Esophagectomy and Gastric Pull-through Procedures: Surgical Techniques, Imaging Features, and Potential Complications[1]

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SA-CME LEARNING OBJECTIVES

After completing this journal-based SA-CME activity, participants will be able to:

- Describe the most commonly performed types of esophagectomy and list their key differences.
- Identify the postoperative radiographic appearances associated with different surgical techniques and recognize areas for potential complications.
- Discuss postoperative complications related to esophagectomy and ways in which radiologists can provide effective postoperative patient care.

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Esophagectomy takes the center stage in the curative treatment of local and local-regional esophageal cancer. It is a complex procedure with a high postoperative complication rate. When interpreting imaging studies, radiologists must understand the surgical techniques used and their potential complications. The most common surgical techniques are transthoracic esophagectomies, such as the Ivor Lewis and McKeown techniques, and transhiatal esophagectomy. Variations of these techniques include different choices of conduit (ie, stomach, colon, or jejunum) to serve in lieu of the resected esophagus. Postoperative imaging and accurate interpretation is vital in the aftercare of these patients. Chest radiographs, esophagrams, and computed tomographic images play an essential role in early identification of complications. Pulmonary complications and anastomotic leaks are the leading causes of postoperative morbidity and mortality secondary to esophagectomy. Other complications include technical and functional problems and delayed complications such as anastomotic strictures and disease recurrence. An esophagographic technique is described that is performed by using hand injection of contrast material into an indwelling nasogastric tube. Familiarity with the various types of esophagectomy and an understanding of possible complications are of utmost importance for radiologists and allow them to be key participants in the treatment of patients undergoing these complicated procedures.

Introduction

Esophageal cancer rates have been on the rise for the past 3 decades, and esophageal cancer is currently the eighth most common malignancy in the world (1). Although squamous cell carcinoma is the predominant form of malignancy worldwide, the incidence of adenocarcinoma exceeds that of squamous cell carcinoma in Australia, the United Kingdom, and the United States (1,2). It has a dismal overall survival rate of 17.5%, but the survival rate improves to 39.6% for those with stage 1 disease, as reported by the Surveillance, Epidemiology, and End Results (SEER) Program of the National Cancer Institute for the years 2004–2010. However, most patients have advanced disease at the time of diagnosis, and less than 50% are eligible for curative treatment (1).

Esophagectomy is currently the primary treatment for local and locally advanced disease. The procedure is technically demanding and carries risk for severe complications. Esophagectomy presently has the highest mortality rate among all elective gastrointestinal surgical interventions, ranging from 8%–23% (3). Esophagectomy is most commonly performed for treatment of esophageal cancer,

TEACHING POINTS

- There is considerable variation in the surgical technique used for esophagectomy. The Society of Thoracic Surgeons General Thoracic Surgery Database lists 14 different methods for performing esophagectomies. The surgical approach is usually selected on the basis of the distance of the tumor site from the incisors, the potential for metastases along the esophagus and stomach, the potential for lymphatic involvement, the patient's physiologic state, and surgeon preference. Traditionally, these surgeries are categorized as either transthoracic or transhiatal esophagectomies.
- The most common types of transthoracic methods are the Ivor Lewis, McKeown, and left thoracoabdominal approaches. Each method includes a thoracotomy. The transthoracic approach is a more complete oncologic operation because it provides direct visualization and greater exposure, which allow the surgeon to achieve wider margins around the tumor and more extensive nodal dissection. The most frequent complications are pulmonary, many of which may be due to pain from the thoracotomy, and anastomotic leak, which, if it occurs in the thorax, can be devastating because of the development of mediastinitis and sepsis.
- The major advantage of the transhiatal technique is the potential to diminish respiratory complications by avoiding a thoracotomy and an intrathoracic anastomosis with a possible intrathoracic anastomotic leak.
- Most leaks occur at the anastomosis, but leaks can develop at any of the resection sites, including the gastric staple line (the site where the anastomotic stapler is introduced to create the esophagogastric anastomosis), the site of a pyloric drainage procedure, or bowel harvest sites. Anastomotic leaks are more commonly seen with gastric conduits than with colon interposition and occur more often with a cervical anastomosis because of the higher possibility of tension and ischemia at the anastomosis. Anastomotic leaks also lead to increased risk for subsequent development of anastomotic strictures.
- We describe an esophagographic technique performed by using a low-osmolar nonionic contrast agent that is hand injected via a nasogastric tube to evaluate the conduit under pressure and detect leaks that may otherwise be missed at a passive swallow test. After esophagectomy, patients are at increased risk for aspiration because of possible recurrent laryngeal nerve injury. Using a low-osmolar, nonionic, water-soluble contrast agent, keeping the head of the table elevated, closely watching for aspiration throughout the study, and being prepared to suction should aspiration occur will help minimize the risk for pulmonary complications from aspiration.

