell cancer, a proximal 10-cm margin should be the aim. It is less common for esophageal cancer to spread distally across the gastroesophageal junction. For the lateral circumferential resection margin, the anatomic location of the esophagus makes achieving this a challenging goal because the organ is surrounded in the mediastinum by other important, indispensable structures. For squamous cell cancers, which are often proximally located near the tracheobronchial tree, extending the lateral extent of resection is limited by the trachea and bronchi. For adenocarcinomas, which are mostly located in the lower esophagus and the gastroesophageal junction, extending the lateral extent of resection by the removal of bilateral pleurae, azygos vein, pericardium, and a cuff of diaphragmatic crura surrounding the esophagus is possible. It has to be explained that the original term “en bloc” resection as coined by Skinner and DeMeester refers specifically to this type of surgery for lower esophageal carcinoma, for which the procedure is most appropriate. However the term is also loosely applied to any tumor resection that involves removal of the tumor with its adjacent tissue “in one unbroken piece.” Another consideration about en bloc resection is the extent of lymphadenectomy; as applied to lower esophageal cancer, this involves lower mediastinal and upper abdominal lymphadenectomy around the celiac axis. However, more “distant” nodes, such as those in the superior mediastinum and even neck are not necessarily resected. Some surgeons, however, describe “en bloc” esophagectomy together with extensive mediastinal and even cervical lymphadenectomy. The term “en bloc” is therefore sometimes used interchangeably with extended lymphadenectomy.

INDICATIONS/CONTRAINDICATIONS

The primary indication for surgical resection of esophageal cancer is for potential cure, which can be achieved in patients whose tumors are confined to the esophageal wall and when only limited local-regional disease is found. One should aim at maximizing the chance of an R0 resection (macroscopic and microscopic clearance of proximal, distal, and lateral margins), a parameter that has consistently been shown to be of major prognostic significance.
Increasingly neoadjuvant treatments including chemotherapy or chemoradiation are used to treat esophageal cancer. Consistently, these strategies have been shown to result in a higher rate of R0 resection, and a pathologic complete response (in resected surgical specimen) can be achieved in approximately 10% for chemotherapy alone, and up to 30% for chemoradiotherapy. Although the benefits of neoadjuvant treatments over surgical resection alone are not proven in randomized controlled trials and remain controversial, these strategies are routinely used in many centers. In patients with advanced staged disease where the chance of an R0 resection is lower such as c-T3/T4 disease or those with multiple local-regional nodal spread, these therapies will result in significant downstaging in many patients, making a subsequent R0 resection possible. Surgery and especially en bloc esophagectomy after radiotherapy can be difficult; postirradiation fibrosis often obscures tissue planes. It is also uncertain if adherence to adjacent structures is related to residual tumor infiltration or merely desmoplastic reaction. This is especially important when minimally invasive surgical techniques are used. How surgical resection should be integrated into programs of multimodality treatment remains controversial and differs among institutions.

PREOPERATIVE PLANNING

Accurate tumor staging should be performed to ensure maximal chance of R0 resection. This usually involves computed tomography (CT) scan, endoscopic ultrasound (EUS) ± fine-needle aspiration cytology of suspicious nodal metastases. Positron emission tomography (PET) scan is becoming the standard investigation at many institutions; it provides additional information on suspicious lesions on EUS and CT scans, especially of distant lesions. Postneoadjuvant staging is notoriously inaccurate. Tissue planes between the tumor and the adjacent structures are still best assessed by EUS, though accuracy decreases substantially after radiation.

Physiologic assessments are important to exclude patients for surgery, and optimization of cardiopulmonary function is of particular importance. Factors often cited as being predictive of morbidity and mortality after esophagectomy include advanced age, poor performance status, nutritional depletion and weight loss, more proximally located tumor, poor pulmonary function, cirrhosis, and abnormal cardiac evaluation. Patients with squamous cell cancers are more likely to be malnourished, have high alcohol intake, be smokers, and have more impairment of pulmonary and hepatic functions. Patients with adenocarcinomas on the other hand are more likely to be overweight and are more at risk from cardiovascular diseases.

Preoperative assessments include a detailed history and clinical physical examination, simple blood profiles, chest radiograph, electrocardiogram, and pulmonary spirometry. More detailed cardiac workup, including echocardiography, myocardial perfusion scans, or angiograms, are selectively applied when specific indications exist. Cirrhosis is not an absolute contraindication to esophagectomy, although the presence of esophageal varices usually contraindicates surgery.

In general, limited improvement can be made to a patient’s physiologic status. However the following measures should be instituted.

- Cessation of smoking and alcohol intake
- Incentive spirometry and chest physiotherapy
- Optimization of bronchodilator therapy in patients with asthma or significant chronic obstructive airway disease
- Consideration of coronary revascularization with angioplasty and coronary stenting in the presence of significant coronary ischemia. Antithrombotic medications, such as aspirin and clopidogrel, are often indicated after coronary intervention for a period of time. In such patients, it may be prudent to treat them with neoadjuvant therapy, so that time is not lost in waiting for an optimal time for surgery after coronary stenting
- In patients with high-grade esophageal tumor stenosis, a fine-bore nasogastric tube can be placed for nutritional support while workup is performed, and is preferable over parenteral nutrition, gastrostomy, or jejunostomy feeding
Diabetic control should be optimized

Immediate preoperative preparations include prophylactic antibiotics to be given at anesthesia induction and deep vein thrombosis prophylaxis. Bowel preparation is not necessary, unless a colonic interposition is intended.

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**SURGERY**

Many factors need consideration in choosing the approach to surgical resection. These include the following.

- The location of the intended anastomosis, whether it should be in the thorax or the neck
- The route of reconstruction: Conduit placed in the thoracic cavity or to the neck via the posterior mediastinum, retrosternal, or subcutaneous route
- The conduit used: Stomach, jejunum, or colon

The following description refers to the standard combined abdominal right thoracic approach for “en bloc” resection with lower mediastinal and upper abdominal lymphadenectomy using the stomach as the conduit with an intrathoracic esophagogastronomy. Variations in the technique are briefly illustrated.

**Positioning and Anesthetic Technique**

The patient is first placed in the supine position for the abdominal part of the surgery. To prepare for the subsequent right thoracotomy, a double-lumen endotracheal tube is usually placed. This, however, can be placed after the abdominal phase of the operation to lessen the duration of airway trauma in using this relatively large endotracheal tube. At the author’s institution, it is routine practice to place a single-lumen endotracheal tube, and during the thoracotomy phase, a right bronchial blocker is placed. This results in less airway trauma and the more flexible tube allows better exposure of areas behind the trachea and also around the left main bronchus. In the thoracic phase of surgery, the patient is placed in a full lateral decubitus position with the right arm approximately at a right angle at the shoulder.

**Operating Technique: Abdominal Phase**

A midline or a bilateral subcostal incision is made. The author prefers the latter because it gives improved exposure to the upper abdomen especially in obese patients. The stomach is mobilized together with celiac trifurcation lymphadenectomy via the following steps.

- The gastrocolic omentum is taken off the greater curvature of the stomach, preserving the right gastroepiploic vessels and arcades. Complete omentum resection is not necessary. Division of the gastrocolic omentum can be carried out just outside the right gastroepiploic vessels. The left crus is exposed when the short gastric vessels are divided and the fundus mobilized medially (Fig. 22.1). The phrenoesophageal membrane is detached, and the abdominal esophagus and cardia can be freed on the left side.

- The gastrohepatic ligament is then detached from the liver and from the portal structures. Dissection from the right side toward the esophageal hiatus frees the right crus, and dissection anterior to the esophagus will meet the already dissected plane from the left. The anterior vagus nerve can be divided at this point. The esophagus is thus freed on both sides as well as anteriorly. A sling placed around the lower esophagus, such as a Penrose or latex drain, may help later dissection by providing retraction.

- For a tumor of the distal esophagus located at the hiatus opening, especially for a transmural T3/T4 tumor, a cuff of diaphragmatic crura can be removed together with the tumor. When a cuff of muscle from the esophageal hiatus is removed, both pleural cavities are likely to be entered, but this is of no serious consequence.
The stomach is then reflected upward and dissection is begun at the celiac trifurcation (Fig. 22.2). Using fine electrocautery, dissection is performed along the anterior aspect of the common hepatic artery. Lymphadenectomy can then proceed laterally toward the hepatoduodenal ligament. It is sufficient to remove nodes along the anterior surface of the common hepatic artery. Medially toward the origin of the left gastric artery at the celiac axis, the left gastric artery and coronary vein require ligation (Fig. 22.3). The origin of the left gastric artery is identified separately as it comes off the celiac axis and it is doubly ligated and cut between ligatures (Fig. 22.4). Further dissection toward the left will clear the lymphatic tissues on the splenic artery. The areolar tissue superior to the common hepatic artery and splenic artery is therefore cleared en bloc with the abdominal esophagus toward the hiatus.

Continued dissection upward can be carried out through the esophageal hiatus along the front of the aorta. Areolar tissues are freed from the aorta and remain attached to the resected specimen. The cardia and the abdominal esophagus are thus freed totally.

On the lesser curvature the right gastric vessels are divided at the angular incisura. One linear stapler is used to transect the stomach from this point upward toward the fundus. This is the first of a series of staplers used to transect the stomach to make a narrow gastric conduit. The application of one stapler at this stage of the operation will make the subsequent use of further staplers during the thoracic phase easier (Fig. 22.5).
Figure 22.3 Origin of coronary vein dissected and about to be ligated. Hepatic artery exposed. CV, coronary vein; HA, hepatic artery.

Figure 22.4 Ligation of left gastric artery at its origin; hepatic artery lymph node already taken off the anterior surface of hepatic artery. LGA, left gastric artery; HA, hepatic artery; HAN, hepatic artery lymph node; ST, stomach.

Figure 22.5 Dissection and ligation of the right gastric artery is done at the angular incisura or at least beyond the third branch from the origin of the left gastric artery (where the incidence of nodal metastases became minimal). A linear stapler is used to partially transect the stomach from this point upward toward the fundus. This makes the subsequent transection of the stomach during the thoracic phase easier. Broken arrow: Pyloroplasty site; small blue arrow: Point at which the right gastric artery has been divided; large blue arrow: Pointing at the linear staple transection line. This forms the first stapled line to transect the stomach; this will be completed in the thoracic cavity.
A Heineke–Mikulicz pyloroplasty is then performed although some surgeons would forgo this step. A Kocher maneuver is not mandatory, provided the stomach is of sufficient length. However, this maneuver is easily performed and does have the advantage of straightening the “axis” of the pyloroduodenal region when the stomach is brought up to the right thoracic cavity. After careful hemostasis, the abdomen is closed. Abdominal drains are not required.

Operating Technique: Thoracic Phase

- A posterolateral thoracotomy through the fifth intercostal space is usually performed; the serratus anterior can be spared. Alternatively, an anterolateral thoracotomy can also be done with sparing of the latissimus dorsi. The author prefers the latter. A controlled fracture of sixth rib posteriorly eases distraction of the rib space. Two rib spreaders placed at right angles to each other are used to open up the rib space.

- The arch of the azygos vein as it crosses the esophagus is divided and transfixed. The right bronchial artery, which can be quite sizable, runs just beneath the vein. It can be preserved if desired.

- For conventional “en bloc” esophagectomy, superior mediastinal nodal dissection is not generally performed for a lower esophageal adenocarcinoma. The superior mediastinal segment of the esophagus can be mobilized close to its wall. The mediastinal pleura is opened on the back of the trachea. The esophagus is freed from the back of the trachea anteriorly and posteriorly from the spine; it can be slung with a tape to ease later dissection. One should avoid cautery in front of the esophagus to avoid tracheal injury. Dissection is carried out to near the apex.

- The inferior pulmonary ligament is divided with electrocautery to the root of the inferior pulmonary vein. Dissection is then continued on the posterior surface of the pericardium. The right main bronchus is identified and lymph nodes and connective tissue inferior to it are taken together with the esophagus. Further dissection will lead to the infracarinal lymph node package. The infracarinal dissection is followed toward the left to expose the left main bronchus and the lymph nodes and fatty tissues inferior to its edge. Sharp dissection with careful hemostasis is essential to avoid thermal injury to the membranous parts of the bronchi.

- The mediastinal pleura is incised along the anterior aspect of the length of the azygos vein from above downward. Some surgeons remove the whole length of the azygos vein and its branches. The posterior limit of dissection can be defined using the vein as a guide. When the point just above the hiatus is reached, the dissection plane deepens onto the surface of the aorta. Anteriorly within the areola tissue between the azygos vein and the surface of the aorta is the thoracic duct, which is identified, isolated, and ligated (Fig. 22.6). When the dissection reaches the esophagus anteriorly, the thoracic duct, the areolar connective tissue, and the connective tissue on the aorta are removed en bloc with the esophagus. This resection continues from below upward, until the previous dissection plane from anteriorly on the left main bronchus is met. The limits of the lymph node dissection extend inferiorly to the crura of the diaphragm, anterior on the pericardium, right main bronchus, apically at the tracheal bifurcation, and posteriorly from the left main bronchus along the length of the descending aorta. Further dissection upward should meet the previously slung upper esophagus so that the whole intrathoracic esophagus is freed. In “classical en bloc” esophagectomy, the pleura on the left side can be resected with the esophagus, so that the left lung is exposed; a cuff of pericardium attached to the primary tumor can also be removed to improve lateral tumor clearance. The author feels that unless the pericardium or azygos vein are obviously involved, these structures could be spared. The subaortic nodes could be removed at this point just above the left main bronchus, taking care not to damage the left recurrent laryngeal nerve medially, and the left pulmonary artery on the deep limit of dissection (Fig. 22.7).
After esophageal mobilization and mediastinal nodal dissection, the gastric tube is delivered up through the diaphragmatic hiatus into the right chest. The gastric conduit can be tailored by starting transection at a chosen point of the fundus downward toward the already fired stapler from the distal lesser curvature during the abdominal phase of the operation. Usually, two to three more linear staplers are necessary (Fig. 22.8).

A Satinsky clamp is then applied across the supra-aortic segment of the esophagus near the apex of the thoracic cavity. The esophagus is divided distal to the clamp. The esophagus with the tumor is removed, and the gastric tube is placed in the mediastinum ready for anastomosis.

The anastomosis can be constructed using a handheld method or stapling technique. The authors prefer the former, which has a similar incidence of anastomotic leakage but a lower stricture rate compared with using circular stapler. The tip of the gastric conduit is removed, and the anastomosis made with a fine absorbable monofilament suture (4-0 polyglyconate) using a one-layer continuous method. The apex of the linear stapled line can be incorporated into the anastomosis (Figs. 22.9 and 22.10).

If a circular stapler is used, the esophageal stump can be prepared in a standard manner by using a purse-string device before placing the anvil. Transoral placement of the anvil may facilitate the placement of the esophageal stump into the gastric tube and the anastomosis (Fig. 22.7).
Figure 22.8 The stomach has been delivered up to the thorax via the diaphragmatic hiatus, the stomach has been partially transected with a linear stapler, the blue line marks the intended line of transection toward the lesser curvature of the stomach distally to complete making a narrow gastric tube. GC, gastric conduit; ES, esophagus.

Figure 22.9 The beginning of the anastomosis between the esophagus and the gastric conduit using a hand-sewn method at the apex of the thoracic cavity. ES, esophagus; GC, gastric conduit.

Figure 22.10 Completion of the anastomosis. Note the tip of the linear stapled line is incorporated into the hand-sewn anastomosis forming a T-junction. ANS, anastomosis; ES, esophagus; GC, gastric conduit.
of the anvil is also possible with an ORVil EEA stapler (Covidien Surgical) for a double-stapling technique.

- Before the linear staplers are used to transect the stomach, a point on the lesser curvature can be chosen to make a gastrotomy; the shaft of the circular stapler can be introduced into the stomach toward a point chosen at the fundus. The central rod of the shaft is advanced through the stomach and then engaged with the anvil and fired. The lesser curvature of the stomach can then be resected using more linear staplers, completing the transection by joining the first stapled line distally.
- After hemostasis, the thoracotomy is closed with a 24-French chest drain.

### POSTOPERATIVE MANAGEMENT

The appropriate selection of surgical procedure, its meticulous execution, and perioperative care have causal relationship with morbidity and mortality. For most patients, a standardized clinical pathway is helpful.

- Most patients have endotracheal tube extubation in the recovery room, unless the surgery has been prolonged, complicated, or performed in high-risk patients.
- Epidural analgesia is the most important in postoperative pain relief. It is continued for the first 4 to 5 days after surgery, and can be replaced by patient-controlled analgesia or oral medications. Adequate pain control is essential to lessen the chance of pulmonary complications.
- The nasogastric tube is removed after 3 to 4 days. The tube is mainly used to avoid gastric distension in the early postoperative period; output is usually minimal. Early tube removal reduces discomfort and facilitates coughing efforts.
- All patients have a bronchoscopic examination on the first postoperative day to check for recurrent laryngeal nerve injury, although this is unusual in the absence of superior mediastinal or cervical lymphadenectomy. Fiber optic bronchoscopic sputum suction is used liberally for sputum retention. Frequent need of bronchoscopic toilet is an indication of tracheostomy. Judicious use of intravenous fluid is also important to avoid overhydration and pulmonary edema.
- Chest physiotherapy is instituted and early ambulation encouraged. Deep vein thrombosis prophylaxis is continued.
- The chest drain is removed on day 4 to 5 postoperatively, unless output is excessive.
- Liquid by mouth is started on postoperative day 4 to 5; this is gently advanced to the 7th postoperative day. After a contrast swallow confirms absence of anastomotic leak, a soft diet with porridge is started. Jejunostomy feeding is not routinely practiced by the author. Early oral alimentation is successful in most patients, and most do not need supplementary nutritional support. Should oral intake is delayed, such as when anastomotic leak occurs, endoscopic placement of a nasoduodenal tube for feeding will suffice.

### COMPLICATIONS

Medical complications after esophagectomy are mostly cardiopulmonary in nature. Arrhythmia, usually in the form of atrial fibrillation and supraventricular tachycardia, may occur in up to 25% of patients. Although its occurrence is usually benign in itself, it should trigger a careful search for underlying causes—surgical sepsis and pulmonary complications being most common. Sputum retention and atelectasis are also common; proactive pulmonary support should be instituted to prevent progression to pneumonia.

Many surgical complications could occur which may include the following:

- Conduit ischemia: Gross ischemia of the conduit usually presents early, within the first 2 to 3 days after operation. Sepsis is obvious but in the early stage signs may be subtle, which could simply be unexplained tachycardia, atrial arrhythmia, or poor arterial oxygenation. It is important to treat this complication expeditiously so that
further deterioration does not occur. A high index of suspicion is required. A low threshold of performing endoscopy on the patient is recommended to examine the state of the conduit and anastomosis whenever there are signs of deterioration. Gross ischemia dictates taking down of the conduit, adequate drainage, and staged reconstruction later, once sepsis is under control. In selected cases with ischemia limited to a small portion of the gastric conduit, when the patient is hemodynamically stable with minimal sepsis, and when an adequate length of stomach remains after resection of the ischemic portion, immediate reanastomosis is an option.

- Anastomotic leak: Clinically apparent thoracic anastomotic leaks usually occur within the first week. Signs of sepsis or excessive output from the chest drain, which may be turbid in color, lead to diagnosis. The location and magnitude of the leak can be visualized by a water-soluble contrast study. A carefully performed flexible endoscopic examination is also helpful. For small contained leaks, CT-guided drainage of pockets of collection may suffice. In septic patients with a sizable leak, exploration is warranted. Direct repair is seldom possible or effective; drainage is the key. Injection of fibrin glue or placement of intraluminal stents is increasingly used to treat leaks; sealing of the leak allows early control of sepsis and resumption of oral alimentation. The stent can be removed afterward, depending on the severity of the leak in the first place. Usually 4 to 6 weeks will suffice for adequate healing.

- Chylothorax: Persistently high output from the chest tube, often more than a liter a day, should prompt the search for chylosus leak. A milk challenge via a nasogastric tube or by mouth, looking at the color change of the drain effluent into a milky fluid, is diagnostic. Other biochemical parameters that could be looked at include triglyceride level and the presence of chylomicrons in the drain output after milk challenge. After the diagnosis is confirmed, low-output chylothorax (less than 1 L/day) could be treated by a short period of nothing by mouth (nil per os) with total parenteral nutrition, or a diet with midchain triglyceride. Early surgical re-exploration, however, has a higher chance of success and prevents deterioration related to constant loss of lymphocytes and proteins from the effluent fluid. A preoperative lymphangiogram may help locate the site of chylosus leak. If uncertain, mass ligation of lymphatic tissue near the diaphragmatic hiatus via thoracic re-exploration may be successful.

- Malrotation of the gastric conduit: This may result in ischemia of the stomach or outlet obstruction. Early surgical exploration is the key.

- Diaphragmatic herniation: A widened diaphragmatic hiatus, especially after crural resection, may lead to herniation of bowel into the thoracic cavity. Most commonly, this involves the transverse colon. An abnormal shadow on the chest radiograph should prompt further investigations. Again, early re-exploration with reduction of hernia and closure of the hiatus around the gastric conduit is indicated.

- Recurrent laryngeal nerve injury: When unilateral, recurrent laryngeal nerve injury results in hoarseness of voice, poor cough effort, and increased chance of aspiration. When it is bilateral, airway compromise is the rule and tracheostomy and delayed feeding are required. Long-term quality of life is also affected.

- Tracheobronchial injury should be rare and is mostly recognized at the time of surgery; primary repair with or without reinforcing tissue (such as muscle flaps) is indicated.

RESULTS

Mortality after en bloc esophagectomy should be rare (<5%) when carried out in high-volume expert centers. With a high-risk population and extensive surgery with many potential pitfalls, morbidity can still be substantial; the total complication rate after en bloc esophagectomy still approaches 40%. The most common of which are sputum retention, atelectasis, pneumonia, and atrial arrhythmia. Anastomotic leakage remains not an uncommon problem, although with appropriate and aggressive treatment, death from this complication should be infrequent. Local disease control is superior with
extended lymphadenectomy compared with less extensive surgery or nonoperative treatments such as chemoradiation; reported local recurrence within the area of dissection can be as low as 1%. Achieving better long-term survival remains a less easily accomplished goal; at present 5-year survival rates of 37% to 52% are reported in series of en bloc resection. In randomized trial comparing extended transthoracic resection and transhiatal resection with limited lymphadenectomy, the more extended surgery led to a trend of better 5-year survival in type I lower esophageal adenocarcinoma (51% vs. 37%), especially in those with limited nodal burden (one to eight positive nodes) (64% vs. 23%). Carefully selected patients treated by combination of multimodality treatment strategies and en bloc resection with extended lymphadenectomy may lead to even longer survival.

CONCLUSIONS

- En bloc esophagectomy aims at complete resection of the fascial envelope of the esophagus. This is most suitable for lower esophageal cancer where the circumferential margin can be extended, and lower mediastinal and upper abdominal lymphadenectomy are carried out.
- Commonly, this is performed with an abdominal and right thoracic approach. An intrathoracic esophagogastronomy with either a handsewn method or stapled technique is employed.
- Proper preoperative evaluation of disease stage (to maximize the chance of an R0 resection) and physiologic status is essential for a good outcome.
- Meticulous application of surgical technique minimizes the chance of surgical complications.
- Perioperative care should be proactive and aggressive. Complications are diagnosed early and treatment instituted.
- Good outcome can be achieved with hospital mortality rate of less than 2% in expert centers.

Recommended References and Readings

Left Thoracoabdominal Exposure for Esophagectomy and Complex Hiatus Pathology

Sudish C. Murthy

Introduction

Esophagectomy through a left thoracotomy approach was described over 60 years ago. It ushered in a new era of transmediastinal placement of the gastric conduit and demonstrated the safety of an intrathoracic anastomosis. Up until this time, an extrathoracic passage (subcutaneous) was used to facilitate transfer of the gastric conduit to the neck for anastomosis to the cervical esophagus. This nonorthotopic reconstruction eventually became relegated to a bypass-type procedure once the left thoracoabdominal approach became popular.

Esophagectomy through a left thoracotomy remained a standard approach for the ensuing 30 years until supplanted by other techniques. By the late 1970s, Ivor Lewis and McKeown procedures proved more appropriate for midesophageal squamous cell cancer resections, and transhiatal (blunt) esophagectomy became the favored approach for the then, less common, adenocarcinoma of the distal esophagus.

Current trends suggest the overall incidence of esophageal cancer is dramatically increasing, and there has been a marked shift in the frequencies of histologic subtypes in the United States. Adenocarcinoma of the distal esophagus and gastroesophageal junction (GEJ) is now the predominant cancer. When considering operations for esophageal cancer, optimal exposure of the distal esophagus and gastric cardia is critical, because this will be the location of the cancer in the majority of patients. Moreover, since N1 lymph node involvement is a likely early characteristic of the disease, exposure of the esophageal hiatus and distal posterior mediastinum for lymphadenectomy must be considered an important component of any operation for adenocarcinoma of the esophagus. To achieve optimum exposure of the hiatus and posterior mediastinum for resection of esophageal cancer, there is no better procedure than the left thoracoabdominal approach.

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To date, no randomized studies exist that advocate which of several esophageal resection techniques provide the most complete resection for cancer nor do any propose what technique may have the best cancer-related outcomes. Little question remains, however, that the less extensive open operation (i.e. transhiatal esophagectomy) has fewer morbidities than any approach utilizing a thoracotomy. Yet, this must be balanced by the possibility of an increased locoregional cancer recurrence rate after transhiatal resection. More recently, minimally invasive esophagectomy techniques have been developed off transhiatal, McKeown, and Ivor Lewis platforms. The clear advantages of less pain and expedited recovery are apparent, though efficacy as cancer operations, when compared with open procedures, still needs to be clearly determined. However, several recent series of minimally invasive operations, including an abstract presented of a prospective, multi-institutional study (Eastern Cooperative Oncology Group Study E2202) that included 16 institutions, demonstrated that morbidity and mortality were acceptable, and the median nodal counts were ≥20 for this operation.

**INDICATIONS/CONTRAINDICATIONS**

If one simply abides by the basic tenants of cancer surgery—(1) optimal exposure of the cancer field, (2) complete resection that includes radial margins, (3) extensive locoregional lymphadenectomy for accurate staging and possible benefit, and (4) ease of reconstruction—left thoracoabdominal esophagectomy with cervical esophagogastric anastomosis still remains relevant today. Morbidity of the approach can be reduced by careful preoperative patient selection, meticulous surgical technique, and early recognition and management of evolving postoperative problems.

Perhaps the greatest utility of the left thoracoabdominal approach arises in the reoperative benign disease setting and for difficult to repair perforations. The wide exposure of the pathology is an advantage for these complex operations. The more recent practice of placing synthetic or biosynthetic mesh to repair large hiatal hernias has created difficulty in sparing the esophagus when reoperations are indicated, and for cases where there has been mesh erosion into the esophagus itself, there is no safer exposure for esophagectomy than the left thoracoabdominal approach. Moreover, when salvage of the esophagus is attempted following a distal esophageal perforation, a left thoracotomy incision can be extended to a thoracoabdominal approach for perforations straddling the hiatus to ensure an adequate primary repair.

Contraindications to a left thoracoabdominal approach are few, but clearly, prior left thoracotomy (for lung resection or empyema) would make this exposure more challenging. Repair of the radial diaphragmatic incision is, in part, dependent upon a normally compliant diaphragm. Any prior left-sided operation can compromise this and complicate diaphragm repair during closure. Candidates for this approach should also be able to tolerate single-lung ventilation, as this greatly enhances the exposure.

The left thoracoabdominal/left neck approach for esophagectomy is principally a cancer operation (Fig. 23.1) though given the explosive increase in the number hiatal hernia operations performed and their failure rates, it should be considered an important approach for reoperative GEJ surgery. Moreover, for the morbidly obese patient with resectable esophageal cancer, left thoracoabdominal/left neck approach may be technically easier than one requiring laparotomy. Due to the location of the aortic arch, a high left-sided intrathoracic anastomosis cannot be created, as in the Ivor Lewis approach. Consequently, a cervical anastomosis is favored for this technique. Of course, when utilized during repair of esophageal perforation, though no anastomosis will be required, the exposure allows for access for G-tube and J-tube placement. A left thoracoabdominal/left neck approach for distal esophageal and GEJ adenocarcinoma provides excellent exposure to the tumor bed, allows en bloc resection of regional lymph nodes (N1) and celiac trunk disease (M1A), and permits the entire procedure to be completed with a single sterile preparation and draping. In addition, it affords the surgeon the opportunity to identify peritoneal carcinomatosis and unresectable
abdominal disease prior to a commitment to extension of the incision into the left thorax. Finally, significant splenic capsular injury is extremely rare because of the superior access to the short gastric arcade.

**PREOPERATIVE PLANNING**

Because the left thoracoabdominal/left neck procedure is performed infrequently, the orientation of abdominal, thoracic, and cervical structures is less familiar to the surgeon, and an appreciation of the anatomic relationships from the left lateral view must be gained. Structures close or to the right of the midline (i.e., duodenum and thoracic duct) are more difficult to access. Protracted ipsilateral lung collapse may be required to complete the mediastinotomy (for cancer operations). Of importance is the morbidity associated with division of the costal arch and circumferential dissection of the left diaphragm. This morbidity can be significant, and accordingly, specific attention to incision closure at the conclusion of the case is warranted.

Given that the appropriate assessment of surgical candidacy has taken place, all patients undergo a standard bowel preparation the day before surgery. Epidural analgesia is favored. Standard support lines include: Left-sided double lumen endotracheal tube, nasogastric tube, right internal jugular central venous access, right radial arterial line, and bladder catheter. Patients are positioned in a modified right lateral decubitus position with the abdomen and pelvis rotated back (*cork-screwed*) toward the table (Fig. 23.2). The sterile prep is extended beyond the midline anteriorly from neck to groin, and posteriorly, to the spine. Regardless of intention of the procedure (benign or malignant indication), the entire left arm is included within the field as is the left neck to allow for possible left neck anastomosis. Until cervical exposure is needed during the case, the left arm is draped across the patient’s body and supported on an arm board. Important musculoskeletal landmarks are the left sternocleidomastoid muscle, scapular tip, costal margin, umbilicus, and anterior iliac spine.
Thoracoabdominal Incision

The thoracoabdominal incision generally extends from two fingerbreadths below the scapula tip along the seventh interspace, across the costal margin, and obliquely toward the umbilicus (Fig. 23.3). The oblique abdominal incision, beginning at the costal arch, is made first. External and internal oblique muscles are divided, and the lateral aspect of the rectus muscle and sheath are incised. The left inferior epigastric vascular pedicle is seldom encountered and usually borders the most medial extent of the abdominal incision. Manual palpation of abdominal viscera is used to determine resectability for cancer cases. Specifically, peritoneal carcinomatosis, as well as liver, porta hepatis, duodenum, pancreatic, and gross celiac involvement would end the procedure after an enteral feeding access (J-tube) was placed. If no contraindications to proceeding are encountered, the incision is extended posteriorly and superiorly along the costal margin and along the seventh interspace toward the scapular tip. Lower slips of serratus muscle are generally divided in the direction of their fibers, and the anterior aspect of the latissimus dorsi muscle is incised depending upon the posterior and superior extent of the incision.

To connect the thoracotomy and oblique laparotomy, the costal margin and the diaphragm must be divided. The costal arch is cut sharply, usually between the seventh and eighth ribs. Beginning at this location, the diaphragm is circumferentially divided posteriorly for 8 to 10 cm. A 2-cm margin of diaphragm should be left attached to the chest wall for diaphragm closure at the conclusion of the case. The ribs are distracted in the standard fashion, and a standard abdominal retractor is used. The GEJ should be in the center of the operative field.

Mobilization of the proximal stomach is much easier, since the short gastric arcade is more superficial and approached laterally. For cancer operations, an abdominal lymphadenectomy is far easier to complete (Fig. 23.4). Mobilization of the duodenum (Kocher maneuver) and gastric conduit drainage (pyloromyotomy or pyloroplasty) will initially seem more awkward because of the unfamiliarity with the exposure, but can, nonetheless, be fully completed.
Despite the use of preoperative chemoradiotherapy for locally advanced cancer cases, dense fibrosis at the hiatus is rarely problematic, even in obese patients. A circumferential cuff of diaphragm can easily be included en bloc. For cancers of the gastric cardia or fundus, or if the stomach were deemed an unsuitable conduit for any reason, and a distal esophagectomy and total gastrectomy would be preferred, this exposure is ideal. The Roux-en-Y limb is easily harvested, passed in a retrocolic fashion, brought through the hiatus, and anastomosed to the distal esophagus at the level of the inferior pulmonary vein without much fanfare.

For en bloc cancer operations, the mediastinal portion of the procedure begins by widely opening the left mediastinal pleura and fully dividing the inferior pulmonary ligament. Posteriorly, the dissection continues over the aortic adventitia to the right,
toward the spine and lower portion of the azygos vein. The right pleural space is frequently opened (especially for cancer operations). Anteriorly, the mediastinal tissues are dissected off the inferior aspect of the pericardium. After these two tissue planes have been established, the en bloc dissection continues cephalad toward the subcarinal region (Fig. 23.5). A Penrose drain can be used to encircle the specimen and provide countertraction. Because of its right-sided location, it may be difficult to identify the thoracic duct. Inclusion of the duct during the resection is often by chance, and attention must be taken to carefully clip or ligate any tissues remaining adjacent to the aorta to prevent postoperative chylothorax. Care must also be taken to avoid injury of the azygos vein, as repair from the left side is difficult.

For benign cases, the mediastinal dissection is often the easiest portion. Control of the esophagus here is often performed first, and then the esophagus is followed back toward the hiatus. For spontaneous perforation cases (Boerhaave’s syndrome), the usual location of the injury is just above the GEJ on the left side of the esophagus. Extension of the left thoracotomy across the costal arch and into the abdomen should be considered for injuries that extend inferiorly because access from the left thorax may not be adequate.

For reoperative hiatal hernia repair, esophagectomy should be considered the fallback option when the distal esophagus or proximal stomach is felt to be unsalvageable. This commonly occurs in the setting of a multiple reoperative case or if some prosthetic was used to reconstruct the hiatus on the initial repair attempt. Irreparable esophageal injury is often the norm for these types of cases, and accordingly, salvage esophagectomy must be discussed with patients as a possible outcome.

When esophagectomy is planned for cancer cases, the mediastinotomy is terminated after evacuation of the subcarinal lymph node packet. Cautery injury of the left main stem bronchus and left pulmonary artery are risks during this aspect of the procedure. Several aortoesophageal collaterals are typically encountered and require surgical control. Above the level of the carina, the esophagus is bluntly dissected off the airway and spine up toward the neck.
Exposure of the cervical esophagus is more challenging than from a standard supine approach. The orientation makes it difficult to use self-retaining retractors, so assistants are relied upon to manually expose the region. A standard oblique incision is made along the anterior border of the sternocleidomastoid muscle (Fig. 23.6). The platysma is incised, and the sternocleidomastoid muscle is mobilized and displaced primarily posteriorly. The omohyoid muscle is then divided and the carotid sheath structures carefully mobilized laterally. A useful anatomic landmark is the middle thyroid vein, which is often bowstrung across the field and requires division. Access to the cervical spine is then facilitated. To properly dissect the tracheoesophageal groove, the spine must be first identified and the cervical esophagus initially approached posteriorly. Isolating the cervical esophagus from the trachea is left as the final maneuver. Circumferentially controlling the esophagus in the superior mediastinum (working back up to the cervical esophagus) reduces the frequency of both right and left recurrent laryngeal nerve injury.

With the cervical esophagus encircled, blunt esophagectomy techniques are used to fully dissect the thoracic esophagus above the aortic arch. The rest of the esophagectomy is performed in the standard fashion given the indication.

A modified Collard anastomosis (Figs. 23.7 and 23.8) is used to re-establish alimentary tract continuity. Once again, more lateral exposure can be slightly disorienting, but the anastomosis is constructed identically to that performed with the patient supine. When finished, the anastomosis is returned orthotopically and repositioned in the superior mediastinum. Gentle traction on the conduit at the hiatus will aid in straightening the stomach out, delivering the anastomosis to the superior mediastinum (Fig. 23.9).

**Incision Closure**

After the neck incision is generously lavaged with warm saline, a two-layer, interrupted suture closure is preferred for the cervical incision. The platysma and dermis are closed separately with absorbable suture. The interrupted technique allows for partial opening of the cervical incision for drainage of leak or infection (5% to 10%). A Silastic closed suction drain is placed into the superior mediastinum through the cervical incision.

Closure of the thoracoabdominal incision begins with repair of the diaphragm. This is routinely conducted with interrupted, large gauge (#1), polyglactin suture. The repair is made significantly easier if 2 cm of diaphragm was left on the chest wall as the sewing
Figure 23.7 Hybrid cervical anastomosis. The posterior aspect of the anastomosis is completed with a 45-mm linear stapler-cutter.

Figure 23.8 The anterior aspect of the anastomosis is performed with a continuous or interrupted suture technique.

Figure 23.9 The anastomosis is repositioned in the superior mediastinum, and the conduit is gently straightened.
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Cuff. Interrupted #2 polyglactin suture is used to coapt the thoracotomy with a figure-of-eight suture placed across the costal margin defect (into the cartilage edges) for realignment purposes. Occasionally, a small segment of cartilage is removed to allow for better reapproximation of the arch. The diaphragm is tacked at the costal margin repair site to fortify the closure. Chest and abdominal wall muscles, as well as abdominal fascia, are repaired in layers with continuous absorbable suturing techniques. The skin and subcutaneous closure is routine.

**POSTOPERATIVE MANAGEMENT**

There is no question that the magnitude of the procedure leads to a more complicated postoperative course. It should be remembered that this procedure, in combination with induction chemoradiation therapy, is principally reserved for fit patients with locally advanced malignancy and with limited, if any, other effective treatment options. Those patients with perforation or GEJ mesh erosion/hiatal hernia repair failure may have infectious disease issues that will require attention. Regardless, the vast majority of patients will require intensive care early postoperatively, if for nothing else than to ensure adequacy of pain control.

**COMPLICATIONS**

For esophagectomy patients, cervical infection, with or without anastomotic leak, occurs in 5% to 10% of patients. Early identification reduces its impact. Treatment usually requires only reopening the cervical incision and widely draining the space. The majority of anastomotic fistulas heal within 2 weeks. A short course of broad-spectrum antibiotics is useful to treat the accompanying cellulitis.

Approximately 5% of patients will develop chylothorax requiring a reintervention. These are defined by early high-volume output (>1,000 mL/day) or chylothorax that fails to resolve after 2 weeks, despite complete bowel rest and total parenteral nutrition. Percutaneous identification and embolization of chylous leak is the standard therapy at our institution. Reoperation and thoracic duct ligation, performed through the right chest, is reserved for treatment failures.

Costal arch dehiscence usually occurs in the setting of a deep surgical site infection. Though the prevalence is rare, operative debridement, wide drainage, and postoperative vacuum dressings are indicated. Uncomplicated costal margin “clicks” are managed expectantly.

To reduce the chance of early gastric distention and herniation of the conduit into the left chest, patients are maintained solely on tube feeds for 4 weeks. Oral intake is gradually advanced, and separation from tube feeds occurs between 6 and 8 weeks.

**CONCLUSIONS**

The left thoracoabdominal/left neck approach provides exceptional exposure for operations centered at the esophageal hiatus. For cancer indications, a complete two-field lymph node dissection is easy to complete; en bloc esophagectomy can be performed without patient repositioning. An emerging population of patients with failed hiatal hernia repairs or complicated esophageal perforations might also benefit from this type of surgical access whether esophagectomy is ultimately indicated or not. The orientation will seem awkward at first, but rapidly becomes appreciated and embraced.
Recommended References and Readings

Introduction

Over the last three decades in North America, the incidence of adenocarcinoma of the esophagus has risen faster than the incidence of any other solid organ malignancy. Surgical resection is the best curative therapy for patients with invasive resectable esophageal cancer. Recently, endoscopic mucosal resection (EMR) has had encouraging results for subsets of patients with Barrett’s esophagus (BE) and high-grade dysplasia (HGD) and in select patients with T1a tumors. However, until recently, most surgical candidates with resectable esophageal cancers underwent esophagectomy, performed by an open technique with the transhiatal approach or transthoracic approaches, such as the Ivor Lewis approach, being most commonly used. The survival from either approach has been similar in prospective randomized studies. According to the Medicare database, complications from these open resections remain high with operative mortality ranging from 8% in high-volume centers to 23% in low-volume centers.

In an attempt to decrease the morbidity and mortality of open esophagectomy, we adopted and have continued to refine a minimally invasive approach. Many hybrid approaches have been reported in the pursuit of the ideal minimally invasive esophagectomy, but the main techniques include laparoscopic transhiatal esophagectomy, laparoscopic–thoracoscopic 3-hole (McKeown) esophagectomy, and laparoscopic–thoracoscopic (Ivor Lewis) esophagectomy. The approach is usually a matter of surgeon preference but on occasion is dictated by the location of the tumor. For the majority of distal esophageal tumors or gastroesophageal junction (GEJ) tumors, an
Ivor Lewis approach allows good exposure and adequate margins. At the present time, we prefer the minimally invasive Ivor Lewis esophagectomy for most patients with esophageal adenocarcinoma, due to the predominant localization of esophageal adenocarcinoma at the GEJ or distal esophagus. Ivor Lewis MIE is also adequate for most esophageal squamous cell carcinomas in the mid- or distal esophagus. Ivor Lewis MIE may not be ideal for upper third or midesophageal cancers with significant proximal extension because resection with adequate margins may be difficult to obtain. In these cases, a modified McKeown MIE (3-hole) may be a good alternative. Esophagectomy may also be performed for patients with BE with HGD. In patients with HGD or early-stage tumors confined to the mucosa (T1a), satisfactory results have been reported with EMR with or without mucosal ablation (e.g., photodynamic therapy, radiofrequency ablation) when used under selected circumstances (e.g., well-circumscribed, well-differentiated tumors with no angiolymphatic invasion). It is important to note, however, that there have been only short- to intermediate-term outcomes reported thus far. In a well-known study, Ell et al. reported the updated results of EMR (with photodynamic therapy in 49%) for 100 highly selected patients with T1 intramucosal cancer (from 667 patients referred for early adenocarcinoma or HGD). The selection criteria for inclusion in their study included no angiolymphatic invasion, and histologic grades G1 and G2 (well differentiated and moderately differentiated, respectively) arising from BE. The lateral margins of resection were positive in 34% of patients, and could not be assessed in 33%. During a median 33-month follow-up, recurrent or metachronous lesions were detected in 11% of patients. While EMR in combination with ablation may offer several immediate benefits to the patient, there are several concerns.

1. Even in Ell’s experience, a large number of patients were screened and excluded from this approach, and only ideal candidates were chosen.
2. Even in experienced hands, positive margins are present in up to 34% of patients, with another 33% of patients with indeterminate margins due to cautery artifact, leaving only 33% with pathologically confirmed clear margins.
3. Subsquamous BE remains at risk for progression to adenocarcinoma, and continued surveillance endoscopy is required.
4. When EMR is performed for early-stage tumors confined to the mucosa, incomplete nodal resection is a concern.

The rate of lymph node metastasis for T1a and T1b lesions is up to 7% and 27%, respectively, thus even when a negative margin is obtained in T1a tumors, a defined subset will fail this approach. Moreover, HGD is often multifocal and there is a high rate of occult carcinoma in patients who undergo resection for the preoperative diagnosis of HGD. Therefore, we continue to offer MIE for multifocal HGD and early-stage adenocarcinoma.

Patients with localized esophageal carcinoma and adequate cardiopulmonary reserve can be offered an MIE. Patients with locally advanced tumors and no distant metastasis on positron emission tomography (PET) scan who have a favorable response to neoadjuvant chemotherapy with or without concurrent radiation are also candidates for MIE.

**PREOPERATIVE PLANNING**

In the planning phase, detailed clinical and pathologic data should be obtained and reviewed by an experienced center. In our center, all patients undergo an upper endoscopy and a biopsy to confirm presence of esophageal cancer, its proximal and distal extent, and the suitability of stomach as a gastric conduit. Other preoperative studies include endoscopic ultrasonography (EUS) and positron emission tomography–computed tomography (PET–CT) scans for proper clinical staging. Many patients also require a stress test to assess underlying coronary artery disease. We perform pulmonary function tests on patients with a heavy smoking history or known chronic obstructive pulmonary disease to stratify their risk of respiratory complications. All patients undergo a bowel preparation the day before surgery. Subcutaneous heparin and intravenous antibiotics are administered on induction of general anesthesia.
Patient Positioning

- A double-lumen endotracheal tube is placed and its location is confirmed with a pediatric endoscope. The bronchial cuff (blue) is deflated during the abdominal portion of the procedure to minimize the risk of left main stem ischemic injury. If the tumor is localized to the upper esophagus or midesophagus, we routinely perform an initial bronchoscopy with a single-lumen endotracheal tube.
- We start the operation by performing an on-table endoscopy to confirm preoperative findings and ensure that the stomach is suitable as a gastric conduit. This defines the exact location of tumor and proximal extent of BE.
- The patient is placed supine and positioned slightly toward the right edge of the table. A footboard is placed to prevent the patient from slipping during steep reverse Trendelenburg positioning.

Laparoscopic Phase

Port Placement/Staging

- The surgeon operates from the right side of the table and the assistant is on the left side. Six abdominal ports are placed, five as depicted in Figure 24.1 and a right lower costal margin port for the Mediflex liver retractor (Mediflex surgical products, Islandia, NY). The peritoneal surface, omentum and the liver are thoroughly inspected during the initial laparoscopic staging to rule out any occult metastasis. If there is a suspicion for liver metastasis on preoperative imaging, an intraoperative liver ultrasound may be performed. The suitability of the stomach for use as a conduit is also assessed laparoscopically.
- The patient is placed in a steep reverse Trendelenburg position and the abdomen is insufflated using 10 to 15 mm Hg carbon dioxide insufflation.

Figure 24.1 Laparoscopic port placement. The 10-mm port is placed first in the right midabdomen using open Hasson trocar insertion technique. An additional 5/11-mm port (not shown) is placed in the right lower quadrant that is helpful for retraction during pyloroplasty and gastric tube creation.
Next, the gastrohepatic ligament is opened using ultrasonic energy. Dissection is carried along the left gastric vessels. A formal left gastric and celiac lymph node dissection is done, and any suspicious nodes are dissected and sent for frozen-section analysis (Fig. 24.2).

Once assured that minimal nodal disease is present and the tumor appears completely resectable, then we proceed to crural dissection and complete mobilization of the lower esophagus.

Esophageal mobilization is performed at the level of the diaphragmatic crura. The right crus is separated from the esophagus; dissection is carried anteriorly and cephalad to free the left crus and the gastric fundus (Figs. 24.3 and 24.4). The esophagus is mobilized circumferentially at the hiatus from the preaortic tissue plane posteriorly to the pericardium anteriorly and from right to left pleura.

At this point, provided there is no metastatic disease, bulky adenopathy, or evidence of a T4 tumor, one can proceed with esophagectomy.

If at this point, a decision is made to delay the MIE and give neoadjuvant therapy, consideration can be given to some vascular conditioning, such as dividing the left gastric artery and vein and the short gastrics. However, we have noted when operation is delayed and a significant amount of peri-esophageal and gastric dissection have been done, this can lead to significant dense scar tissue and adhesions at the time of definitive resection.

**Mobilization of the Stomach**

The medial border of the right crus is dissected inferiorly toward the decussation of the crura. A retroesophageal window is created. Additional mobilization of the lesser curve along the left gastric vascular pedicle is performed.
The superior portion of the greater curve is mobilized, starting at the level where the last gastroepiploic arcade vessel enters the gastric wall, and proceeds cephalad along the greater curve. Care is taken to avoid direct handling of the conduit portion of the stomach. We try to grasp areas that will be resected as opposed to handling the neoesophagus proper. Short gastric vessels are divided up to the left crus. We use autosonic shears or the Ligasure device (Covidien Surgical, Mansfield, MA).

The lesser sac is entered below the gastric antrum, preserving the right gastroepiploic arcade. The attachments to the transverse colon are mobilized to fully free the greater curve. This completes the antropyloric mobilization.

The fundus is rotated toward the patient’s right side and all retrogastric attachments in the lesser sac are taken down toward the lesser curve until the left gastric vessels are seen. This retrogastric dissection is carried posteriorly toward the pylorus. The degree of Kocher maneuver that is needed is up to the judgment of the surgeon. In general, we free up the antrum and pylorus and free the first portion of the duodenum from the gall bladder. Once the pylorus is mobilized enough to be lifted and reach the right crus without any tension, the mobilization is usually sufficient.
The left gastric vessels are skeletonized and divided at the take off from the celiac artery with a vascular load of the Endo GIA stapler. Care is taken to maximize lymph node yield by sweeping all lymph nodes and fatty tissue up to the specimen side.

Creation of Gastric Conduit

The first assistant stretches the gastric fundus by holding it along the line of the short gastrics and gently pulling it above the upper pole of the spleen. The gastric antrum is pulled toward the right lower quadrant from the additional 5/11-mm port (Fig. 24.5). This stretches the stomach to some degree, leading to a longer conduit as staple loads are applied and minimizes the risk of spiralling of the gastric tube.

The vascular tissue along the lesser curve is divided above the level of the right gastric artery with a vascular load (tan load, three rows of staples [tri-staple technology] of height 2 mm, 2.5 mm, and 3 mm) of an Endo GIA stapler (Covidien Surgical). Next, sequential firing of Endo GIA purple loads (three rows of staples; height 3 mm, 3.5 mm, 4 mm) is performed across the antrum and toward the fundus trying to keep the staple line parallel to the line of the short gastrics with a distance of 2.5 to 3 cm between the staple line and the short gastric vessels.

An unusually thick antrum may require that one chooses a greater staple height (e.g., the black Endo GIA loads, staple height 4 mm, 4.5 mm, 5 mm) to get an adequate staple line integrity. Generally, even when there is a thick antrum, the final stapler firings across the thinner fundus can be reduced to the purple loads with 3 mm, 3.5 mm, and 4 mm tri-staple heights (Fig. 24.6).

The gastric tube is generally created before completion of other abdominal steps to provide time to assess the viability of the gastric tube as a conduit before bringing it into the chest.

Recently, we have added an omental flap on all cases where preoperative radiation therapy was used.14 This can be performed by sparing two or three of the omental...
arcades that leave the gastroepiploic arcade in a perpendicular fashion. We then carefully follow these arcades out toward the free omentum for a distance of 10 cm or more, thus creating 2- to 3-cm wide, 10 cm or more long vascularized omental pedicle (Fig. 24.7).

**Creation of Pyloroplasty**

- Stay sutures (2-0 Surgidac; Covidien Surgical) are placed at the superior and inferior edges of the pylorus to help with retraction. With experience, the pylorus can be readily identified by gentle touching of the grasper across the surface, and one can feel the “bump” of the thickened muscle. Frequently, one can also visualize the small veins of Mayo from each edge of the stomach at the pyloric location. The pylorus is oriented with traction on the stay sutures longitudinally so that the upper stitch is at the 12 o’clock position and the lower stitch is at the 6 o’clock position. The anterior wall is opened transversely with ultrasonic energy. It is important to ensure that the pyloric muscle is completely divided.

- The pylorus is then closed in a Heineke–Mikulicz fashion using 2-0 Surgidac interrupted sutures with the Endostitch device (Covidien Surgical). Usually, four to six sutures are required (Fig. 24.8).

- At the end of the abdominal portion, a flap of omentum is mobilized and brought over the pyloroplasty. It is secured over the pyloroplasty with one or two interrupted sutures of 2-0 Surgidac using the Endostitch.

**Placement of Feeding Jejunostomy**

- A 10-French jejunostomy catheter is placed in the left lower quadrant using the Seldinger technique.
The camera is switched to the 5/12-mm right upper quadrant port. The omentum and the transverse colon are elevated into the upper abdomen and the ligament of Treitz is identified. Approximately 30 to 40 cm distal to the ligament of Treitz, a mobile loop of jejunum is identified, and a site on the left abdominal wall is identified for tube placement. The 5/11-mm right lower quadrant port is the surgeon’s right-hand port for jejunostomy tube creation. The jejunum is sutured to the abdominal wall along the antimesenteric border (Fig. 24.9).

A feeding jejunostomy tube (J-tube) kit needle is inserted into the bowel lumen just distal to the tacking suture in a Witzel fashion. Air insufflation is performed to confirm intraluminal placement. The guidewire is advanced over the needle into the lumen and carefully guided downstream under laparoscopic vision, and the dilator sheath complex is introduced over the wire. The wire and dilator are removed, and the J-tube is introduced and the peel-away housing removed.

After placing the tube into the jejunum under direct vision and placing one or two Witzel-type 2-0 Surgidac Endostitches, the jejunum is tacked to the abdominal wall using a single 2-0 Endostitch placed in a triangular fashion to completely bury the J-tube between the peritoneum and the jejunum. An antitorsion stitch is placed ~3 cm distally, securing the jejunum to the anterior abdominal wall (Fig. 24.9).
Final Abdominal Steps

- The most superior edge of the gastric conduit along the greater curve is sutured to the specimen along the staple line by the lesser curve with a horizontal mattress suture. This helps with the proper orientation of the conduit during delivery into the chest (Fig. 24.10).
- If the esophageal hiatus is generous, a 0-Surgidac Endostitch is placed to reapproximate the crura to prevent herniation of the conduit and other organs into the chest.

Figure 24.9 Placement of a 10-French needle jejunostomy catheter and an antitorsion stitch 3 to 4 cm distally along the antimesenteric border.

Figure 24.10 The gastric conduit is secured to the specimen along the lesser curve staple line for proper orientation during the thoroscopic portion with a horizontal U stitch.
The pyloroplasty site is covered with a patch of omentum, as described above.
If an omental pedicle was created, we suture the free end of this near the fundic tip to facilitate entry into the chest in an atraumatic fashion.

Thoracoscopic Phase

Thoracoscopic Port Placement

Before turning the patient in the left lateral decubitus position, a nasogastric (NG) tube is advanced into the midesophagus. Appropriate placement of the double-lumen endotracheal tube placed at the beginning of the procedure is confirmed after turning the patient. Five ports are placed for thoracoscopic esophageal mobilization and anastomosis (Fig. 24.11). The surgeon works from the right side of the table while the first assistant stands on the lower left side. The first assistant manages the camera and the suction. The second assistant stands on the left upper side and controls lung retraction.

- A 10-mm camera port is placed above the costophrenic angle, usually in the eighth or ninth intercostal space along the anterior axillary line. The goal is to have this port just above the diaphragm.
- The surgeon’s working port is a 10-mm port, usually one intercostal space below the camera port, generally at the eighth or ninth intercostal space, in line with the tip of the scapula and at least one hand’s breadth away from the camera port.
- Another 10-mm port is placed anteriorly in the fourth intercostal space. A fan-shaped lung retractor is placed through this port.
- A 5-mm port is placed just posterior and inferior to the tip of the scapula and is surgeon’s left-hand port used for retraction.
- An additional 5-mm port is placed in the sixth intercostal space along the anterior axillary line for suction by the first assistant.

Thoracoscopic Esophageal Mobilization

- A stitch is placed in the central tendon of the diaphragm, at the dome, to pull the diaphragm anteroinferiorly. We bring this stitch out low, near the costophrenic junction to allow the downward retraction of the diaphragm.
- Mobilization is begun by dividing the inferior pulmonary ligament, and the mediastinal pleura is incised along the edge of the lung, anterior to the esophagus, up to the level of the azygos vein (Fig. 24.12). The azygos vein is mobilized and divided with an Endo GIA vascular stapler load.
- Further anterior esophageal mobilization is started inferiorly along the pericardium, retracting the esophagus posteriorly. This plane is carried cephalad, identifying the inferior pulmonary vein, then the inferior extent of the bronchus intermedius, up to the right main stem bronchus, and the carina. At this point, we try to resect all nodes.
and keep on a plane near these structures, but taking care not to apply energy to these areas, in particular to the posterior membranous airway structures.

- As the carina is approached, there are always one or two large bronchial arteries and branches to the subcarinal lymph node packet must be carefully divided with a coagulating energy device. As we reach this point, we are also sweeping the nodal packet off of the pericardium between the “v” formed by the bronchus intermedius and the left main bronchus. This dissection plane is carried down the left main stem bronchus. Subcarinal lymph nodes are removed en bloc with the specimen. Above the azygos vein, the dissection is kept on the esophagus.

- The vagus nerve is divided just above the azygos vein and reflected anteriorly, avoiding excess traction on the vagus nerve as you dissect superiorly to avoid injury to the recurrent laryngeal nerve.

- The posterior esophageal mobilization is begun by retracting the distal esophagus anteriorly and incising the pleura over the posterior esophageal groove anterior to the thoracic duct. Endoclips are used liberally along the aortoesophageal branches and lymphatic tributaries. This dissection is carried cephalad above the level of the azygos vein. Care must be taken with the posterior plane of dissection to avoid injury to the aorta and the thoracic duct. We generally do not resect the thoracic duct or the azygos vein, although occasionally we have done this if a large node is adherent in this location.

- The specimen with the attached gastric conduit is pulled into the chest taking care to preserve proper orientation of the conduit. The divided, gastric end of the specimen is used as a handle to lift the specimen and complete division of the posterior attachments in the mediastinum. Clips are used liberally in this area.

- A 5-cm access incision is made one or two interspaces above the surgeon’s working port. A wound protector is placed.

- The esophagus is transected using Endoshears (Covidien Surgical) above the azygos vein as the NG tube is slowly pulled back. The exact point of transection may be varied based on the proximal extent of the tumor and the presence of BE. Also,
consideration to the length of the new conduit should be given prior to this step. The specimen is removed through the access incision, opened and grossly examined by the surgeon, and sent for frozen-section analysis of the resection margins.

Creation of Esophagogastric Anastomosis

- The anvil of a 28-mm end-to-end anastomosis (EEA) stapler is sutured into the proximal esophagus. We prefer to secure this with two purse-string sutures using 2-0 Surgidac Endostitches. The first suture is used to secure the anvil. The second suture is used to ensure that all edges are circumferentially pulled around the anvil.
- The gastric conduit is pulled up into the chest, maintaining its orientation. The lesser curve staple line should be facing the camera. A gastrotomy is created at the tip of the conduit, opening to the right of the staple line. The lubricated EEA stapler is placed through the minithoracotomy and into the conduit. The conduit should be pulled onto the stapler like a sock is pulled onto a foot.
- The tip of the EEA point pierces the new conduit, is brought out along the greater curve of the conduit, and is carefully docked into the anvil that is sutured into the esophagus (Fig. 24.13). The exact location of this site on the posterior wall of the neoesophagus for the anastomosis is based on several considerations.
  1. Do you have a nice, healthy neoesophagus that will easily reach the transection point of the esophagus? If not, you may want to consider leaving some extra length to the remaining proximal esophagus.
  2. Was there any concern over the actual gastric margin, and do you need to potentially resect additional conduit to achieve an adequate margin? This is not seen often, but with cardia extension, it can be an issue.
  3. What was the viability of the gastric conduit tip? Was there any duskeness? If so, you may want to have the EEA point exit several centimeters lower on the conduit and allow more of the proximal conduit to be resected.
- Once the exit point of the EEA tip is decided, the point of the EEA is brought out of the posterior conduit and docked with the anvil under direct vision. The esophagus

![Figure 24.13 Creation of the esophagogastric anastomosis.](image-url)
and conduit are carefully approximated as you screw down on the EEA slowly bringing the anvil and proximal esophagus toward the stapler to remove any slack proximally. Care is taken not to place undue tension on the anvil as you tighten the EEA, as it is possible to actually pull the anvil out of the proximal purse-string sutures if careful observation is not done.

- The tightening continues slowly allowing the EEA to drag up the conduit, and docking is completed as you visualize the “green” mark on the EEA device. As this docking occurs, everyone must be paying attention to avoid an incomplete ring due to tension, or having fat or another structure get into the plane of the EEA rings.
- Finally, the EEA stapler is fired, creating an end-of-proximal-esophagus to side-of-gastric-conduit anastomosis. The EEA rings are inspected grossly by the surgeon to ensure that they are complete rings and then sent for permanent pathology.
- The gastrotomy through which the EEA stapler was placed is excised with the Endo GIA stapler; generally we use the purple loads as described above (Fig. 24.14). It is important not to transect this excess portion of the gastric tube too close to the EEA staple line. This is sent for analysis as the final gastric margin.

**Final Thoracoscopic Steps**

- If an omental flap was created during the abdominal dissection, it is wrapped around the anastomosis and secured in place with interrupted sutures.
- The chest cavity is irrigated with several liters of warm antibiotic irrigation solution to remove any saliva or gastric contents spilled during the anastomotic steps.
- The conduit is secured to the crus of the diaphragm with a single 2-0 Surgidac stitch to prevent potential herniation of conduit through the esophageal hiatus. A final schematic of the reconstruction is shown in Figure 24.15.
- The NG tube is pushed down across the anastomosis under direct vision and is positioned in the middle of the gastric conduit above the pylorus.
- A Jackson-Pratt (JP) drain is placed in the esophageal bed, posteriorly behind the conduit and next to the anastomosis and exited out the lateral chest wall near the costophrenic recess.
- A 28-French chest tube is placed through the camera port and is positioned posteriorly going toward the apex of the chest.
At the end of the procedure, the patient is placed in a supine position, and the mouth and nasopharynx are cleared of all saliva and secretions that may have built up during the case. This must be done before the balloon in the tracheal portion of the double-lumen tube is deflated to avoid aspiration of gastric contents and saliva. A single-lumen endotracheal tube is placed and thorough bronchoscopy is performed to clear the secretions and check for any airway injuries.

### POSTOPERATIVE MANAGEMENT

The patient is transferred to the intensive care unit (ICU) for overnight observation. The NG tube is kept on low, intermittent suction. Patients are given intravenous narcotics for pain control and are encouraged to participate in aggressive pulmonary toilet. Aggressive pulmonary toilet bronchoscopy is performed as needed. The NG tube is typically removed on the second postoperative day and slow, trickle-rate tube feeds (20 mL/hr) are begun via the jejunostomy tube. The Foley catheter is also removed on postoperative day 2. A barium study is performed on the third or fourth postoperative day provided the patient has a good cough and is able to clear secretions. If the contrast study is negative for leak, a small amount of oral intake is allowed. We allow 1 to 2 oz an hour of a clear oral liquid diet, which is advanced to 3 to 4 oz per hour over 2 days. The chest tube is removed when output is low (<200 mL/day) and the JP drain is slightly pulled back before discharge. The patients are discharged on an oral diet regimen of up to 4 oz per hour maximum of full liquid diet. Jejunostomy tube feeds are typically cycled on at night from 3 PM to 9 AM at approximately 100 mL per hour, but may vary based on the type of tube feeds and the caloric needs and weight of the patient. Patients return to the clinic 10 to 14 days after discharge, if the chest x-ray is clear and there is no drainage from the JP drain, it is removed. If the patient is taking 4 to 6 oz per hour of a full liquid diet at this point, we remove the jejunostomy tube and advance the oral diet.
COMPLICATIONS

Recently, we published our results in more 1,000 patients who underwent MIE. Patients were stratified by surgical approach, and perioperative outcomes were analyzed. The primary end point studied was 30-day mortality. A McKeown-type, 3-incision MIE was performed in 481 patients (48%) and an Ivor Lewis MIE in 530 patients (52%). In this largest series to date on minimally invasive Ivor Lewis esophagectomy, we reported a median ICU stay of 1 day and a median hospital stay of 8 days. The mortality rate after Ivor Lewis MIE was 0.9%, and rate of anastomotic leak requiring surgery was observed at 4%. The median number of lymph nodes resected was 21. The overall operative mortality in this series of 1,011 patients was 1.68%. In comparing the experience with our prior series, the mortality rate had decreased from 1.4% from previous series to 0.9% with an Ivor Lewis MIE. Notably, the incidence of vocal cord paralysis was significantly lower with the Ivor Lewis approach (1%) compared with the McKeown, 3-incision technique (8%). The low rate of leaks from the Ivor Lewis chest anastomosis was also of note, with less than half of these requiring any operative intervention. Generally, if we see a small leak, with no sepsis, and good drainage out the JP drain, we do not intervene other than a short course of antibiotics, EGD with gentle dilations, and monitoring. If the patient is stable, some of these can be monitored after discharge as well. For small leaks that go right to the drain, we allow the patient to continue sips of clear liquid during this time.

RESULTS

In our series of over 1,000 patients who underwent MIE, the oncologic resection (negative surgical margins and lymph node harvest) was comparable with most open series and compared favorably with our previously published series on minimally invasive 3-hole esophagectomy. At a median follow-up of 20 months, the stage-specific survival for patients undergoing MIE was comparable with previously published open series. Moreover, we recently conducted a multicenter study with 17 centers in the United States performing MIE in a controlled, prospective fashion. This was coordinated through the Eastern Cooperative Oncology Group (ECOG 2202) with participation of the Cancer and Leukemia Group B (CALGB) and the American College of Surgeons Oncology Group (ACOSOG). The initial results were presented in abstract form at the ASCO Annual Meeting. Of note, even in this 17 center study, the early operative outcomes were favorable, with a median of 19 lymph nodes resected per case, negative margins (R0 resections) in 96% of patients, median hospital length of stay of 9 days, an anastomotic leak rate of 8.6%, and a mortality rate of 2%.9

<table>
<thead>
<tr>
<th>Major Morbidity</th>
<th>MIE-Neck n = 481 (48%)</th>
<th>MIE-Chest n = 530 (52%)</th>
<th>Total n = 1011</th>
<th>p-value</th>
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<tbody>
<tr>
<td>Vocal fold paresis/paralysis</td>
<td>37 (8)</td>
<td>5 (1)</td>
<td>42 (4)</td>
<td>&lt;0.001</td>
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<tr>
<td>Empyema</td>
<td>31 (6)</td>
<td>28 (5)</td>
<td>59 (6)</td>
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<td>Acute respiratory distress syndrome</td>
<td>18 (4)</td>
<td>8 (2)</td>
<td>26 (3)</td>
<td>0.026</td>
</tr>
<tr>
<td>Myocardial infarction</td>
<td>9 (2)</td>
<td>11 (2)</td>
<td>20 (2)</td>
<td>0.809</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>20 (4)</td>
<td>10 (2)</td>
<td>30 (3)</td>
<td>0.033</td>
</tr>
<tr>
<td>Anastomotic leak requiring surgery</td>
<td>26 (5)</td>
<td>23 (4)</td>
<td>49 (5)</td>
<td>0.439</td>
</tr>
<tr>
<td>Gastric tube necrosis</td>
<td>15 (3)</td>
<td>9 (2)</td>
<td>24 (2)</td>
<td>0.140</td>
</tr>
<tr>
<td>Mortality at 30 days</td>
<td>12 (2.5)</td>
<td>5 (0.9)</td>
<td>17 (1.7)</td>
<td>0.083</td>
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</tbody>
</table>

CONCLUSIONS

It has been clearly demonstrated that minimally invasive esophageal resection is technically feasible and can be performed as safely as open esophagectomy by surgeons who are experienced in both open and minimally invasive esophageal surgery. MIE should be performed in centers with significant experience in open esophagectomy and by surgeons who are well trained in advanced laparoscopic and thoracoscopic procedures.

Recommended References and Readings

Esophagectomy with Substernal Pull-up

Jie Zhang, Haichuan Hu, and Haiquan Chen

Introduction

After resection of the esophagus, the alimentary tract is most commonly substituted using the gastric conduit through the prevertebral route (also called the posterior mediastinal or native esophageal route) or the substernal route (also called the retrosternal route). As scarce evidence is available, the surgeons’ experience and preference most often determine the choice of route. Since Orringer and Sloan introduced the substernal route in a gastric bypass surgery for palliation of esophageal carcinoma in 1975, esophagectomy with substernal pull-up is now widely applied when a neck anastomosis is to be performed and esophageal replacement is delayed for any reason. This procedure is also highly recommended in patients whose R0 resection is questionable, because substernal pull-up avoids infiltration of the conduit that may subsequently occur due to locally recurrent neoplasia. This option also allows postoperative irradiation to the tumor bed without causing damage to the conduit. In addition, substernal pull-up allows delayed reconstruction and is always available in esophagectomy surgeries regardless of whether a thoracotomy is performed.

INDICATIONS/CONTRAINDICATIONS

Indications

- Patients for whom postoperative adjuvant therapy is indicated due to a locally advanced tumor or because a complete (R0) resection in the native esophageal bed is questionable.
- Delayed reconstruction in patients with esophageal exclusion and cervical esphagogostomy.
- Previous posterior mediastinal surgery (for instance, repair of a thoracic esophageal fistula).
Relative Contraindications

- Young patients or patients with a benign esophageal lesion, in whom a cardiac surgery may be required in the foreseeable future.
- Previous anterior mediastinal surgery.

PREOPERATIVE PLANNING

Preoperative work-up begins with collection of a thorough medical and surgical history and a physical examination. Patients with previous anterior mediastinal surgery are not ideal for substernal reconstruction. If the patient has previously undergone partial gastric resection, or has a condition that might preclude application of the gastric tube as the replacement conduit, an alternate conduit (typically colon) must be prepared.

Systemic assessment of nutritional status and hepatic, renal, and cardiopulmonary function are essential for perioperative treatment. Radiologic investigations, including a barium swallow and a computed tomography (CT) scan, are performed to detect the location, length, and extent of the local lesion. To improve the staging, an endoscopic ultrasound (EUS), and a positron emission tomography (PET) scan may be complementary to determine the T, N, and M status. In some cases, we perform laparoscopic staging to further evaluate the patient for possible immediate surgical resection versus neoadjuvant treatment. Esophagogastroduodenoscopy must be performed to obtain a biopsy for histologic diagnosis and ensure suitability of the gastric conduit as an esophageal replacement.

SURGERY

Anatomy

The substernal route lies in the anterior mediastinal space between the sternum and the pericardia and the large vessels. Gastric, colonic, and jejunal interposition can all be achieved through the substernal route. Currently, there is a debate regarding whether reconstruction using the stomach substernally results in a longer distance for the conduit to travel. Limited cadaveric anatomic studies indicated that the prevertebral route was 2 to 3 cm shorter than the substernal route. In some instances, this has been used as an argument against the substernal pull-up procedure. However, we questioned whether the subject and reference selection in these studies was representative of that seen clinically in our practice. Therefore, we examined patients who underwent surgery at our institution and found that the substernal route was unexpectedly 2.8 cm shorter than the prevertebral route.

Position and Incision

In this procedure, the patient should be placed in the supine position. The location of the incision depends on the purpose of the surgery. Usually, a midline laparotomy incision and an oblique cervical incision are necessary for a substernal pull-up procedure with an anastomosis at the neck. A laparoscopic approach is also considered appropriate for experienced and well-trained surgeons.

Operative Technique

Here we describe the main surgical techniques when a gastric tube is formed as the conduit to substitute for the esophagus.

- The stomach is isolated and the gastric conduit is constructed as described in other chapters. Because a cervical anastomosis will be constructed, the conduit has to be completed in the abdomen (Fig. 25.1). Different surgeons have recommended differing conduit diameters, ranging from as small as 2.5 to 3 cm in diameter to as large as 6 to 8 cm. We prefer a gastric conduit approximately 4 to 6 cm in diameter for
subternal pull-up because we believe an excessively narrow conduit might increase
the incidence of cervical anastomotic leaks (Fig. 25.2). Usually, a 30- to 35-cm long
conduit is long enough for substernal pull-up to reach the hypopharynx, though a
longer tube can be fashioned, if needed.
■ An optional Kocher maneuver may give extra mobility to the conduit during the
gastric pull-up. In the authors’ practice, this procedure is not routinely performed,
and usually the complete Kocher maneuver is not necessary.
■ We routinely perform a jejunostomy for an enteral feeding tube. We prefer jejunos-
tomy tube feeding over nasal tube feeding for the comfort of the patient. In addition,
we believe nasal tube feeding might increase the risk of aspiration.

Figure 25.1 The gastric conduit can be created with a stapler as described in other chapters.

Figure 25.2 A gastric conduit 4 to 6 cm in diameter is recommended.
An oblique cervical incision is made anterior to the left sternocleidomastoid muscle. The space between the carotid sheath and the trachea is dissected, and the cervical esophagus is identified and dissociated from the carotid artery, internal jugular vein, and the left side of the thyroid gland. It is important to distinguish and protect the left recurrent laryngeal nerve, which lies in the tracheoesophageal groove (Fig. 25.3).

In our practice, instead of removing the left sternoclavicular joint, we incise part of the sternothyroid muscle inside the sternum, when needed, to expand the thoracic inlet and decrease the pressure caused by muscle contraction, thus alleviating compression on the microvascular network in the gastric wall.

After that, a space within the retrosternal mediastinum was created and widened using a combination of blunt and sharp dissection under direct visualization, and the width of the tunnel is expanded as much as possible (Fig. 25.4A to C).

With combination of pushing and carefully pulling, the conduit can then be positioned substernally (Fig. 25.5A to C). It can also be placed in a plastic bag, such as a laparoscopic camera bag, which is tied and guided cephalad by pulling on an umbilical tape.

Fix the proximate portion of the gastric tube with the surrounding tissues at the neck and the distal part with peritoneum under the diaphragm (Fig. 25.6). This procedure is of great importance to avoiding twisting of the gastric conduit and postoperative hernia.

Anastomosis of the cervical esophagus may be performed with an end-to-end anastomosis using a hand-sewn, double-layer technique. Cervical drainage is then placed. Stapled anastomotic techniques have been described as well.

The laparotomy incision and the cervical incision are closed, and some patients may then be positioned in the left lateral decubitus position for a right thoracotomy, if indicated.

The esophagus is isolated from diaphragm to the thoracic inlet, and all lymph nodes are dissected. Note: This step is optional and not performed in most palliative cases.

POSTOPERATIVE MANAGEMENT

Most patients are extubated immediately in the operation room and transferred to ICU. Postoperative management includes adequate pain control, intravenous fluid support, prophylactic antibiotic, anticoagulants, antacids, and enteral nutrition. Enteral nutrition through jejunostomy tube feeds begins 24 hours postoperatively. If no anastomotic leak is identified and satisfactory gastric emptying is demonstrated, the nasogastric
tube can be removed and oral food or fluids can be taken, generally beginning on postoperative day 5–7, based on the patient's status. The patient is then allowed to slowly progress with oral intake. Later, the cervical drainage tube can be removed if the volume is limited and there is no sign of leak, generally around postoperative day 7. When the patients are discharged, usually on day 7, they should be able to manage several small meals of a soft diet every day. The jejunostomy tube is kept in place and used for additional nutritional support till the patient's first postoperative follow-up.

An anastomotic leak should be immediately managed by open drainage. Drainage should be assessed daily, and antibiotics should be considered if necessary. Assessment of the upper mediastinum should be included in patients with a cervical leak as it is not uncommon for the actual anastomosis to lie below the level of the thoracic inlet and leaks may not be completely drained by opening the cervical incision. An anastomotic stricture can be identified by delayed emptying in a barium swallow test, and usually benign strictures can be treated effectively by repeated endoscopic dilatation, though occasionally it might be difficult in an individual whose substernal gastric conduit is curved in the tunnel.10 Usually, the substernal pull-up procedure facilitates drainage for leaks and reoperation for anastomotic stricture.11,12

Figure 25.4 A to C: The substernal route is created under direct visualization by a combination of sharp and blunt dissection and should be as wide as possible.
Figure 25.5 A and B: By a combination of pushing and carefully pulling, the conduit can be positioned through the tunnel.

Figure 25.6 Both ends of the gastric tube should be fixed to the surrounding tissues. This photograph shows the distal part, which is fixed to peritoneum under the diaphragm.
Anastomotic leak is considered one of the major postoperative complications of esophagectomy and the reported incidence after esophagectomy with substernal pull-up varies. Most retrospective studies on esophagectomy with a substernal pull-up have examined esophagectomy performed for palliative purposes and the incidence of leak reported ranged from 19% to 27%. In three randomized trials that compared substernal and prevertebral pull-up after transhiatal esophagectomy, the incidence of leak was 10% to 20% in the substernal group and was not significantly different from the prevertebral group in any of the trials (Bartels et al. 17 10% vs. 11%, \( p > 0.05 \); van Lanschot et al.18 20% vs. 27%, \( p > 0.05 \); Khiria et al.19 16.7% vs. 16%, \( p > 0.05 \)). From 2006 to 2009, 208 patients received esophagectomy with three-field lymph node dissection in our center. In these patients, we retrospectively found that individuals who underwent esophagectomy with a substernal approach had a higher leak incidence (29 leaks in 109 patients; 27%) than those with a prevertebral approach (18 leaks in 99 patients; 18%). We further compared outcomes in 40 patients who underwent esophagectomy with substernal pull-up from May 2007 to February 2008 with outcomes in 62 patients who underwent esophagectomy with substernal pull-up from March 2008 to March 2009, after we made modifications to the procedure. We found that the incidence of leaks could be reduced dramatically—from 8 leaks in 40 patients (20%) to 3 leaks in 62 patients (5%)—if the following aspects had been ensured: (1) Expanding the retrosternal tunnel as wide as possible; (2) Forming a 4- to 6-cm wide gastric tube; (3) Resecting part of the sternothyroid muscle to expand the thoracic inlet and decrease the pressure caused by muscle contraction; (4) Fixing the gastric tube to avoid twisting.

In a meta-analysis comparing postoperative events after esophagectomy with substernal pull-up and esophagectomy with prevertebral pull-up, there were no significant differences in the incidences of anastomotic stricture, cardiopulmonary complications, or perioperative mortality, and no differences in the patients’ quality of life (including assessment of reflux, dysphagia, delayed gastric emptying, and dumping syndrome).

In the past, substernal pull-up was usually adopted as an unwilling method of choice after palliative esophagectomy. With modification to the surgical technique and improved perioperative care, the procedure of esophagectomy with substernal pull-up seems to give satisfying outcomes. Data for some outcomes, such as overall survival, is not yet sufficiently available. Although the choice between prevertebral and substernal pull-up procedure after esophagectomy is still debated, substernal pull-up should be considered in patients who cannot undergo reconstruction via the prevertebral route.

Substernal pull-up is one option for esophageal reconstruction and an alternative when the prevertebral route is unavailable.

Substernal pull-up is recommended for patients when postoperative adjuvant radiation therapy or delayed reconstruction is indicated, and in patients with previous posterior mediastinal surgery.

Substernal pull-up is relatively contraindicated in patients who may need cardiac surgery in the future and patients with prior anterior mediastinal surgery.

Preoperative planning should be based on the purpose of the surgery and the possible options.

Key principles of the surgery technique are to maximize the thoracic inlet and improve the local “microenvironment” of the esophagogastric anastomosis, which can significantly improve the blood supply.
The anastomotic complications mainly include anastomotic leak and stricture. With modification to the surgical technique and improved perioperative care, substernal pull-up may equal or even exceed prevertebral pull-up in terms of reducing morbidity and mortality.

Acknowledgments

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Recommended References and Readings


Introduction

The modified Merendino procedure is the limited resection of the distal esophagus and gastroesophageal junction (GEJ) with regional lymphadenectomy and reconstruction with an interposed pedicled isoperistaltic jejunal segment. Merendino and Dillard first introduced this operation in 1955 as an antireflux procedure. They showed that the interposition of a 15-cm isoperistaltic jejunal segment acts as a substitute for the lower esophageal sphincter protecting against gastroesophageal reflux after resection of the esophagogastric junction. The use of mechanical anastomotic staplers has made this procedure simple and safe and extended its indication to the treatment of various benign and malignant lesions involving the distal esophagus and the gastric cardia.

INDICATIONS

The Merendino procedure can be employed when a limited resection of the distal esophagus and the GEJ is required. These include the following.

- Caustic nondilatable strictures of the distal esophagus
- Revisional surgery after multiple failed antireflux procedures
- Benign and semimalignant tumors at the esophagogastric junction
- Early adenocarcinoma of the distal esophagus or GEJ

In this chapter, we describe the patient selection and operative steps of the Merendino operation for early adenocarcinoma of the distal esophagus and GEJ in detail; nevertheless, most of the surgical technique is applicable to the other indications as well.

PREOPERATIVE PLANNING

There are several proposed advantages specific to the Merendino procedure when compared with other competing procedures (total esophagectomy and endoscopic mucosal resection [EMR]) for treating early adenocarcinoma of the distal esophagus and the gastric cardia.
Potential advantages are as follows:

- An oncologically adequate organ-preserving approach with low morbidity and mortality and superior long-term quality of life as compared with total esophagectomy.
- Full-thickness resection of the cancerous lesion with adequate tumor-free margins versus endoscopic resections in a piecemeal fashion.
- Removal of the entire esophageal segment with intestinal metaplasia to avoid recurrences and the need for life-long surveillance as seen after EMR.
- Regional en bloc lymphadenectomy providing locoregional control in patients with submucosal adenocarcinoma (T1b); these patients have a >20% chance of lymph node metastases.
- Combines esophageal reconstruction with an antireflux procedure controlling the underlying, usually severe reflux disease.

Evaluation of the patient with suspected early esophageal adenocarcinoma should include extensive diagnostic work-up with systematic biopsies aided by high-resolution endoscopy and endoscopic ultrasound to assess the depth of tumor invasion and the possible presence of multicentric disease. In patients with early cancer limited to the mucosa and without a multicentric tumor manifestation, an endoscopic mucosectomy can be performed to confirm the depth of tumor invasion. If a complete tumor removal (R0 situation) can be achieved, and the tumor is truly limited to the mucosa (T1a), with an endoscopic ultrasound showing no suspicious lymph nodes and a PET scan showing no evidence of distant metastasis, life-long close endoscopic surveillance may be justified, provided the patient is able and willing to undergo this follow-up and other unfavorable tumor characteristics are absent (e.g., angiolymphatic invasion, poor differentiation, ulceration, size >2 cm). All other patients including patients with intramucosal carcinoma with unfavorable tumor characteristics (as described above), multicentric lesions, submucosal tumor invasion, R1-mucosal resections, or recurrence after endoscopic mucosectomy are candidates for limited surgical resection. A computed tomography (CT) scan of the thorax and abdomen should be performed to evaluate for distant metastatic spread or lymph nodes outside the field of resection.

**SURGERY**

**Surgical Considerations**

The goal of the operation is the full-thickness removal of the entire esophageal segment with Barrett’s mucosa and an additional en bloc regional lymphadenectomy. An antireflux procedure should be added to treat the underlying gastroesophageal reflux disease (Fig. 26.1A, B).