but other indications include treatment of benign diseases such as esophageal strictures, esophageal perforation, lye ingestion, Barrett esophagus, recurrent tracheoesophageal fistulas, and achalasia. Currently there are many different esophagectomy techniques, although in recent years there has been a shift toward minimally invasive surgery and robotic-assisted thoracoscopic esophagectomy (4).

For the radiologist to provide effective postoperative patient care, he or she should have a fundamental knowledge of the various types of esophagectomies, their imaging appearances, and ways to detect acute and delayed complications. We review the most common esophagectomy techniques and describe their imaging appearances and potential complications.

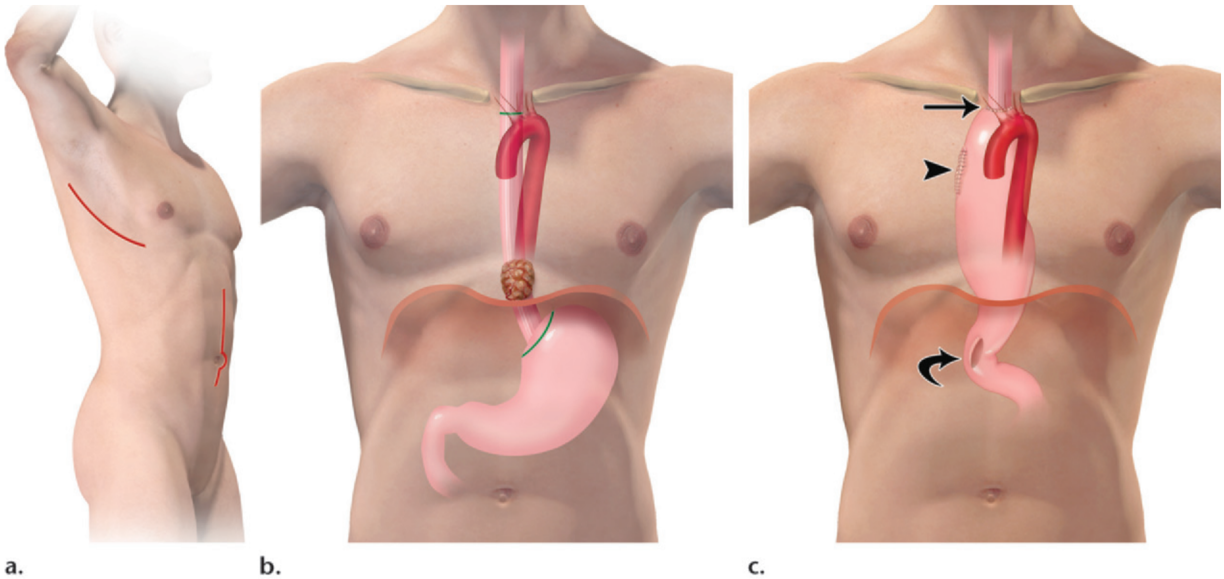
Surgical Techniques

There is considerable variation in the surgical technique used for esophagectomy. The Society of Thoracic Surgeons General Thoracic Surgery Database lists 14 different methods for performing esophagectomies (5). The surgical approach is usually selected on the basis of the distance of the tumor site from the incisors, the potential for metastases along the esophagus and stomach, the potential for lymphatic involvement, the patient's physiologic state, and surgeon preference. Traditionally, these surgeries are categorized as either transthoracic or transhiatal esophagectomies. The stomach is the most common conduit used to replace the resected esophagus and is used in the descriptions of surgical methods in this article; however, alternative grafts, including the colon or jejunum, can be used and are discussed separately (2,4).