**Surgical Technique/Sequence of Operative Steps**

**Positioning**

The patient is positioned supine in a slight reverse Trendelenburg position on the operating room table, and at the time of induction a single dose of a broad-spectrum antibiotic is administered. The patient’s chest and abdomen are prepared with an antiseptic solution.

**Exploration**

The abdomen is entered via a generous bilateral subcostal incision. Although a midline incision affords excellent exposure of the upper abdomen as well, we prefer a transverse incision as this provides a wider exposure of the esophageal hiatus. The falciform ligament is divided and retractors are placed on the abdominal wall. The abdomen is then carefully explored to evaluate the extent of locoregional disease as well as the presence of unexpected peritoneal or hepatic metastases. Furthermore, at this point, the adequacy (length) of the jejunal mesentery for the intrathoracic pull-up should be assessed.
Dissection of the Diaphragmatic Hiatus and the GEJ

First, the greater curvature of the stomach is mobilized and the bursa omentalis is entered by dividing the greater omentum from the colon through the avascular plane using the electrocautery. Then, the gastrohepatic ligament at the lesser omentum is dissected. Here, running beside the hepatic branch of the vagus nerve, a sizeable hepatic branch of left gastric artery can be encountered in fewer than 5% of patients, which may comprise the majority of arterial inflow to the left lateral segment of the liver. For this reason, it should be preserved by ligating the minor branches providing the lesser curvature of the stomach while conserving the main branch. Further dissection from the right side toward the esophageal hiatus and the division of the gastrophrenic ligament frees the right diaphragmatic crus. From the left side, the short gastric vessels are divided, the left diaphragmatic crus is identified (Fig. 26.2). After circular dissection of
the abdominal esophagus, a Penrose drain is slung around the esophagus to provide retraction for the further dissection. The vagal nerves can be divided at this point. Preservation of the vagal nerves compromises lymphadenectomy and should thus only be attempted in patients with mucosal cancer or high-grade neoplasia. The diaphragmatic hiatus is widely opened by incision of the left diaphragmatic crus. This provides good access to the lower posterior mediastinum.

**Transection of the Distal Esophagus**

The distal esophagus should be transected above the most proximal margin of Barrett’s mucosa under the guidance of intraoperative endoscopy to avoid residual intestinal metaplasia. After a proximal placement of a purse-string clamp (Fig. 26.3), nonabsorbable monofilament purse-string sutures are placed with a straight needle and the esophagus transected with a scissor. Frozen section analysis of the proximal margin is performed if there is concern about an R1 resection. After removal of the purse-string clamp, the proximal esophagus is gently dilated with two forceps allowing the easy insertion of the anvil of the circular stapler.

The largest stapler that can be safely inserted into the proximal esophagus should be selected to avoid anastomotic strictures associated with the smaller staplers. It is important to avoid 21-mm diameter staplers as the stricturing can be difficult to manage. After the successful placement of the entire anvil into the proximal esophageal lumen, the purse-string suture is securely tightened around it (Fig. 26.4).
En Bloc Dissection of the Distal Esophagus and Gastric Cardia with Mediastinal and Abdominal Lymphadenectomy

The hiatus is exposed with narrow deep retractors, and the distal esophagus and GEJ along with the entire fatty tissue with the accompanying lymph nodes in the lower posterior mediastinum up to the level of the tracheal bifurcation are dissected en bloc. Abdominal lymphadenectomy comprises an en bloc removal of all lymphatic tissue along the cardia, proximal two-thirds of the lesser curvature, fundus, and along the common hepatic and splenic artery toward the celiac axis. After the left gastric artery is transected at its origin, the entire lymphatic tissue around the artery is dissected with the resection specimen.

Transection of the Proximal Stomach

The stomach is transected using linear staplers. The first GIA stapler is applied at the proximal third of the lesser curvature proceeding toward the tip of the gastric fundus, thus preserving the gastric antrum and the vast majority of the corpus. Usually two to three linear staplers are necessary (Fig. 26.5A, B). The staple line is reinforced with interrupted 3-0 absorbable sutures (Fig. 26.6).

Preparation of the Isoperistaltic Jejunal Conduit

Reconstruction is performed by a retrocolic and retrogastric interposition of a pedicled isoperistaltic jejunal segment. The jejunal mesentery is examined for completeness of
the vascular arcades with transillumination by a strong light from behind (Fig. 26.7). Selection of a segment with a good single-vessel blood supply is essential. The mesentery is divided, and the isolated jejunal segment is transposed retrocolically through the transverse mesocolon to place it tension-free in juxtaposition to the esophagus (Fig. 26.8). An end-to-end jejunoojejunostomy is performed with a running monofilament 3-0 suture between the remaining ends of the small bowel. The length of the interposed jejunal segment should be tailored to size of the defect between the esophagus and stomach. A minimum length of 10 to 12 cm is, however, required to protect against postoperative reflux. On the other hand, excess length of the interponate (interposition graft) will result in kinking and dysphagia.

**Reconstruction by Esophagojejunostomy and Jejunogastrostomy**

The esophagojejunostomy is performed in end-to-side (functional end-to-end) fashion using a circular stapler with the entry point of the stapler through the proximal end of the isoperistaltic jejunal segment (Fig. 26.9). The redundant proximal end of the interponate is then resected and closed with a linear stapler. A 4- to 5-cm segment of the gastric staple line at the greater curvature is excised with the electrocautery for the subsequent jejunogastrostomy. Mechanical pyloric dilation or a formal pyloromyotomy is performed to avoid postoperative delayed gastric emptying (Fig. 26.10). The anastomosis is performed in an end-to-end fashion using a single-layer of interrupted absorbable 3-0 sutures. Three additional interrupted absorbable 3-0 sutures are used to secure the fundus to the diaphragm. These serve to recreate the angle of His (Figs. 26.11 and
Figure 26.9 Reconstruction using the EEA stapler.

Figure 26.10 Dilation of the pylorus with a large curved clamp.

Figure 26.11 Reconstruction of the angle of His with interrupted absorbable 3-0 sutures to secure the fundus to the diaphragm.
26.12). A 24-French chest tube is placed in left pleural cavity and connected to underwater suction.

**Keys to Success**
- Good exposure at the hiatus
- Adequate lymphadenectomy
- Interponate (interposition graft) length: 10 to 15 cm with an adequate vessel for blood supply
- Straight interposition: No redundancy, no tension
- Retrocolic and retrogastric route
- Isoperistaltic reconstruction
- Creation of the angle of His and fixation of the neofundus
- Pyloric dilation or pyloroplasty

**POSTOPERATIVE MANAGEMENT**

Routine extubation in the recovery room is practiced at the authors' institution. A nasogastric tube, which is passed at the time of the procedure to aid the hiatal dissection, is removed in the recovery room. The patient is kept NPO (*nil per os*, nothing by mouth) for 2 to 3 days on intravenous fluids and parenteral analgesics. A routine meglumine diatrizoate (Gastrografin) swallow is not performed. On the third or fourth postoperative day, the patient is started on a clear liquid diet and is instructed to drink in an upright position only. The patient is advanced to a regular diet as tolerated.

**COMPLICATIONS**

Complications that occur during the initial 24 hours are usually related to bleeding from inadequate hemostasis or iatrogenic injury of the spleen during surgery. A resulting anemia or hypotension could jeopardize the viability of the interponated jejunal segment. Clinical suspicion of major hemorrhage (tachycardia and a significant drop in hemoglobin in arterial blood gas) should prompt immediate re-exploration even in the absence of large amounts of blood in the abdominal drainage. Respiratory complications (atelectasis, pneumonia) due to poor cough effort or aspiration are the most common cause of morbidity. Perioperative physiotherapy, early postoperative ambulation and adequate pain relief, and returning to oral diet only if an upright position can be maintained are essential.
Anastomotic Leakage

In patients with suspected anastomotic leakage, a CT scan with a water-soluble contrast study and a careful endoscopic assessment are performed. If a leak occurs, oral intake is limited. Early leaks with fulminant sepsis are usually due to necrosis of the interponated jejunal segment. Operative intervention and resection of the interponate is mandatory. Smaller, contained leaks can be usually treated conservatively with NPO (nil per os; nothing by mouth) measures, total parenteral nutrition, broad-spectrum antibiotics, CT-guided drainage of the fluid collections, and in selected cases with the implantation of self-expanding plastic stents.

RESULTS

More than 100 Merendino procedures have been performed at the authors’ present and previous institutions; approximately 80% of these operations have been for malignancy, and 20% for benign disease. The median number of removed lymph nodes was 20. Perioperative mortality was 0% and postoperative morbidity was 16%. All patients with cancer underwent an R0 resection; there were no tumor recurrences. Barrett’s metaplasia persisted in less than 5%, and postoperative reflux was present in less than 10% of the patients at the 1-year follow-up. Personal communications with other surgeons (Luketich J.D., personal communications) performing this operation indicate that stricturing at the esophagojejunlal and jejunal-gastric anastomoses can be severe in some cases. In addition, others have reported significant stasis within the jejunal segment, significant clinical dysphagia, and in some cases herniation of redundant jejunal interposed segment with the resulting dysphagia.

Recommended References and Readings

27 Long Segment Reconstruction with Jejunum

Shanda H. Blackmon and Wayne L. Hofstetter

Introduction

Full length esophageal reconstruction using a pedicled jejunal flap augmented by cervical vascular microanastomosis (supercharged pedicled jejunum [SPJ]) represents a collection of historically important contributions to surgical technique. Roux was the first to report the use of jejunum as an esophageal substitute, but the first successful intrathoracic esophagojejunostomy was performed by Reinhoff in 1942. Prior to this, anesthetic techniques limiting the application of thoracic surgery only allowed for subcutaneous reconstructions. Longmire and Ravitch reported the first successful use of a segment of jejunum as a free graft to replace the esophagus by enclosing it in a skin tube with sequential transposition in three patients. Reinhoff’s successful one-stage surgery accomplished what Longmire and Ravitch previously aimed to achieve in their laboratory and clinical work. Harrison described the first reconstruction of the entire esophagus with jejunum using a transpleural route in 1949 using the experiences of Roux, Herzen, Yudin, and Reinhoff. In 1950, Robertson and Sarjeant first described construction of the substernal route. Merendino and Dillard expanded the use of jejunal interposition by describing the use of an isoperistaltic segment of jejunum to replace the lower esophageal sphincter and protect the esophagus from acid-peptic injury in 1955. Androsov and a group of engineers in Moscow successfully used metal clips to perform microvascular anastomoses between the internal mammary vessels to an interposed segment of intestine in 11 patients in 1956. Seidenberg performed the first free jejunal interposition with a microvascular anastomosis to replace the cervical esophagus. Kasai suggested an alternative means for supplying blood to a short segment of jejunum based on a long pedicle to reconstruct the cervical esophagus. The utility of small bowel for esophageal reconstruction was confirmed with publications by Allison, Wooler, and Gunning, who reported 3-year follow-up of most patients having normal nutritional intake and work capacity. Ascioti reported the first large series of pedicled jejunal interposition to replace the entire esophagus in cancer patients by using the “supercharging” technique.
INDICATIONS

Patients who have acquired long segment esophageal discontinuity and lack stomach as a viable replacement conduit primarily have two options for reconstruction: jejunum and colon. The jejunum is uniquely suitable for esophageal reconstruction because it is relatively abundant, does not require a formal preparation, has similar luminal size compared with esophagus, and does not undergo senescent lengthening like the colon does.

CONTRAINDICATIONS

Typical contraindications include Crohn disease, radiation enteritis, portal hypertension, short bowel syndrome, extensive fibrous adhesions, and superior mesenteric artery (SMA) syndrome. Patients who have unfavorable jejunal anatomy may require modifications to the standard approach or an alternative conduit.

PREOPERATIVE PLANNING

The most important part of the surgery is planning and preparation. When a patient is known to have an extensive disease that will preclude reconstruction with a stomach conduit, the operating room, staff, and patients and their families need to be prepared. The first step in planning the surgery is deciding which route will be taken for the small bowel. There are two main routes for reconstruction with jejunum: Posterior mediastinal and substernal. The posterior mediastinal route is frequently used when patients have immediate reconstruction with any conduit and the substernal route is more often used for delayed reconstruction due to scar tissue precluding the use of the posterior mediastinum. Given below is a list of characteristics of each route (Fig. 27.1A,B).

Figure 27.1 A: Posterior mediastinal route for supercharged jejunal conduit. B: Substernal route for supercharged jejunal conduit.
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Posterior Mediastinal Route
- Already present if initial reconstruction
- More anatomic
- Potentially shorter route

Substernal Route
- Best option for delayed reconstruction
- Easier access to chest vessels
- Outside field for potential recurrence or radiation
- May be unavailable if a previous coronary artery bypass graft (CABG) was placed
- May empty better

Anatomy
The jejunum is a long, hollow organ that extends from the ligament of Treitz and transverse mesocolon (superior and inferior duodenal recesses) to the ileum, which has an indistinct boundary of transition. The mesentry serves as the sole attachment of this organ to the body. The serosa, muscularis propria, and mucosa comprise the three layers of the jejunum wall. The muscularis propria, like the esophagus, has an outer longitudinal layer and an inner circular layer. The lumen is lined by folds that run perpendicular to the longitudinal axis called valvulae conniventes.

The blood supply to the jejunum arises from the SMA. Jejunal branches arise from the left side of this artery and the right side of the SMA provides branches to the ileum and colon. There are one to five jejunal arteries.11

Positioning
Patients are placed in the supine position. The legs are prepared into the field in the event that a saphenous vein graft harvest would be required. The head is turned slightly to the right and a roll is placed beneath the shoulders. The neck is prepared into the field. Slight modifications may need to be made for patients who have a tracheostomy or who require esophageal diversion reversal.

Dissection of the Jejunum
- Midline abdominal incision
- Lysis of adhesions if present
- Identification of the ligament of Treitz
- Transillumination and mobilization of the bowel mesentery
- Identification of the segmental blood supply to the jejunum
- Take down any feeding jejunostomy site
- Do not divide any of the branches of the small bowel until the neck and tunnel have been prepared to minimize ischemia time

Preparing the Neck
Dissection of the Neck and Blood Supply/Partial manubriectomy and resection of the first rib (Fig. 27.2)
- Make an incision anterior to the sternocleidomastoid muscle low on the neck extending onto the chest either at or to the left of the midline.
- Detach the sternocleidomastoid at the head of the clavicle.
Part III Techniques and Approaches for Esophageal Resection

Dissect around the left first rib ~3 cm lateral of the sternal border.

Divide the clavicle just lateral to the head and medial to the ligamentous attachments of the clavicle to the first rib. Divide the first rib 3 cm lateral to the sternal border; allow enough space to dissect the left internal mammary artery (LIMA) for microvascular augmentation of the jejunal flap.

A hemimanubriectomy is performed angled to the left on top of the second rib. The manubrium, the head of clavicle, and the proximal first rib are removed en bloc. Use caution because the internal mammary artery will be located underneath the cartilaginous portion of the ribs, about 1 cm from the sternal border.

A rongeur is used to resect additional bone if needed, smooth the edges so that nothing sharp will injure the bowel or mesentery.

Prepare the recipient vessels for microvascular anastomosis. The LIMA is typically an adequate artery, the left internal mammary vein (LIMV) may or may not be robust enough for use. If not, consider using the jugular vein for mesenteric venous anastomosis. A saphenous vein graft can be used to lengthen the artery or vein depending on the position of the conduit and recipient mesenteric vessels.

Creating the Tunnel for the Conduit

Creation of the Substernal Tunnel

From the abdomen, an incision is made on the anterior midline aspect of the diaphragm.

Create a midline substernal tunnel while attempting to stay extrapleural. An intrapleural route may be necessary in some cases. Allow enough space for the conduit and mesentery to pass unobstructed (approximately 5 cm diameter should be adequate).

The posterior mediastinal route is an alternative avenue for positioning of the jejunal conduit depending on the individual patient’s anatomic circumstances and the nature of the esophageal pathology being approached.

Selection and Division of Jejunal Branches

One must choose the arcade based on transilluminated visualization of the mesenteric vascular segmental anatomy and the length of bowel being considered for transposition.

There will be anatomic variations and shortened mesenteries from scar tissue, but the ideal jejunal arterial choice is depicted in Figure 27.3A, B.
The first branch of the jejunal blood supply provides blood to the proximal segment beginning after the ligament of Treitz; this first segment with its blood supply is typically left in situ for the Roux limb reconstruction.

Perform all of the dissection before dividing any of the blood supply to the small bowel to minimize ischemic time. Once the second arcade has been identified and the remaining segments appear to be appropriate, the mesentery is divided a little proximal to the second arcade to provide additional proximal bowel length for what will become the monitoring flap.

This second arcade will eventually be connected by a microvascular anastomosis to the LIMA and LIMV or jugular vein.

Open up the mesentery to allow lengthening of the flap (Fig. 27.3B)

The mesentery between the third and fourth arcades can be divided only up to the level of the bridging arteries. If the division of the mesentery is continued up to the level of the bowel wall, the third arcade segment of bowel will die.

The second and third jejunal branches to the SMA are tied off. It is the key to divide the vessels as close to the SMA as possible so that collateral blood flow is maximized.

The fourth arcade is left attached to the superior mesenteric artery (vascular pedicle).

The mesentery between the second and third arcades can be divided up to the level of the bowel to allow the proximal jejunum to unfurl (Fig. 27.3A); this is a critical step to establish a straight jejunal conduit. At this point the most proximal end of the bowel is ischemic.

Once the blood supply has been divided, the clock starts for ischemia time (do not divide this segment until the tunnel has been created and the donor vessels have been prepared).

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**Figure 27.3** A: Selection and division of jejunal branches. Typical branching pattern of proximal jejunum; mesenteric and jejunal cut points are indicated. B: Divided jejunal branches prepared for anastomosis. Vessel loops are placed around recipient vessels for augmentation.
The blood supply to the small bowel is fairly brisk. Even after ligation of the proximal branches, it may not appear ischemic, making it unclear that vascular augmentation is actually necessary. Although the bowel may appear pink, over the ensuing several days after the procedure, a significant amount of edema enters into the bowel wall and mesentery, allowing for adequate venous drainage which is most critical during this period.

Planning the Intra-abdominal Route for Jejunum

Plan A (Antecolic Tunneling of the Jejunal Segment) (Fig. 27.4A)
- Little preparation is needed for an antecolic route but measure the length needed.
- Plan for additional length with an antecolic route.

Plan B (Retrocolic Tunneling of the Jejunal Segment) (Fig. 27.4B)
- Transverse mesentery of the colon is transilluminated.
- Select a portion of the transverse colon mesentery away from the marginal artery of Drummond and the middle colic artery and use Bovie electrocautery to create a window at least twice the size of the small bowel such that it may pass through the window without resistance.
- Once the jejunum has passed through the window and has been connected to the new blood supply and the bowel anastomosis is complete, make sure the edge of the mesentery is tacked to the edge of the jejunum to prevent herniation through the transverse colon mesentery.
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**Delivery of the Jejunum Through the Substernal Tunnel**
- Prepare a large camera bag or an ultrasound probe cover.
- Ensure that the tunnel is large enough to allow for the bowel and mesentery and postoperative edema.
- Bag is delivered through the tunnel, bottom to top.
- Trace the bowel back to the mesentery and place the *untwisted* segment of jejunum into the bag, moisten the inside and outside of the bag. Feed the bag and jejunum into the tunnel from below while placing gentle traction from above. Suction can be placed inside the bag to facilitate delivery of the conduit if necessary.

**Microvascular Anastomosis**
- The vascular augmentation is performed prior to esophagojejunostomy.
- Operating microscope is used to prepare the recipient vessels.
- 2- to 4-mm coupler device is typically used to create the venous anastomosis.
- Saphenous vein grafts can be used to compensate for length issues.
- Venous anastomosis is performed prior to arterial anastomosis to lessen congestion.
- 9-0 nylon sutures are typically used for the arterial anastomosis with the aid of the operating microscope.

**Creation of the Indicator Flap**
- The very distal segment of jejunum with its own mesenteric blood supply is externalized at the end of the case to serve as an indicator flap of bowel ischemia.
- Transilluminate to ensure that there is adequate blood supply to the indicator flap.
- Divide the jejunum and mesentery to create enough length to externalize.
- 3-0 silk ties or clips are used to tie off the connection in the distal mesentery to provide length for the monitoring segment to pass outside the chest.
- Once the anastomosis is complete and the skin is closed, the monitoring flap should exit from a small opening in the initial incision (Fig. 27.5).
- Be sure to open the segment of bowel so that it can drain secretions.
- This is resected to skin level at the bedside just prior to discharge.

**Esophagojejunal Anastomosis**
- We describe three anastomotic techniques available to connect the esophagus to the proximal segment of jejunum.
- Stapled, functional end-to-end: This technique is also referred to as the modified Collard or Orringer technique (Fig. 27.6). The proximal segment of esophagus is

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Figure 27.5 Indicator flap.
positioned adjacent to the segment of jejunum in a side-by-side fashion. The tip of the jejunum is closed with a stapler and the jejunum is passed behind the esophagus. A tacking suture is used to hold the bowel in this position. An enterotomy 45 to 60 mm away from the terminal end of the bowel is created and Endo GIA 60-mm (purple tristaple for Covidien or blue stapler for Ethicon) single stapler ends are passed into the open end of the esophagus and the antimesenteric enterotomy of the jejunum. By firing the stapler, a functional end-to-end anastomosis is created. The “hood” is closed with interrupted absorbable sutures or alternatively with a TA stapler if there is adequate residual lumen.

- Handsewn end-to-end anastomosis (either single layer or double layer): An interrupted absorbable suture is typically used for this anastomosis.
- Stapled circular EEA device: The anvil is placed into the terminal end of the esophagus and a purse-string 3-0 prolene suture is used to secure all layers of the esophageal wall tightly around the anvil. The circular stapler is passed into the proximal open end of jejunum and through the antimesenteric side of the bowel to join to the anvil. Once the two devices are coupled and the stapler is fired, the rings are inspected and the terminal end of the jejunum is closed with a longitudinal staple line.
- Beware: The defunctionalized limb that remains must be short; we have seen blowouts of this staple line, and the limb may act as a pseudo-Zenker’s diverticulum if left too large. For these reasons this is not the authors’ choice for anastomotic technique.
- Care is taken not to disturb the vascular anastomosis while the anastomosis is being performed.

Recreating Continuity in the Abdomen

Plan A: Creation of the Roux Anastomosis (Preferred)

- The bowel and the mesentery must be correctly oriented.
- An isoperistaltic anastomosis between the proximal jejunum and the downstream segment of jejunum is created in a side-to-side (functional end-to-side) stapled manner.
- Optimally, this anastomosis is made about 20 to 40 cm past the diaphragmatic tunnel to lessen bilious passage toward the neck. The longer the segment, the less absorption time and potential for more side effects.
- The afferent limb of jejunum is connected to the jejunal interposition.

Plan B: Jejunogastric Anastomosis

- The bowel must be oriented such that the mesentery is passing behind the stomach.
- A posterior-stapled EEA anastomosis can be made by placing an anvil into the stomach and passing the EEA stapler through the terminal end of the small bowel exiting from the antimesenteric side of the jejunum about 4 cm from the distal end.
The ends of the circular stapler are connected (stapler sizes ranging from 25–29 mm) and fired. Donuts are inspected for completeness. Do not forget to reconnect the ends of jejunum back together (stapled side-to-side, functional end-to-end anastomosis).

**Feeding Jejunostomy**
- Tunnel the feeding tube through a very small hole through the left anterior side of the bowel and cap the feeding tube.
- An antimesenteric portion of proximal jejunum is selected for placement.
- Place a 3-0 silk purse-string suture on the antimesenteric side of the jejunum.
- Use the Bovie electrocautery to make a hole through the center of the pursestring.
- Place the feeding tube into the bowel lumen and tighten the pursestring.
- Use the Witzel procedure to place the tube or merely pexy the jejunum in four quadrants to the anterior abdominal wall (we do both to lessen drainage around the tube).
- Fix the tube to the outside of the abdomen.

**Intraoperative and Postoperative Management**
- Meticulous laparotomy and instrument count.
- Modifications in the event the patient has a tracheostomy.
- Securing lines and tubes to the abdomen is a key part of postoperative management of these patients.
- We have found that an NGT is not necessary and may even cause problems postoperatively.
- Do not place drains directly on the anastomosis.
- Make sure the conduit is not redundant and is as straight as possible and avoid pockets during creation of the anastomosis where food may pool.
- Make sure the patient is not placed on inotropic or vasoconstrictor drugs intra- or postoperatively.
- Keep the operating and recovery rooms warm.

**COMPLICATIONS**
Fortunately, rarely, bowel ischemia is a dreaded complication. The monitoring flap created intraoperatively serves as a constant indicator of the proximal jejunal perfusion until discharge. Nonobstructive mesenteric ischemia (NOMI) is a well recognized but infrequently encountered complication in under-resuscitated patients who have advancement of tube feeding too early. We typically start feeds on day 3 and advance slowly. When patients complain of abdominal pain, they should have the tube feedings stopped and in severe cases, consideration for abdominal exploration to evaluate for ischemia may be appropriate. In spite of possible lactic acidosis, their monitoring flaps may continue to appear healthy, and the segment of bowel downstream to the tube feeding may require investigation directly.

**Other Potential Complications**
- Bleeding
- Thrombosis of vessels
- Aspiration pneumonia
- Recurrent laryngeal nerve damage
- Stricture
- Dumping syndrome
From June 2000 to December 2010, 60 consecutive patients underwent esophageal replacement with a supercharged pedicled jejunal (SPJ) interposition. A multi-institutional database was used to evaluate patient characteristics, operative technique, and outcomes. Of the 60 patients undergoing SCJ reconstruction, 73% (44) were males and the mean age was 56 years (range, 28 to 76 years). SCJ reconstruction was used when stomach was not available or considered an optimal replacement. Twenty-three patients (38.3%) had the surgery performed to reverse esophageal discontinuity. Fifty-seven patients (95%) had reconstruction for cancer. Subternal reconstruction was performed in 39 (65%) patients. Roux-en-Y reconstruction of the jejunum was performed in 31 (52%) and jejunogastric anastomosis was performed in 29 (48%) patients. Anastomotic leak occurred in 19 patients (32%) and there were five cases (8%) of graft loss. Fifty patients (83%) were able to return to an oral diet after jejunal reconstruction. Characteristic postoperative manometric findings in several patients included segmental peristalsis as is typical for in situ jejunum. Thirty-day or hospital mortality was 5% (three patients). Ninety-day mortality was 10% (six patients). Median survival and the 5-year survival were 28 months and 30%, respectively.

The SPJ is a viable option for reconstruction of the esophagus when other options such as the stomach or colon are not available. SPJ is uncommonly indicated and is more complex and associated with significantly more morbidity and mortality than a gastric pull-up, but in some cases this may be the best option for the patient in order to restore the ability to take an oral diet.

**Recommended References and Readings**

Colon Interposition

Thomas J. Watson and Christian G. Peyre

Introduction

The stomach is the most commonly utilized conduit for esophageal replacement. Based on surgeon preference or the unavailability of the stomach, the colon may be chosen for use in foregut reconstruction and is the next most frequent substitute. The colon is well suited to the task, given its reliable blood supply, long length, and resistance to acid injury. Colon interposition, however, is a technically demanding operation rewarded by meticulous attention to detail and punished by minor mistakes in judgment that may lead to disastrous consequences. The esophageal surgeon should be knowledgeable in the principles underlying the use of the colon in esophageal replacement surgery, including advantages and disadvantages relative to other options, patient selection and preparation, technical aspects of colon mobilization and vascular assessment, routes of transposition, anastomotic techniques, and perioperative management.

The colon possesses several advantages relative to the stomach when utilized in foregut reconstruction. The interposed colonic segment separates the remaining esophageal mucosa from acid-producing gastric mucosa and duodenal content, lowering the potential for reflux-induced mucosal complications. The blood supply to the colon, when mobilized appropriately, is generally quite robust and the incidence of ischemic complications at the esophageal anastomosis, such as leaks or strictures, is quite low. The colon possesses a reservoir function, allowing for a sizeable meal capacity. The distal colonic segment and residual stomach remain in the positive pressure environment of the abdomen, helping to guard against reflux. In some individuals, the stomach is not suitable or available for use as an esophageal substitute. In such cases, the colon may serve the purpose quite well and can be anastomosed distally to the gastric antrum or to a Roux limb of jejunum, if the antrum has been resected or there is a significant gastric outlet obstruction. Finally, if the interposed colon becomes dilated or tortuous over time, it often can be successfully revised.1,2

Disadvantages of the colon as an esophageal substitute are also apparent. The colon must be free of significant pathology such as extensive diverticulosis, polyposis, or malignancy, and must be adequately evaluated and prepared for use, as for elective colon resection. Requiring three anastomoses (esophagocolonic, cologastric, and colocolonic), colonic interposition is inherently longer and more complex with a greater degree of dissection compared with a gastric pull-up. The operation is technically challenging, especially in terms of preserving the arterial inflow and venous drainage of the conduit. Seemingly minor mistakes in judgment or technique can have disastrous
consequences with regard to maintenance of adequate vascularity. Leaks or strictures can occur at any of the anastomoses, and bowel obstruction can occur if the colonic mesentery is not adequately closed. Minimally invasive techniques for completion of the operation have yet to be mastered. The colon is generally thought to be slower to allow resumption of alimentation compared with the stomach. Finally, and of great importance, colon interpositions can become dilated or tortuous when in place for many years. Such redundancy can lead to problems with dysphagia, regurgitation, or aspiration, though surgical remediation is often feasible.

**INDICATIONS/CONTRAINDICATIONS**

Colon interposition is performed most frequently when the stomach is not suitable or available for use as an esophageal substitute. Possible reasons include previous gastrectomy, tumor involvement of the stomach, and synchronous gastric cancer. The general indications for esophagectomy are similar to those described elsewhere in this text, and include esophageal cancer, end-stage motility disorders, and stenoses that have not responded to other treatments, and corrosive injury or trauma to the esophagus. The surgeon’s preferences, the presence of nonmalignant disease, and whether a vagal-sparing approach is being considered may also play a role in the decision to perform colon interposition. Colon interposition is also indicated as a salvage operation necessitated by failure of a previous esophageal substitute.

Mild diverticular disease is generally not a contraindication to the use of colon as an esophageal replacement, though extensive diverticulosis, frank diverticulitis, or inflammatory fibrosis may be. Similarly, the presence of a few colonic polyps, whether hyperplastic or adenomatous, that can be removed before surgery does not preclude colon interposition. The presence of extensive polyposis or malignancy, however, is an absolute contraindication.

**PREOPERATIVE PLANNING**

An assessment of the patient’s cardiopulmonary reserve is essential prior to any major surgical undertaking such as esophagectomy. A thorough history should be obtained, focusing on respiratory difficulties at rest or with exertion, exercise tolerance, chest pain, or fatigability. In addition, any symptoms suggestive of possible colonic pathology, such as diarrhea or constipation, or a history of inflammatory bowel disease, diverticular disease, colonic neoplasia, prior colon resection, or abdominal aortic disease should be elicited.

Physical examination should concentrate on cardiopulmonary findings. When questions arise about coexistent cardiac or pulmonary disease based on the patient’s age, comorbidities, physical signs or symptoms, formal physiologic testing should be pursued. Pulmonary function testing, including expiratory flows, lung volumes and diffusion capacity, can objectify the severity of concomitant obstructive or restrictive lung disease. Lung function should be optimized through smoking cessation, bronchodilators, expectorants, antibiotics, and pulmonary rehabilitation, as necessary. Cardiac imaging and stress testing can elicit subtle changes in cardiac function suggestive of ischemia, cardiomyopathy, or valvular heart disease. When coronary artery or valvular pathology is deemed significant, interventions such as angioplasty, coronary stenting, or even open heart surgery should be completed prior to elective esophageal surgery in an effort to minimize perioperative risk at the time of esophagectomy.

One advantage of esophagectomy in the setting of benign disease compared to malignancy is that surgery can often be delayed pending optimization of cardiopulmonary issues, nutrition, or other comorbidities. While the patient and treating physicians may feel a time pressure to treat an esophageal malignancy, end-stage benign esophageal disorders tend to be fairly long-standing problems that can be temporized while a thorough work-up is completed and risk factors addressed. Enteral or parenteral support
may be pursued if a patient is unable to tolerate an adequate oral diet. While no absolute thresholds exist for abandoning surgery due to pulmonary or cardiac compromise, such objective information can often influence the surgeon in making a decision for or against esophageal reconstruction and in the type of operation chosen.

When the colon is being considered as a potential esophageal substitute, colonoscopy should be performed to evaluate the status of the colonic mucosa. Colonoscopy is preferred to an air contrast barium enema because mucosal detail is better assessed and polyps or masses can be biopsied or resected.

As the colon should be adequately prepared for colonoscopy as well as for subsequent surgery, the colonoscopy may be scheduled a day or two before foregut reconstruction to allow both procedures following a single bowel prep. Our preferred regimen is to admit the patient to the hospital 2 days before surgery for bowel prep, consisting of 4 L of GoLYTELY (polyethylene glycol electrolyte solution; Braintree Laboratories Inc., Braintree, Massachusetts) administered orally, followed by colonoscopy the day before surgery along with oral neomycin and metronidazole.

Controversy exists regarding the necessity of routine preoperative mesenteric arteriography when colonic interposition is planned. As the successful use of colon is dependent upon an adequate vasculature, the surgeon should have a low threshold to perform such studies. When arteriography is performed, selective injections of the celiac artery, superior mesenteric artery (SMA) and inferior mesenteric artery (IMA) should be undertaken, including lateral views, and paying particular attention to any anatomic aberrancy. When the left colon is to be utilized for interposition, the most important angiographic finding is the status of the IMA, particularly at its origin, which can be stenosed in elderly individuals or in those with peripheral vascular disease. As the blood supply of a left colon interposition critically depends upon adequate inflow from the IMA, a significant stenosis of this vessel is a contraindication to the use of the left colon for esophageal reconstruction. A right colon interposition, based on the middle colic branches of the SMA, can be used in this situation, as it is not dependent upon IMA inflow. Other angiographic features thought important to the successful use of left colon for interposition include a visible ascending branch of the left colic artery, a well-defined anastomosis between the left colic and middle colic systems (along the marginal artery of Drummond), and a single middle colic trunk prior to division into right and left branches. Because of its more reliable and predictable arterial inflow and venous outflow, not to mention its better size match to the native esophagus, the left colon is generally preferred over the right colon for esophageal replacement.

As patients undergoing foregut reconstruction frequently have undergone multiple prior abdominal operations, mesenteric arteriography can help to define the resultant vascular anatomy and ascertain that vessels supplying planned esophageal substitutes are patent. In particular, prior operations involving the greater curvature of the stomach may have disrupted the right gastroepiploic artery, critical to the blood supply of a gastric pull-up, or the middle colic artery and marginal artery of Drummond, critical to the blood supply of a colon interposition. Preoperative knowledge of such vascular abnormalities can help the surgeon navigate the operation and save considerable time and effort during the procedure.

**Choosing Short-segment or Long-segment Colon Interposition**

Given the ability of the colon to reach either into the thorax or all of the way to the neck, colonic interposition may be undertaken after resection of either short or long segments of the esophagus. While the surgeon may want to preserve as much normally functioning esophagus as possible for certain indications, such as a nondilatable esophageal stricture, resecting only a limited distal segment carries several concerns about subsequent
reconstruction. The esophageal anastomosis, whether it is to stomach, small intestine, or colon, frequently must be intrathoracic in location after a limited distal esophagectomy. Only if there is sufficient length of abdominal esophagus can the subsequent anastomosis be placed in the abdominal compartment.

Three potential problems relate to placement of the anastomosis within the thorax. First, a thoracotomy or thoracoabdominal incision is generally necessary and is associated with significant pain, a poor cosmetic or functional outcome, and the necessity for single-lung ventilation during surgery, as well as the additional operative time necessary to open and close the incision and reposition the patient. While a transhiatal stapled anastomosis using a circular stapling device, or a thoracoscopic esophageal mobilization and anastomosis may obviate the need for a large thoracic incision, such techniques may not be feasible, especially in the setting of a reoperative procedure.

The second potential problem is that the consequences of an intrathoracic leak may be more devastating than those resulting from a leak in the neck. Multiple surgical series have reported higher morbidity and mortality associated with intrathoracic esophageal leaks, leading to mediastinitis, empyema and systemic sepsis, although these risks may be decreasing in recent years.5 Relative to near-total esophagectomy with a cervical anastomosis, which can often be completed without a thoracic incision and places the anastomosis near the thoracic inlet, resection of a limited segment of the distal esophagus carries with it the potential morbidity of both the thoracic incision and the intrathoracic anastomosis.

The third potential problem is reflux through the short colonic conduit, leading to esophageal mucosal injury or heartburn. Anastomoses high in the chest or in the neck appear to be less prone to subsequent reflux, though the length of the interposed conduit may be an important determinant of the volume of refluxate as well.

In general, we avoid short-segment colonic interpositions and prefer near-total esophagectomy with a cervical esophagocolonic anastomosis whenever possible. If the length of colon available for interposition is a concern, an intrathoracic anastomosis is preferably made high in the chest to minimize postoperative reflux.

>Colon Conduit Preparation in Foregut Replacement

Both left and right colon interposition techniques have been described. In general, the left colon is preferred because of the better predictability of its blood supply and the better size match to the remnant esophagus. A successful outcome following colonic interposition requires close teamwork between the surgeon and the anesthesiologist. The maintenance of adequate mesenteric perfusion is critical to prevent ischemia of the conduit. Vasopressors should be avoided and adequate blood pressure provided through the use of intravenous fluid replacement and blood products, as indicated. This plan should be clearly communicated and discussed with the anesthesia team prior to induction of general anesthesia, as well as with any new staff substituted throughout what is often a prolonged procedure.

When the vagus nerves have been resected as part of an esophagectomy and colon interposition is planned, the proximal three quarters of the stomach should be removed to avoid problems with delayed gastric emptying that can result when the denervated stomach is left intact. Typically the colon is anastomosed distally to the gastric antrum, and a pyloric drainage procedure is added. If a vagal-sparing esophagectomy is performed, the whole stomach may be left intact and gastric drainage avoided.

>Left Colon Interposition

The term “left colon interposition” is a misnomer in that it refers to interposition of the transverse colon, not the left colon. The name is derived from the fact that its blood supply is based off of the ascending left colic artery, a branch of the IMA, and the left colic vein, a tributary of the inferior mesenteric vein (IMV). The blood supply to the conduit is dependent upon communication between these vessels and the marginal
arteries and veins originating from the middle colic circulation, the origins of which get divided as part of the procedure (Fig. 28.1).

The operation is performed through an upper midline laparotomy incision and commences by dissection and vascular isolation of the colon conduit prior to resection of the esophagus and stomach. This sequence is chosen to allow for adequate time to assess the perfusion of the prepared colon conduit before committing to its use. The descending colon is mobilized laterally along the white line of Toldt from the splenic flexure to the beginning of the sigmoid colon, as for a colectomy. Care should be taken to prevent disruption of the colonic mesentery as well as to avoid the left ureter. The ascending branch of the left colic artery is assessed by direct palpation. The right colon is then mobilized in a similar fashion. The greater omentum is dissected from the transverse colon, preserving the transverse mesocolon. The base of the left and transverse mesocolon is next freed from the retroperitoneum, preventing inadvertent division of the IMV in the region of the ligament of Treitz.

The middle colic artery and vein are identified by transillumination of the transverse mesocolon and by direct palpation, then dissected near their origins from the superior mesenteric artery and vein, respectively. This part of the operation is one of the most challenging and important. It is critical to divide these vessels as near their origins as possible, in order to preserve communications between the right and left branches of the middle colic artery (as well as branches of the middle colic veins) and any vascular arcades within the transverse mesocolon. Once these vessels have been dissected, they are occluded with bulldog vascular clamps to allow assessment of colon perfusion while the operation is progressing and prior to the irreversible step of vessel transection.

The region of the distal transverse colon is then grasped and retracted cephalad, demonstrating the tether point of the ascending left colic vessels (Fig. 28.2). This portion of the colon typically reaches the level of the xiphoid process and is marked with a suture along the antimesenteric border. Using an umbilical tape, the distance between the xiphoid and the planned proximal anastomosis (typically within the left neck) is measured, adding several additional centimeters of length to assure an adequate reach. The umbilical tape is cut to this length and used to measure the distance proximally along the colon from the suture on the distal transverse colon, usually reaching
a point at approximately the mid-ascending colon. The colon is marked with a second suture at this point to denote the location for subsequent bowel division, defining what will become the proximal end of the isoperistaltic colon conduit. Vascular contributions to the colon conduit from the right colic and ileocolic vessels residing within the right mesocolon are dissected and occluded with bulldog vascular clamps, as they will need to be divided subsequently to allow interposition.

With the right-sided and middle colic vessels occluded with vascular clamps, the colon is observed while the esophagogastrectomy is completed. Pulsations along the marginal artery within the transverse mesocolon should be assessed frequently by palpation. If doubt exists about the adequacy of arterial perfusion, a Doppler probe should be utilized to assure the presence of triphasic flow. Despite the preoperative angiographic findings, the adequacy of colon conduit perfusion is determined intraoperatively after all vessels planned for division are occluded. If the colon becomes ischemic, the vascular clamps should be removed while options are considered for an alternate form of foregut reconstruction. One possible solution in this scenario may be “supercharging” the colon by microvascular anastomosis of the right or middle colic arteries and veins to suitable vessels in the neck or upper thorax.6,7

Once the perfusion of the colon conduit is deemed adequate, the clamped vessels are ligated and divided. The previously marked point of the ascending colon is also divided using a cutting stapler, and the most proximal portion of the colon interposition is advanced cephalad for subsequent anastomosis to the remnant esophagus (Fig. 28.3). Delivery of the conduit to the neck may be accomplished by any of a number of methods. The authors prefer suturing one end of a Penrose drain to the staple line at the tip of the conduit, and the other end to a 28-French chest tube that has been passed from the neck through the chest into the abdomen. As the colon is drawn cephalad, care must be taken to prevent torsion of the mesentery by maintaining it toward the right side of the interposition. Most surgeons prefer to bring the conduit through the posterior mediastinum when possible. If the posterior mediastinum is not suitable for passage of
the colon to the neck, a substernal route can be used. Extreme care must be taken to ensure no tension is placed on the vascular arcade. The vein is particularly vulnerable to injury and once an injured major vessel is encountered, the colon conduit will likely not be salvageable. In some cases of substernal routing, for this reason, we prefer to open the sternum and do the pull-up under direct vision.

Esophagocolonic anastomosis may be accomplished by any of a number of techniques. The authors prefer an end-to-end anastomosis, utilizing a single layer of interrupted 4-0 monofilament suture with the knots tied on the inside, after excision of staple lines from the remnant esophagus and colon conduit. The final few sutures consist of modified Gambee stitches placed anteriorly with the knots on the outside.

Once the esophagocolonic anastomosis has been completed, the colon is withdrawn inferiorly to straighten it. When brought through the posterior mediastinum, the colon should be sutured to the hiatus anteriorly so as to prevent subsequent herniation of viscera alongside it and to help prevent the development of subsequent redundancy of the interposed colon segment. Similarly, colon brought through the retrosternal space should be affixed to the diaphragm.

The colon is then divided just beyond the level chosen for the cologastric anastomosis. Excess colon and loops in the colon conduit are not desirable and can lead to functional emptying problems. An important technical detail is to preserve the entirety of the mesocolon at the point of distal colon transection, so as not to disrupt the blood supply to the interposed colon. Dissection of the mesentery should be adjacent to the colon wall, and the colon transected without any division whatsoever of the mesocolon. The cologastric anastomosis is then completed either with staplers or a hand-sewn technique in a side-to-end fashion.

The remaining ends of the proximal right colon and distal left colon are then anastomosed in a side-to-side or end-to-end fashion. The mesentery of these two portions of colon ideally should be reapproximated so as to prevent internal herniation, though such closure at times is not technically feasible.
Right Colon Interposition

The right colon also may be utilized for interposition. An issue of controversy is whether the right colon conduit should be positioned in an isoperistaltic or antiperistaltic fashion. A number of studies have confirmed that such interpositions typically empty by gravity and are not peristaltic. Case reports, however, would suggest that an antiperistaltic conduit, over time, might propel a food bolus in a retrograde fashion. Most surgeons, therefore, prefer to place the esophageal replacement conduit in an isoperistaltic fashion.

For an isoperistaltic right colon interposition based on the middle colic vessels, the colon is mobilized from the hepatic flexure to beyond the cecum, including the distal ileum. The ileocolic and right colic arteries are dissected at their bases and temporarily occluded with vascular bulldog clamps, as described for left colon interposition. The distance from xiphoid to the esophageal remnant is measured with an umbilical tape, and that same distance then measured proximally from the mid-transverse colon to a point typically within the distal ileum. Once adequate vascularity has been assured, the ileum and previously clamped blood vessels are divided and the bowel delivered proximally. After the esophagocolonic anastomosis has been completed, the transverse colon is divided at an appropriate level to allow distal anastomosis to the remnant stomach or a Roux limb of jejunum. The proximal end of the ileum and distal end of transverse colon are then anastomosed, and the mesenteric defect closed, as per left colon interposition.

Vagal-sparing Esophagectomy

The surgeon may choose to perform a vagal-sparing esophagectomy, particularly in patients who undergo esophageal resection for nonmalignant conditions. The technical details of the operation include making a small anterior gastrotomy along the gastric cardia, mobilization and division of the cervical esophagus, passage of a vein stripper of suitable size through the gastrotomy proximally to the cervical esophagus, fixation of the cap of the vein stripper to the divided end of the esophagus by suture ligature, and eversion of the esophagus out of the stomach. In the process, the esophagus is stripped from its mediastinal divestments, commonly leaving a layer of longitudinal esophageal muscle in situ. The dissection plane is typically quite easy to develop and does not offer much resistance upon stripping. An umbilical tape is affixed to the proximal tip of the esophagus being resected prior to eversion so as to allow passage of the tape through the mediastinum. The vagal plexus and main trunks are left intact. The esophagus is then divided near the GEJ. The resultant mediastinal tunnel must be dilated to allow adequate space for passage of the esophageal replacement conduit. Foley catheters with balloons inflated to progressively larger sizes (e.g., 30, 60, 90 mL) can be used for this purpose. The umbilical tape within the mediastinum denotes the proper plane for passage of the colon segment among the vagal fibers, which can be somewhat web like. The operation can be performed via open laparotomy or, in experienced hands, using a laparoscopic or hand-assisted technique. The colon should be passed up through the posterior mediastinum along the path established by the umbilical tape. Anastomosis can then be performed proximally to the esophagus in the neck and distally to the intact stomach. Important differences between the techniques of colon interposition when performed following a vagal-sparing esophagectomy versus after a standard esophagectomy are that a pyloroplasty is not necessary, as pyloric innervation is preserved, and the proximal stomach is left intact.

POSTOPERATIVE MANAGEMENT

Patients are admitted to the intensive care unit for initial postoperative observation. We routinely place an epidural catheter before surgery to facilitate subsequent pain management and pulmonary toilet. Intravenous fluid administration initially should be liberal
to counter third-space losses and prevent intravascular volume depletion with resultant mesenteric vasoconstriction. Vasopressor medications generally are avoided, as during surgery. Parenteral antibiotics are administered for less than 24 hours. A nasocolonic Salem sump tube is placed during surgery and kept on low continuous or intermittent suction until the output is low and bowel function has returned, generally in the range of 4 to 5 days. A feeding jejunostomy tube is placed during surgery, and tube feedings are commenced starting on the third postoperative day. The feedings are advanced slowly to the goal volume over a few days.

The utility of a postoperative contrast upper gastrointestinal radiographic study (Fig. 28.4) is widely debated. The intent of such studies is to assess possible anastomotic leakage at either the esophagocolonic or cologastric anastomosis, as well as to assess the adequacy of conduit drainage. While such studies, typically on the sixth or seventh postoperative day, previously were our policy, we no longer utilize them routinely and have gone to the liberal use of flexible upper endoscopy instead. Our belief is that endoscopy offers a more sensitive assessment of mucosal ischemia and anastomotic dehiscence than contrast radiography, which is associated with a high false-negative rate for conduit and anastomotic complications.

**Complications**

Perioperative mortality has ranged from 2% to 10% in larger series published since 1995. Conduit necrosis occurred in 2.5% to 6% of the patients in these current-era series. Anastomotic complications were reported in 3% to 15% of patients and are more common at the esophagocolonic anastomosis than at the cologastric or colocolonic anastomoses.

When the colon is mobilized appropriately, the blood supply to the colon is generally quite robust, reducing the incidence of ischemic complications at the esophageal anastomosis, such as leaks or strictures. Watson et al. reported on 85 patients who underwent colonic interposition for benign disease, with an esophagocolonic leak rate of 3.5% and a need for postoperative anastomotic dilation in only 5% of patients. Both of these rates were much less than those after cervical esophagogastrostomy, where anastomotic leaks occurred in 20% and dilation was required in 30% of patients. Briët et al. reported on 395 consecutive patients who underwent esophagectomy for either malignant or benign diseases. The development of either anastomotic leak or stricture was analyzed in patients who underwent gastric pull-up and compared with colonic interposition. Leaks and strictures were more common (14.3% vs. 6.1%, \( p = 0.013 \), 31.3% vs. 8.7%, \( p < 0.0001 \), respectively) and strictures were more severe after gastric pull-up. In contrast, a large series from Japan by Mine et al. included 95 patients who underwent colon interposition after esophagectomy with extended lymphadenectomy for esophageal...
cancer between 1990 and 2008. Most (92/95) of the patients underwent reconstruction via the retrosternal route, and 3 required microvascular supercharging. Anastomotic leak occurred in 13%, the relatively high rate, likely secondary to their preference for the retrosternal route. Conduit necrosis was rare. In Mine’s series, pulmonary complications occurred in 32.6% of patients and vocal cord paralysis in 12.6%. Similarly in Thomas’ series of 60 patients who underwent colon interposition, pulmonary complications occurred in 30% of patients.

**RESULTS**

An objective analysis of foregut reconstruction should include both perioperative data, including complications, mortality and length of stay, as well as long-term functional outcomes. Comparisons between series and types of esophageal replacement are difficult, given the lack of uniformity in the reporting of data, the variability in methods of assessing postoperative gastrointestinal function and side effects, the variety of colon interposition techniques including supercharging, and the fact that many reports lump together cohorts of patients with different esophageal replacement conduits.

Curet-Scott et al. reported on the University of Chicago experience with colon interposition for benign disease. Perioperative mortality was 3.8% in the 53 patients who underwent surgery, with a 26.4% major complication rate. Follow-up was complete in 83% of patients at an average of 5 years after reconstruction. Results were rated by the patients and physicians, with 75% of the patients claiming good or excellent results and 72% of the patients classified by the physicians as having good or excellent results. There was, however, a 37% reoperative rate for treatment of delayed gastric emptying, anastomotic stricture, leak, or persistent symptoms. Despite the complication and reoperation rates, the authors stated that colon interposition remained their preferred technique for reconstruction after esophagectomy for benign disease.

At the University of Southern California, 104 patients with benign esophageal disease underwent esophageal reconstruction over a 21-year period. For esophageal replacement, colon was used in 85 patients, stomach in 10 patients, and jejunum in 9 patients. Overall hospital mortality was 2% and the median hospital stay was 17 days. Forty-two patients answered a postoperative questionnaire at least 1 year after surgery concerning their long-term functional outcome. Ninety-eight percent of patients reported that the operation improved or cured the symptom driving the surgery. Ninety-three percent were satisfied with the outcome of the operation. The numbers of patients who underwent esophageal reconstruction using stomach or jejunum, however, were too small to allow meaningful comparisons between the different types of reconstructions.

A report from the Mayo Clinic analyzed outcomes in 255 patients undergoing esophagectomy for benign disease between 1956 and 1997. The esophageal substitute was stomach in 66%, colon in 27%, and small bowel in 7%. Perioperative mortality was 5% and morbidity was 56%. Median hospitalization was 14 days. Follow-up was available in 88.6% of patients at a median of 52 months after surgery. Improvement was noted in 77.4% of patients, with functional results classified as excellent in 31.8%, good in 10.2%, fair in 35.4%, and poor in 22.6%. The method of reconstruction did not appear to impact late functional results.

In Mine’s series of 95 patients who underwent colon interposition after esophagectomy with extended lymphadenectomy, mortality was 5.3%, with no mortality during the last 10 years of the study period, and 5-year survival was 43%. Dysphagia (39%) and diarrhea (38%) were common, though stricture was uncommon (6%) after discharge.

Colon interposition grafts can become dilated or tortuous when in place for many years (Fig. 28.5), leading to problems with dysphagia, regurgitation, or aspiration. This colonic redundancy is the most common long-term mechanical complication after long-segment colon interposition. Surgical revision is often possible via a tailoring coloplasty or segmental resection with reanastomosis.
The esophageal surgeon should be well versed in a number of techniques of foregut reconstruction. While the stomach remains the most common esophageal replacement conduit utilized today, circumstances arise when the stomach is not preferred or is unsuitable for this purpose and an alternative conduit is sought. Colon interpositions possess several advantages over gastric pull-ups and are the next most common strategy for esophageal replacement. While technically nuanced, the procedure of colon interposition can be performed successfully in the vast majority of cases after appropriate patient selection and preoperative evaluation. In experienced hands, the interposed colon allows return of satisfactory alimentation after esophageal extirpation with an acceptable risk of perioperative morbidity, mortality, and long-term gastrointestinal side effects. Given the infrequency with which colon interposition is utilized in the community at large, procedures requiring the use of colon for esophageal replacement are best restricted to specialty centers caring for a high volume of patients with complex foregut pathology.

**Recommended References and Readings**

Open Resection of Esophageal Leiomyoma and GIST

Alberto de Hoyos and Malcolm DeCamp

Introduction

In this chapter, we discuss the general approach to leiomyoma and gastrointestinal stromal tumors (GISTs) of the esophagus and resection via thoracotomy. Many surgeons today prefer a thoracoscopic approach for resection of most of these benign tumors, and the thoracoscopic approach will be discussed in the next chapter.

Esophageal Leiomyoma

Benign esophageal tumors are uncommon and account for less than 1% of all esophageal neoplasms. The majority of these tumors are asymptomatic and often discovered incidentally. Symptoms, when they develop, include dysphagia and chest pain and are the result of intraluminal extension or large intramural tumors. Leiomyoma is the most common benign esophageal tumor (50% to 70%) and esophageal leiomyoma accounts for about 6% to 12% of gastrointestinal leiomyomas. Because esophageal cancer is 50 times more common than leiomyoma, and leiomyosarcoma is exceedingly rare, surgeons encounter few leiomyomas during their careers. The majority of esophageal leiomyomas present between the ages of 20 and 60 years (mean age 44), are rare in children, and are twice as common in men than in women.

Leiomyomas arise from smooth muscle cells and thus are more common in the middle third (~40%) and lower third (~50%) of the esophagus than in the upper third (~10%) (Fig. 29.1, See also Fig 30.1). Leiomyomas most commonly arise from the circular layer of the muscularis propria and infrequently from the muscularis mucosa in which case they can present as polypoid intraluminal tumors. Leiomyomas are usually solitary (97%) and measure between 2 and 5 cm in diameter although tumors measuring from 2 mm to 20 cm have been described. Leiomyomas uncommonly present as extraesophageal tumors causing compression of adjacent structures. In a review of 838 cases, 97% of the leiomyomas were intramural, 1% were polypoid intraluminal, and 2% were extraesophageal. Leiomyomas appear histologically as smooth muscle fibers arranged in
whorls of long thin spindle cells with eosinophilic cytoplasm mixed within a hypovascular connective tissue matrix. It can sometimes be very difficult to differentiate between leiomyoma, leiomyosarcoma, and GISTs. It is controversial whether leiomyomas can undergo malignant degeneration although if it occurs, it must be exceedingly rare. In a comprehensive review of more than 800 cases reported in the world literature, only two (0.2%) were documented to show transformation from leiomyoma to leiomyosarcoma.

Clinical Presentation and Diagnosis

More than 50% of leiomyomas are asymptomatic. Symptoms develop when the tumor has reached a large size, typically 5 cm or more. Dysphagia and retrosternal discomfort are the two most common symptoms. Respiratory complaints such as cough, dyspnea, or wheezing may result from large tumors causing compression of the tracheobronchial tree. Bleeding is uncommon since the overlying mucosa is almost always intact. Leiomyomas in the distal esophagus may be associated with gastroesophageal reflux disease.

Diagnosis of leiomyoma can be made with confidence with a careful history, physical examination, barium swallow, computed tomography, and endoscopy with ultrasonography. Tissue diagnosis is not necessary except when the diagnosis of GIST or malignancy is a possibility. On endoscopic ultrasonography, typical leiomyomas appear as homogeneous anechoic lesions within the muscularis propria. A heterogeneous echo pattern may be seen in benign tumors but the presence of a lesion of greater than 4 cm is more suggestive of malignancy. Nonetheless, malignancy is exceedingly rare.

INDICATIONS/CONTRAINDICATIONS

Leiomyomas grow slowly and may be stable in size during observation for many years. There is general consensus in the literature that esophageal leiomyomas should be surgically removed in symptomatic patients; however, treatment of asymptomatic patients continues to be debated. Many may advocate for the resection of these tumors because of the possibility of malignant degeneration, the possibility of symptom development in the future, the desire to obtain a definitive histologic diagnosis, and the ability to exclude the possibility of malignancy. However, the literature and experience have shown that asymptomatic patients rarely develop complications from their leiomyomas if untreated. Therefore, since the risk of malignant transformation is low and development of complications is rare in asymptomatic patients, it seems that
asymptomatic patients with a tumor less than 2 to 3 cm can be managed with clinical and radiographic/endoscopic follow-up. Endoscopic ultrasound seems to be the ideal way to follow these tumors with a CT scan every 1 to 2 years. Indications for surgical resection of a leiomyoma include the following.

- Symptoms – typically dysphagia and/or chest pain
- Increasing size of tumor during follow-up
- Need to obtain histologic diagnosis (i.e., clinical diagnosis is in doubt)
- Facilitation of other esophageal procedures (i.e., fundoplication, myotomy)

Giant leiomyomas requiring esophagectomy have been described but most commonly they can be treated effectively by esophageal-sparing techniques. Indications for esophagectomy include the following.

- A very large or annular tumor that cannot be enucleated
- Esophageal mucosa or muscular wall that is badly ulcerated or damaged during enucleation that cannot be repaired in a satisfactory manner
- Symptomatic multiple leiomyomas that cannot be enucleated or diffuse leiomyomatosis
- Leiomyosarcoma suspected and confirmed on biopsy

There are no specific contraindications for the resection of esophageal leiomyomas. Resection is typically contraindicated for small (1 to 2 cm) tumors in asymptomatic patients or when the general condition of the patient prohibits general anesthesia and complications of resection may outweigh the benefits.

**PREOPERATIVE PLANNING**

Resection of esophageal leiomyomas can be performed by utilizing a number of approaches that include thoracotomy, video-assisted thoracoscopic surgery (VATS), and endoscopic resections when the lesion is small, pedunculated, and submucosal in location. Enucleation, or shelling out of the intramural leiomyoma, is the preferred treatment. Rarely, the tumor will require esophageal resection with reconstruction due to size and degree of esophageal involvement.

**SURGERY**

**Anesthesia**

For open thoracotomy, a thoracic epidural catheter is placed by the anesthesiologist for optimal management of postoperative pain. For thoracoscopic resection, an epidural is generally not necessary. The patient is intubated with a left double-lumen tube or a single-lumen tube and a bronchial blocker.

**Positioning**

Tumors of the upper and middle thoracic esophagus are best approached through a right lateral or posterolateral thoracotomy, while those in the lower third require a left thoracotomy (Fig. 29.2). Sequential compression devices are placed in the lower extremities to deter deep vein thrombosis. A Foley catheter is placed. The patient is then turned to the lateral position and a sandbag or a soft roll is placed under the upper ribs to avoid pressure on the brachial plexus, while the head is supported in neutral spine alignment. The arm on the side of the operation is supported and secured providing ample exposure of the axillary region. The lower leg is slightly bent at the knee while the upper leg is kept straight with pillows in between. Care is also taken to apply pads to all pressure points. The patient is supported on a bean bag which is set after the operating table is gently angulated at the level of the lower chest. A belt strap is placed over the hips to secure the patient to the table (Fig. 29.2). The chest is prepped and draped.
Resection of Benign Esophageal Tumors

**Technique**

For leiomyoma, the principles of the operation include resection of the tumor (enucleation) without injury to the underlying mucosa or vagus nerves and closure of the muscularis propria, if possible, to prevent mucosal bulging and pseudodiverticulum formation.

- On-table esophagogastroduodenoscopy (EGD) is performed to confirm tumor location and size and assure the surgeon that the lateral approach chosen (left or right) will work for the indicated patient.
- A standard lateral thoracotomy is performed (Fig. 29.3). On the right, the incision is planned to enter the chest at the level of the fifth intercostal space while on the left, at the level of the sixth or seventh intercostal space. Alternatively, a muscle-sparing thoracotomy can be performed, preserving the integrity of the latissimus dorsi and serratus anterior muscles (Fig. 29.4).
- Once the subcutaneous tissues have been divided, the latissimus dorsi muscle is divided with cautery, while the serratus anterior muscle is mobilized anteriorly and preserved (Fig. 29.5).
Figure 29.4 Skin incision for a muscle-sparing thoracotomy. The incision extends from a point just posterior to the tip of the scapula to just anterior to the anterior border of the latissimus dorsi muscle. A plane of dissection is performed between the latissimus and serratus muscles and a retractor placed under both muscles. Undermined skin flaps facilitate mobilization and retraction of the muscles. Keeping the flaps small reduces the incidence of seroma formation.

Figure 29.5 The latissimus dorsi muscle is divided with electrocautery leaving the serratus anterior muscle intact.
The areolar tissue along the posterior edge of the serratus is divided obliquely extending inferiorly toward the anterior inferior margin of the latissimus (Fig. 29.6).

A plane of dissection is established above the ribs, and a hand is inserted under the chest wall musculature to identify the first (flat upper surface) and second ribs (insertion of middle scalene muscle).

The ribs are then counted, and the selected intercostal space for entry is identified. The intercostal tissues and pleura are divided along the top border of the corresponding rib and entry into the thoracic cavity is accomplished.

The posterior margin of the thoracotomy is at the level of the longitudinal spinous ligament.

The parietal pleura and intercostal muscles are incised from within the thoracic cavity beyond the external margin of the incision in an effort to further relax the opening. We do not routinely resect a portion of a rib.

A Rienhoff retractor is inserted and slowly opened. Gradual opening of the retractor to no more than 6 to 8 cm helps to prevent rib fractures and may reduce the occurrence of postthoracotomy pain syndrome. A Balfour retractor or a second Rienhoff retractor positioned anteroposteriorly in the soft tissues of the chest wall at a right angle to the Rienhoff retractor may help to improve exposure (Fig. 29.7).

The lung is mobilized anteriorly and the posterior mediastinum is exposed. A leiomyoma will often appear as a large bulge (>3 cm) under the parietal pleura covering the esophagus (Fig. 29.8).

Most leiomyomas are easily seen through the intact mediastinal pleura. If the leiomyoma is not immediately seen through the intact pleura, it will frequently become apparent after initial esophageal dissection. However, smaller, less than ideally situated leiomyoma may require simultaneous EGD and careful mobilization and palpation to confirm the location.

The mediastinal pleura is incised to expose the leiomyoma and the esophagus above and below.
Full esophageal mobilization is unnecessary unless the tumor is extensive and encircles the esophagus. Resection can usually be achieved by extramucosal enucleation or shelling out. When the outer longitudinal muscle layer over the tumor is divided along the orientation of the fibers with electrocautery, the leiomyoma appears as an avascular encapsulated mass. The dissection is performed with care to preserve the vagus trunk and its branches and to preserve the integrity of the longitudinal muscle fibers and to some degree the circular fibers.

Leiomyomas are easily enucleated using blunt dissection away from the surrounding muscle fibers and the mucosa unless there is inflammation or mucosal damage caused by preoperative endoscopic biopsy. A plane of dissection is established in the submucosal layer using a combination of blunt and sharp dissection. Gentle traction in the exposed part of the tumor is applied to facilitate development of the plane of dissection. Care is taken not to enter the esophageal lumen (Fig. 29.9).
After enucleation, the tumor is removed and the pleural cavity irrigated with saline. Intraoperative endoscopy with air insufflation is performed to confirm mucosal integrity. If the mucosa is perforated during the dissection, it should be repaired with fine absorbable suture and the muscularis propria closed over the top with interrupted silk suture (Fig. 29.10).

It is important to carefully preserve and close both muscle layers to minimize the likelihood of postoperative dysphagia and development of esophageal dysmotility especially with larger, more complex leiomyoma.

In the absence of perforation, there is some disagreement as to whether the myotomy should be sutured closed after enucleation; however, most experts recommend reapproximation of the muscular layer to prevent bulging with subsequent diverticulum formation.

One or two chest tubes are placed in the thoracic cavity. After unflexing the table, the ribs are reapproximated with large absorbable suture taking care not to create overapproximation or to entrap the neurovascular bundle under the rib below (Fig. 29.11).

The muscle layers are closed meticulously to include full thickness bites and the corresponding fascia (Fig. 29.12). The lung is re-expanded and the subcutaneous tissues and skin are closed in layers.

A nasogastric tube is not necessary.
Figure 29.11 The ribs are reaproximated with heavy gauge reabsorbable sutures taking care not to create overapproximation or to entrap the neurovascular bundle under the rib below.

Figure 29.12 The chest wall musculature (latissimus and serratus) is reapproximated in layers with heavy reabsorbable suture taking full thickness bites.
POSTOPERATIVE MANAGEMENT

After resection of a leiomyoma, patients are started on oral liquids on postoperative day 1 following a thin barium esophagram that does not demonstrate a leak. Diet is advanced to a mechanical soft diet and eventually to regular foods. The epidural catheter is removed on postoperative day 2 or 3, and the patient is started on an oral regimen of pain medication. Subcutaneous heparin is administered three times daily until discharge. Patients are usually discharged on day 4 to 5 after resection.

COMPlications

Theoretically, enucleation of a large leiomyoma may result in an esophagus that functionally resembles achalasia due to the extent of the myotomy. Tumors up to 10 cm long can be enucleated without significant postoperative dysphagia as long as the mucosa is intact and the myotomy is reapproximated. If the myotomy is not reapproximated, a pseudodiverticulum may form leading to dysphagia. If the tumor is large and the mucosa is badly damaged during resection of the tumor, esophagectomy may be required if the mucosa cannot be satisfactorily repaired.

Postoperative esophageal leak is a serious complication that can arise due to mucosal injury that is missed or inadequately repaired during the initial operation. Routine use of intraoperative endoscopy with insufflation is recommended to safeguard against this potentially catastrophic complication. If a leak is detected and repaired at the time of the original operation, a soft drain, such as a Jackson-Pratt tube, is placed in the vicinity of the repair and the barium swallow is delayed for 5 to 7 days.

Difficulty in establishing a plane of dissection and performing the enucleation may be signs of leiomyosarcoma, which typically infiltrates the surrounding muscle. Frozen section biopsy of the enucleated tumor may suggest leiomyosarcoma if it is very cellular with a large number of mitotic figures, nuclear atypia, hemorrhage, and necrosis. However, as described earlier, the distinction of benign from malignant tumors may be very difficult even using permanent sections. If leiomyosarcoma is strongly suspected, then esophagectomy is the treatment of choice.

RESULTS

The surgical therapy of leiomyoma is safe and effective with low morbidity and mortality rates (0% to 1%). The majority of patients experience complete resolution of preoperative symptoms. Long-term results are also excellent with more than 90% of patients remaining asymptomatic 5 years later. Tumor recurrence after enucleation and diverticulum formation are extremely rare. Careful long-term follow-up is recommended because patients may develop gastroesophageal reflux that may require medication or antireflux repair.

GISTs

GISTs are the most common mesenchymal tumors of the gastrointestinal tract and are quite distinct from esophageal leiomyoma. GIST can arise anywhere in the gastrointestinal tract, but their most frequent location is the stomach (50%) or the small bowel (25%). Other locations include the colon (10%), omentum, retroperitoneum, and pelvis (10%). Esophageal GISTs are uncommon (<1% of 1,458 GISTs reported in the Surveillance Epidemiology and End Results database) but may be recognized as such more frequently since the development of immunohistochemistry techniques to detect KIT mutations. Because esophageal GISTs are uncommon and the majority arise at the gastroesophageal junction, a GIST located at the level of the thoracic esophagus is extremely rare.
GISTs most commonly result from activating mutations in one of two receptor protein tyrosine kinases: KIT (CD117) or platelet-derived growth factor receptor alpha (PDG-FRA). GISTs also share phenotypic characteristics with the interstitial pacemaker cells, known as interstitial cells of Cajal, and are thought to arise from a common precursor cell. These are innervated cells associated with Auerbach plexus that have autonomous pacemaker function and coordinate peristalsis throughout the gastrointestinal tract.

GIST can have substantial histologic variation (epithelioid, spindle cell, or mixed), and immunohistochemistry is often needed to verify the diagnosis. GIST can be positive for KIT (CD117, 95%), CD34 (60% to 70%) and other mesenchymal markers, such as smooth muscle actin (30% to 40%), desmin (≤5%), and S100 protein (5%). KIT is the most specific and sensitive marker but about 5% of GISTs are KIT-negative. DOG1 (discovered on GIST 1) is also a specific and sensitive marker for GIST and some GISTs are DOG1-positive and KIT-negative. Binding of ligand (stem cell factor) to mutated KIT results in activation of receptors and phosphorylation of several signaling substrates known to promote cell growth and survival. Imatinib, a small molecule with a structure similar to ATP, is a tyrosine kinase inhibitor (TKI) that binds competitively to the ATP binding sites of KIT resulting in inhibition of growth in GIST containing a KIT gene mutation.

Presentation and Diagnosis

Patients with esophageal GIST usually present with dysphagia and retrosternal discomfort or gastroesophageal reflux disease if the tumor is located near the lower esophageal sphincter (Fig. 29.13). Small clinically insignificant lesions may be found incidentally during endoscopy or on CT scan. GISTs range in size from tiny incidental tumors, measuring less than 10 mm in diameter to large tumors measuring more than 20 cm. Since all GISTs greater than 2 cm are considered malignant due to their potential for recurrence and metastatic disease, they should be resected. The management of incidentally encountered esophageal GIST smaller than 2 cm remains controversial. However, because not all intramural esophageal lesions are GISTs and the type of resection may differ from that of leiomyoma, a preoperative diagnosis should be obtained. Because the overlying esophageal mucosa is most commonly normal, conventional endoscopy with biopsy has suboptimal accuracy. Diagnosis of GIST is based on endoscopic ultrasound with fine needle aspiration to obtain material for immunohistochemical analysis for KIT mutations.
Prediction of prognosis in patients with GIST has been studied extensively. In intra-abdominal GIST, tumor size >5 cm, mitotic index >5 per 50 high-power fields, and small bowel origin correlate with risk of progressive disease. Data for esophageal GIST are too few to offer meaningful information but the behavior of esophageal GIST may be considered equal to their abdominal counterpart.

**TREATMENT**

Management guidelines for GIST have been defined by consensus of the National Comprehensive Cancer Network (NCCN), the Canadian Advisory Committee on GIST, and the European Society of Medical Oncology. As opposed to leiomyomas, GISTs are usually soft, fleshy, and fragile, and they should be handled with care to avoid tumor rupture (“no touch technique”). If the pseudocapsule is torn, bleeding and tumor seeding may ensue. The goal is complete gross resection with an intact pseudocapsule and negative microscopic margins. Treatment of esophageal GIST remains controversial because resection techniques in the esophagus are limited to enucleation or esophagectomy and segmental resections, as performed for gastric and small bowel GIST, are usually not technically feasible except for tumors located near the gastroesophageal junction. In most cases, esophagectomy with clear margins and with an intact pseudocapsule has been recommended although there are some reports of esophageal-sparing resections. The value of prophylactic lymphadenectomy has not been established and is not currently recommended.

Patients who present with esophageal GIST and metastatic disease should be considered for targeted therapy with a TKI such as imatinib. The value of adjuvant treatment with a TKI is uncertain. However, in a recent phase III randomized study of adjuvant imatinib therapy after surgical resection of c-kit-positive GIST, patients who received adjuvant therapy had significantly better recurrence-free survival 1 year after surgery than patients who received placebo (8% vs. 20%). The incidence of recurrence of esophageal GIST after resection was high in small series; therefore, adjuvant therapy should be considered in selected patients.

**RESULTS**

The current literature on esophageal GIST remains limited with fewer than 100 cases reported. Most series are from single institutions and include fewer than 10 patients each. The 5-year survival after diagnosis of esophageal GIST was 14% from the Surveillance Epidemiology and End Results database. Due to the possibility of recurrence and potential for metastatic disease, esophageal-sparing resection is only recommended for GISTs smaller than 5 cm. Larger lesions or involvement of the esophageal mucosa require esophagectomy.

**CONCLUSIONS**

**Esophageal Leiomyoma**

- Leiomyomas of the esophagus are rare and occur more frequently in the lower two-thirds of the esophagus.
- Although the majority of these tumors may be asymptomatic, all symptomatic tumors should be resected.
- Enucleation or shelling out of the tumor is the procedure of choice. This can be accomplished with very low incidence of complications and with excellent long-term functional outcomes.
GISTs

- Esophageal GIST is a rare tumor that may mimic a leiomyoma on imaging studies.
- A definitive diagnosis of GIST is established by immunohistochemistry on samples obtained by endoscopic ultrasound and fine needle aspiration.
- As opposed to leiomyomas, GISTs are unencapsulated, fragile tumors that may rupture if not handled with care. Small GIST (<2 cm) may be resected locally but esophagectomy is usually recommended to prevent recurrences for larger and/or symptomatic lesions.
- After surgical resection of GIST, adjuvant therapy with a c-kit inhibitor, such as imatinib, should be considered to decrease the likelihood of recurrence.

Recommended References and Readings

30 Resection of GIST and Leiomyoma: Thoracoscopic Approach
Ian Makey, Rodney J. Landreneau, and Michael Kent

Introduction

Leiomyomas (LMs) account for 70% of esophageal submucosal tumors. Other submucosal tumors of the esophagus include gastrointestinal stromal tumor (GIST), leiomyosarcoma, lipoma, fibroma, neurofibroma, schwannoma, granular cell tumor, glomus tumor, and carcinoid tumor. The focus of this chapter will be the thoracoscopic management of tumors that arise from the muscularis propria. These tumors include LMs, GISTs, and leiomyosarcomas.

LMs are benign tumors that show unequivocal smooth muscle differentiation by light microscopy. They were once thought to be the most common mesenchymal tumor of the GI tract, but that distinction now goes to GISTs. LMs stain for the smooth muscle markers actin and desmin but lack KIT mutations. A minority of esophageal LMs arise from the muscularis mucosa. These LMs tend to be polypoid and can be resected endoscopically.1 LMs that arise from the muscularis propria are well-circumscribed lobulated masses and occur most frequently in the lower third of the esophagus (Figs. 30.1 and 30.2).2

GISTs are spindle cell tumors that arise from the muscularis propria and are clinically indistinguishable from LMs1 (Fig. 30.3). Historically, GISTs were misclassified as either cellular LMs or leiomyosarcomas.3 Today they are defined by KIT (CD117) positivity or platelet-derived growth factor receptor alpha (PDGFRα) mutations.4 Some experts are reluctant to use the term “benign” for any GIST. Therefore, GISTs are risk stratified according to mitotic count and tumor size.5 The most common location of GISTs is the stomach (50% to 60%) followed by the small intestine (30% to 40%). Only 5% are located in the esophagus.6

Leiomyosarcomas are high-grade sarcomas that commonly have infiltrated into the surrounding tissue or metastasized by the time of diagnosis.1 Importantly, leiomyosarcomas do not develop from malignant degeneration of LMs.7 With the classification of GIST now based on immunohistochemistry, the reported incidence of leiomyosarcoma has dropped while that of GIST has risen.8
Incidence and Presentation of Leiomyoma

LMs have traditionally been thought of as very rare. Seremetis et al. stated that esophageal carcinoma is 50 times more common than LM. However, the incidence of LM varies greatly depending on the degree of inspection. Recent papers with detailed pathologic inspection have reported a much higher incidence of esophageal LM than previously thought. For example, in a study of 150 esophagectomy specimens, there was a 47% incidence of seedling (<7 mm) LM tumors and a 10% incidence of seedling GISTs. This would suggest that the incidence of LMs and GISTs is actually higher than carcinoma. This is relevant when considering the management of asymptomatic lesions 1 to 2 cm in size.

Most small esophageal submucosal tumors are asymptomatic, and are usually detected during routine upper endoscopy. When symptoms do occur, dysphagia and retrosternal discomfort are the two most common complaints.
There is a general consensus that esophageal LMs should be surgically removed in symptomatic patients. Most authors also advocate removal of lesions >5 cm in size, lesions that are enlarging, or those in which a definite diagnosis cannot be obtained by biopsy.\textsuperscript{11} There is some controversy regarding the need for surgery in asymptomatic patients. Many surgeons believe that asymptomatic patients with small, well-encapsulated LMs <5 cm in size can be observed.\textsuperscript{12} Reports of malignant degeneration have been vanishingly rare and are probably due to misdiagnosis.\textsuperscript{7} Other surgeons advocate resection of all lesions.

A barium esophagram may be the only diagnostic study needed for classic esophageal LMs that are symptomatic and easily resectable. If additional information is needed, an endoscopic ultrasound (EUS) is the best imaging procedure to further characterize submucosal tumors of the esophagus. The differential diagnosis of submucosal tumors can be narrowed based on the sonographic layer of origin, the echo pattern, and the margins of the lesion. LMs, GISTs, and leiomyosarcomas originate from the fourth sonographic layer (muscularis propria). LMs appear hypoechoic, well-circumscribed, and homogeneous. At the other end of the spectrum, leiomyosarcomas appear heterogeneous with irregular margins. Although LMs and leiomyosarcomas appear quite different, GISTs can have features of both and therefore, cannot be reliably distinguished by EUS.\textsuperscript{13}

The threshold to biopsy submucosal tumors should be fairly low. Landi and Palazzo\textsuperscript{13} recommended a histologic diagnosis whenever possible. For tumors arising from the muscularis propria, <2 cm in size, and with smooth borders, the overwhelming majority will be LMs\textsuperscript{14} and a biopsy may be omitted.

For lesions 2 to 5 cm in size, the decision to biopsy is predicated on the decision to resect or not. If resection is planned, then a biopsy can be deferred. If surveillance is the planned course of action, then biopsy is recommended to rule out a GIST.
One concern of obtaining an endoscopic biopsy is that scarring between the tumor and the submucosa will lead to a higher rate of mucosal perforation during resection. However, more recently, surgeons have noted that fine-needle aspirations (FNAs) done prior to surgical extirpation do not lead to any significant dissection difficulties. Most authors advocate FNA if EUS shows a tumor with irregular borders or that is not confined to the muscularis propria. Because there is significant overlap in size, growth rate, and EUS appearance between benign and malignant tumors, some authors set a low threshold to obtain biopsies. For example, Blum recommends EUS–FNA for submucosal tumors larger than 2 cm, those that are enlarging on serial examination, or those with activity on PET scan. On the other hand, Lee et al. defer preoperative biopsy of well-encapsulated tumors confined to the muscularis propria up to 5 cm. For submucosal tumors larger than 5 cm, most authors advocate preoperative biopsy. At this size, the likelihood of GIST or leiomyosarcoma is higher. Moreover, 5 cm is the size at which GISTs move into the intermediate risk category despite the mitotic count. For GISTs 5 cm or larger, the preoperative biopsy may determine the decision to enucleate versus perform an esophagectomy.

The accuracy of EUS-guided or EUS-assisted needle biopsy is based on studies analyzing gastric GISTs. The average diagnostic yield for FNA was 67%. The average diagnostic yield for fine needle biopsy or true-cut biopsy was 91%. Forceps biopsy should be avoided.

In our experience of 20 patients with submucosal tumors, 15 of the 20 (75%) were leiomyomas and 3 were GISTs (15%). There were 12 tumors ≤5 cm of which 2 were GISTs. In a large series of GISTs, leiomyomas, and leiomyosarcomas, GISTs (17/68 tumors, 25%) ranged from 2.6 to 25 cm in maximum diameter (median: 8 cm). The leiomyomas (48/68 tumors, 71%) ranged from 1 to 18 cm in maximum diameter with a median maximum diameter of 5 cm.

### General Principles

The approach to the upper and middle esophagus is through a right thoracotomy or right video-assisted thoracoscopic surgery (VATS). The traditional approach to the lower third of the esophagus is through a left thoracotomy. With the application of minimally invasive techniques, the lower third of the esophagus can be approached from the right chest, left chest, or abdomen. The surgeon’s experience should dictate the approach to the lower esophagus rather than the laterality of the tumor. Surgeons with minimally invasive experience have approached tumors of the lower esophagus via a right VATS or left VATS. Laparoscopy provides excellent visualization and exposure for tumors in the distal thoracic esophagus, intra-abdominal esophagus or gastroesophageal junction. This approach permits fundoplication in the event of extensive myotomy.

### Right VATS Technique

The patient is intubated with a double-lumen tube. Endoscopy is performed to confirm the location of the tumor. Knowing the precise location of the tumor is critical for tumors in the upper esophagus because access via a VATS approach can be an issue if the tumor is less than 20 cm from the incisors. Very high tumors may need to be excised via a cervical incision approach.

For mid-to-lower esophageal tumors, we place a camera port in the eighth intercostal space, at the mid-axillary line. A 5-mm port is placed at the eighth or ninth intercostal space, posterior to the posterior axillary line, for the autosonic shears (Covidien), harmonic scalpel (Ethicon), or other energy device. A 5-mm port is placed in the anterior axillary line at the fourth intercostal space to retract the lung anteriorly. The last 5-mm port is placed just posterior to the tip of the scapula and is used for retraction and countertraction by the surgeon. The surgeon stands at the back of the patient; the assistant with the camera and retractor stands at the front.
Often, the diaphragm may prevent adequate exposure of tumors in the distal esophagus. In this case, a suture is placed through the central tendon of the diaphragm and pulled out through the chest wall using a fascial closure device. In this way, the diaphragm is retracted caudally without the need for an assistant. The inferior pulmonary ligament is then divided using the harmonic scissors to completely mobilize the lung from the esophagus. If the tumor is not immediately visible, the flexible esophagoscopy can be placed adjacent to the tumor to delineate its location. In some cases, a 54-French bougie is placed to accentuate the location of the tumor and facilitate dissection.