Transthoracic Esophagectomy

The most common types of transthoracic methods are the Ivor Lewis, McKeown, and left thoracoabdominal approaches. Each method includes a thoracotomy (6). The transthoracic approach is a more complete oncologic operation because it provides direct visualization and greater exposure, which allow the surgeon to achieve wider margins around the tumor and more extensive nodal dissection (7). The most frequent complications are pulmonary, many of which may be due to pain from the thoracotomy, and anastomotic leak, which, if it occurs in the thorax, can be devastating because of the development of mediastinitis and sepsis (8).

Ivor Lewis Esophagectomy.—The Ivor Lewis esophagectomy was first described in 1946 and continues to be one of the most commonly performed methods of esophageal resection for disease in the middle and lower third of the esophagus (8). This approach begins with a laparotomy and is followed by a right thoracotomy (Fig 1a, 1b). The laparotomy focuses initially on mobilization of the stomach, followed by mobilization of the esophagus within the hiatus. A gastric tube may then be created, followed by an upper abdominal lymphadenectomy with resection of the lymph nodes along the celiac trunk and splenic and common hepatic arteries (6). The last step before the thoracotomy has traditionally been a pyloric drainage procedure such as pyloroplasty, pylorotomy, pyloromyomectomy, or botulinum toxin injection into the pyloric muscle. Although



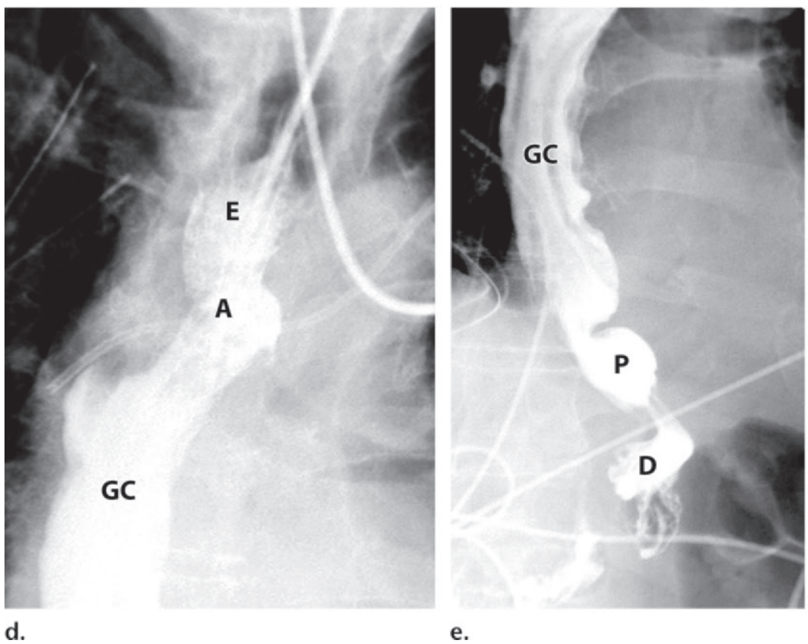
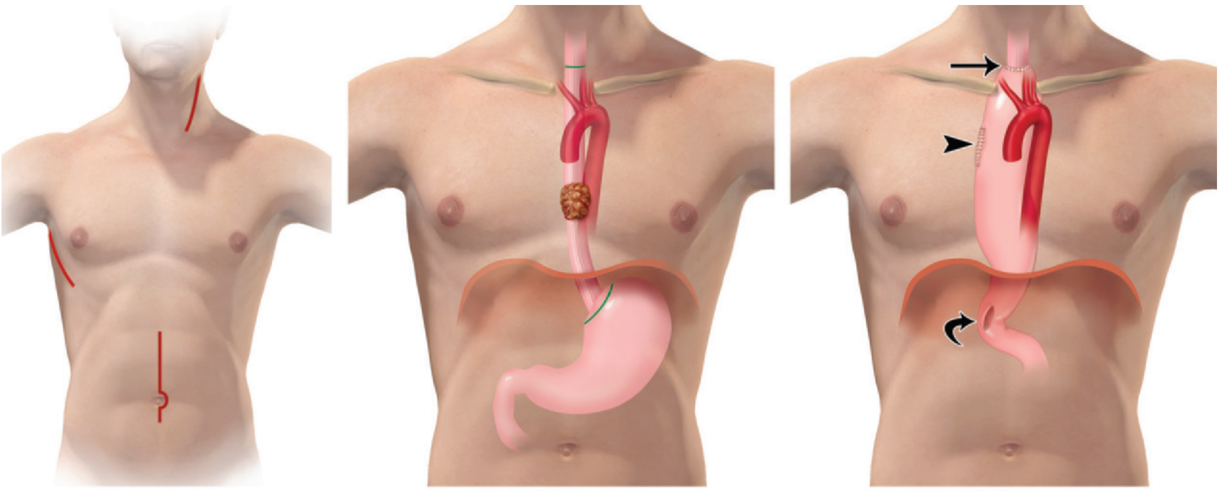