Next, the pleura that overlies the esophagus is divided. If necessary, the esophagus can be circumferentially mobilized for exposure of the tumor (Fig. 30.4). A Penrose drain is then placed around the esophagus, and if necessary, the esophagus can be rotated to some degree so the tumor is visible. A longitudinal myotomy is then performed over the tumor, taking care to preserve the main vagal trunks (Fig. 30.5).
plane between the tumor, muscularis propria, and underlying submucosa is developed. To avoid grasping and fragmenting the tumor, it is useful to place a retracting suture in the tumor itself (Fig. 30.6). Opposing tension will help develop the proper dissection plane between the tumor and the esophageal submucosa. The tumor is enucleated by a combination of dissection and gentle pushing away of the mucosa from the tumor surface. Care should be taken to avoid mucosal injury. Next the specimen is placed in a retrieval bag and removed. The integrity of the mucosa is then inspected with the endoscope by submerging the esophagus underwater and insufflating the lumen with air. If a small leak is identified, it is repaired primarily. The longitudinal muscle layer is then re-approximated using sutures (Fig. 30.7). The ports are closed in a standard

Figure 30.6 Dissecting tumor away from the submucosa.

Figure 30.7 Closure of myotomy.
fashion, and a 28-French chest tube is placed. If there is any concern that the dissection was difficult and the mucosa may subsequently leak, we place a Jackson-Pratt (JP) drain along the muscle closure line until the patient resumes oral intake. If no leak is observed after several days of oral intake, we remove the drain.

POSTOPERATIVE MANAGEMENT

The chest tube is removed the day after surgery after the barium swallow has been reviewed. The JP drain is removed after a period of observation on an oral diet. We do not routinely place a nasogastric tube.

COMPLICATIONS

The complications of VATS enucleation are the same as for enucleation performed through a thoracotomy.

- **Leak:** Bilious drainage from the chest tube will be an early sign of an esophageal leak. A leak from enucleation may be due to a missed injury or a delayed ischemic insult due to trauma from the dissection. The techniques described above should help identify mucosal injuries at the time of the initial operation. Although a leak is rare, if it occurs and is a small, contained leak that is completely drained by the JP drain, one may observe carefully and then subsequently slowly remove the drain over the next few weeks. If there is a significant leak that is not fully contained or drained, we recommend taking the patient promptly to the operating room for primary repair in most cases.

- **Gastroesophageal reflux:** Enucleating tumors at or near the GE junction may lead to new onset GERD or exacerbate pre-existing GERD symptoms. This is likely due to damage to the lower esophageal sphincter during the enucleation. The decision to perform an antireflux operation at the time of an enucleation should be made preoperatively but ultimately it may need to be made intraoperatively.

RESULTS

VATS enucleation of LMs appears to be the technique of choice for most authors. Von Rahden et al. recommended it be the standard procedure. They found that VATS enucleation reduced pulmonary complications, hospital stay (4.1 days), and postoperative wound-related pain. Bonavina et al. and Kent et al. also found that hospital stay was shorter compared with open enucleation by 3.4 days and 2.75 days, respectively.

Management of Esophageal GISTs

The optimal management of esophageal GISTs is unknown because of their rarity. In the SEER database, 45% of patients with esophageal GISTs presented with localized disease while another 45% had regional or metastatic disease. The National Comprehensive Cancer Network (NCCN) guidelines recommend complete resection of all GISTs >2 cm. No specific guidelines were offered for incidentally encountered GISTs <2 cm in size. Otani et al. reported excellent results using nonoperative management and surveillance of gastric GISTs <2 cm in size.

NCCN guidelines do not make specific recommendations regarding the role of enucleation versus esophagectomy for esophageal GISTs. Regardless of the operative approach, complete microscopic resection and avoidance of tumor rupture should be achieved. Certainly esophagectomy carries the potential for significant morbidity and
should be avoided if enucleation is feasible. Lee et al.\(^{17}\) suggest consideration of esophagectomy if the GIST has features such as size >5 cm, mucosal involvement, or involvement at the GE junction. Patients with tumors >10 cm and with a high mitotic count should undergo esophagectomy.

There is no evidence that patients treated with enucleation who have a microscopic-positive margin (R1 resection) should undergo re-excision. An analysis of the American College of Surgeons Oncology Group Z9000 and Z9001 trials showed that there was no difference in recurrence-free survival in those patients who underwent a complete (R0) versus those who underwent an R1 resection.\(^{21}\) NCCN guidelines recommend imatinib therapy for patients who have persistent gross residual disease (R2 resection) or patients with completely resected GISTs who have an intermediate-to-high risk of recurrence.\(^{22}\) As mentioned previously, the most useful predictors of malignant behavior in GISTs are size and mitotic count. Joensuu et al.\(^{23}\) analyzed the recurrence-free survival of resected GISTs. Esophageal GISTs (\(n = 8\)) had similar recurrence-free survival as intestinal GISTs (60% at 5 years). An additional finding by Joensuu et al. relevant to VATS enucleation was that tumor rupture was an independent adverse prognostic factor. Conversion from VATS to open enucleation should be performed if it will help delineate dissection planes or prevent tumor rupture. Lymphadenectomy is unnecessary because lymph node metastases are rare with GIST.

GISTs have an unpredictable behavior and long-term follow-up is essential for all patients, independent of their tumors’ benign or malignant characteristics. According to the NCCN guidelines, contrast CT is recommended every 3 to 6 months for 3 to 5 years and then yearly. Flexible upper endoscopy is performed at 6 months and 1 year postoperatively and then annually for 2 years.\(^{4}\)

There is less agreement in the literature regarding the optimal resection technique for GISTs. Table 30.1 is a list of all the series published in English with more than one GIST resection and with the method of resection and tumor size reported for each patient. From these five series, there were 137 esophageal resections and a total of 26 GISTs. More than half of the GISTs (17/26, 65%) were enucleated. The average size of enucleated GISTs was 6 cm. The follow-up varied but there was only one recurrence for a recurrence rate of 5.9% in the enucleation group. Nine of the GISTs (35%) were resected with the full thickness of the esophageal wall or via an esophagectomy. The average size of GISTs resected in this manner was 11 cm. There were seven recurrences for a recurrence rate of 78% in the full-thickness/esophagectomy group. The difference in recurrence rate most likely reflects the nature of the disease rather than therapeutic efficacy. This limited data does suggest that enucleation is an effective resection technique for GISTs <5 cm.

The largest series of resected esophageal GISTs is by Miettinen. Of the 17 GISTs, 10 were enucleated and 7 were removed by esophagectomy or full-thickness resection. The average follow-up was 53.5 months and there were nine recurrences. The median survival for the patients with recurrences was 29 months and all died of their disease. Although individual tumor size was not detailed, all patients with tumors larger than 10 cm died of disease, whereas none of the patients with tumors smaller than 5 cm died of disease.\(^{19}\)

<table>
<thead>
<tr>
<th>Series</th>
<th>GIST (No.)</th>
<th>Enucleation</th>
<th>Size (cm)</th>
<th>Follow-up (mos)</th>
<th>Recurrence</th>
<th>Esophagectomy/Full-thickness Resection</th>
<th>Tumor Size</th>
<th>Follow-up (mos)</th>
<th>Recurrence</th>
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<td>Blum(^4)</td>
<td>4</td>
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<td>6.85</td>
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<td>1</td>
</tr>
<tr>
<td>Von Rahden(^16)</td>
<td>4</td>
<td>4</td>
<td>4.8</td>
<td>&gt;3</td>
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<td>n/a</td>
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<td>Kent(^18)</td>
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<td>3</td>
<td>n/a</td>
<td>6</td>
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<td>n/a</td>
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<td>Lee(^17)</td>
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<td>n/a</td>
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<td>0</td>
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<td>n/a</td>
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<td>Jiang(^24)</td>
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<tr>
<td>Total</td>
<td>26</td>
<td>17 (65%)</td>
<td>6</td>
<td>44.6</td>
<td>1 (5.9%)</td>
<td>9 (35%)</td>
<td>11</td>
<td>54</td>
<td>7 (78%)</td>
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</table>
CONCLUSIONS

- LMs, GISTs, and leiomyosarcomas are submucosal tumors that arise from the muscularis propria. The overwhelming majority of oesophageal submucosal tumors will be LMs.
- For routine submucosal tumors < 5 cm that are asymptomatic and easily resectable, a barium esophagram is our diagnostic procedure of choice.
- For more complex submucosal tumors or high-risk lesions or those more difficult to resect, we recommend EUS to further characterize the tumor and a biopsy should be considered for larger tumors or those with malignant characteristics on EUS.
- Pathologic differentiation of GISTs, LMs, and leiomyosarcomas must be performed using immunohistochemistry and, therefore, cannot be verified in frozen section analysis.
- Asymptomatic LMs < 5 cm in size can be managed nonoperatively, but patients should undergo routine radiographic or endoscopic surveillance.
- Management of esophageal GISTs < 2 cm in size is controversial because data is limited. GISTs > 2 cm in size should be resected.
- With the application of minimally invasive techniques, the lower third of the esophagus can be approached from the right VATS, left VATS, or for very low tumors, laparoscopically. The tumor location and surgeon’s experience should dictate the approach.
- Localized small GISTs should be resected with an intact pseudocapsule and negative microscopic margins. If this is not possible via enucleation, then an esophagectomy should be performed. In some cases of GE junction GISTs, a wedge resection of the gastric cardia with a negative margin may be adequate.

Recommended References and Readings

Esophageal Radiofrequency Ablation for the Treatment of Barrett’s Esophagus with and without Dysplasia

Felix G. Fernandez and Seth D. Force

Introduction

Barrett’s Esophagus (BE) is defined as the replacement of the normal esophageal squamous epithelium with columnar epithelium, also known as intestinal metaplasia (IM). Historically BE has been categorized according to endoscopic extent, short segment (<3 cm) versus long segment (>3 cm), but often there can be discontinuous segments of columnar mucosa or even abnormal mucosa that is not readily apparent with conventional endoscopy. The incidence of BE reported in the literature ranges from 1.6% to 6.8%.1–3 This is of importance, because the presence of BE is considered to carry a 50 to 100 times increased risk for the development of esophageal carcinoma. The true cancer risk is unknown but it has been estimated that 1 out of every 200 persons with BE will develop esophageal cancer over their lifetime.4

Concerns for the development of progressive grades of dysplasia and invasive cancer in patients with BE has led to recommendations for lifelong serial endoscopic surveillance and biopsies. More recently, ablative techniques, including photodynamic therapy (PDT), endoscopic mucosal resection (EMR), cryotherapy, and radiofrequency ablation (RFA), have been studied for the preventative removal of metaplastic and dysplastic esophageal mucosa. However, some of these therapies can be associated with significant cost and morbidity. PDT is associated with postprocedure photosensitivity that lasts 6 to 8 weeks (or even longer in some patients) and strictures in up to 36% of patients following one or two treatments.5 EMR is associated with a low incidence of perforation and postprocedure stricture formation. Generally, it is not possible to perform circumferential mucosal resection. EMR also has a significant learning curve and is usually reserved for visible mucosal lesions (nodules) and for histologic staging of these abnormalities. Cryotherapy is relatively new and available data on its efficacy and indications are sparse.
RFA devices generate an alternating electrical current to create thermal energy that when applied directly to tissue leads to controlled tissue injury by way of water vaporization, coagulation of proteins, and cell necrosis. There are a number of advantages of RFA over other ablative modalities. One is that the desiccated tissue, which has a greater resistance to current than normal tissues, can act as an insulator that controls ablation depth. In addition, RFA devices also allow circumferential treatment or focal treatment, and RFA is relatively easy to learn and perform compared with other ablative techniques. This chapter reviews the current indications, technique, clinical results, and recommendations for RFA.

INDICATIONS/CONTRAINDICATIONS

Indications

- High-grade dysplasia (HGD): Recent reports have shown superior results of RFA compared with surveillance alone, and RFA is associated with significantly less morbidity than esophagectomy.
- Low-grade dysplasia (LGD): Good success rates are reported in the literature; however, the natural course of LGD in BE is uncertain, and therefore surveillance is also an appropriate strategy.
- Non-dysplastic BE: Most controversial indication for RFA because the risk of progression to cancer in these patients is small. Good results with RFA for BE have been reported in the literature.

Contraindications

- Pregnancy.
- Prior radiation therapy to the esophagus.
- Esophageal varices.
- Prior Heller myotomy.
- Nodular or ulcerated BE: Nodular or ulcerated areas in BE must undergo EMR to rule out carcinoma.
- Esophageal adenocarcinoma: Standard management for esophageal cancer remains esophagectomy. For intramucosal carcinomas, endoscopic resection followed by RFA of residual BE is becoming a viable option.
- BE or dysplasia in the setting of a known stricture is a relative contraindication.

PREOPERATIVE PLANNING

All patients should undergo a preoperative endoscopy with biopsy and identification of the type and extent of BE and/or dysplasia. This allows for proper planning for the procedure, such as the need for multiple initial treatments for longer lesions or consideration of the presence of a hiatal hernia when selecting a sizing balloon. Patients should be maintained on proton pump inhibitor (PPI) therapy and should not eat or drink the evening prior to the procedure.

SURGERY

RFA Device

In 2000, the BARRX corporation (Sunnyvale, CA) introduced the HALO 360 RFA device, which received FDA approval for clinical use in 2001 (Fig. 31.1). The HALO 360 is a pneumatic balloon that is connected to a computerized energy source. The balloon-based
ablation catheter contains a microelectrode array, encircling a balloon, that is capable of delivering radiofrequency energy. The array is composed of 60 tightly spaced, bipolar electrodes that circumferentially surround the balloon and cover a length of 3 cm. The energy source calculates the optimal RFA balloon size, utilizing a computer-controlled balloon sizer (Fig. 31.2 A,B). It then distributes energy through the electrode on the RFA balloon. Ten to twelve J/cm² are delivered in a 360-degree radius over the length of the 3-cm electrode allowing for a treatment depth of 1,000 microns. This depth is critical to ensure complete treatment of the BE, which has been measured at 500 microns, while avoiding deeper tissue destruction, which could lead to perforation or strictures.6 A second RFA catheter, the HALO 90, was introduced by BARRX in 2006. This catheter is affixed to the end of an endoscope and delivers the same amount of energy as the HALO 360 but confined to a 90-degree radius. This allows for treatment of non-circumferential BE without treating adjacent, normal, esophageal mucosa (Fig. 31.3).

RFA Procedure

Ablation procedures may be performed under conscious sedation or general anesthesia in an outpatient setting. The procedure begins with an esophagoscopy to carefully identify the location and length of the IM or dysplasia. N-acetylcysteine (1%) is then injected through the endoscope to remove mucus from the mucosa to improve the contact of the electrodes with the tissue. A stiff guidewire (e.g., Amplatz extra stiff 0.035-inch; Cook Europe, Bjaeverskov, Denmark) is then placed through the endoscope into the stomach and the scope is removed. A sizing catheter, with a 4-cm long balloon at its distal end, is placed over the guidewire to measure the diameter of the esophagus. This is performed as a blind procedure using the 1-cm scale on the catheter shaft for reference, and measurements are begun with the catheter positioned 5 cm above the proximal extent of the IM. The sizing balloon is inflated by the HALO 360 energy generator, and the mean esophageal diameter is automatically calculated for the entire length of the 4-cm balloon. Measurement is then repeated for every centimeter of the targeted portion of the esophagus. Once this has been done, an appropriately sized RFA balloon can be chosen (22, 25, 28, 31, or 34 mm). The balloon may oversize the esophagus in patients with large hiatal hernias, and in these patients, the operator should choose the average or smaller balloon size to prevent esophageal injury.
The RFA catheter is then placed over the guidewire, positioned at the level of the abnormal mucosa and the endoscope is placed down the esophagus next to the RFA catheter (Fig. 31.4). The RFA balloon is inflated and energy is delivered by stepping on a foot pedal control, while simultaneously, suction is applied on the endoscope to ensure good contact between the IM/dysplasia and the electrode. The electrode is advanced in 3 cm increments until the entire length of the targeted tissue has been ablated (Fig. 31.5). The RFA catheter is then removed and cleaned to clear the sloughed mucosa off of the electrode. A soft plastic cap is attached to the endoscope and used to debride all coagulative debris away from the treated area to prepare the area for a second treatment. A second treatment is then performed. For ablation of IM, 10 J/cm² is used, and 12 J/cm² is used for ablation of dysplastic tissue. The length of treatment for a single session should be limited to 6 cm to decrease the chance of stricture formation.

At a minimum of 8 weeks after the first circumferential ablation, patients are rescheduled for a second ablation. Localized IM found on subsequent surveillance endoscopy can be treated with the HALO 90 catheter. Focal ablation, delivered with the HALO 90 system, is performed by placing the endoscope-mounted electrode in contact with the target epithelium by deflecting the tip of the endoscope upward, flatly opposing the electrode to the esophageal wall (Fig. 31.6). Energy is delivered twice to the ablation target. After the first application, the endoscope is removed, the device is cleaned, and the procedure is repeated. This results in a total of four treatments to each
area. Ablation can be repeated every 2 to 3 months until all IM has been eradicated visually and eradication confirmed histologically.

**POSTOPERATIVE MANAGEMENT**

Almost all patients experience some chest discomfort, sore throat, difficulty or pain with swallowing, and/or nausea after therapy. This may be treated with viscous lidocaine, liquid acetaminophen with or without codeine, and antiemetics. Antisecretory therapy with PPIs is continued before and after the procedure to minimize discomfort.

![Figure 31.5 Esophagoscopy revealing the ablation zone.](image1)

![Figure 31.6 Focal ablation with endoscope-mounted HALO 90 RFA system.](image2)
and allow the esophagus to heal and regenerate with squamous epithelium. Patients are placed on a liquid diet for 24 hours after the procedure and may then gradually advance their diet as tolerated. In absence of long-term follow-up data for RFA, it is advised that patients undergo endoscopy 2 and 6 months after the last treatment and then annually.

**COMPLICATIONS**

The most common postprocedural complication is chest discomfort, which in severe cases may be accompanied by fever. The rate of stricture formation after RFA ranged from 0% to 6% in most large studies. Perforation of the esophagus and the development of significant bleeding after RFA are both rare events. Finally, the development of BE underneath the neosquamous epithelium has been rarely reported.

**RESULTS**

Multiple clinical trials have shown RFA to be safe and effective for treating IM and dysplasia. The ablation of intestinal metaplasia (AIM) trial included 100 patients, from eight different centers, who underwent circumferential RFA for BE. The study was separated into two phases, AIM-I and AIM-II. The AIM-I trial determined that 10 J/cm² was the optimal RFA dose for treating BE; the AIM-II trial enrolled 70 patients who were treated at this optimal dose. One-year results showed a 70% complete response rate and 25% partial response rate. Sixty-two patients required a second ablation for residual BE. There were no strictures or buried glandular mucosa found in any of the patients. The authors cited possible causes for significant residual BE as: Imperfect balloon sizing (the study was conducted before the advent of the computerized sizer), failure to clean the electrode between ablations, and the use of acetic acid instead of 1% N-acetylcysteine to remove mucus covering the esophageal mucosa.

Three recent studies have focused on the use of RFA in patients with dysplasia in the setting of BE. Sharma et al. evaluated 24 patients with BE/HGD and 39 patients BE/LGD who underwent a protocol of stepwise progressive ablation until complete remission of BE was achieved. Results at 18 months showed an 89% complete response rate for dysplasia (95% for LGD, 79% for HGD) and a 79% complete response rate for BE. Ganz et al. evaluated 142 patients who underwent RFA, at 12 J/cm², for BE in the setting of BE. Twenty-four patients underwent EMR prior to RFA and two patients underwent esophagectomy after their initial 3-month endoscopy. Results at 1 year were available for 92 patients; and showed 90% of patients with no evidence of HGD, 80% of patients with no evidence of any dysplasia and 54% of patients with no evidence of BE. Subgroup analysis showed no difference in response rates between patients who underwent pre-RFA EMR as compared with patients who were treated with RFA alone. The authors cited failure to clean the electrode between RFA treatments and not using the HALO 90 to treat isolated, non-circumferential lesions, as possible reasons for the lower-than-expected complete response rates for RFA treatment of BE.

Shaheen et al. recently reported their AIM Dysplasia trial data, which was a 19-center, randomized trial comparing RFA + PPI + surveillance versus sham endoscopy + PPI + surveillance for patients with LGD or HGD. The study randomized 127 patients with dysplasia in a 2:1 ratio of RFA to sham. It must be noted that patients with nodular BE or BE length greater than 8 cm were excluded from the trial. Complete response rates in the RFA group were 92% for dysplasia and 83% for metaplasia. In comparison, the complete response rates in the sham RFA group were significantly lower (23% for dysplasia [p < 0.001] and 3% for metaplasia [p < 0.001]). The rate of progression to worsening dysplasia or invasive cancer was also lower in the RFA treatment group compared with PPI and surveillance alone. However, in HGD patients treated with RFA, 19% had persistent dysplasia, 26% had persistent BE/IM.
Chapter 31  Esophageal Radiofrequency Ablation for the Treatment of Barrett's Esophagus with and without Dysplasia

Predictors of response to RFA included shorter length of BE, lower BMI, and shorter history of dysplasia.

In an interesting study, DeMeester et al. performed a retrospective comparison of endoscopic treatment for early esophageal neoplasia \( (n = 40, \text{HGD in 22 and T1a intramucosal in 18}) \) versus esophagectomy \( (n = 61; \text{HGD in 13 and T1a intramucosal cancer in 48}) \). In this series of 40 patients treated with endoscopic intervention, a median of 3 ablations per patient were performed for a total of 102 EMRs and 79 mucosal ablations primarily using RFA. The duration of follow-up was significantly longer in the esophagectomy group (34 months vs. 17 months for endotherapy). There was no mortality in either group, and morbidity was lower in the endoscopic group. Local failure after endoscopic treatment was higher, and a new or metachronous lesion developed in 20% \( (n = 8) \) of patients who underwent endoscopic therapy, but none who underwent esophagectomy. In the endoscopic group, 58% had eradication of all BE after multiple treatments. Esophagectomy eradicated BE in all patients and none of the patients who underwent esophagectomy developed BE in the remnant cervical esophagus. An antireflux procedure after control of dysplasia was performed in eight patients in the endoscopic group.

Among the T1a cancer patients treated with endotherapy \( (n = 18) \), 3 (18%) developed metachronous cancer. Ultimately one patient in this group underwent esophagectomy. Among the HGD patients \( (n = 22) \) treated with endotherapy, 2 (10%) later underwent esophagectomy for HGD, and one died of an unrelated cause. Of the remaining 19 patients, progression to cancer occurred in 26% \( (n = 5) \) of patients. All of these patients were treated with endotherapy, one with submucosal invasion declined surgery. With treatment of local failure, there were no differences overall or cancer-specific survival in between the groups. The authors recommended repeated endoscopic therapy every 2 months until all BE is eradicated.

DeMeester et al. also highlighted factors to consider in selection of treatment including tumor-related factors (e.g., length of BE and whether all BE can be eliminated), esophageal factors (e.g., end-stage esophageal dysfunction) and patient factors (e.g., the willingness and ability for close follow-up, recognition that the endoscopic therapy may fail, the ability to live with the uncertainty of complete disease eradication). The authors also emphasized that failure to carefully monitor and aggressively eradicate all BE with repeated endoscopic therapies could potentially result in recurrent disease and advanced cancer. Previous systematic reviews of esophagectomy for HGD have shown a mean incidence of invasive esophageal cancer in 41% (range, 18% to 75%) of patients.\(^1\) It is important that the risks and benefits of all options, including esophagectomy (with potential lower morbidity with MIE and vagal-sparing approaches), be discussed with the patient, and so that he or she can make an informed decision.

**Surveillance After RFA**

Currently, there are no published guidelines on short- or long-term follow-up for patients who have undergone esophageal RFA for IM, LGD, or HGD. Most recommendations are modifications of surveillance protocols for patients who have not undergone treatment for their IM or dysplastic tissue. DeMeester et al. used the following surveillance for patients with HGD in their study comparing RFA with esophagectomy for patients with HGD and intramucosal carcinoma: Endoscopy and biopsy every 3 months for 1 year with no evidence of abnormal mucosa, followed by every 6 months for a year and then annually, provided that there was no recurrence of IM or dysplasia.\(^2\) Standardization of surveillance practices will be an important topic, as RFA becomes a more common treatment approach for patients with dysplastic esophageal mucosa.
Part V  Endoscopic Ablative Therapies and Resection

CONCLUSIONS

Historically, non-dysplastic BE and LGD have been treated by surveillance endoscopy, antisecretory medicines, and antireflux procedures, and HGD was treated with esophagectomy. Recently, ablative techniques, such as RFA, are being used with encouraging short-term results for these indications. Prior to RFA, ablative procedures such as PDT or other laser treatments existed for BE, but many of these carried significant morbidity, were operator dependent, and had varying results. The advent of esophageal RFA has provided an easily reproducible procedure for treating BE with and without dysplasia. Short-term results from multiple studies have shown reasonable complete response rates, on the order of 70% for IM and higher for LGD and HGD with low morbidity rates. However, most of these studies excluded patients at higher risk for complications or progression. For example, patients with nodular BE and BE length greater than 8 cm were excluded from the Shaheen RFA trial and other RFA trials. In the DeMeester study\textsuperscript{12} comparing RFA and esophagectomy for HGD, it was noted that with close follow-up, recurrent cancer occurs in up to 20% of patients who undergo RFA even during a short follow-up (median, 17 months). This significant failure rate occurred even at a very specialized center with exceptional follow-up. In this particular study, RFA failure was recognized in a timely fashion and patients underwent esophagectomy with good results, but other less experienced centers may not be capable of duplicating these results. In spite of these concerns and without controlled trials or long-term follow-up of RFA, this technology has begun to cause a paradigm shift with respect to the recommended treatment for esophageal mucosal abnormalities. The American Gastroenterological Association recently released a position statement recommending endoscopic treatment (RFA, EMR, or PDT) for patients with HGD and possibly for patients with LGD and high-risk patients with BE.\textsuperscript{13} Current recommendations, however, still do not recommend the routine use of RFA for BE in the absence of dysplasia in the general population, over routine surveillance endoscopy and biopsy.

Given the short-term follow-up of RFA for HGD and the known failure rates, we recommend that a number of variables should be considered before treatment. For example, is the HGD multi-focal or nodular? What is the experience level of the endoscopist doing the biopsies and the pathologist reading the slides? What is the length of BE and the functional status of the esophagus? What is the age of the patient and are they reliable and willing to undergo repeated lifetime surveillance and frequently additional ablations? In some of these higher-risk patients, especially in younger patients and in patients otherwise fit for surgery, minimally invasive esophagectomy should be considered and at a minimum discussed with the patient and family. Recently, mortality rates following minimally invasive esophagectomy or open esophagectomy in experienced centers are approaching 1% with good quality of life in the majority of patients.\textsuperscript{14}

Also, it is important to note that not all clinicians are skilled enough or have the expertise and tools to rule out coexisting cancers in the setting of a biopsy of HGD. Previous studies have shown that invasive cancers were missed in a significant proportion of patients diagnosed with HGD who subsequently underwent esophagectomy. Thus, it is clear that if a patient is undergoing non-surgical ablation for HGD, ablation should be performed by individuals with significant expertise in the recognition and management of BE. Physicians and patients need to understand that RFA for HGD requires a very careful initial diagnosis and clear education about the follow-up, the need for repeated endoscopies and repeated RFA, and the unknown risk of developing an occult progressive invasive cancer during long-term follow-up.

We currently await long-term data assessing the durability of RFA treatment and answers to questions such as: Should all patients with IM be treated with RFA and how long do we need to perform surveillance endoscopy on patients after RFA? Low morbidity rates, a short learning curve, and good interim results have made RFA an excellent option for patients with HGD and possibly LGD. Concerns will remain about using RFA for HGD for fear of incompletely treating an unrecognized invasive cancer or developing an invasive cancer during follow-up.
Chapter 31 Esophageal Radiofrequency Ablation for the Treatment of Barrett’s Esophagus with and without Dysplasia

Recommended References and Readings


Photodynamic Therapy, Lasers, and Cryotherapy for Esophageal Neoplasia

Virginia R. Litle and Mary S. Maish

32

Introduction

Endoscopic modalities for treatment of esophageal neoplasia have evolved from thermal ablation with argon plasma coagulation (APC) and neodymium: yttrium-aluminum garnet (Nd:YAG) lasers to photodynamic therapy (PDT), and the newest technique cryotherapy.1–4 Other endoscopic modalities to treat Barrett’s metaplasia, high-grade dysplasia (HGD), and some early-stage cancers in medically inoperable patients include radiofrequency ablation (RFA) and endoscopic mucosal resection, and these are discussed in other chapters. While surgical resection is the standard treatment for resectable esophageal cancer, endoscopic approaches are particularly applicable in high-risk patients.5 In this chapter, we discuss PDT, lasers and cryotherapy in the treatment of early esophageal neoplasia.

Photodynamic Therapy

PDT requires a photosensitizer that can accumulate in tumor tissue. The most widely used and studied photosensitizer is porfimer sodium (Photofrin; Pinnacle Biologics Inc., Bannockburn, IL). Porfimer sodium achieves an excited state after exposure to 630-nm wavelength light, the absorption maxima of porfimer sodium, which then leads to reaction with oxygen to generate singlet oxygen and other reactive oxygen species.6–9 The 630-nm wavelength of light leads to a penetration depth of 5 to 6 mm.9 The reactive oxygen species cause damage, leading to disruption of multiple intracellular processes that eventually result in cellular apoptosis, necrosis, ischemia, inflammation, and immune responses.7 Other photosensitizers that have been utilized include 5-aminolevulinic acid (ALA); however, this compound is not approved for use in the United States. Administration of ALA results in the production of protoporphyrin IX (PpIX), a photoactive compound, that is activated when exposed to red light at 630 nm. PpIX is selectively produced by the esophageal mucosa, in comparison to the muscularis, which may lead to a lower rate of strictures.7,10
Laser Therapy

Nd:YAG and potassium-titanyl-phosphate (KTP):YAG lasers have been studied in the treatment of Barrett’s esophagus (BE). Nd:YAG laser has been used as an adjuvant to PDT in the ablation of BE.\textsuperscript{7,12} Argon gas (plasma) is used in APC, and this conveys electrical energy to tissue, resulting in thermal destruction. As the tissue is burnt, it dries, decreasing further conduction, which limits the depth of injury. It is an easy-to-use technique and has been studied extensively for the ablation of BE.\textsuperscript{7,11–13} The coagulation depth is generally in the range of 1 to 3 mm.

Cryotherapy

During cryotherapy, freeze cycles are mediated by nitrogen (liquid or gas), carbon dioxide gas, or argon gas systems. Rapid cooling leads to disruption of enzyme and cell membrane function, and ongoing crystallization with prolonged cooling perpetuates this damage. In addition, hypertonicity is caused by ice formation in the extracellular matrix and leads to intracellular dehydration via osmotic efflux of water from the cell. With thawing, rapid intracellular return of water induces cell lysis.\textsuperscript{14} Multiple freeze/thaw cycles are generally applied to achieve tumor destruction.

INDICATIONS/CONTRAINDICATIONS

The indications for PDT, laser and cryotherapy range from ablation of superficial early cancers in high-risk patients to palliative treatment of malignant dysphagia and bleeding from advanced esophageal cancer. With the advent of RFA (Barrx Medical, Sunnyvale, CA) for dysplastic BE, the indications for laser ablation and PDT are now limited mostly to palliation of bleeding or obstructing esophageal cancers. RFA burns the mucosal layer of the esophagus while PDT using porfimer sodium (Photofrin; Pinnacle Biologies Inc., Bannockburn, IL) penetrates to the submucosal layer, thus resulting in strictures in up to 42% of patients.\textsuperscript{15} Cryotherapy is becoming increasingly more available and is being used to ablate dysplastic BE and early neoplasms, palliate malignant dysphagia, and control bleeding. Concurrent chemotherapy and radiation therapy are not considered contraindications to these endoscopic laser and freezing treatments. The presence of a tracheoesophageal or bronchoesophageal fistula is a contraindication for all three modalities (PDT, laser ablation, and cryotherapy).

Photodynamic Therapy and Thermal Laser Therapy Indications

- Palliate malignant dysphagia
- Control superficial bleeding from esophageal cancer
- Used as a primary or adjunct for treatment of BE, HGD, and intramucosal cancers in medically inoperable patients\textsuperscript{15–17}

Cryotherapy Indications

- Ablation of dysplastic BE
- Primary tumors of the esophagus
- Definitive treatment of intramucosal tumors
- Local control of esophageal cancer in patients deemed high risk for esophagectomy due to comorbidities
- Control bleeding from esophageal cancer

Photodynamic Therapy Contraindications

- Porphyria
- Tracheoesophageal or bronchoesophageal fistula
- Relative: Hepatic or renal impairment
Chapter 32  Photodynamic Therapy, Lasers, and Cryotherapy for Esophageal Neoplasia

Cryotherapy Contraindications

- Tumor that is completely obstructing or near-completely obstructing the esophagus.
- Tracheoesophageal or bronchoesophageal fistula

**PREOPERATIVE PLANNING**

Prior to the selection of endoscopic therapy, the patient is staged and evaluated, and in patients with early-stage or locally advanced cancer the risk for surgical therapy is assessed. An endoscopy is done to evaluate the extent of disease. If the therapy is offered with curative intent, then a CT scan of the chest and abdomen, endoscopic ultrasound to evaluate the depth of the tumor and nodal status, and a PET-CT scan are done before administering endoscopic therapy to confirm that the tumor is early stage. In patients with more advanced disease, endoscopic therapies can be offered as part of palliative treatment.

**Photodynamic Therapy**

- Before PDT, the surgeon must educate the patient about the systemic photosensitizing risks of the porfimer sodium. Photofrin (Pinnacle Biologics Inc., Bannockburn, IL) is the most widely used photosensitizing agent, and is approved for use in the United States. Aside from the primary risk of a severe sunburn, other potential side effects include an allergic reaction, chest pain, and wheezing. These must be discussed with the patient before injecting them with Photofrin.

**Thermal Laser Therapy (APC; Nd:YAG)**

- No specific planning

**Cryotherapy**

- Cryotherapy involves the use of nitrogen, a rapidly expanding gas, that if not properly evacuated may lead to perforation of a hollow viscus. A decompression tube is placed in the stomach to eliminate the gas and reduce the risk of injury to the enteric viscera. Placement of this tube may result in postoperative oropharyngeal discomfort. Expelling gas after the procedure is expected.
- As the cryogen is released into the esophagus, a transmural freeze occurs and may affect surrounding organs, including the heart. Cardiac arrhythmias from these associated temperature changes may occur. A preoperative cardiac assessment including a recent electrocardiogram is recommended.
- Risks and side effects should be discussed with the patient prior to surgery.

**SURGERY**

All of these endoscopic modalities can be performed as an outpatient procedure either in the main operating room or in a controlled outpatient endoscopy suite. In the operating room, the patient remains supine and is placed under general anesthesia or under monitored anesthesiology care. In the endoscopy suite, the patient is positioned into the left lateral decubitus position; oropharyngeal anesthesia is achieved with Lidocaine spray, and intravenous conscious sedation is administered. After the endoscope is inserted (Fig. 32.1), the extent of the tumor is examined, biopsies are obtained if indicated, and the procedure is initiated.

**Photodynamic Therapy Technique**

- The dose of Photofrin is 2 mg/kg, intravenously administered slowly over 3 to 5 minutes.\textsuperscript{7,10} We wait for 48 hours before administering endoscopic treatment (from
photosensitizer injection to administration of light therapy) because tumor cells need time to selectively retain more photosensitizer than normal tissue. This selective retention is due to differences in cancerous tissue vascular supply and lymphatic drainage.\textsuperscript{7,10}

- The injection can be done in the outpatient setting but more often is indicated when the patient has been admitted for bleeding from the tumor or to treat aspiration from malignant obstruction.
- 5-ALA may be used as a photosensitizing agent in Europe. It is not approved as such in the United States.
- During endoscopic therapy/light administration, protective eyewear is required for all operating personnel (Fig. 32.2).
- A diffusing tip fiber is introduced through the biopsy channel of the endoscope. Available fiber lengths are 1, 2.5, and 5 cm and are chosen depending on the target area.\textsuperscript{7,18}
- A 630-nm wavelength laser light is administered at a dose of 300 J/cm of fiber optic diffuser length (Fig. 32.3).
- Since the mucosal folds are not flattened, light delivery may not be uniform, and this may lead to an increased dose in some areas, resulting in stricture, and inadequate dosing in others, resulting in incomplete ablation. The use of balloon centering

\textbf{Figure 32.1} Patient is in left lateral decubitus position, sedated and the endoscope is inserted transorally.

\textbf{Figure 32.2} PDT laser eyewear is required for ocular safety.
devices may help address this issue by decreasing the mucosal folds and facilitating more uniform delivery (Fig. 32.4).

- A balloon centering device may allow more uniform light exposure resulting in better treatment and fewer strictures. Caution is necessary to avoid overdistention of the esophagus using the balloon as this may decrease blood flow and make the treatment less effective.

- A balloon fiber (Wizard X-Cell PDT balloon, Wilson-Cook Medical, Winston-Salem, NC, USA) has been approved for esophageal PDT. The balloon induces distention of esophageal lumen leading to the flattening of the mucosal folds and is available in
three lengths (3, 5, and 7 cm). A pediatric endoscope alongside the balloon can be used to verify the position of the balloon.

- A total power output is set to deliver about 12 minutes of exposure.
- Follow-up endoscopy 24 to 48 hours after ablation is often done to assess the degree of tumor necrosis and to clean up the necrotic debris.

**Thermal Laser Therapy Technique**

- Protective eyewear is required for all operating personnel.
- Laser energy was delivered with a noncontact technique via quartz fibers.
- Nd: YAG settings are adjusted. In a randomized trial investigating Nd: YAG, the laser power setting of between 15 and 90 W and a pulse duration starting from 0.5 seconds was used.\(^{19}\)

**Cryotherapy Technique**

- Place an orogastric decompression tube.
- Prime the cryospray catheter (Fig. 32.5) and place the decompression tube on continuous suction.

![Figure 32.4](image-url) Esophageal centering balloons. Reprinted from: Overholt BF, Panjehpour M, Haydek JM. Photodynamic therapy for Barrett’s esophagus: Follow-up in 100 patients. *Gastrointest Endosc.* 1999;49:1–7. Copyright (1999), with permission from Elsevier.

![Figure 32.5](image-url) Priming the cryospray from endoscope.
Expose the upper abdomen and apply gentle pressure consistently throughout the procedure.

A protective cap (as used with endoscopic mucosal resection) may be placed on the tip of the endoscope to shield the camera from the cryogen. (This is optional.)

Direct the catheter tip toward the tumor, beginning distal and moving caudad.

Apply the cryogen spray for 10 seconds for dysplastic BE and small (<2 cm) tumors and 20 seconds for larger (>2 cm) tumors (Fig. 32.6).

Allow complete thawing of tissue in between freezes (2 to 3 minutes).

Apply three separate freezes.

Remove the decompression tube.

Perform endoscopy to evacuate air and evaluate for injury.

Withdraw the endoscope.

---

**POSTOPERATIVE MANAGEMENT**

**Photodynamic Therapy**

- Postprocedural monitoring (~2 hours).
- Liquid diet for 24 hours.
- Tylenol or ibuprofen for discomfort.
- Avoid direct sunlight and bright indoor light for 4 to 6 weeks. Ambient indoor light exposure is encouraged. Patients must wear hats and gloves at all times while outside to reduce the risk of sunburn.
- Proton pump inhibitors are used for acid suppression.
- Ocular sensitivity is rare but can occur and typically manifests as eye discomfort.
- PDT laser treatment may be repeated within 30 days without reinjection of additional Photofrin.
- Repeat injection of Photofrin can be administered after 90 days for additional treatments.

**Thermal Laser Therapy (APC and Nd:YAG)**

- Postoperative observation for bleeding (4% to 6%) or perforation (<4%). Major bleeding has been reported in up to 3.9% of patients after APC therapy and minor bleeding in 6% of Nd:YAG-treated patients. Patients are observed in the recovery room for about 2 hours for evidence of any bleeding and then may be discharged home if vital signs are stable.
- Liquid diet for 24 hours.
- Acetaminophen or ibuprofen for discomfort.
Cryotherapy
- Postprocedural monitoring (2 hours)
- Liquid diet for 24 hours
- Tylenol or Ibuprofen for discomfort
- Repeat procedure in 2 to 8 weeks
- Continue with treatment until one of the following is noted
  - No evidence of disease on two consecutive biopsies spaced 3 months apart
  - Persistent disease after six to eight treatments
  - Progression of disease on therapy
  - Poor patient tolerance

COMPLICATIONS

Photodynamic Therapy Complications

Early Complications (10% of patients)\(^6,20\)
- Photosensitivity reaction, sunburn (6% to 19%)
- Pleural effusion (3%)
- Perforation risk is low (<2%)
- Aspiration pneumonia (1%)
- Chest pain
- Fever

Later Complications
- Strictures occur in 30% to 40% of patients when PDT is used to treat HGD and superficial cancers. Strictures can present from 2 weeks to 6 months after treatment. The management of strictures involves esophageal dilation with a 50% success rate with one to five dilations. Oral steroids do not significantly reduce stricture rate.
- Stricture rate after palliative PDT is 2%.

Thermal Laser Therapy Complications
- Pain (occurs in 2% to 48% of patients)
- Perforation
- Fistula or stricture formation (12%)

Cryotherapy Complications and Side Effects
- Perforation
- Chest pain
- Heartburn
- Dysphagia

RESULTS

Photodynamic and Thermal Laser Therapy
In 2003, Little and colleagues from the University of Pittsburgh reported in a series of PDT in 215 patients with bleeding, obstructing, or bleeding and obstructing esophageal cancer, and this series remains one of the largest published to date. They evaluated
Chapter 32  Photodynamic Therapy, Lasers, and Cryotherapy for Esophageal Neoplasia

dysphagia scores, duration of palliation, reinterventions, complications, and survival. Successful palliation of malignant dysphagia occurred in 85% of patients with a mean dysphagia-free interval of 66 days.\textsuperscript{5,20} Tumor bleeding was controlled in 93% of patients with one course of PDT. Further, a subgroup of patients (30%) was able to discontinue their supplemental nutrition as they were able to nourish themselves by mouth. Esophageal stents were placed in 35 patients, with a mean interval to reintervention of 58.5 days.

In a study comparing Nd:YAG and PDT for treatment of malignant dysphagia, the patients who received PDT experienced a 50% longer period of palliation (84 days with PDT vs. 57 days with Nd: YAG).\textsuperscript{21} In a prospective randomized multicenter trial, the efficacy and safety of PDT with porfimer sodium was compared with Nd:YAG laser in the treatment of patients with obstructing esophageal cancer.\textsuperscript{19} A total of 236 patients from 24 institutions were randomized, of which 218 patients were treated (110 with PDT and 108 with Nd:YAG laser). Objective tumor response was equivalent at 1 week, but was significantly better at 1 month in the PDT group. Improvement in dysphagia was equivalent in the two groups. Of note, sunburn occurred in 19% of patients in the PDT group and termination of the laser endoscopy session due to adverse reaction occurred more frequently in the Nd:YAG group (19% vs. 3%; \( p < 0.05 \)). Similarly perforations from the treatment or associated dilation occurred significantly more often in the Nd:YAG group (7%) compared with the PDT group (1%, \( p < 0.05 \)). These authors concluded that PDT and Nd:YAG laser ablation resulted in equal relief of dysphagia; however, the objective tumor response was equal or better in the PDT group. In addition, PDT was associated with fewer acute perforations when compared with the Nd:YAG laser therapy.

Overholt et al.\textsuperscript{16} conducted a multicenter randomized Phase III trial of PDT and omeprazole versus omeprazole alone for BE with HGD.\textsuperscript{16} A total of 208 patients were enrolled, 138 patients in PDT arm (of which 132 patients underwent treatment) and 70 patients in the omeprazole only arm, after central pathology confirmation of HGD in BE. The primary endpoint, ablation of HGD, occurred in 77% of patients in the PDT group versus 39% in the omeprazole only group. The secondary end points studied were elimination of all BE, which occurred in 52% in the PDT group versus 7% in the omeprazole group, and ablation of all grades of dysplasia which occurred in 59% in the PDT arm versus 14% in the omeprazole only group, respectively. However 13% in the PDT group and 28% in the omeprazole group were diagnosed with adenocarcinoma. In our experience with PDT in medically inoperable patients, PDT was effective in approximately one-third of patients with superficial cancer\textsuperscript{15} PDT can be used as adjunct to other endoscopic therapies such as endoscopic mucosal resection. Ell et al.\textsuperscript{17} reported the use of PDT in approximately 50% of 100 selected patients who were treated with endoscopic mucosal resection for intramucosal cancer.

Overholt et al.\textsuperscript{22} reported treating residual areas of BE after Photofrin PDT with Nd:YAG laser. A wide range of initial success rates of APC ablation of BE eradication has been reported with a long-term relapse of intestinal metaplasia up to 68%.\textsuperscript{16–18} Persistent acid exposure after APC is an important predictor of relapse.\textsuperscript{12} One of the concerns after PDT is the persistence of genetic abnormalities after ablation.\textsuperscript{7,23} In addition, studies have shown submerged BE underneath squamous mucosa has the potential for neoplastic progression after argon photocoagulation and PDT.\textsuperscript{24,25}

Cryotherapy

Relative to PDT and thermal laser ablation, there is far less reported experience with cryoablation of esophageal tumors. For early stage disease (T1a), the best data shows a 72% endoscopic complete response (CR) at a mean follow-up of 1 year. For moderate stage disease (T2), the best data shows 30% endoscopic CR at 1-year mean follow-up. For advanced stage disease (T3), the best data shows a 50% endoscopic CR at a mean of 1-year follow-up.\textsuperscript{26–28}
PDT successfully palliates malignant dysphagia from obstructing esophageal cancers and is also effective in bleeding tumors. A randomized trial data of PDT versus Nd:YAG laser therapy demonstrated similar palliation of endoluminal lesions, with a decreased risk of perforation with PDT. While endoscopic therapy has its limitations in early esophageal neoplasia, PDT has also been used as primary or adjunct to endoscopic mucosal resection in the treatment of BE, HGD and superficial tumors and is applicable in medically inoperable patients. Cryotherapy is a relatively new but promising technology for premalignant and malignant lesions of the esophagus. It can be used in combination with chemotherapy to treat nodal disease but it is not a replacement for potentially curative esophagectomy if the patient is a good operative candidate. Follow-up after treatment of early cancer may require repeat endoscopies and additional cryotherapy administrations. Clinical trials using cryospray followed by esophagectomy would help determine the response of esophageal cancer to cryoablation.

Recommended References and Readings

Endoscopic Mucosal Resection
Toshitaka Hoppo and Blair A. Jobe

INDICATIONS/CONTRAINDICATIONS

Endoscopic resection is a minimally invasive, organ-preserving technique to endoscopically remove premalignancy or early-stage cancer arising from the gastrointestinal epithelium as a mucosal–submucosal complex. Patients with no risk of lymph node involvement or lower risk for developing lymph node metastasis compared with the risk of mortality from surgery are ideal candidates for endoscopic treatments such as endoscopic resection and ablation therapy. Unlike endoscopic ablation therapy, such as radiofrequency ablation and cryoablation, endoscopic resection can provide specimens for complete histologic assessment including depth of cancer invasion, degree of cellular differentiation, and lymphovascular invasion. Accurate staging based on the histologic assessment is crucial to assess the risk of lymph node involvement and determine whether endoscopic treatment is appropriate for the individual patient. For the purposes of staging, the mucosal and submucosal layers have been subdivided into thirds with each third going deeper into the gastrointestinal wall. As such, T1 tumors have six different layers of invasion: T1m1–m3 (m1 = limited to the epithelial layer, m2 = invades into the lamina propria, m3 = invades into but not through the muscularis mucosa) and T1sm1–sm3 (different thirds of the submucosa) (Fig. 33.1).

Indications for endoscopic resection for each type of esophageal cancer are summarized in Tables 33.1 and 33.2. For esophageal high-grade dysplasia (HGD) and intramucosal adenocarcinoma, esophagectomy has been recommended as a standard of care based on the fact that HGD is likely to progress to cancer and unexpected cancer is found in approximately 40% of surgically resected specimens obtained from patients with the preoperative diagnosis of only HGD. However, the rate of lymph node involvement is low (<10% for intramucosal cancer) and endoscopic resection can be a good option in some patients to avoid unnecessary, invasive surgery, particularly, in patients with medical comorbidities. It is crucial to differentiate patients at higher risk for progression or for having concomitant invasive cancer with possible lymph node involvement based on the criteria of low- and high-risk factors (Table 33.1). Patients with high-risk for progression will likely be better treated with esophagectomy. Low-risk factors include unifocal (limited or focal) or flat HGD, type I, Iia <2 cm, IIb, IIc
<1 cm, well or moderately differentiated adenocarcinoma, mucosal cancer (m) and no lymphovascular invasion. Esophageal squamous cell cancer appears to be biologically more aggressive compared with adenocarcinoma and the risk of lymph node involvement appears higher in patients with squamous cell cancer. Intraepithelial cancers (m1) and cancers invading the lamina propria (m2) are associated with almost no risk of lymph node metastasis. However, the risk of lymph node involvement in cancers invading the muscularis mucosa (m3) and the submucosa ranges from 0% to 10% and 50% to 55%, respectively.

Therefore, endoscopic resection can be indicated for superficial well or moderately differentiated squamous cell carcinoma (scc) limited to the lamina propria (m1–m2). Patients with cancers invading the muscularis mucosa (m3) may be treated endoscopically if there are no further risk factors for lymph node involvement. However, patients with submucosal invasion should be considered for surgery (Table 33.2).

Endoscopic resection includes two techniques: Endoscopic mucosal resection (EMR) and endoscopic submucosal dissection (ESD). Overall, EMR is commonly used as both a diagnostic as well as a therapeutic tool for the tumor <2 cm in diameter, and ESD is considered for en bloc resection when the diameter of tumors is >2 cm. In any situation, en bloc resection is ideal. Piecemeal resection is acceptable, but is associated with the high rate of metachronous lesions due to incomplete resection and compromised histologic assessment.

**Table 33.1** Factors to Consider for Endoscopic Resection of High-grade Dysplasia (HGD) and Intramucosal Adenocarcinoma

<table>
<thead>
<tr>
<th>Indications</th>
<th>Relative Contraindications</th>
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<tbody>
<tr>
<td>Low-risk for Progression</td>
<td>High-risk for Progression</td>
</tr>
<tr>
<td>Unifocal (limited or focal), flat HGD</td>
<td>Multifocal HGD, HGD with nodules</td>
</tr>
<tr>
<td>Type I, IIA &lt;2 cm, IIB, IIC &lt;1 cm</td>
<td>Type I, II &gt;3 cm, Type III</td>
</tr>
<tr>
<td>Well or moderately differentiated adenocarcinoma Lesions limited to the mucosa (m) No lymphovascular invasion</td>
<td>Poorly differentiated adenocarcinoma Invasion into the submucosa (sm) Presence of lymphovascular invasion</td>
</tr>
</tbody>
</table>

Type I, polypoid type; IIA, flat, elevated; IIB, level with the mucosa; IIC, slightly depressed; III, ulcerated type.
Accurate endoscopic examination and clinical staging are essential to select patients who are appropriate candidates for endoscopic resection. It is crucial to exclude patients with high risk of lymph node involvement or metastatic disease. Therefore, preoperative work-up should include endoscopic ultrasound (EUS), and positron emission tomography/computed tomography (PET/CT) to assess lymph node involvement and metastatic disease, in addition to the careful evaluation of extension of the tumor using advanced imaging techniques such as high-resolution endoscopy, chromoendoscopy, or narrow-band imaging. A diagnostic endoscopic resection can be included for staging. The depth of tumor invasion is highly associated with the likelihood of lymph node metastasis.

The role of EUS is to exclude lymph node metastasis and to determine the depth of tumor invasion. It has been shown that EUS can accurately differentiate T1 and T2 tumors but not T1a (m cancer) and T1b (sm cancer) with the current technology. Even the high-frequency miniprobe (20 or 30 MHz) still has a limited accuracy to discriminate between T1a and T1b tumors. Because EUS may not be sufficiently reliable to exclude submucosal invasion in early cancers, the EMR must be diagnostic for this staging purpose. EMR provides specimens for histologic analysis including both mucosa and submucosa, and can reliably determine the T stage of suspicious lesions (i.e., differentiating T1a from T1b). A positive lateral margin can be addressed with further endoscopic intervention, but a positive deep margin should be addressed with surgery. Because PET/CT has been shown to be less accurate than EUS in determining nodal staging but EUS is ineffective in detection of distant metastasis, these modalities should be used in combination during the preoperative work-up. The major role of PET/CT is to confirm the absence of metastatic disease.

Endoscopic resection often requires several sessions. In addition, an intensive follow-up endoscopy is required. Strict acid suppression with high-dose proton pump inhibitors (PPIs) and/or H2 blockade is critical to allow the resected area to heal to normal “neosquamous” epithelium, especially in patients with esophageal HGD or intramucosal adenocarcinoma. These points should be discussed with patients prior to the initiation of treatment.

Endoscopic resection can be performed under deep sedation using the combination of narcotics and short-acting benzodiazepines in either the GI laboratory or the operating room. ESD often requires a longer time to complete and the general anesthesia in the operating room should be considered. As is typical for endoscopy, the patient is placed in the left lateral decubitus position with the proper monitoring such as cardiogram, blood pressure, and percutaneous oxygen saturation. At the beginning of the procedure, it is important to re-evaluate the extension of the lesions. Placement of an overtube may be useful to keep an easy access to the lesions and facilitate the following procedure.
Endoscopic Mucosal Resection

Although several EMR techniques have been introduced (Fig. 33.2), two methods commonly used for EMR are the endoscopic cap resection technique (Fig. 33.2C) and the ligate-and-cut technique (Fig. 33.2D). These two methods were found to be similarly efficacious in a randomized trial. Both methods start with injection of normal saline or diluted epinephrine into the submucosal space to lift the lesions away from the muscularis propria. The injection needle should be inserted into the submucosal space at a sharp angle to avoid transmural penetration of the needle. Injected saline acts as a “safety cushion” between the mucosa and the muscle layer to prevent mechanical or electrocautery damage to the deep layers of the gastrointestinal tract wall. However, the injected saline disappears within a few minutes and the repeat injection of saline should be considered to reduce the risk of unexpected complications, such as perforation, during the procedure. Marking the tumor margin using an electrocautery may be helpful to guide accurate resection after the submucosal injection of saline. For the cap resection technique, a clear plastic cap is attached to the tip of the forward-viewing endoscope, and the endoscope is introduced through the overtube if an overtube has been placed. The caps are available with flat, circular (straight)- or oblique-shaped tips both with outer diameters ranging from 12.9 to 18 mm (Fig. 33.3). The oblique caps are usually used for esophageal lesions, whereas the straight caps are most commonly used in the stomach and colon. Mucosa and submucosa are sucked into the cap to create a pseudopolyp and a specially designed crescent-shaped electrocautery snare positioned inside the cap is then closed to resect the pseudopolyp. For the ligate-and-cut technique, suction is applied to retract the lesion into the banding device, and a band is deployed to create a pseudopolyp. The pseudopolyp is then resected by being captured at its base using an electrocautery snare. This technique requires the repeated withdrawal and insertion of the endoscope for band ligation and subsequent resection. A novel multiband mucosectomy device (Duette, Cook Medical Inc., Bloomington, IN),
which uses a specially designed 6-band ligator, has been commonly used in our practice (Fig. 33.4). Because a snare wire can be passed through the ligator handle, the band deployment for ligation and subsequent resection can be performed immediately without withdrawal of the endoscope. Two sizes of ligating caps are available to fit endoscopes with outer diameters of 9.5 to 13 mm and 11 to 14 mm. Regardless of the EMR technique employed, residual Barrett’s esophagus (BE) or HGD after EMR should be treated with endoscopic ablation.

**Endoscopic Submucosal Dissection**

ESD has been established in Japan for en bloc resection of tumors greater than 2 cm in diameter, thus allowing more accurate histologic evaluation of the lateral and deep margins of the lesion, and potentially preventing the development of metachronous...
lesions. The procedure is usually performed in several steps (Fig. 33.5 and 33.6). Since ESD targets larger lesions (>2 cm), marking around the lesion using an electrocautery is particularly important to guide the successful en bloc resection. After the markings are placed (Fig. 33.6A), the lesion should be lifted away from the muscularis propria by injecting a solution into the submucosal space. The injection solutions for ESD include normal saline, glycerol solution, and sodium hyaluronate solution. Sodium hyaluronate solution stays in the submucosal space longer than other solutions so that the submucosal plane can be effectively visible during the submucosal dissection. Diluted sodium hyaluronate (∼0.5% solution) is usually mixed with epinephrine (0.01 mg/mL) and indigo carmine (0.04 mg/mL). At this point, the mucosal cutting, ~5 mm outside the markings, is performed using a specialized endoscopic electrocautery needle knife (Fig. 33.6B). Several types of needle knife having the different-shaped tips have been introduced and are available in Japan (Fig. 33.7). However, only one type of needle knife (Olympus America Inc., Center Valley, PA) is currently available in the United States. Once the access to the submucosal space is achieved, tension and counter-tension are maintained by an endoscope-mounted cap, which is placed in the plane between the mucosal–submucosal complex and the muscularis propria. The submucosal dissection is then carried out using the needle knife by dissecting the attachments and bridging vessels between these two layers (Fig. 33.6C). At the completion of the procedure, the tumor can be resected en bloc regardless of its size and the remaining thin layer of sm3 is observed over the muscle layer (Fig. 33.6D). It is important to
Figure 33.6 Endoscopic submucosal dissection of early esophageal SCC. A: Chromoendoscopy showed the presence of an irregular unstained area in the middle esophagus. Markings were made using an electrocautery. B: After the submucosal injection of sodium hyaluronate, the submucosal dissection plane becomes apparent, and dissection can begin. C: The entry for submucosal dissection was created and submucosal dissection was performed using the needle knife. D: The tumor was resected en bloc. A thin layer of sm was observed over the muscle layer. E: The resected specimen was spread out and pinned on a flat cork.

Figure 33.7 Different types of needle knives for endoscopic submucosal dissection. A: Insulation-tipped diathermic electrosurgical knife (IT knife). B: Hook knife. C: Flex knife. D: Triangle-tip knife (TT knife).
preserve this thin layer to avoid the damage to the muscle layer. ESD is a “one-person” procedure and the surgeon cannot use an assistant’s hands. Therefore, it is critical to maintain somehow the adequate countertraction on the resecting mucosa throughout the procedure. For this purpose, a partial mucosal incision should be made rather than a circumferential mucosal incision, and mucosal incision and submucosal dissection should be repeated step by step. To take advantage of gravity, mucosal incision and subsequent submucosal dissection should be started from the upper portion of lesion, so that the dissected mucosa is pulled down by gravity and the submucosal layer can be exposed spontaneously. The position of patient can be changed to move the lesion to an appropriate position to take advantage of gravity.

**Handling of Resected Specimens**

Accurate staging can only be achieved when the specimen is properly oriented by the endoscopist or the assistant immediately after excision, prior to the specimen being immersed in formalin solution. For this purpose, the specimen should be spread out and pinned on a flat cork (Fig. 33.6E). Fixed specimens should be sectioned serially at 2-mm intervals parallel to a line that includes the closest resection margin of the specimen, so that both lateral and deep margins can be assessed. The depth of tumor invasion is then evaluated in conjunction with the degree of differentiation and the lymphatic or vascular involvement.

### POSTOPERATIVE MANAGEMENT

Patients should be observed in the recovery room until they awaken. Repetitive, careful, physical examination is important to exclude subcutaneous emphysema and chest or abdominal pain suspicious for perforation. For patients who underwent EMR, no further examinations, such as chest x-rays or blood tests, are required if there is no evidence of bleeding or perforation, and they can be discharged on the same day of the procedure. For patients who underwent ESD, a chest x-ray or an upper GI contrast study is often required depending on the intraoperative findings and patient’s condition. Patients are instructed to stay on the liquid diet for 24 hours and then advance to the regular diet as tolerated. Temporal antisecretory medication, such as PPIs or H2 blockers, should be prescribed. Especially for patients with BE or esophageal adenocarcinoma, strict acid suppression with the maximal dose of PPIs and nocturnal H2 blockade is critical for the normal tissue healing process.

Currently, there is no consensus on the optimal protocol for the follow-up after endoscopic resection. Most patients should be closely followed with multiple follow-up endoscopies and serial treatments, if needed. Our current approach is to perform the first follow-up endoscopy 6 weeks after endoscopic resection to ensure that normal tissue healing occurs, and to repeat endoscopic surveillance with biopsies every 3 months.

### COMPLICATIONS

The most frequent complication of endoscopic resection is bleeding, ranging from 1% to 45% with average rates of 10% in larger series. Most bleeding occurs intraoperatively or within the first 24 hours. Delayed bleeding has been reported in approximately 14% of patients. Bleeding can be addressed by grasping and coagulation of the bleeding vessels using hot biopsy forceps. Endoclips can be deployed for severe bleeding. The most serious complication is perforation. The perforation rate during ESD has been reported to be much higher compared with that during EMR (4%–10% vs. 0.3%–0.5%, respectively). Small perforations recognized during the procedure can be addressed by deploying
endoclips. However, large perforations require an emergent surgery to avoid peritonitis or mediastinitis. In addition, another major complication of ESD is stenosis due to stricture formation. Stenosis is more likely to occur after ESD for esophageal lesions (up to 26%). Esophageal stricture can cause severe dysphagia and sometimes requires multiple sessions of dilation. Because of the high rates of perforation and stenosis, ESD has not been widely accepted especially for esophageal lesions.

**RESULTS**

**Esophageal High-grade Dysplasia and Intramucosal Adenocarcinoma**

Long-term follow-up data of endoscopic resection in patients with esophageal HGD and intramucosal adenocarcinoma are limited. In the only available large prospective study with long-term follow-up, Pech et al. investigated the efficacy, safety, and risk factors for recurrence in 349 patients with HGD and intramucosal adenocarcinoma who received endoscopic therapy with curative intent (279 underwent EMR). During a mean follow-up of 5 years, complete response (CR; defined as an R0 resection and one normal endoscopic follow-up evaluation) was achieved in 96.6% of patients and surgery was required in only 3.7% of patients. Importantly, in patients who received ablation therapy for the remaining nonneoplastic field of BE, 16.5% developed a metachronous neoplasia during the follow-up, compared with 28.3% in the group that did not receive ablation. The rate of bleeding (major and minor) was 12%, and the rate of stenosis was 4.3%. Risk factors for recurrence of early esophageal cancer after endoscopic resection included piecemeal resection, long-segment BE, no ablative therapy of Barrett’s lesion after CR, time until CR achieved >10 months, and multifocal neoplasia (Table 33.3).

**Esophageal Squamous Cell Carcinoma**

Excellent results with a low complication rate and a good disease-specific 5-year survival rate for the endoscopic resection of esophageal SCC have been reported. In the most recent retrospective cohort study by Ciocirlan et al., 51 patients with either dysplasia or mucosal (m) cancer underwent repeated EMR until complete local remission was achieved. Complete response was achieved in 91% of patients and the disease-specific 5-year survival rate was 95%. There were no perforations, but minor bleeding was observed in 17% of patients and three patients (6%) developed mild stenosis requiring dilation. During the follow-up period, local disease recurrence was observed in 26% of patients.

<table>
<thead>
<tr>
<th>TABLE 33.3</th>
<th>Risk Factors Potentially Associated with Recurrence after Endoscopic Resection of Early Esophageal Cancer</th>
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<tbody>
<tr>
<td>Risk Factors for Recurrence after Endoscopic Resection of Early Esophageal Cancer</td>
<td></td>
</tr>
<tr>
<td>1. Piecemeal resection</td>
<td></td>
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<tr>
<td>2. Long-segment BE</td>
<td></td>
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<tr>
<td>3. No ablation therapy of BE after CR</td>
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<tr>
<td>4. Time until CR achieved &gt;10 mo</td>
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<tr>
<td>5. Multifocal neoplasia</td>
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Endoscopic resection, such as EMR and ESD, is a minimally invasive, organ-preserving approach to treat premalignancy or early-stage cancer in the gastrointestinal tract. Accurate staging is crucial to avoid inappropriate endoscopic treatments in patients with a high risk of lymph node involvement and metastatic disease. Overall, the outcomes of endoscopic resection are acceptable. However, endoscopic resection is highly associated with the development of metachronous lesions especially when tumors cannot be resected en bloc, and an intensive endoscopic follow-up is therefore required. ESD has been introduced as a promising technique to resect the larger tumors (>2 cm) en bloc. However, ESD is a time-consuming procedure and requires highly advanced skills. In addition, ESD is still associated with the high rate of complications such as perforation, bleeding, and stenosis. A large, prospective, randomized-controlled trial with a long-term follow-up will be required to determine the true benefit of ESD. In addition, advanced instrumentation, especially the needle knife, is an important component for successful ESD. Further refinement of devices to enhance the safety of ESD is needed.

**Recommended References and Readings**

Esophageal Stents
Matthew J. Schuchert

Introduction

The primary goals of palliation in patients with unresectable esophageal cancer include the relief of dysphagia and the maintenance of oral intake; management of complications; relief of pain; and prevention of reflux, regurgitation and aspiration, while minimizing the length of hospital stay and maximizing quality of life. Although a variety of treatment options exist (including photodynamic therapy [PDT], chemotherapy, radiation therapy, brachytherapy, and laser ablation), esophageal stenting provides immediate and durable results in the majority of patients (Table 34.1). A combination of modalities can be employed to maximize the palliative effects if needed.

Stenting of the esophagus is the most commonly used first-line modality to palliate dysphagia and prevent malnutrition secondary to esophageal and proximal gastric cancers (Fig. 34.1). Over the last two decades, there has been a dramatic evolution in stenting technology that has broadened its application in the management of a variety of malignant and benign esophageal conditions. The repertoire of available devices includes rigid plastic conduits as well as self-expandable metal and plastic stents. Uncovered stents have the advantage of better purchase on the esophageal wall, thus limiting stent migration. However, they allow (and even stimulate) tumor and granulation tissue ingrowth. Expandable stents may be covered with a plastic coating to retard tissue ingrowth, but have an increased risk of stent migration. Stent selection is tailored to the individual patient, and is dependent on such variables as tumor length, bulk, and location. Deployment is achieved under simultaneous fluoroscopic and endoscopic guidance. Stents are highly effective in palliating dysphagia in the setting of esophageal malignancy, but can be associated with a substantial complication rate, predominantly due to the patient’s poor functional and nutritional status as well as the extent of the underlying esophageal disease. In this chapter, we review the indications, technique, and outcomes of esophageal stenting for both malignant and benign esophageal diseases.

**INDICATIONS**

Current indications for stent placement approved by U.S. Food and Drug Administration include the palliation of esophageal obstruction and tracheoesophageal fistulas secondary to malignancy. Other less common applications for esophageal stent placement include dysphagia secondary to external compression by benign neoplasms, benign strictures, and esophageal leak or perforation.
The most common indication for esophageal stent insertion is relief of dysphagia in the setting of unresectable esophageal cancer. The majority of newly diagnosed patients with esophageal cancer have advanced disease at the time of diagnosis, with dismal 5-year survival rates of less than 20%. Palliation of dysphagia, therefore, becomes a paramount component of care in this setting. Stents provide safe and expeditious relief of dysphagia, thereby enhancing the patient’s nutritional status and quality of life. Dysphagia can also result from obstructing lesions of the esophagus related to adjacent lung cancer or mediastinal lymphadenopathy due to extrinsic compression. Benign, refractory strictures related to peptic ulcer disease or prior caustic injury can be treated with stent insertion in selected cases. Stent placement may be either temporary or permanent, depending upon the clinical circumstances. In the setting of malignancy, temporary stents represent useful adjuncts prior to surgical resection by relieving dysphagia and enhancing nutrition. However, we have noted, as have others, that expandable metal stent placement is...

**Figure 34.1** Esophageal stent insertion for malignant disease.

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**TABLE 34.1** Available Modalities for the Palliation of Dysphagia from Esophageal Cancer

<table>
<thead>
<tr>
<th>Stent placement</th>
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<tbody>
<tr>
<td>Laser therapy (Nd:YAG; photodynamic therapy)</td>
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<tr>
<td>Radiation therapy (External beam; intraluminal brachytherapy)</td>
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<tr>
<td>Chemotherapy</td>
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<tr>
<td>Dilatation</td>
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<tr>
<td>Electrocoagulation (BICAP Probe)</td>
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<tr>
<td>Chemical injection therapy</td>
</tr>
<tr>
<td>Best supportive care (nutritional support, feeding tube)</td>
</tr>
</tbody>
</table>

stents deployed prior to chemotherapy and radiation therapy have been associated with significant esophageal fibrosis, and even perforation, that can cause significant technical difficulties during subsequent surgical resection. Thus, we recommend avoiding esophageal stents in the setting of planned chemotherapy and radiation therapy in the neoadjuvant setting. Temporary stent placement has been successful when used selectively in the management of perforations, leaks, and benign strictures.

**Special Considerations**

**Bridge to surgery:** Esophageal stents can be utilized as a temporary measure to enhance oral intake in preparation for definitive surgical resection. Potential limitations of the use of partially covered and uncovered nonremovable stents in this setting include the finding of increased periesophageal desmoplastic reaction that can obscure tissue planes and make the planned surgery difficult. This is especially notable in the setting of neoadjuvant therapy (chemotherapy, chemoradiation). Some authors have suggested that the concomitant use of esophageal stents during chemotherapy and radiation therapy may be associated with an increased risk of complications including migration, bleeding, and fistulization. Fully covered stents can be placed preoperatively and removed prior to surgery during the course of neoadjuvant therapy to minimize the risk of these delayed complications. In our experience, the combination of chemotherapy and radiation has been the most problematic in the setting of an expandable metal stent in the esophagus.

**Proximal esophageal cancer:** Esophageal stents can be employed in the proximal esophagus to relieve esophageal obstruction and control fistulae. The use of stents in this setting can be limited due to patient intolerance secondary to pain and globus sensation, as well as airway compression. Stent positioning distal to the cricopharyngeus is critical in minimizing the risk of these symptoms. Performing flexible bronchoscopy before placing a stent for proximal obstructing esophageal cancers can be helpful in minimizing complications of airway compression. In some cases, we place a guidewire and a Savary dilator of the approximate size of the planned esophageal stent, then flexible bronchoscopy can be performed to assess airway compression. If airway compression is present, it may be prudent to consider an alternative mode of palliating the proximal esophageal obstruction, such as PDT, or even a smaller stent. In some cases, we have placed an airway stent at the same setting to maintain airway patency.

**Antireflux valves:** For tumors involving the gastroesophageal (GE) junction, stent placement can lead to the development of severe reflux symptoms due to compromise of the lower esophageal sphincter valve mechanism. Several stent modifications have been developed in an attempt to create an antireflux valve mechanism. Dua et al. reported a significant improvement in reflux in patients treated with a modified Z stent containing a windsock valve. Results from randomized studies, however, are mixed. Laasch et al. demonstrated a significant reduction (12% vs. 96%, \( p < 0.001 \)) in reflux among 50 patients receiving either the Dua-modified Z stent compared with those treated with the Flamingo Wallstent. In another study evaluating the effectiveness of an S-shaped antireflux valve (Dostent, MI Tech Co. Ltd., Incheon, South Korea), the fraction of time with an intraesophageal \( \text{pH} < 4 \) was 3% in the group with the antireflux stent and 15% in the group with self-expanding metallic stents (SEMS). Other randomized trials, however, have failed to demonstrate improvement in reflux symptoms or objective measures of gastroesophageal reflux during \( \text{pH} \) testing with the use of antireflux valves. As a result of these disparate findings, antireflux valves are not routinely used during esophageal stenting in the setting of malignancy.

**Drug-eluting stents:** Drug-eluting stents have been developed in an attempt to minimize tissue ingrowth in partially covered stents. This type of stent is not currently available for use in humans.

**Biodegradable stents:** Stents composed of biodegradable material (knitted poly-L-lactic acid monofilaments) have been used to prevent stricture formation following large area endoscopic mucosal resection. Another biodegradable stent model (Ella-CS) has been studied in Europe for the treatment of benign disease. Biodegradable stents have
the advantage of potentially reducing the need for repeat endoscopy to accomplish stent removal.

**Stent Design**

Prior to 1990, virtually all esophageal stents were composed of polyvinyl plastic or rubber. These early stents were cumbersome and very difficult to place, requiring insertion at the time of open surgery or during rigid endoscopy. With the introduction of SEMS, the use of rigid stent prostheses fell out of favor. SEMS are easier to deploy, achieve a wider luminal diameter and are associated with a reduced periprocedural complication rate (including mortality). Although the cost of SEMS is greater than rigid prostheses, the need for repeat interventions is less, leading to an overall reduced cost over the limited expected lifetime of a patient with advanced esophageal cancer.

Most SEMS that are currently available today are constructed with Nitinol (a composite of nickel and titanium), which is a highly elastic alloy with intrinsic properties of elasticity and shape memory that allow conformation to varying degrees of stenosis and angulation. The application of these pliable constructs allows the use of a lower profile delivery system while achieving efficient transmission of adequate radial force upon stent expansion. Initially, all SEMS were uncovered (Fig. 34.2A). Examples of uncovered stents include the Ultraflex uncovered esophageal stent and the Microvasive Wallstent I (Boston Scientific, Natick, MA). Uncovered stents expand radially and incorporate into the wall of the esophagus with time. This incorporation effect dramatically reduces the potential for stent migration seen with rigid plastic prostheses and with covered metal stents. However, the open spaces within the interstices of the uncovered metallic stent permit the ingrowth of granulation tissue or tumor leading to recurrent symptoms of dysphagia in 13% to 26% of cases.
To minimize the occurrence of tumor ingrowth and the development of esophageal erosions or tracheoesophageal fistulas, stents were developed that were partially covered with silicone, polyurethane, or other polymers (Fig. 34.2B). Current designs maintain a 1- to 1.5-cm margin of exposed wire struts on the proximal and distal flanges of the stent to optimize stent purchase and permit integration into the esophageal wall (Fig. 34.3). The use of a covered stent has been shown to significantly decrease the severity of tumor ingrowth and consequent dysphagia, but is associated with a slightly higher migration rate. In a large retrospective analysis of 152 patients who underwent either uncovered \( n = 54 \) or covered \( n = 98 \) SEMS placement, uncovered stents were associated with reduced migration (0% vs. 10%, \( p = 0.04 \)) but were also associated with a significantly increased rate of tissue ingrowth (100% vs. 53%, \( p < 0.0001 \)) and a markedly higher restenosis rate resulting in recurrent dysphagia (37% vs. 8%, \( p < 0.0001 \)). In a prospective, randomized comparison of 62 patients with inoperable GE junction tumors treated with either covered or uncovered stents, a significantly higher reintervention rate was noted in patients with uncovered stents compared with covered stents (27% vs. 0%). There was comparable relief of dysphagia between groups. Tumor ingrowth or granulation tissue was more commonly encountered in the uncovered stent group (30% vs. 3%, \( p = 0.005 \)). There was no difference in survival noted between groups. Although this new generation of covered stents dramatically reduced tumor ingrowth, mucosal hyperplasia/hypertrophic granulation tissue still develops at the uncovered proximal and distal margins of the stent leading to recurrent obstruction. Incorporated stents may thus be difficult or impossible to remove. Examples of currently available covered stents include the Ultraflex Covered Esophageal Stent (Microvasive Endoscopy/Boston Scientific Corp., Natick, MA), the Alimaxx-E (Alveolus, Inc., Charlotte, NC), the Flamingo Wallstent (Schneider AG, Bulach, Switzerland), the Gianturco-Z stent (Wilson-Cook Europe AIS, Bjøverskov, Denmark), the Song stent (Sooho Meditech, Seoul, Korea), and the Esophacoil stent (Medtronic/InStent Inc., Eden Prairie, MN) (Fig. 34.3; Table 34.2). The most commonly used partially covered stent in the United States is the Ultraflex stent. The Ultraflex stent is made of nitinol and is covered along its midsection by a polyurethane coat. There is approximately 1.5 cm of uncovered nitinol mesh at the proximal and distal ends of the stent. The stent is positioned over a guidewire and is deployed with the release of a slip-knotted binding string. Proximal and distal drawstrings allow adjustment of stent position following deployment. The Wallflex stent is also composed of nitinol and may be partially covered or completely covered. Its deployment mechanism allows recapture of the stent up to approximately 75% deployment. Similar to the Ultraflex stent, a proximal purse-string suture can be utilized to adjust stent position. The length of the proximal and distal flares is longer than the Ultraflex stent in the hope of reducing stent migration. The Z stents, also known as Gianturco-Rösch Z stents (Cook Endoscopy, Winston-Salem, NC), are constructed from stainless steel woven in an interlocking “Z” configuration. A modification
of the standard configuration involves the addition of a windsock extension at the distal end of the stent which acts as a one-way valve, thus reducing the risk of reflux (Dua antireflux system). Cook has also produced the Evolution partially covered stent that is deployed with a gun-like deployment mechanism. Similar to the Wallflex stent, this mechanism allows for recapture prior to complete deployment.

To date, prospective, randomized trials have not demonstrated any significant advantage of one design of covered SEMS over another in terms of technical success, morbidity, relief of dysphagia, or survival in the setting of malignant obstruction.21,22 In a direct, prospective, randomized comparison of the Ultraflex, Wallstent, and Gianturco Z stent, there was no significant difference noted in the palliation of dysphagia. The Flamingo Wall stent had the lowest morbidity profile (18%), but this finding did not achieve statistical significance when compared with the Ultraflex stent (24%) and the Gianturco Z stent (36%).21 Similar findings were obtained in another study comparing these same three stent types, with equivalent relief of dysphagia. In this study, the Gianturco Z stent was associated with a significantly higher complication rate compared with the Ultraflex and Flamingo Wallstent.23 The Gianturco Z stent is no longer available in the United States.

Completely covered plastic stents were introduced into the market in 2001, and expanded the number of applications for stent usage, including benign conditions not readily treatable by SEMS due to their erosive tendencies. These stents lack the ingrowth properties of metallic stents and are removable. Plastic stents are limited, however, by increased migration rates due to the mechanical characteristics of the plastic coating and decreased purchase upon the esophageal wall. Plastic stents do exert greater radial force than SEMS, which can lead to migration by “squirting” either proximally or distally with respect to the narrowed segment. The increased radial force can also lead to discomfort or pain. Some of the plastic stent delivery systems are stiff and bulky, making deployment difficult in severely narrowed segments. The Polyflex stent (Boston Scientific, Natick, MA) is composed of a polyester mesh coated with an outer layer of silicone. It is deployed via a push-and-release technique after being loaded into the delivery system. The proximal portion of the stent is flared to help minimize the risk of migration. The Alimaxx-E stent is composed of a nitinol core structure completely covered with silicone. The outer surface of the stent has small struts that help to keep the stent anchored to the esophageal lumen and to prevent migration. This stent can be released over a wire using a trigger-graded release mechanism, and can also be loaded directly onto a pediatric endoscope and deployed under direct visualization without the need

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**Table 34.2**

<table>
<thead>
<tr>
<th>Stent</th>
<th>Manufacturer</th>
<th>Material</th>
<th>Length (cm)</th>
<th>Diameter Shaft/Flare (mm)</th>
<th>Covering</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ultraflex</td>
<td>Boston Scientific</td>
<td>Nitinol</td>
<td>10/12/15</td>
<td>18/23</td>
<td>NC; PC</td>
</tr>
<tr>
<td>Wallflex</td>
<td>Boston Scientific</td>
<td>Nitinol</td>
<td>10/12/15</td>
<td>12/28</td>
<td>PC; TC</td>
</tr>
<tr>
<td>Esophageal Z</td>
<td>Cook</td>
<td>Stainless steel</td>
<td>8/10/12/14</td>
<td>18/25</td>
<td>PC</td>
</tr>
<tr>
<td>Evolution</td>
<td>Cook</td>
<td>Nitinol</td>
<td>8/10/12.5/15</td>
<td>20/25</td>
<td>PC</td>
</tr>
<tr>
<td>Niti-S</td>
<td>Taewoong Medical</td>
<td>Nitinol</td>
<td>7/10/12</td>
<td>18/22</td>
<td>TC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>8/10/12/14</td>
<td>16/20</td>
<td>TC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18/23</td>
<td>TC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20/25</td>
<td>TC</td>
</tr>
<tr>
<td>Polyflex</td>
<td>Boston Scientific</td>
<td>Polyester</td>
<td>9/12/15</td>
<td>16/20</td>
<td>TC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18/23</td>
<td>TC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>21/28</td>
<td>TC</td>
</tr>
</tbody>
</table>

FDA, Food and Drug Administration; NC, noncovered; PC, partially covered; TC, totally covered.

for fluoroscopy. Another completely covered stent is the Niti-S stent (Taewoong Medical, Seoul, Korea). This stent has a design that is similar to the Wallflex stent with broad flaring ends. It is currently in limited distribution within the United States (Fig. 34.4).

Early experience with the use of self-expanding plastic stents reveals similar relief of dysphagia compared with SEMS in >98% of patients. The most notable problem with expandable, plastic stents is the issue of stent migration. Conigliaro et al. documented a 20% stent migration rate (n = 12/60) with seven early migrations and five occurring late. Prospective randomized studies comparing SEMS with self-expanding plastic stents have demonstrated equivalent relief of dysphagia in the setting of esophageal cancer; however, self-expanding plastic stents have been associated with increased difficulty of insertion and complication rates (migration, hemorrhage, food impaction) in comparison with SEMS. In a randomized comparison of 101 patients (Ultraflex = 54; Polyflex = 47) who underwent stent placement for unresectable esophageal carcinoma, success of stent insertion, initial relief of dysphagia, and overall survival were similar between groups. Self-expanding plastic stents were, however, associated with a significantly higher complication rate (hyperplastic overgrowth, migration, food impaction) compared with SEMS (odds ratio = 2.3; 95% confidence interval: 1.2 to 4.4). In another prospective, randomized comparison of patients undergoing stent placement for malignant dysphagia (Ultraflex = 42, Niti-S = 42, Polyflex = 41), relief of dysphagia, and overall survival was similar between groups. There was an increased rate of tissue ingrowth in the partially covered SEMS (Ultraflex) group, though this did not attain statistical significance. Self-expanding plastic stents were associated with an increased rate of stent migration (29%, p = 0.01) as well as increased technical difficulties in stent placement (p = 0.008) when compared with SEMS.