Figure 1. Ivor Lewis esophagectomy. **(a–c)** Drawings show skin incisions (red lines) for upper abdominal laparotomy and right thoracotomy **(a)**, resection lines (green) and a tumor in the distal esophagus **(b)**, and postoperative anatomy after resection of the esophagus and creation of an intrathoracic anastomosis (straight arrow) high in the thorax between the remnant esophagus and the gastric conduit **(c)**. Arrowhead in **c** = original resection line in the proximal stomach, curved arrow in **c** = pyloromyotomy. **(d, e)** Left posterior oblique esophagrams of the mid **(d)** and lower **(e)** thorax in a 63-year-old man with adenocarcinoma of the gastroesophageal junction show the anatomy after an Ivor Lewis esophagectomy. *A* = intrathoracic esophagogastric anastomosis, *D* = duodenum, *E* = remnant esophagus, *GC* = gastric conduit, *P* = pylorus.

this step may prevent postvagotomy gastric outlet obstruction due to stasis, its necessity and benefits remain somewhat controversial (9,10). Next, the patient is placed in the left lateral decubitus position, and a right thoracotomy is performed. The azygos vein may be divided, and the esophagus and its adjacent mediastinal lymphatic tissue are resected en bloc. The resection may include the thoracic duct and distal portion of the pericardial vein and other mediastinal structures. The lymphadenectomy is important for accurate pathologic N staging and to reduce risk for local recurrence (11). Specific areas of interest include the periesophageal, aortopulmonary, subcarinal, and left recurrent laryngeal nerve nodal groups. The gastric tube or whole-stomach conduit is then pulled up into the chest, and the stomach is divided at the cardia. An intrathoracic anastomosis is created between the residual esophagus and the gastric conduit with use of an end-to-end anastomotic stapler inserted through a cut along the greater curvature, which is then repaired with use of a gastrointestinal anastomotic stapler (Fig 1c–1e). Ideally, the esophagogastric anastomosis is placed as high as possible in the chest, above the level of the azygos vein, to achieve the best surgical margin and decrease reflux. The conduit is most often placed in the paravertebral space; alternate routes include a substernal or right paratracheal position.

McKeown Esophagectomy.—The McKeown (tri-incisional) esophagectomy is appropriate in patients with tumors located above the gastroesophageal junction up to the level of the clavicles (12). This technique involves a right thoracotomy,