The most recent generation of stents highlights fully covered SEMS that are designed to overcome the limitations of partially covered SEMS and self-expanding plastic stents (Fig. 34.4). These stents may promote less granulation tissue and associated stenosis, and may be removable after several weeks. However, an increased migration rate still may be expected as a result. Published data on the performance of fully covered stents are awaited.

**PREOPERATIVE PLANNING**

Preoperative assessment of clinical symptoms should be objectively recorded. Dysphagia scores are utilized to gauge the degree of symptomatic esophageal obstruction. The following scoring system is commonly employed: 0, tolerating a regular diet, no dysphagia; 1, difficulty with solids; 2, difficulty with soft foods; 3, difficulty with liquids; 4, difficulty managing saliva. Careful preoperative radiographic assessment is imperative in planning the optimal approach. Barium esophagography provides a roadmap of the esophagus, and allows assessment of the extent of obstruction, the length...
of esophageal involvement, and the presence of other anatomic abnormalities such as leak, perforation, or fistula. Computed tomography and PET scanning are critical in the setting of malignancy in helping to stage the extent of disease. Esophagogastroduodenoscopy (EGD) allows confirmation of the underlying pathology, a real-time assessment of the extent of disease, and whether the obstruction is intrinsic or extrinsic in nature. Flexible bronchoscopy is a useful adjunct in assessing patients with esophageal cancers of the proximal-mid esophagus and in those with suspected tracheoesophageal fistulas.

TECHNIQUE

Esophageal stents may be inserted endoscopically under conscious sedation or via a general anesthetic. The authors prefer to employ a general anesthetic in most cases in an effort to minimize the risk of aspiration and optimize stent positioning. During EGD, the following features of the case are assessed: (1) degree of esophageal narrowing, (2) location and length of esophageal involvement, and (3) the integrity of surrounding esophageal tissues. On occasion, significant narrowing may prevent the safe passage of the endoscope, and gentle dilation is performed to enable advancement of the scope beyond the distal extent of the lesion. Care should be taken to minimize the extent of dilation if anticipating the need for stent insertion. Overdilation of a malignant stricture might decrease stent purchase after deployment, leading to a higher risk of stent migration. Once the obstructing lesion has been assessed, the proximal and distal extent of the lesion is mapped with radio-opaque markers that are placed on the skin of the chest wall (Fig. 34.5). The scope is then advanced into the duodenum, and a guidewire is inserted. The scope is withdrawn, and the distance between the two external markers is measured. This distance is used to estimate the length of the stent chosen to cover the lesion. Overall stent length will need to extend 1 to 2 cm above and below the marked interval to ensure complete coverage and to optimize stent position and minimize the risk of the end of the stent “crimping” and not fully deploying if it is too near the obstructive tumor. The stent delivery system (Fig. 34.6) is then advanced over the wire under fluoroscopic guidance. The stent is identified by radio-opaque proximal and

Figure 34.5 Deployment of esophageal stent. Note the proximal and distal skin markers that delineate the extent of obstructing tumor (arrows). Fluoroscopy demonstrates good stent position and expansion. (From: Perry Y, Luketich JD. The use of esophageal stents. Cameron JL, ed. Current Surgical Therapy. 8th ed. Philadelphia, PA: Mosby, 2004: 49–55.)
distal markers that are aligned with the previously placed skin markers. Once adequate position is confirmed, the stent is deployed under fluoroscopic guidance. Delivery systems may employ a proximal release or distal release technique. Slight adjustments to stent position can be made during deployment to optimize stent position. Following deployment, the delivery system and guidewire are removed, and repeat endoscopy is performed to assess the adequacy of stent position and expansion (Fig. 34.7). Stents should be slightly oversized to permit increased pressure of the stent against the esophageal wall, so as to minimize the risk of stent migration. Care should be taken not to select a diameter that is too large, which can lead to pain and incomplete stent expansion with residual infolding of the stent that will partially obstruct the stent lumen. Appropriate deployment will result in a stent that is well expanded with good purchase along the esophageal wall. A slight indentation at the level of obstruction is evident on fluoroscopy (Fig. 34.8). Ideally, there should be no gap between the esophageal wall and proximal stent lumen. Areas of incomplete expansion can be augmented with the assistance of a balloon dilator. Most stents are equipped with proximal and distal purse strings that permit stent repositioning as required following deployment. Utilizing careful technique, success rates of 80% to 90% for stent deployment can be expected.

**POSTOPERATIVE MANAGEMENT**

Post-stent management includes a barium esophagram to assess luminal patency, and then a trial of oral liquids and dietary advancement. Nutritional counseling is imperative to educate the patient and the family about the goals of the stent and limitations. For example, patients need to understand that many solid foods will stick and cause
obstructive problems. Stents that traverse the GE junction can be expected to increase reflux, and proton pump inhibitors (PPIs) and other measures to minimize reflux, such as elevating the head of the bed and minimizing oral consumption before lying down, should be discussed. The patient should be seen again in clinic early after stent placement to assess how the patient is doing with regard to nutritional intake and determine if side effects of the stent are present.

Figure 34.7 Endoscopic (A) and radiographic (B) appearance of esophageal stent after deployment. (From: http://www.gastrohep.com/images/image.asp?id=455. Accessed July 19, 2013.)

Figure 34.8 Barium esophagram before (A) and after (B) esophageal stent placement for a malignant stricture. (From: Cameron JL, ed. Current Surgical Therapy. 8th ed. Philadelphia, PA: Mosby, 2004: 49–55)
Chapter 34  Esophageal Stents

Numerous complications related to stent placement have been documented and range from 30% to 50% in most series (Table 34.3). The most common complication encountered with SEMS placement is the development of exuberant granulation tissue or tumor ingrowth in the proximal and distal uncovered portions of the stent, which occurs in approximately half of the patients within 2 to 3 months of stent placement (Fig. 34.9). Tumor ingrowth can result in recurring dysphagia, necessitating mechanical debridement or further endoluminal therapy (e.g., Nd:YAG laser, PDT, brachytherapy). Stent migration can occur in 10% to 40% of cases, and is more common when self-expanding plastic stents are employed (Fig. 34.10) (see Stent Design above). Proximal stents are associated with a higher rate of airway compromise due to tracheal compression and migration, and distal stents (especially those that span the GE junction) can lead to wide open reflux (10% to 20%), regurgitation, and even aspiration (1% to 2%). Stents can be associated with severe discomfort and/or nausea following placement that may be unremitting in nature and may require stent repositioning, revision, or removal (1% to 2%). Procedure-related perforation has been reported in 1% to 2% of cases. Other less common stent-related complications include hemorrhage, tracheoesophageal fistula formation, food impaction, stent fracture during manipulation, entrapment of the stent delivery system, and epidural abscess formation (in the setting of perforation/leak). It has been reported that over

### TABLE 34.3 Complications of Esophageal Stent Placement

<table>
<thead>
<tr>
<th>Complication</th>
<th>Incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tumor ingrowth/overgrowth</td>
<td>42 (33%)</td>
</tr>
<tr>
<td>Severe reflux</td>
<td>14 (11%)</td>
</tr>
<tr>
<td>Stent migration</td>
<td>11 (8.7%)</td>
</tr>
<tr>
<td>Food impaction</td>
<td>10 (7.9%)</td>
</tr>
<tr>
<td>Unsuccessful deployment</td>
<td>4 (3.1%)</td>
</tr>
<tr>
<td>Esophageal erosion/fistula</td>
<td>3 (2.3%)</td>
</tr>
<tr>
<td>Intractable pain requiring removal</td>
<td>2 (1.6%)</td>
</tr>
<tr>
<td>Perforation</td>
<td>1 (0.8%)</td>
</tr>
</tbody>
</table>


Figure 34.9 Extensive overgrowth of exuberant granulation tissue at the distal end of an Ultraflex stent 4 months after insertion. (From: Schembre D. Advances in esophageal stenting: The evolution of fully covered stents for malignant and benign disease. Adv Ther. 2010;27(7):413–425.)
half of the patients require endoscopic reintervention for complications at a mean interval of 82 days.\(^3^2\) Despite numerous modifications in stent design over time, there has been no significant reduction in postprocedure complications, which is likely due to the generally poor medical and nutritional status of patients experiencing malignant esophageal obstruction.\(^3^3\)

Pitfalls in the deployment of esophageal stents include undersizing or oversizing the stents both in terms of stent length and stent width. Undersized stents will have reduced purchase against the esophageal wall and will be prone to leaks of ingested material around the stent and stent migration. Excessive dilation of strictures prior to stent insertion will similarly reduce stent traction and increase the risk of stent migration. Ideally, dilation should be limited to a size necessary to permit safe stent insertion. Furthermore, inadequate length might lead to residual obstruction at either the proximal or distal margin of the stent by tumor (technical error). Oversized stents can lead to pain and incomplete stent expansion with residual infolding of the stent that will partially obstruct the stent lumen. Stents that are too long can telescope into the stomach, which can create intermittent stent obstruction with gastric mucosa being drawn into the stent lumen due to the negative intrathoracic pressure. Proximal stents that are deployed in proximity to the cricopharyngeus can create discomfort and globus sensation, as well as acute airway compression. When both the esophagus and trachea are stented, overlapping stents can be associated with a high incidence of tracheoesophageal fistula formation from mechanical stent-on-stent erosion. The combination of stent placement and radiation may also be associated with a higher rate of stent erosion and fistula formation. Following stent insertion, patients should be carefully followed to ensure adequate symptomatic palliation, and to monitor for any of the abovementioned complications. Adequacy of stent position can be assessed with a standard chest x-ray in most cases, or via chest CT. Objective assessment of swallowing function can be performed with a barium swallow.
RESULTS

Rigid Versus Expandable Stents

With the advent of flexible endoscopic techniques, a new generation SEMS was introduced that greatly simplified stent insertion. With the publication of the seminal prospective, randomized trial by Knyrim et al.,34 SEMS were found to be associated with significant reduction of perioperative complications, reduced perioperative 30-day mortality (29% vs. 14%) and were found to be cost effective when compared with rigid prostheses. In another prospective study, SEMS were compared with plastic prostheses in 31 consecutive patients undergoing palliation for inoperable malignant obstruction. In this study, complication rates were similar between groups, but SEMS were associated with better palliation of dysphagia, earlier patient discharge and prolonged survival when compared with patients who received plastic rigid prostheses.35 In a larger, retrospective study of 158 patients undergoing SEMS placement versus rigid prostheses, SEMS placement was associated with comparable reduction in dysphagia and significantly reduced complication rates.36 These studies have established that SEMS are superior to rigid prostheses in the management of patients with malignant esophageal obstruction. Self-expanding esophageal stents are now the most commonly used method of palliation in esophageal cancer.

Esophageal Stents in the Management of Malignant Disease

The majority of patients (>60%) with esophageal cancer will present with unresectable or inoperable esophageal cancer due to local invasion, distant metastases, or medical comorbidities. Quality of life, therefore, will tend to take precedence over long-term prognosis. Multiple modalities exist that can be employed in the treatment of dysphagia due to cancer (Table 34.1). Esophageal stents provide a safe and expeditious method of relieving dysphagia, while minimizing length of stay and the risk of complications. It is probably the simplest and quickest method for improving quality of life in this setting. Most series document successful stent insertion in 80% to 95% of patients. In a series of 100 consecutive stent placements, immediate improvement of dysphagia was obtained in 85% of patients, with no procedure-related deaths.32 Although SEMS are associated with immediate relief of symptoms and lower cost than other palliative measures such as PDT and Nd:YAG laser ablation, quality of life may be worse in certain circumstances due to complications.37 In a retrospective analysis of 82 patients comparing the outcomes of Gianturco-Rösch Z stents (n = 20), Wallstents (covered, n = 31; uncovered, n = 13) and Ultraflex stents (covered, n = 8; uncovered, n = 10), the mean survival was 4.5 months after stent placement, and the incidence of complications was 75%, 68.1%, and 44.4%, respectively. Complications were more frequently encountered when stents were placed in the proximal third of the esophagus. Thirteen patients (15.9%) died from complications directly related to stent placement.38

Nd:YAG laser therapy has been shown to be effective at reducing tumor bulk, controlling bleeding, and relieving obstruction due to endoluminal tumor involvement. Less reflux is encountered when compared with stents that traverse the GE junction. Esophageal stent placement is quicker and appears to be equally effective in relieving dysphagia, and has been shown to be more effective in cases of extrinsic compression.39 There have been a few studies examining the impact of Nd:YAG laser therapy (with or without radiation) versus expandable stent placement in the setting of malignant dysphagia. In one study, 125 patients with malignant dysphagia were treated with either Nd:YAG laser ± radiation therapy versus stent placement. Relief of dysphagia was similar between groups. However, stent placement was associated with a significant increase in perioperative morbidity, including an 8- to 10-fold increase in major complications.40 In another study comparing the use of Nd:YAG laser therapy and brachytherapy versus stent insertion, the Nd:YAG/brachytherapy arm demonstrated a higher rate of bleeding, fistula formation, and need for retreatment and higher cost compared with stent insertion.41
PDT has also been employed in the palliation of malignant dysphagia. It is especially useful in reducing endoluminal tumor bulk and minimizing tumor-related bleeding. Palliation of dysphagia is achieved in 5 to 7 days, and persists from 9.5 to 14.4 weeks. Although YAG laser ablation and PDT represent useful adjuncts in the palliation of malignant dysphagia, the ease and simplicity of stent insertion, and the rapidity of symptomatic improvement have made esophageal stenting the first-line approach in the majority of patients.

Chemotherapy and radiation therapy can improve survival in patients with advanced esophageal cancer, and can be very effective in controlling malignant dysphagia but the time from starting therapy to relief of dysphagia can be several weeks. In the setting of malignancy, esophageal stent placement has been compared with chemotherapy and radiation therapy. In a study of 66 patients who were treated with esophageal stent insertion, freedom from dysphagia was achieved in 81%, compared with 49% in the chemotherapy group and 56% in the radiation therapy group. Prior radiation and/or chemotherapy have not been consistently demonstrated as risk factors for complications or poor outcomes following placement of esophageal stents for malignancy.

Single-dose intraluminal brachytherapy has also been demonstrated to be effective in reducing dysphagia. In a prospective, randomized comparison, patients were treated with either single-dose brachytherapy (n = 101) or stent placement (n = 108). Dysphagia was relieved more rapidly with stent placement; however, brachytherapy achieved better long-term control of symptoms. A greater number of complications were seen in the stent group (33% vs. 21%, p = 0.02). In a study comparing outcomes following single-dose (12 Gy) brachytherapy and esophageal stent placement by the Dutch SIRE study group, the application of a single dose of brachytherapy resulted in a 75% improvement in dysphagia at 4 weeks. Although esophageal stenting was associated with a more rapid improvement in dysphagia, brachytherapy was associated with a more sustained effect with improved quality of life at 6 months compared with stenting. In a cost-effectiveness analysis, brachytherapy was found to be more cost-effective than Nd:YAG laser therapy or stent placement, producing the largest net health benefit. The reduced availability of brachytherapy in many hospitals, however, has limited the application of this modality in the management of patients with malignant dysphagia. A multimodality approach in the management of malignant obstruction probably yields the best results (Fig. 34.11). Following initial stenting, the use of PDT and brachytherapy can be used to control the tissue ingrowth. The chosen treatment strategy should be tailored to individual patient and tumor characteristics.

Esophageal stents have also demonstrated efficacy in the management of tracheoesophageal fistulas associated with malignancy. In a study that included 22 patients with tracheoesophageal fistula secondary to malignancy, airway symptoms improved in 90%. In the largest study, Shin et al. treated 61 patients with esophagorespiratory fistulas utilizing covered esophageal stents, with successful control of the fistula in 80%. Concomitant airway stenting was required in 16.4% of cases. During long-term follow-up, approximately one-third of patients were noted to develop recurrent fistulas, approximately one-half of whom were successfully managed with placement of a second SEMS.
Esophageal Stents in the Management of Benign Disease

Esophageal stents have also demonstrated utility in the case of benign disease. Due to a high rate of delayed complications (erosion, granulation tissue, bleeding, fistula), metallic stents are not indicated in the setting of benign disease. With the emergence of self-expanding plastic stents, multiple reports have reexplored the utility of stenting in the setting of benign disease. Success rates range from 17% to 95%. Fully covered plastic stents (e.g., Polyflex) exhibit a reduced tendency for ingrowth of granulation tissue or fistula formation, and are readily removed when clinically indicated. Conditions amenable to esophageal stenting include peptic strictures, caustic or postradiation strictures, esophageal perforations, and anastomotic leaks. In the case of benign, recalcitrant strictures (e.g., peptic, radiation-induced), the use of plastic stents has been shown to provide immediate relief of dysphagia, and the radial force of the stent encourages gradual and progressive dilation of the strictured segment and underlying tissue remodeling. Following removal of these stents, up to 80% of patients may experience substantial improvement in their symptoms without the need for further dilation over a 2-year follow-up period. Other studies have reported lower success rates in the management of benign strictures and fistulae, including a prospective evaluation of 40 patients with benign strictures treated with insertion of a plastic stent for 4 weeks. Stent deployment was unsuccessful in two patients. Only 32% experienced lasting improvement in symptoms. Complications included stent migration (22%), severe chest pain (11%), bleeding (8%), inability to remove stent (6%), and fistula (3%). Other studies have demonstrated a very high migration rate (up to 73%) with the use of self-expanding plastic stents (e.g., Polyflex stent) and a reintervention rate of 81.6%. Fully covered SEMS can also be used for benign disease, but have been shown to have similar problems with stent migration (36%), and lack of sustained improvement (29%).

Although results of fully covered removable stents have been variable in the management of strictures, greater efficacy has been demonstrated in the management of leaks and perforations [Fig. 34.12]. Multiple studies have reported efficacy in managing limited perforations of the esophagus, both spontaneous and iatrogenic, with esophageal stent placement. Freeman et al. employed stents for the management of intrathoracic, iatrogenic esophageal perforations. Leaks were successfully occluded in 16/17 (94%) of the patients, with 14/17 (82%) being able to reinitiate an oral diet within

Figure 34.12 A: Self-expanding plastic stent insertion to cover an iatrogenic esophageal perforation (arrow). B: Endoscopic view depicting complete coverage of perforation. (From: Bunch TJ, Nelson J, Foley T, et al. Temporary esophageal stenting allows healing of esophageal perforations following atrial fibrillation ablation procedures. J Cardiovasc Electrophysiol. 2006;17:435–439.)
72 hours of stent placement. Only 3/17 (18%) patients required stent repositioning due to stent migration. There was one failure (6%) that went on to require surgical intervention secondary to continued leak following stent placement. All stents were removed at a mean of 52 ± 20 days from the time of initial stent placement. In another study of 32 patients with spontaneous perforations and postsurgical leaks that were managed with the placement of self-expanding plastic stents, successful closure was achieved in 70% of patients.

Placement of retrievable stents in the setting of spontaneous esophageal perforation (Boerhaave syndrome) has been detailed in several case reports. In these reports, stenting allowed healing of the perforation, and safe removal of the stent within 2 to 6 months. In the setting of iatrogenic perforations, stenting has been shown to achieve early closure of the perforation in 9/11 (81.8%) cases. In another prospective study reporting the use of esophageal stents in 13 cases of benign esophageal perforation, stenting achieved successful closure of the perforation in 12/13 (92.3%) cases. All stents were retrieved endoscopically after 3 weeks. Self-expanding plastic stents have also been employed successfully in the management of esophageal perforations. In a prospective series evaluating the use of self-expanding plastic stents in 17 patients with esophageal perforations, leak occlusion was accomplished in 16/17 (94.1%) of patients as demonstrated by barium esophagram. Stent migration was seen with the use of self-expanding plastic stents in three (17.6%) of the patients. Other reports have described the use of partially covered SEMS in controlling esophageal anastomotic leaks, with successful closure of all reported leaks, allowing for earlier resumption of oral intake.

The placement of large diameter self-expanding plastic stents has also been found to be effective in this setting (78% to 89% leak occlusion). Radecke et al. reported their experience with the placement of 60 plastic stents in 39 patients for a variety of benign and malignant stenoses and fistulae. Following stent placement, 69% of patients could resume eating, and another 15% could handle their own secretions but were still unable to eat. Due to the focal and less constrictive nature of most benign lesions, plastic stent migration is the most common complication encountered. Early migration rates have been reported in 25% to 30% of patients, with late migration seen in an additional one-third of those treated with self-expanding plastic stents. Prospective, randomized trials are needed to better delineate the advantages and drawbacks of fully covered stents in benign disease.

CONCLUSIONS

The use of expandable stents represents a safe and expeditious approach in the palliation of malignant dysphagia. Changes in stent design have simplified stent insertion and have broadened its application to a variety of benign conditions. SEMS have emerged as a superior construct when compared to rigid prostheses in terms of ease of insertion and procedure-related morbidity. Partially covered SEMS are associated with reduced tissue ingrowth and recurrent dysphagia when compared with uncovered stents. Among partially covered SEMS, there are no proven advantages of one design versus another. Although self-expanding plastic stents have demonstrated equivalent relief of dysphagia when compared to SEMS, self-expanding plastic stents have been associated with increased difficulty of insertion and complication rates (migration, hemorrhage, food impaction) in the management of patients with malignant dysphagia. The use of temporary SEMS or self-expanding plastic stents for the management of esophageal perforation and anastomotic leaks is clearly emerging as an option in selected patients. Most successful series include surgical drainage of any significant areas of extravasation after stent placement. The use of stents in this setting is promising, but the ideal patients and technique will need to be validated in larger studies with more detailed follow-up. Long-term, prospective randomized data regarding the use of retrievable, fully covered SEMS will be necessary to delineate their usefulness in benign disease. Careful patient selection and postoperative follow-up are required to optimize
patient outcomes. As technology improves, and as clinicians gain experience in employing an individualized multimodality approach in the treatment of malignant obstruction of the esophagus (stenting, dilation, laser, PDT, XRT, chemotherapy), the palliative benefits of these approaches will be optimized.

**Recommended References and Readings**


Bougie and Balloon Dilation of Esophageal Strictures—Malignant and Benign
Konstantinos I. Makris and Christy M. Dunst

Introduction

Esophageal dilation or bougienage was first reported in the sixteenth century and was initially used for disimpaction of the esophagus by pushing the obstructing food bolus into the stomach. Wax-made dilators were used for that purpose. The term bougie originates from the name of the Algerian city Bouijah, a medieval center of wax and candle trade. Leather, iron, lead, and whalebone are some of the materials subsequently used for the construction of esophageal dilators until the advent of the modern-era synthetic bougies.¹

Esophageal dilation evolved over the years from a blind technique with a high risk of perforation to a sophisticated and safe technique facilitated by flexible endoscopy, guidewires, fluoroscopy, and other adjunct tools. The armamentarium of the modern endoscopist offers a variety of treatment options and a multitude of approaches, which can address the majority of obstructing lesions in the esophagus.

Several types of esophageal dilators are available (Table 35.1) and are usually classified as push dilators (i.e., Maloney, Savary-Gilliard), and balloon dilators (i.e., through-the-scope [TTS] balloon dilators). Push dilators can be advanced with or without the use of a guidewire, under fluoroscopic monitoring. The balloon dilators can be used in a similar fashion over a guidewire or passed through the flexible endoscope and dilation is performed under direct endoscopic view.

The mechanical aim of dilation is the effective stretching and disruption of the stenotic features in the submucosal and muscular layers of the esophageal wall, while optimally a full thickness disruption does not occur. Balloon dilation transmits only radial forces to the esophageal wall, which theoretically represents the desired mechanism of dilation of short stenotic lesions. In contrast, push dilators generate both a radial and an additional longitudinal force as a result of shearing effects. Despite this difference, no clear advantage of one type of dilator over the other has been demonstrated when used for the most common indications of esophageal dilation.
TABLE 35.1  Types of Esophageal Dilators

**Push Dilators**
A. Nonguided rubber bougies
   - Maloney (tapered, mercury-filled, 12–60F in 2-French increments)
   - Hurst (blunt-tipped, tungsten-filled, 12–60F in 2-French increments)
B. Wire-guided dilators
   - Savary-Gilliard (polyvinyl, tapered, central channel for guidewire, 5–20-mm diameter)
   - Eder-Puestow (flexible system with metal olive tips, 12 olive sizes, 6.6–19.3-mm diameter)
C. Other
   - Gum elastic dilators (semi-flexible, passed through rigid esophagoscope, rarely used)
   - KeyMed dilator (variation of Eder-Puestow system, not used anymore)
   - Celestin and Buess dilators (variations of Savary system, not commonly used)
   - Optical dilator (clear, over-the-scope bougie with sequential dilating segments)

**Through-the-scope (TTS) Balloon Dilators**
TTS balloon dilators (used under endoscopic or fluoroscopic vision, with or without guidewire, 6–40-mm diameter), single or multiple-diameter

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**INDICATIONS/CONTRAINDICATIONS**

Esophageal dilation is indicated for the treatment of dysphagia caused by esophageal-obstructing pathologies and functional disorders (Table 35.2). Achalasia, malignant strictures, and postoperative anastomotic strictures constitute the most common indications.2 Peptic strictures are also an indication, although the incidence of peptic strictures has markedly declined since the introduction of proton pump inhibitors (PPIs).

The clinical goal of esophageal dilation is the relief of dysphagia by eliminating the obstructing process in the esophagus. This allows maintenance of adequate oral nutrition and prevents aspiration. Dysphagia is usually significantly improved when a luminal diameter of 12 to 15 mm is achieved or at least a 36F dilator is passed. Maintenance of a 15-mm-diameter lumen (45 French) generally allows near normal dietary intake. Dilation of an obstructing esophageal lesion also allows the passage of the endoscope to the stomach for gastroscopy, the endoscopic ultrasound (EUS) probe for evaluation of the esophageal pathology, and for the potential placement of a stent. Large diameter esophageal dilators (50 to 60 French) are also frequently used intraoperatively during the creation of a fundoplication to lower the risk of iatrogenic dysphagia.3 Similarly, these dilators can be used to treat postfundoplication dysphagia. Early dilation has been cited by many experienced esophageal surgeons to be beneficial in the early management of esophageal anastomotic

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**TABLE 35.2  Most Common Indications for Esophageal Dilation**

**Motility Disorders**
- Achalasia
- Cricopharyngeal dysphagia

**Benign Diseases**
- Peptic stricture
- Corrosive esophagitis
- Schatzki’s ring and esophageal webs
- Iatrogenic (radiation, esophageal ablation, postfundoplication, anastomotic, postinstrumentation)
- Eosinophilic esophagitis
- Other (fungal–viral–mycobacterial infections, autoimmune disorders, drug-induced esophagitis)

**Malignant Diseases**
- Primary esophageal cancer
- Secondary thoracic neoplasia with extrinsic compression/infiltration (tracheal, lung, laryngeal neoplasia or lymphoma)
leaks to help preserve a distal patent lumen and facilitate fistula closure. In other settings, esophageal dilation may be required prior to placement of an expandable stent.

Active esophageal perforation is an absolute contraindication to esophageal dilation. History of previous esophageal perforation is a relative contraindication to future dilations and extreme caution should be used. Conditions that increase the difficulty of the procedure and increase the risk of perforation or other complications also constitute relative contraindications. This includes esophageal malignancy, large thoracic aortic aneurysms, and pharyngeal or cervical deformities including vertebral bone spurs, compromised cardiorespiratory status, and severe coagulopathy. Radiotherapy and concurrent esophageal biopsies are not considered contraindications to esophageal dilation.

**PREOPERATIVE PLANNING**

Candidates for esophageal dilation should be thoroughly evaluated prior to the procedure to determine the cause of the esophageal obstruction as well as the procedural risks associated with the patients’ comorbidities. History should be taken and physical examination performed before making the decision to intervene. A barium swallow is obtained to assess the extent and nature of the obstruction, although endoscopic assessment is essential as well. It should be noted that patients with proximal dysphagia may be harboring other pathologies (i.e., pharyngeal pouch, Zenker’s diverticulum, postcricoid web) that increase the risk of perforation. Other available imaging studies should also be reviewed.

Endoscopy provides valuable information on the anatomic site, the length, and the nature of the obstructing lesion. Biopsies or brush cytology should be performed to detect malignancy, which would affect the overall management and may increase the risk of perforation. Other endoscopic findings, such as hiatal hernia, tortuous esophagus, angulation of the stricture, and esophageal diverticula can also influence the decision on the type of dilators that need to be used. Simple strictures can be biopsied and dilated in the same session, while suspicion of malignancy may defer dilation due to the increased risk of perforation.

The procedure should be explained in detail to the patient. The anticipated benefits, the alternative treatment options, and the potential risks should be discussed, and consent should be obtained.

Esophageal dilation can cause bleeding in patients receiving anticoagulants, which may be difficult to control endoscopically. Therefore, warfarin should be discontinued prior to the dilation, and a prothrombin time test should be performed. In patients at high risk for thromboembolic events, bridging with heparin may be considered. Heparin should be withheld 4 to 6 hours prior to the procedure and resumed 4 to 6 hours after. Warfarin can typically be restarted on the night of the procedure. There is no solid data indicating the need to discontinue aspirin or nonsteroidal anti-inflammatory medications prior to esophageal dilation. However, antiplatelet agents like clopidogrel should be discontinued 7 to 10 days prior to the procedure.

The patients fast for 4 to 6 hours prior to the procedure to ensure that the stomach and the esophagus are empty for the procedure. This is essential not only for a technically successful endoscopy and dilation, but also for prevention of aspiration. Achalasia patients, who develop severe esophageal stasis, may require longer fasting.

Transient bacteremia with esophageal dilation has been observed. Therefore, preprocedure antibiotics should be administered to patients at risk for endocarditis and patients with immunosuppression. The guidelines on antibiotic coverage for endoscopy should be followed.

Although upper endoscopy and esophageal dilation may be performed on awake patients, deeper levels of sedation or even general anesthesia may be required for the patient’s comfort during the procedure. The type of sedation is decided on the basis of the patient’s overall health condition, the expected duration and type of intervention, the patient’s previous tolerance to common sedative medications, and the
preferences of the endoscopist. Most commonly, sedation is obtained with intravenous midazolam, fentanyl, or propofol. Continuous pulse oximetry and hemodynamic monitoring are provided. Spraying the oropharynx with lidocaine or asking the patient to swallow viscous lidocaine prior to the procedure can make the endoscopy and dilation more comfortable, but is generally not needed. Under specific circumstances, general endotracheal anesthesia is required or may be preferred by some patients.

The plan on which approach and what type of dilator will be used should be formulated before the procedure and finalized during the endoscopy based on the findings. Nonguided bougies (Maloney) can be used with simple strictures, webs, or rings in a fairly straight esophagus. However, it must be noted that esophageal perforation is always a consideration and may be mitigated by fluoroscopy, guidewires, and endoscopic direct visualization. Patients with particularly refractory and straightforward strictures, such as cervical radiation or anastomotic strictures, can be taught to use these types of bougies at home. Tighter or more complex strictures are approached with guided dilators, either TTS balloons or push dilators (Savary-Gilliard). The use of contrast and fluoroscopy enhances the safety of the intervention in difficult situations. The experience and facility of the endoscopist with a specific type of dilator also play a key role in the decision making.4

**Principles**

Despite the specific differences in the technique used, there are some principles that apply to all the types of esophageal dilation. (a) The size of the first dilator used, either balloon or bougie, should correspond to the diameter of the stricture; (b) Traditionally, it is advised that no more than three bougie dilators of sequentially increasing size should be used in every one session (“rule of three”). Multiple sessions may be required for the desired total dilation; (c) The clinical end point of esophageal dilation is the relief of dysphagia. It has been suggested that luminal diameter of 12 to 15 mm suffices for unobstructed swallowing. Esophageal webs or Schatzki’s rings require larger-caliber dilators (16 to 20 mm), whereas treatment of achalasia is attempted with even larger dilators (30 to 40 mm). The risk of perforation, though, increases linearly with the size of the dilator. Caution should be used when malignant strictures are dilated because of the higher risk of perforation. Dilation should be gentle and wide enough to allow biopsy, passage of the EUS probe, and palliative stent placement; (d) Dilation of the stenotic lesion starts when moderate resistance is encountered during passage of the bougie through the stricture or during balloon inflation. Excessive resistance should be avoided, since rupturing forces are developing.

**Positioning**

Most commonly, the patient is placed in the left lateral decubitus position, which is the typical for upper endoscopy. This allows the use of all types of esophageal dilators and does not interfere with patient monitoring, while it facilitates the management if intraoperative regurgitation occurs and minimizes the risk of aspiration. The supine position can be used when general endotracheal anesthesia is administered or fluoroscopy is planned, in order to improve the view without the overlying humerus. Transnasal, office-based esophageal dilations have also been reported in the sitting position.7 Dilation with Maloney bougies can be done in the sitting position as well, particularly when self-dilations are performed.

**Push Dilators**

The guided passage of push dilators, such as the Savary-Gilliard, lowers the risk of perforation. These dilators have a central lumen which allows their advancement over
a stiff guidewire with a soft spring tip (Savary guidewire) (Figs. 35.1 and 35.2). Softer guidewires can be used with caution when more complex strictures need to be negotiated. However, these may be too flexible to direct the dilator and can lead to perforation.

The guidewire is advanced through the working channel of the endoscope and its tip is preferably positioned in the antrum or positioned through the pylorus into the duodenum. If the stricture cannot be traversed by the endoscope, a pediatric endoscope might transverse the stricture, or a guidewire can be passed using endoscopic vision and fluoroscopic guidance through the stricture and into the stomach. Subsequent fluoroscopic controlled bougienage can then be performed. Alternatively, a dilating balloon catheter can be similarly passed through the narrowing, and dilation performed. Typically, the endoscope can be subsequently passed through the dilated stricture into the stomach for full evaluation of the esophagus and stomach. Alternatively, the guidewire can be placed under fluoroscopy ensuring that the tip passes at least 20 to 30 cm distal to the stenotic lesion. Endoscopic use of contrast may improve the evaluation of the stricture intraoperatively.

After proper positioning of the guidewire, the endoscope is withdrawn slowly with synchronous equal advancement of the guidewire through the working channel so that the tip of the wire remains stable. This is the standard Seldinger technique also used for advancement of central vascular access catheters. This task is more easily performed
by the coordinated actions of two people and can be monitored either endoscopically or under fluoroscopy. As soon as the tip of the endoscope is outside the patient’s mouth, the guidewire is grasped and stabilized against the bite-block. The guidewire is marked for depth and the position should be noted before passing the dilator to make sure that the guidewire tip has remained in the stomach.

The Savary-Gilliard dilator is then back-loaded and slowly advanced in the patient’s mouth and upper esophagus. Insertion and advancement is facilitated by lubrication of the dilator (i.e., lubrication gel) and occasionally the dilator’s central channel (i.e., lubrication spray), through which the guidewire is passed. The guidewire is kept steady while the dilator is pushed, by holding the proximal end of the guidewire against a fixed point outside the patient’s body. This prevents distal migration of the guidewire or kinking in front of the dilator tip. The dilators are radio-opaque or have a radio-opaque band at the transition zone (between the tapered tip and the widest portion of the dilator) allowing fluoroscopic monitoring during advancement.

Advancement should be slow and gentle with a finger grasp of the dilator close to the patient’s mouth. If resistance is encountered, advancement is stopped; and fluoroscopic assessment of the alignment of the dilator to the esophageal axis is assessed. If alignment is correct, continued advancement can be attempted. If resistance is significant, the dilation at that bougie size should be stopped and repeat endoscopic examination of the esophagus performed. If further dilation is planned, the dilator is withdrawn, while the guidewire is kept steady as described above. Dilation is repeated with larger-caliber dilators as needed. Some consider blood on the dilator to be a sign that no further dilation should be done in that setting or, at a minimum, a sign that caution should be exercised. The guidewire is removed simultaneously with the last dilator.

The Maloney dilators are advanced in a similar manner but without a guidewire (Fig. 35.3). After the endoscope is removed, the tapered tip of the dilator is lubricated and placed in the patient’s hypopharynx. Slow passes are attempted until the tip traverses the upper esophageal sphincter and enters the upper esophagus. Swallowing can facilitate this passage. The dilator is then advanced slowly with the same precautions regarding pressure described for the Savary-Gilliard system. Dilation is completed when 10 to 15 cm of dilator length is left outside the mouth (particularly for distal strictures) and the dilator is kept in place for 20 to 60 seconds.

**Balloon Dilators**

The TTS balloon dilators exist as single or multi-diameter balloon catheters. The desired diameter of expansion is obtained when infusion of fluid (water or contrast) in the balloon reaches predefined levels of pressure (Fig. 35.4A). In multi-diameter balloon dilators,
three separate inflation pressures correspond to three different diameters of the same balloon, allowing staged dilation of a stricture without removal of the dilator. Accuracy and control of the inflation is ensured by the use of a manometer attached to the system.

The TTS balloon dilator is advanced through the working channel of the standard flexible endoscope (Fig. 35.5). The soft tip of the balloon is passed through the stricture under endoscopic vision (Fig. 35.4B). If the stricture is wide enough, the endoscope is

![Figure 35.4 A: Through-the-scope (TTS) balloon dilator. B: Endoscopic view of balloon dilation of anastomotic stricture.](image)

![Figure 35.5 A: Insertion of the balloon dilator into a channel endoscope. B: Full endoscopic set-up with balloon catheter and piston pump.](image)
advanced into the stomach where the deflated balloon is exposed. Then, they are slowly withdrawn into the esophagus, so that the mid-portion of the balloon is positioned at the level of the tightest part of the stricture. In the case of a complex, tight stricture that does not allow passage of the endoscope, a guidewire (with or without fluoroscopy) can be used for guidance of the balloon dilator. Depiction of the poststenotic part of the esophagus with contrast infused through an endoscopic catheter can confirm patency of the stricture prior to any attempt at advancing the balloon or the guidewire and can facilitate proper positioning of the dilator.

The proximal end of the balloon is kept at the tip of the endoscope for continuous visualization. After positioning of the balloon through the stricture, the system is stabilized, with the endoscopist holding the dilator catheter against the working port of the endoscope with one hand and the endoscope against the bite-block with the other hand. This two-point control ensures stability of the balloon during dilation and allows microadjustments if small migration is endoscopically observed. The balloon is inflated by the endoscopy assistant. The duration of the inflation has not been standardized but most endoscopists report 20 to 60 seconds as with the Savary-Gilliard dilators.

The dilated stricture is reassessed after the balloon is deflated and further dilation to a larger diameter can be performed in the same session. Fluoroscopy and contrast for balloon filling could be used for complex or tight strictures, when clinically indicated to avoid luminal injury distal to the narrowing during passage of the balloon catheter and during inflation, but these adjuncts are not routinely required.

Rendezvous Procedure

In some clinical scenarios, there appears to be complete or near-complete luminal closure. Examples might include a poorly managed anastomotic stricture or postradiation stricture or strictures caused by caustic injury. In a rendezvous procedure, the surgeon scopes from above and from below through a gastrostomy site, attempting to meet the scopes and gently transverse a short area of luminal obliteration (Fig. 35.6). These are
risky but may be the only option. In these unusual cases of complete luminal obliteration, the goal is re-establishment of a distal, functional esophageal lumen. In some cases, this may not be possible or advisable without major reoperation and possibly a new conduit. However, one can consider antegrade and simultaneous retrograde endoscopy via a gastrostomy. We refer to this as a rendezvous procedure. In this setting, an endoscope is passed from above and via the G-tube site. Using the endoscopic view and fluoroscopy, one can assess the length of luminal obliteration and determine if it can be re-established with acceptable risk using wires, biopsy forceps, laser, etc. If the length of luminal obliteration is negligible or considered manageable, one can attempt to re-establish patency. Again, only in very controlled circumstances with risk of perforation fully explained to the patient and, in general, by experienced endoscopists capable of simultaneous surgical intervention, if needed. In this setting extreme caution should be used including on-the-table contrast studies, admission and observation, and prophylactic antibiotics. We frequently leave a proline suture across this area and return for dilation and endoscopy at frequent intervals, up to 2 to 3 per week initially (J.D. Luketich, personal communication).

The patient is closely monitored after the completion of the dilation, while the sedatives wear off. Attention is given to the heart rate, blood pressure, oximetry, and temperature for detection of early signs of sepsis. Subcutaneous emphysema could be indicative of esophageal perforation. Although this may represent clinically insignificant microperforations, the presence of subcutaneous air mandates a careful evaluation and clinical observation with prophylactic antibiotics. While routine barium or gastrografin swallows are not performed following every dilation, they should be used liberally if there is any concern over results of the dilation or to assess for perforation.

The patient should be able to drink liquids, and detailed instructions should be given prior to discharge regarding diet modifications, if any. Expectations of possible discomfort and chance of recurrent symptoms should be addressed with the patient depending on individualized findings. We typically advise a soft diet for 24 hours. Any concerning clinical findings should prompt further evaluation including contrast esophagography. However, contrast esophagography may have a false-negative rate of 10% to 38% and CT scan with on-table esophageal contrast may be helpful. Admission to the hospital for closer observation may be warranted, and treatment is decided based on the findings and clinical circumstances regarding concern for perforation.