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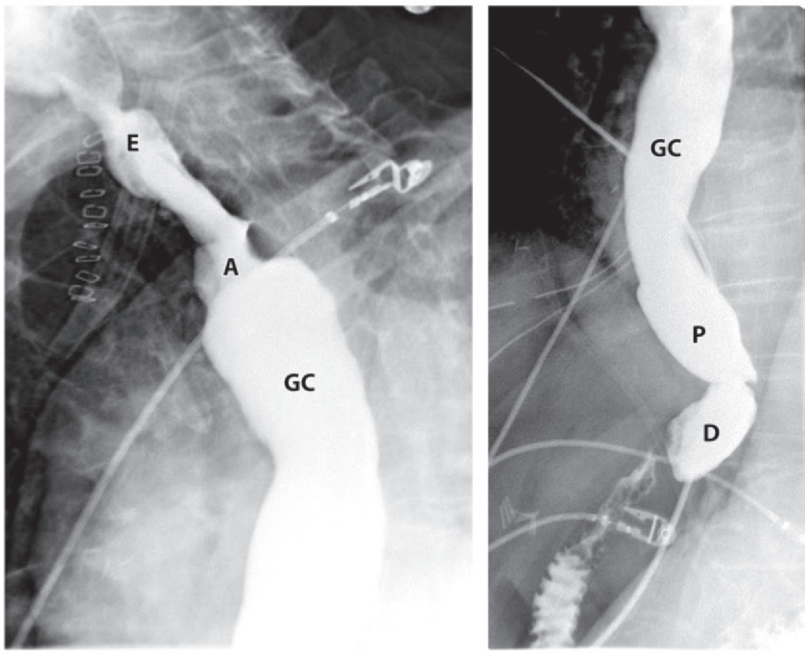

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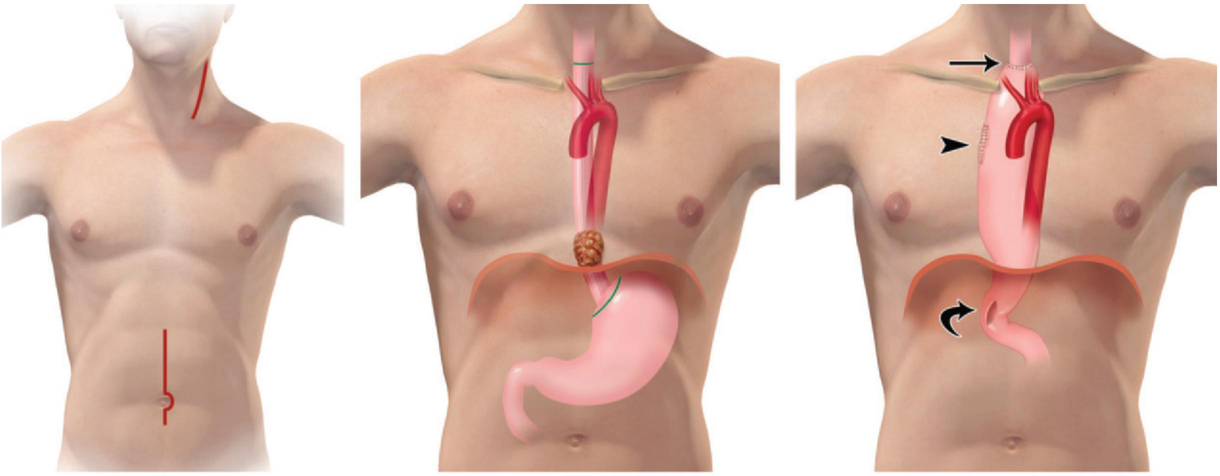
Figure 2. McKeown esophagectomy. **(a–c)** Drawings show skin incisions (red lines) for right thoracotomy, upper abdominal laparotomy, and creation of a cervical anastomosis (left neck) **(a)**; resection lines (green) and a tumor in the mid esophagus **(b)**; and postoperative anatomy after resection of the esophagus and creation of a cervical anastomosis (straight arrow) between the remnant esophagus and the gastric conduit **(c)**. Arrowhead in **c** = original resection line in the proximal stomach, curved arrow in **c** = pyloromyotomy. **(d, e)** Right posterior oblique esophagrams of the upper **(d)** and lower **(e)** thorax in a 73-year-old woman with squamous cell carcinoma of the distal esophagus show the anatomy after a McKeown esophagectomy. *A* = cervical anastomosis, *D* = duodenum, *E* = remnant esophagus, *GC* = gastric conduit, *P* = pylorus.