Repeat dilation may be needed until the goal diameter of the esophageal lumen is reached, if complete dilation of the stricture cannot be safely completed in one session. The interval between these sessions is not clearly defined but usually ranges between 3 and 6 weeks. In some patients with very tight strictures or with near loss of lumen, dilations may need to be performed more frequently and for longer durations.

Recurrence of dysphagia also triggers repeat endoscopy and dilation. Strictures that recur and require multiple dilations despite adequate initial expansion are considered refractory. These are usually anastomotic strictures after esophageal or gastric surgery, radiation therapy, or endoscopic ablation; or corrosive esophagitis-related strictures. Patients with such strictures are good candidates for training for independent self-dilations using the Maloney dilators. This requires careful evaluation, education, and instruction of the patient by the surgeon or endoscopist.

The main complications of esophageal stricture dilation are perforation, bleeding, and aspiration. The perforation rate for esophageal stricture dilation has been reported to be 0.1% to 2.6% with a mortality rate of 1%. Perforation is more common with
malignant strictures (6.4% with a mortality of 2.3%) compared with benign strictures (1.1% with a mortality of 0.5%). The risk of perforation is higher with complex strictures, or when the patients are elderly, nonguided bougies are used or if the endoscopist is inexperienced. Perforation rates may be higher in the treatment of achalasia (up to 7% risk) and usually occur during the first dilation. Some experts feel that the perforation rate is higher in peptic strictures than in other benign strictures. However, no definitive data exists to support this claim when careful standards of safe dilation are met. As always, starting with a smaller caliber dilator using the Seldinger technique with endoscopic or fluoroscopic guidance is usually the safest method. However, even with the best intentions, perforation can occur even with a small-caliber dilator or a guidewire. The site of perforation is usually at the area of the stricture and may be cervical, intrathoracic, or intra-abdominal. The diagnosis is made primarily on clinical grounds, with the additional help of imaging studies (chest x-ray, water-soluble contrast study, computed tomography). Treatment can range from antibiotic therapy only, to endoscopic management with covered stents or clips, to surgery depending on the location and severity of the perforation. Future dilations in the setting of a perforated esophagus should be considered with caution. Subsequent dilation attempts will depend on the extent of perforation, the patient’s symptoms, and the time from the perforation event. In these circumstances, esophageal stenting may be indicated.

Bleeding after dilation is usually minimal and self-limiting. More pronounced bleeding can be encountered in patients taking anticoagulants and may require endoscopic control with clipping or ablation techniques. Aspiration is another potential risk with upper endoscopy and dilation, particularly in patients with long-lasting obstructions or inadequate preparation. It is imperative to attempt evacuation of the esophagus and stomach endoscopically prior to the dilation. Protection of the airway should be a priority during sedation for the intervention or during induction of general anesthesia with endotracheal intubation. Transient bacteremia has also been reported after dilation and, therefore, antibiotic prophylaxis should be offered to patients at risk of cardiac or systemic infection as already discussed.

**RESULTS**

Esophageal dilation is usually successful although the rate of success and the long-term duration of symptom relief depend on the underlying pathology. Overall, benign strictures are successfully dilated in 85% to 95% of the cases. Anastomotic and peptic strictures are more easily dilated compared with the relatively more resilient corrosive and postradiation strictures. The anatomic complexity of the strictures (length, angulation, degree of stenosis) may also affect adversely the expected success rate.

Studies have been performed comparing push dilators with balloon dilators. No clear benefit of one type over the other has been demonstrated. Success rates and risk of complications are similar and, therefore, decisions are based on the endoscopist’s experience and the morphology of the stricture intended to be dilated.

Recurrence of dysphagia after dilation warrants endoscopic reassessment and redilation. Several factors have been identified as predictive of the need for repeated dilations: Nonpeptic benign strictures (e.g., radiation or corrosive-induced strictures), fibrous strictures, and postdilation diameter <14 mm. Occasionally, tight strictures may require scheduled repeated dilations in short intervals (i.e., weekly) to achieve optimal results before recurrence of symptoms. The combined use of esophageal dilation with endoscopic injection of steroids has been suggested as an effective strategy for recurrent benign strictures and is commonly used in some clinical practices. However, the reported success rates vary widely.

The treatment of the underlying pathology, when possible, is of paramount significance in preventing the recurrence of the strictures. Addressing gastroesophageal reflux either by optimizing medical management or performing antireflux surgery should be
Part VI: Miscellaneous Procedures

Chapter 35 Bougie and Balloon Dilation of Esophageal Strictures—Malignant and Benign

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Esophageal dilation is used for a multitude of obstructing esophageal pathologies. Most commonly, it is used in the management of iatrogenic strictures (e.g., anastomotic strictures), peptic strictures, corrosive strictures, and esophageal malignancies.

Several types of dilators are available, which are usually classified as push (Maloney, Savary-Gilliard) or balloon (TTS) dilators. Although different dilators are commonly used for specific indications in clinical practice, comparative studies have not demonstrated a benefit of one type over the other.

The passage of push dilators over a guidewire and the advancement of balloon dilators under endoscopic vision have increased the safety of the procedure. The risk of perforation is further reduced with the selective use of contrast and fluoroscopy, which is usually reserved for difficult situations.

The most common risks of esophageal dilation are perforation, bleeding, and aspiration during the procedure.

Success rates vary depending on the pathology. Peptic strictures are successfully dilated in 85% to 95% of the patients. Corrosive or radiation-induced strictures are harder to dilate. Recurrence may be managed with repeated dilations and endoscopic injection of steroids. It is important to address the underlying pathology (e.g., GERD, paraesophageal hernia, fibrous stricture, important esophageal motor disorders) in order to decrease the risk of recurrence.

Malignant strictures may be dilated but carry a higher risk of iatrogenic perforation. The effect of dilation is usually short-lived and repeated dilations with potential placement of a stent may be needed. The need of passage of the EUS probe through a malignant esophageal lesion is a common clinical indication for dilation of a malignant stricture.

CONCLUSIONS

Integrally linked to the treatment of peptic strictures. Careful surgical planning is needed when antireflux surgery is considered in the presence of recurrent or difficult to manage lower esophageal stricture, since recurrence of the stricture in the setting of a fundoplication can severely aggravate dysphagia. In general, an aggressive regimen of serial dilations (e.g., weekly for 1 to 3 weeks) followed by antireflux surgery or high-dose PPIs will maximize success in difficult peptic strictures. Surgical resection may be required in extreme situations, where the stricture does not improve with dilation or recurs after multiple previous dilations.

Most malignant strictures can be dilated with a higher risk of perforation. Therefore, these strictures should be dilated with caution over a guidewire with fluoroscopic guidance. However, they uniformly recur rather rapidly. Chemotherapy or radiation therapy can reduce stricture recurrence, if tumor response is noted. The short-lived results of malignant stricture dilation can be prolonged with the use of esophageal stents. The main clinical applications of dilation in the setting of a primary esophageal malignancy are the enlargement of the lumen for passage of the EUS probe during staging and the relief of dysphagia with a palliative intent. Following esophageal dilation and possible esophageal stenting, induction systemic therapy, with or without local radiation therapy, can often be accomplished while the patient is able to maintain adequate oral nutrition. Maintenance of the patient’s nutritional and functional status can reduce the risks of a future surgical resection (esophagectomy), when indicated, after this combination therapy.

Extrinsic esophageal compression by secondary tumors does not respond well to esophageal dilation. Primary pathologic processes resulting in extrinsic esophageal compression include aortic aneurysms, congenital aberrant subclavian arteries and vascular rings, substernal thyroid goiters, lymphomas, and vertebral osteophytic processes. Treatment of the underlying cause of the extrinsic compression should be the primary concern.
Recommended References and Readings


Introduction

Esophageal perforation is a serious and potentially life-threatening medical emergency. Given the variability in its presentation and clinical manifestations, esophageal rupture demands considerable judgment on the part of the treating physician to achieve an optimal outcome. In 1947, Barrett published the first report of a successfully repaired perforation of the esophagus, ushering in an era when surgical therapy became the standard of care. Over the next half-century, the principles in the management of esophageal perforation were elucidated and management was refined. Despite decades of experience with surgical therapy, as well as improvements in antibiotics, anesthesia, critical care, radiologic imaging, and percutaneous interventions, mortality and morbidity rates following esophageal perforation remain high. More recently, nonoperative and endoscopic approaches have gained popularity as alternatives to surgery in appropriately selected patients, further advancing the ability to treat this condition. Today, the esophageal surgeon needs to be knowledgeable in the treatment principles, as well as the full spectrum of related diagnostic and therapeutic alternatives, to best manage this challenging problem.

In 1724, the Dutch physician Hermann Boerhaave published the first treatise on spontaneous esophageal perforation, describing the demise of Baron de Wassenaer, the Grand Admiral of the Dutch fleet, after an episode of self-induced vomiting. Boerhaave syndrome is due to an acute rise in intraluminal pressure in the esophagus during emesis resulting in transmural rupture of the esophageal wall. Fortunately, Boerhaave syndrome is uncommon and represents only 15% of esophageal perforations today. The most common contemporary cause of esophageal perforation is iatrogenic injury following esophageal instrumentation, accounting for nearly 60% of all perforations. With increasing use of flexible upper endoscopy for diagnostic evaluation and therapeutic intervention, such as esophageal dilation or endoscopic resection, and the widespread utilization of transesophageal echocardiography for the assessment of cardiac function, the incidence of esophageal perforation is likely to rise (Fig. 36.1). Other common etiologies of esophageal perforation include foreign body ingestion, trauma, operative injury, and malignancy.

Presentation

The clinical manifestations of esophageal perforation are variable and depend on the size of the perforation, the extent of mediastinal, pleural, or abdominal contamination,
the time interval since perforation, associated esophageal pathology, and patient comor-
bidities. The most common presenting symptom is chest pain, often accompanied by
odynophagia, dyspnea, fevers, and chills. If the perforation is relatively recent, symp-
toms may be mild and subtle. Careful assessment of heart rate, urine output, and white
blood cell count may be helpful in determining if systemic sepsis is evolving. Twenty-
four to forty-eight hours after injury, frank sepsis with tachycardia, hypotension, altered
mental status, and respiratory failure can become evident. It is important during the
initial evaluation to perform a thorough history, focusing on pre-existing dysphagia,
heartburn, or regurgitation, as well as any prior esophageal surgery or endoscopic find-
ings, as concomitant esophageal pathology may influence the ultimate treatment strategy.
A high clinical suspicion for esophageal perforation is necessary in any patient present-
ing to the emergency room with upper gastrointestinal symptoms and a history of
esophageal disease or recent esophageal instrumentation.

**PREOPERATIVE PLANNING**

The initial diagnostic examination to evaluate a patient with a suspected esophageal
perforation is a chest radiograph. It is a quick and inexpensive test that may reveal a
pleural effusion (frequently unilateral), pneumothorax, pneumoperitoneum, subcutane-
ous or mediastinal emphysema, or mediastinal widening. A normal chest radiograph,
however, does not exclude the diagnosis of an esophageal perforation, especially when
contained or in the early time period after the suspected insult.

The most widely utilized radiologic test for esophageal perforation has been a con-
trast esophagogram (Fig. 36.2). Traditional teaching has been to commence the study
with a water-soluble contrast agent, such as Gastrografin (Bracco Diagnostics Inc.,
Princeton, NJ), out of concern for exacerbating mediastinal, pleural, or abdominal con-
tamination should barium be leaked. This examination requires an alert and cooperative
patient who is able to swallow without aspirating, because Gastrografin has the potential
to induce a severe chemical pneumonitis. Judgment must be exercised in considering
this study for the elderly patient or others at high risk for aspiration, as any resultant pulmonary injury can be a significant additional insult. The study typically provides a reasonable assessment of esophageal anatomy, the location and extent of the perforation (contained vs. free pleural or peritoneal rupture), and the presence of coexisting conditions such as an esophageal stricture, malignancy, diverticulum, or motility disorder. A negative study with Gastrografin should be followed by the use of thin barium to increase the sensitivity of the examination. Films also should be taken with the patient in both the left lateral and right lateral decubitus positions. A negative esophagogram, however, does not exclude the diagnosis, as the false-negative rate is 10% to 38%.4,5

More recently, computed tomography (CT) has proven an extremely useful diagnostic modality for assessing the various manifestations of esophageal rupture (Figs. 36.3 and 36.4). The CT findings suggestive of perforation include pneumomediastinum, pneumoperitoneum, subcutaneous emphysema, mediastinal fluid collection or inflammatory changes, pleural effusion, or abdominal abscess. The definitive finding of frank leakage of oral contrast is not always seen and should not be relied upon to prove or disprove the diagnosis. Importantly, CT provides critical information regarding the extent and
Finally, upper endoscopy serves a critical role in the assessment of the full spectrum of esophageal pathology including perforations. Not only can endoscopy determine the location and size of a mucosal injury, but it also allows identification of concomitant mucosal ischemia, inflammation or ulceration, as well as more chronic or subacute pathology such as a stricture, diverticulum, or malignancy. While concern may exist about the safety of flexible endoscopy, with its need for insufflation, in the setting of acute perforation, the examination typically can be completed in experienced hands without impact on the extent of injury and provides invaluable information. Insufflation should be kept at the minimum level necessary for adequate visualization of the entire mucosa. Consideration should be given to placement of a chest tube prior to the procedure if concern exists about the potential to induce or exacerbate a pneumothorax. Some perforations are subtle and may not demonstrate an obvious tear, but rather only an ecchymotic and slightly disrupted mucosa that flutters with insufflation. As a therapeutic maneuver, endoscopy can be utilized for irrigation and suctioning of contained extraluminal fluid collections, and may even assist with guidance of chest tube placement by advancement of the flexible endoscope through a transmural perforation into the pleural space.

Unfortunately, no diagnostic examination is perfect in the evaluation of esophageal perforation. Esophagography is limited by its false-negative rate and the risk of aspiration, as well as the relative inability to assess mucosal detail. CT is poor at localizing perforations and detecting pre-existing esophageal pathology. Endoscopy is invasive and does not usually allow determination of the extent of extraesophageal contamination. Considerable judgment, therefore, is required in deciding the order and number of diagnostic studies based upon the clinical suspicion, information desired, patient tolerance, and possible therapeutic considerations. A point worthy of emphasis is that the location and extent of perforation must be determined prior to any surgical intervention, in that the planning of incisions and the type of procedure performed will depend critically on the diagnostic findings.

**Figure 36.4 A, B:** Computed tomography of the chest demonstrating a large right hydropneumothorax, mediastinal air, right lower lobe lung consolidation, and small amount of extravasation of oral contrast into the right pleural space, diagnostic of esophageal perforation.
Principles of Initial Management

The major sequelae of esophageal perforation are sepsis and death resulting from leakage of gastrointestinal contents. Accordingly, the mainstays of treatment are: (1) Eliminating the source of sepsis by repairing or otherwise controlling the leak, and (2) drainage of extraluminal fluid collections. Any treatment strategy, whether nonoperative, endoscopic or operative, must address these two fundamental principles.

Initial therapy should include avoidance of food by mouth, administration of intravenous fluids, and initiation of broad-spectrum antibiotics. Leaked enteric contents incite a chemical burn in the mediastinum, pleural space, or peritoneal cavity and may lead to sequestration of large amounts of fluid, further exacerbating hypotension from developing sepsis. Antibiotics should be directed toward a polymicrobial infection including gram-positive, gram-negative, and anaerobic bacteria. In addition, antifungal agents should be considered in those individuals with a history of long-standing proton pump inhibitor use, due to the increased risk of fungal colonization in the stomach.\(^7\) Chest tube thoracostomy should be considered early to drain large pleural effusions while preparations are made for definitive intervention.

Determining the Treatment Plan

The overall treatment plan must be individualized, considering the spectrum of nonoperative, endoscopic, and operative alternatives. The criteria for nonoperative management have been elucidated, though considerable judgment may be required in deciding when to utilize or abandon such an approach. Available endoscopic therapies include fully covered stents or mucosal clips. Surgical options include primary repair of the perforation, esophagectomy, wide drainage, and esophageal exclusion or diversion. If endoscopic therapy is pursued, one must consider drainage and/or debridement of any periesophageal collections which might be accomplished percutaneously, thoracoscopically or with open surgery. As multiple treatment strategies exist, the decision regarding how best to intervene may not be an easy one. Important questions to guide decision making include the following.

- What is the etiology of the perforation?
- Where is the perforation located (cervical, thoracic, or abdominal esophagus)?
- Is it a contained perforation or free perforation into the pleural or peritoneal space?
- How extensive is the extraluminal soilage?
- What is the time interval since the perforation?
- What is the clinical condition of the patient and what are their comorbidities?
- Is there pre-existing esophageal pathology?
- Is the esophagus worth salvaging?
- Does the patient meet criteria for nonoperative management?

Nonoperative Management

For decades, surgery was the preferred treatment modality for esophageal perforation, but was associated with high rates of morbidity and mortality. In carefully selected patients, a nonoperative approach has proven successful and has avoided the potential complications of esophageal surgery in the emergent setting. The criteria for nonoperative management were initially described by Cameron et al. and modified by Altorjay (Table 36.1).\(^{14,15}\) The initial experience was in management of patients sustaining a spontaneous perforation, though the data have been extrapolated to other causes of perforation as well. In general, patients selected for nonoperative management have limited perforations with minimal extraluminal contamination that is contained by adjacent tissues (Fig. 36.3). Other important considerations include absence of sepsis, no associated distal obstruction, and an esophagus worth salvage (i.e., no malignancy or end stage benign disease). Patients who meet these criteria can be treated with intravenous antibiotics and nothing
by mouth. The duration of such therapy is predicated by the patient’s overall condition. Repeat endoscopy or radiographic imaging is useful in determining the response to treatment and when to resume a diet. The development of sepsis mandates repeat investigation and strong consideration of more invasive therapeutic measures.

**Endoscopic Management**

Advances in endoscopic therapies have created new ways to manage esophageal perforations and their sequelae. As an alternative to surgical repair in those patients not deemed candidates for nonoperative management, esophageal stents are increasingly being used to occlude the perforation and prevent ongoing soilage of extraesophageal tissues (Fig. 36.5). Stents traditionally were utilized for palliation of dysphagia or occlusion of fistulae in patients with end-stage esophageal malignancy and a short life expectancy. With the introduction of fully covered, self-expanding, removable, plastic, metal, and hybrid stents, the indications for stenting have increased to include nonmalignant conditions. A stent should be selected that provides adequate coverage of the entire length of the perforation, ideally with several centimeters of overlap both above and below the esophageal injury. Endoscopy with fluoroscopy is used to mark the proximal and distal extent of the perforation. A guidewire is advanced into the stomach and the stent is deployed over the guidewire with fluoroscopic guidance to assess proper positioning. Repeat endoscopy is performed to ensure adequate sealing of the perforation. The final stent position can be manipulated with biopsy forceps.

**Figure 36.5** Contrast upper gastrointestinal radiograph demonstrating a fully covered stent placed to occlude a cervical esophagogastric anastomotic leak following esophagectomy.
Some perforations are not amenable to stenting, such as those high in the cervical esophagus where a stent would extend into the pharynx or cause significant patient discomfort, or those spanning the gastroesophageal junction that are difficult to completely occlude due to the bulbous nature of the gastric cardia and minimal distal overlap of the perforation. The timing of stent removal is a matter of controversy, because it is difficult to know when the perforation has healed and long-term stent placement increases the risk of complications such as erosion into surrounding structures. Additional complications from esophageal stenting include stent migration, luminal obstruction and potential inability to remove the stent at a later date.\(^8\)

While a stent may be effective at controlling the leak, endoscopic management will fail if extraluminal contamination is not addressed by appropriate drainage of the mediastinum, pleural space, or peritoneum.\(^9\) The surgeon endoscopist also must be alert to the possibility of isolating an extraluminal fluid collection and preventing it from draining back into the esophagus. Chest tubes or CT-guided pigtail catheters can be placed into small- to moderate-sized collections. Alternatively, a thoracotomy or minimally invasive VATS approach can be used to debride the pleural space, decorticate the lung, and place drains under visual guidance while avoiding the potential morbidity and mortality of extensive esophageal surgery.

**Operative Management**

**Primary Surgical Repair**

While endoscopic and nonoperative therapy of selected patients with esophageal perforation has gained in popularity, the gold standard therapy has been surgical repair. One must remember to move to open surgical repair should the patient become septic and further endoscopic or CT directed approaches appear to be futile.\(^10\)

Primary repair is best accomplished by a two-layer closure, the first of the mucosa and submucosa and the second of the overlying smooth muscle layers of the esophagus.\(^11\) A key principle underlying successful repair is that the deeper mucosal defect commonly extends beyond the more superficial muscular one, such that a proximal and distal myotomy is necessary to identify the edges of the mucosa and to facilitate complete closure. The mucosal edges, once adequately exposed, should be debrided back to healthy, noninflamed tissue and reapproximated with absorbable or nonabsorbable sutures (Fig. 36.6). A stapled technique has also been described to close the mucosal...
layer using a linear GIA or TA stapler, though care must be taken to prevent luminal narrowing; stapling over an esophageal bougie is recommended. The muscular layer can then be closed independently with interrupted nonabsorbable sutures.

Depending upon the quality of tissues involved in closure and the extent of surrounding contamination, consideration should be given to buttressing the repair with adjacent viable tissue such as intercostal muscle, parietal pleura, pericardial fat, omentum, or gastric fundus (Fig. 36.7). At the time of repair, washout, debridement, and wide drainage of the contaminated spaces are also important. A drain should be placed adjacent to, but not directly abutting, the suture line in case a recurrent leak develops in the early postoperative period. In addition, a feeding tube should be placed to facilitate nutritional support while the esophagus heals. Whether the feeding tube is placed into the stomach, such as with percutaneous endoscopic gastrostomy, or more distally into the jejunum is a matter of judgment based on the clinical circumstances.

Figure 36.7  **A:** Mobilization of a parietal pleural flap for buttressing of a distal esophageal perforation. **B:** The pleural flap is wrapped around the perforated esophagus. **C:** Numerous fine sutures are used to tack the pleural flap to the healthy esophageal muscle, isolating the perforation.
Esophagectomy
If the decision is made that esophageal repair or stenting is futile, or the esophagus is deemed not worth salvaging (e.g., end-stage achalasia), esophagectomy may be required (Table 36.2). In general, a transthoracic approach is best, as it allows the removal of the perforated esophagus and irrigation and wide drainage of the infected pleural and mediastinal spaces. A transhiatal resection may be appropriate in selected cases. Classically, the thoracotomy or thoracoscopic incisions are made on the side of a pleural effusion, as this pleural space will need to be washed out and the ipsilateral lung decorticated. During the abdominal phase of the operation, it is important to provide nutritional access with a gastric or jejunal feeding tube.

If the patient is septic or at risk for becoming hemodynamically unstable in the early postoperative period, foregut reconstruction should be delayed due to concern of inducing conduit ischemia if esophageal replacement were completed. In this situation, a cervical end esophagostomy is fashioned for drainage of oral secretions. Important surgical principles include a left neck incision to dissect out the cervical esophagus, protection of the recurrent laryngeal nerves, and preservation of as much proximal esophagus as possible to aid in future reconstruction. A longer length of proximal esophageal remnant also permits placement of the esophagostomy on the chest wall rather than in the neck, facilitating secure application of an external drainage bag and increasing patient comfort. In such cases, the esophagus should be tunneled superficial to the clavicle to reach the skin on the anterior chest.

Esophageal Diversion
The most complete method to divert the flow of gastrointestinal contents from the mediastinum is esophagectomy with end esophagostomy. Some surgeons, however, have advocated esophageal diversion without esophagectomy to facilitate an easier reconstruction after recovery. Proximal diversion is most commonly accomplished by end cervical esophagostomy, although esophageal T-tube and side cervical esophagostomy have been described.13 Distal diversion can be achieved by surgical division at the gastroesophageal junction using a linear cutting stapler or, alternatively, using a TA stapler without division of tissues. This latter technique for distal diversion has been touted to make future reconstruction easier, though it should be used with caution. Early recanalization of the stapled, undivided esophagus can occur, resulting in ongoing soilage if the perforation has not healed. In general, esophageal diversion rarely should be necessary.

Special Considerations
Location of the Perforation
Most perforations occur in the thoracic esophagus, though rupture of the cervical or intra-abdominal portions may occur as well. Cervical perforations are generally well tolerated. Fascial investments surrounding the esophagus in the neck often contain cervical perforations, facilitating nonoperative therapy with antibiotics alone. However, deteriorating clinical condition which may manifest by worsening neck swelling or tenderness, increasing cervical cellulitis or subcutaneous emphysema or development of a cervical abscess or mediastinitis warrants surgical exploration with irrigation,

TABLE 36.2 Factors That May Mandate Esophagectomy Over Primary Repair or Endoscopic Stenting

| Inability to surgically repair the perforation (e.g., perforated malignancy) |
| High likelihood of repair failure (e.g., high-grade distal obstruction, delayed presentation) |
| Persistent esophageal disease with high likelihood of poor functional outcome (e.g., recalcitrant esophageal stricture, end-stage achalasia) |
debridement and wide drainage through a cervical incision. In most situations, such drainage is sufficient and attempts at direct visualization and repair of the perforation may prove difficult, unsuccessful and unnecessary. Careful physical examination and CT scans of the chest and neck are important studies to rule out undrained collections and early abscess formation that can lead to ascending or descending mediastinitis.

As there are typically only a few centimeters of intra-abdominal esophagus, perforations into the peritoneal cavity are less common than those occurring into the thorax. Such perforations can occur, however, with endoscopic interventions aimed at the lower esophageal sphincter, such as pneumatic dilation or per oral endoscopic myotomy (POEM) for achalasia, balloon or rigid dilation for benign strictures or tumors, or any variety of endoscopic mucosal resective or ablative technologies. An important anatomic consideration in patients with sliding or paraesophageal hernias is that the hernia sac is bounded cranially by the phrenoesophageal ligament, rendering the herniated distal esophagus an intra-abdominal structure. As a result, a distal esophageal perforation may be best addressed by laparotomy or laparoscopy. Preoperative CT imaging may assist in the decision as to whether a distal perforation is optimally approached through the chest or through the abdomen. When repair is performed below the diaphragm, the stomach can be used as a buttress by fashioning a partial or complete fundoplication to cover the repair site. While placing such a fundoplication above the hiatus in the chest has been described, conventional wisdom holds that such repairs lead to the problems inherent in any recurrent hiatal hernia including the potential for ischemia, pain, obstruction, or postoperative gastroesophageal reflux.

Pre-existing Esophageal Pathology
Esophageal perforation may occur in the face of pre-existing esophageal disease, and both must be considered when devising a treatment plan. The concomitant pathology may influence the type of primary repair, or may tip the decision toward esophagectomy (Table 36.2).

The classic example is the patient with achalasia who experiences an iatrogenic esophageal perforation at time of pneumatic dilation. Repair of the perforation alone will not ameliorate the symptoms of achalasia. Equally important, the unrelieved distal esophageal obstruction imposed by a poorly relaxing or hypertensive lower esophageal sphincter may increase the risk of postoperative leak from the repair site. In this circumstance, the best approach is to close the perforation in two layers, perform a distal esophageal (modified Heller) myotomy on the contralateral side of the esophagus away from the perforation, and create a partial fundoplication that serves as both an antireflux valve and a buttress of the mucosal repair. In patients with end-stage achalasia or recalcitrant esophageal strictures, repair alone may lead to ongoing dysphagia or regurgitation; such individuals may benefit from esophagectomy. In addition, patients with esophageal malignancy should be considered for definitive surgical resection of their cancer at the time of treatment of the perforation.

COMPLICATIONS AND RESULTS

The results following treatment of esophageal perforation historically were poor with significant morbidity and mortality. A recent meta-analysis of 726 patients revealed a mortality rate of 18%. Nonoperative management in carefully selected patients (Table 36.1) has been shown to be safe and effective. Altorjay reported on a series of 20 patients treated with an initial nonoperative approach. Sixteen patients (80%) were successfully managed, while four (20%) required operative intervention of which two (10%) died. The morbidity rate was 20%. The authors commented that the mortalities were failures of the decision to manage nonoperatively and were negatively impacted by the delayed operative intervention, underscoring the importance of appropriate patient selection. More recently, Keeling et al. reported on a series of 25 patients treated nonoperatively using strict criteria similar to those described in Table 36.1. Their treatment algorithm resulted in a mortality of 8% and morbidity of 48%, with the two deaths in patients with metastatic esophageal cancer who refused operative intervention.
In patients undergoing surgical treatment for the management of esophageal perforation, the results have been quite varied. In a meta-analysis of 572 patients, collective mortality ranged from 0% to 80% among the case series reviewed. For patients undergoing primary repair \((n = 322)\), the average mortality was 12% (0% to 31%), while after esophagectomy it was 17% (0% to 43%, \(n = 129\)), following esophageal exclusion it was 24% (0% to 80%, \(n = 34\)) and following surgical drainage alone it was 36% (0% to 47%, \(n = 88\)). Care must be exercised in interpreting these data as straightforward cases treated early after perforation may have been selected for primary repair, while more complicated or delayed perforations likely mandated resection, diversion, or drainage.

Traditional dogma warned against attempting primary surgical repair in patients whose treatment was delayed beyond 24 hours from the time of perforation; resection or drainage procedures historically were recommended for such cases. In a recent meta-analysis, the mortality of primary repair was 4% when surgery occurred less than 24 hours after the perforation, compared with 14% for those patients whose treatment was delayed longer. Of note, when all treatment modalities including primary repair, esophagectomy, drainage, and exclusion procedures were examined, the mortality was 14% for those treated in less than 24 hours and increased to 27% for those treated beyond 24 hours from perforation. These data highlight the increased risk associated with delayed treatment regardless of the surgical therapy rendered.

Whyte et al. reported a series of 22 patients, 9 of which were treated beyond 24 hours with an overall mortality of 5%. Of the nine patients, three had a recurrent leak compared with only one who underwent early repair. All postoperative leaks were successfully managed with drainage alone. Their experience suggests that primary repair of perforations beyond 24 hours can be accomplished successfully in selected cases with acceptable mortality.

With the introduction and popularization of self-expanding esophageal stents, enthusiasm for their application in the treatment of esophageal perforation has been increasing. Results from endoscopic treatment strategies compare favorably with surgical repair. A recent meta-analysis of 267 patients treated with esophageal stenting found a success rate of 85% at managing the leakage. Concurrent drainage of an extraluminal fluid collection was necessary in 59% of cases. Mortality for these patients was 13%, similar to patients who underwent surgical repair. Thirty-four percent of patients suffered a stent-related complication including stent migration in 29%, bleeding in 2%, and tissue overgrowth in 5%. Other complications included erosion, failure to achieve a functional seal, and inability to remove the stent at a later date. Surgical intervention for incomplete sealing or a stent-related complication was necessary in 13% of patients. Patients at increased risk for failure of endoscopic management include those with perforations of the cervical esophagus or gastroesophageal junction and those with esophageal injuries longer than 6 cm.

**CONCLUSIONS**

Esophageal perforation remains a serious and challenging clinical problem that requires considerable skill, judgment, and creativity to manage. While the treatment tools within the surgeon’s armamentarium continue to evolve, the principles underlying therapy remain constant and guide decision making. The basic tenets of managing the esophageal defect, draining extraluminal fluid, and alleviating distal esophageal obstruction, while treating infection and providing supportive care including nutrition, are critical whether an operative, endoscopic, or nonoperative therapy ultimately is rendered. A treatment plan must not only consider the details of the perforation, including size, site, time interval from onset, and extent of contamination, but also the presence of comorbidities and performance status. The introduction of fully covered and potentially removable self-expanding esophageal stents has increased the utilization of endoscopy for definitive therapy, avoiding the need for surgery in many patients for whom previously there was no other alternative. It must be continually emphasized that successful
stenting of esophageal perforations will only occur if all periesophageal collections of any significance are drained simultaneously or as soon as they develop; thus, mandating careful follow-up of any patient who is stented. The decision to proceed with an operation, whether it is for attempted primary repair and drainage or for esophageal extirpation, can be a difficult one, weighing the magnitude of the procedure against the risk to the patient of persistent leakage and sepsis going unabated. The esophageal surgeon must be well versed in the treatment principles and the full spectrum of diagnostic and therapeutic modalities, including endoscopic techniques and operations involving the neck, thorax, and abdomen, to manage the various manifestations of esophageal perforations in an optimal manner.

Recommended References and Readings

In general, the presence of a congenital diaphragmatic hernia (CDH) is an indication for repair (Figs. 37.1 and 37.2). Most patients with CDH will present in the first 24 hours of life although, they can present as late as adulthood. The first reported survivor from repair in the first 24 hours of life was by Gross in 1946. It required advances in anesthesia, neonatal critical care, and mechanical ventilation before a number of infants would survive. By the late 1960s, centers were reporting the survival of ~50% in infants with CDH. Surgical repair was traditionally performed via a laparotomy or thoracotomy until the advent of minimally invasive surgery in infants. The timing of repair was generally considered a surgical emergency until the late 1980s when reports of delayed repair were first seen. It is now rare that a CDH is repaired in the first 6 to 12 hours of life, and many are repaired after 5 days of life. Contraindications to repair would include fatal chromosomal anomalies such as trisomy 13 and 18. While not an absolute contraindication, survival in infants with single ventricle physiology is so poor that many would not routinely offer surgical correction to these patients. Prematurity is not a contraindication and successful repair has been performed on infants who were 26 weeks’ gestational age.Operative repair of a CDH should be performed when the patient is medically stable. This definition varies amongst centers. In the patient who is not on extracorporeal life support (ECMO), we plan for operation when the patient does not require significant ventilator support (peak inspiratory pressures <25, FiO₂ < 0.5) with preductal oxygen saturations over 90. Ideally, the pulmonary hypertension has resolved, but this may not always occur. If the patient is on ECMO, we will usually operate within the first 24 to 48 hours on ECMO unless the patient is significantly edematous in which case we delay until the infant is at dry weight.
The location for repair will depend on the patient’s stability. If the patient is not on ECMO or high-frequency oscillatory ventilation (HFOV), we will often plan for repair in the operating room. If the patient is on ECMO, repair is performed in the intensive care unit as transport on ECMO can be difficult. Patients on ECMO receive aminocaproic acid as a loading dose 1 hour before operation, and this is continued for 36 to 48 hours after repair. We also make liberal use of the argon cautery when doing repair on ECMO.

**Planning**
- Repair on minimal ventilator support
- Repair ideally when pulmonary hypertension is resolved
- Early repair with aminocaproic acid if on ECMO

**Surgery**

There are several operative approaches to the repair of a CDH. Repair can be done via an open laparotomy or thoracotomy or using minimally invasive techniques via laparoscopy or thoracoscopy. We approach the open repair via a subcostal incision and a minimally invasive repair via thoracoscopy.
Open Repair

Positioning
Patients are placed in the supine position with a small shoulder roll on the side of the defect. It is important to assure the chest is in the sterile field in the rare instance when a thoracotomy may be needed to help reduce the contents. This is more likely to occur with right-sided defects.

Technique
We use a broad subcostal incision approximately 2 cm below the costal margin. Once the abdomen is entered, the bowel is carefully manipulated from the chest into the abdomen. It may occasionally be difficult to get the spleen down. In that instance, using a vein retractor on the anterior edge of the diaphragm and gentle traction on the stomach can be helpful. In patients who are not on ECMO, the posterior lip of the diaphragm is mobilized (Fig. 37.3). This dissection is minimized in patients on ECMO due to the bleeding risk.

Primary repair can be performed using pledgeted 2-0 polyester suture or silk sutures (Fig. 37.4). We use the 1 mm polytetrafluoroethylene (PTFE) soft tissue patch for those patients who require a patch repair. We create a cone-shaped patch by taking pleats in the patch as it is sewn to the edges of the diaphragm or ribs (Fig. 37.5). Alternatively, the patch can be preformed and then sewn in place. This allows for improved pulmonary compliance postoperatively and a potentially decreased risk of recurrent herniation. The defect size can be quite variable and very large defects may be a challenge to repair. The defect should be characterized into one of four standardized classes (A to D) (Fig. 37.6).
While fascial closure is ideal, it may not be possible to close the abdomen at the time of CDH repair. If it appears that the closure will be tight, we will either sew a patch onto the abdominal wall or perform closure of just the skin. The patch can be slowly reduced and if skin closure is used, the resultant ventral hernia can be closed at a later date. We do not routinely use a drainage tube in the thorax, but do use a Silastic Blake or Jackson-Pratt drain if the patient is on ECMO.

**Minimally Invasive Repair**

**Positioning**

Infants who are candidates for thoracoscopic repair are on low levels of mechanical ventilator support. The patient is placed with the affected side up. These infants are usually on minimal levels of mechanical ventilation and are transported to the operating room for repair. The patient is positioned at a right angle to the table at the foot of the bed. We position the infant in a modified thoracotomy position which allows for...
conversion to open repair if necessary. The operating surgeons are positioned at the patient’s head (Fig. 37.7).

**Technique**

We place a 5-mm port just below the tip of the scapula. After confirming appropriate location, 4 mm Hg of CO₂ inflation is used. This facilitates both visualization and reduction of contents. Two 3-mm ports or stab wounds are then placed on either side of the scapula (Fig. 37.8). The defect is identified and the bowel is carefully reduced. One must avoid trying to reduce the contents too rapidly as this can lead to bowel injury. Similar to an open repair, it can sometimes be a little difficult to reduce the spleen into the abdomen. Once the contents are reduced, the defect is carefully inspected (Fig. 37.9). If it appears that a primary repair can be achieved, we will continue with a thoracoscopic approach. The recurrence rate with this approach is much higher than with the open approach.

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**Minimally Invasive Repair**

- Stable patient
- Not performed in patients on ECMO
- Position for possible open repair
- Position the patient with the affected side up
- Careful manipulation of bowel and spleen
- 3-mm instruments are used for the repair
repair, hence if it appears as if the repair will be under too much tension, we will con-
vert to an open repair. We use 3-0 silk sutures for the repair (Fig. 37.10).

We do not routinely leave a thoracic drainage tube in place with either approach. Patients are kept on minimal pressures for their ventilator support postoperatively as they were preoperatively.

**POSTOPERATIVE MANAGEMENT**

Management of infants with CDH will vary depending on the severity of their illness. In the patients on ECMO, we will continue the aminocaproic acid for 36 hours after operation. Patients are weaned from ECMO over the course of 7 to 14 days. If the patient has a patch placed on the abdomen, we do not routinely manipulate it until off ECMO.

In those patients off ECMO and those who wean from ECMO, we continue to strive for a minimal ventilation strategy to avoid further lung injury.\(^8\) We will tolerate Pco\(_2\) levels in the 60s if necessary to avoid higher airway pressures. Management of the pulmonary hypertension is a cornerstone of caring for these infants. We have a policy of liberal use of echocardiography to direct appropriate use of nitric oxide, vasopres-
sors, and other pulmonary vasodilators. In the era of preoperative ECMO, the need for ECMO after operation is infrequent.
While management of infants with smaller defects is relatively straightforward, management of those patients in the high risk/large defect group requires close attention to ventilator and cardiopulmonary management. They may take weeks to stabilize and adapt to the high pulmonary pressures. We start enteral feedings as soon as there is evidence of GI tract function. Most infants do not require further operations, but a percentage will need feeding access, antireflux surgery, and repair of early recurrences.

**COMPLICATIONS**

There are a number of postoperative complications that can occur following the repair of CDH. Recurrent herniation while in the hospital occurs in just over 2% of infants with open repair and in almost 9% of infants who have thoracoscopic repair. Late recurrence is relatively common in those infants with a large defect. Postoperative chylothorax can occur in about 5% of cases. This usually resolves without surgical intervention. There are also a number of problems that can arise following hospital discharge to include hearing abnormalities, chest wall deformities, wound hernias, and gastroesophageal reflux.

**RESULTS**

Overall survival for infants with CDH approaches 70% on average. Survival of infants who undergo surgical repair exceeds 80%. Almost all infants with a smaller defect will survive, but patients with large defects have a survival between 50% and 70%. Outcomes of these patients appear to be improved when cared for in centers seeing more than 6 to 10 patients per year. While recurrent herniation is not uncommon in patients with very large defects, these can usually be repaired without significant risk of further reherniation. The role of thoracoscopic repair is unclear. While the approach clearly offers better cosmesis and reduction of the herniated content is fairly straightforward, the recurrence rate of almost 9% is worrisome. Others have also shown that the infants can develop a marked acidosis during operation due to the carbon dioxide insufflation in the chest.

As mentioned above, long-term follow-up for these patients is quite important. There are a number of problems that can arise over the course of follow-up. The American Academy of Pediatrics has published guidelines for follow-up.

**CONCLUSIONS**

- CDH is a spectrum of disease. Some infants with small defects are repaired easily and do well. Infants with absence of the diaphragm and other anomalies are much higher risk for both survival and long-term complications
- Repair should be undertaken when the infant has stabilized
- If the infant requires ECMO to stabilize, then repair can be done early in the ECMO run
- Thoracoscopic repair can be attempted in patients on low levels of support
- Large defects should be repaired with a cone-shaped patch to avoid tension
- Open repair can be done via a subcostal incision
- Repair on ECMO should include use of aminocaproic acid to decrease hemorrhage
- Patients with large defects are at the highest risk for mortality
- Careful monitoring of cardiopulmonary function is crucial in the acute phase
- Long-term follow-up is important due to a number of problems that can arise over time
Recommended References and Readings


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