laparotomy, and left neck incision for creation of a cervical anastomosis (Fig 2a, 2b). First, the patient is placed in the left lateral decubitus position. Through a right thoracotomy in the fifth intercostal space, the esophagus and all of the adjacent nodal and, as necessary, mediastinal tissues are mobilized en bloc from uninvolved healthy-appearing mediastinal structures, leaving the esophagus in continuity. Often the thoracic duct is ligated to reduce the likelihood of postoperative chylothorax. After surgical drains are placed, the chest is closed and the patient is placed in the supine position. The second phase is performed through a midline laparotomy, and the stomach and adjacent lymphatic tissue are mobilized in the same manner as with the Ivor Lewis technique. A gastric conduit is created by using either a whole-stomach or a gastric tube, with or without a pyloric drainage procedure (12). The gastric conduit with the right gastroepiploic blood supply is brought to the neck through the left cervical incision. After removal of the esophagus through either the left neck incision or the upper midline incision (depending on the size of the lesion), the cervical esophagogastric anastomosis is created (Fig 2c–2e). In Ivor Lewis and McKeown esophagectomies, a feeding jejunostomy is often performed (12).

The key difference between the Ivor Lewis and McKeown procedures is the addition of a left neck incision with a cervical anastomosis in the McKeown method, which allows resection of more proximal esophageal tumors and makes management of potential anastomotic leaks easier. The Ivor Lewis approach allows exploration of the peritoneum early in the operation, thus



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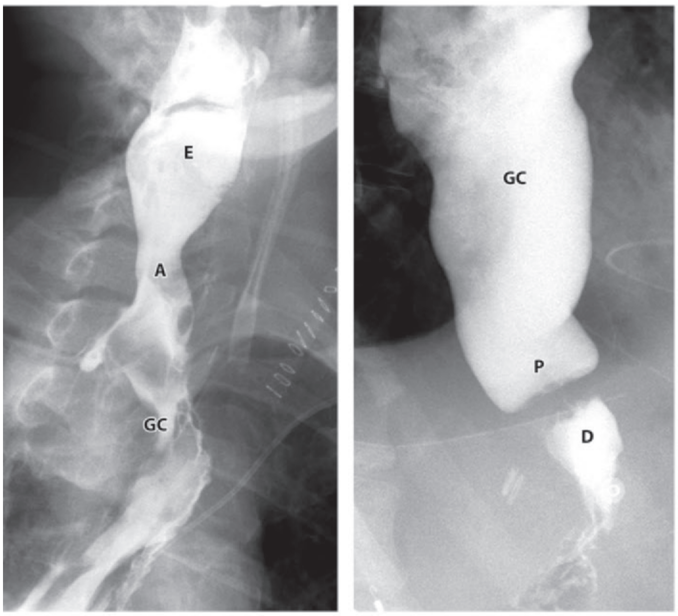

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Figure 3. Transhiatal esophagectomy. **(a–c)** Drawings show skin incisions (red lines) for upper abdominal laparotomy and creation of a cervical anastomosis (left neck) **(a)**, resection lines (green) and a tumor in the distal esophagus **(b)**, and postoperative anatomy after resection of the esophagus and creation of a cervical anastomosis (straight arrow) between the remnant esophagus and the gastric conduit **(c)**. Arrowhead in **c** = original resection line in the proximal stomach, curved arrow in **c** = pyloromyotomy. **(d, e)** Left posterior oblique esophagrams of the upper **(d)** and lower **(e)** thorax in a 63-year-old man show the anatomy after a transhiatal esophagectomy for recurrent benign strictures. *A* = cervical esophagogastric anastomosis, *D* = duodenum, *E* = remnant esophagus, *GC* = gastric conduit, *P* = pylorus.

avoiding a thoracotomy and the potential morbidity of thoracic esophagus devascularization in patients with metastatic peritoneal disease.

Left Thoracoabdominal Approach.—The left thoracoabdominal approach is used primarily for distal esophageal and gastroesophageal junction tumors and provides exposure of the superior abdominal and posterior mediastinal compartments through a single incision (6). Extensive lymphadenectomy can be performed in the abdomen and posterior mediastinum with this technique (13). However, thoracoabdominal incisions may be poorly tolerated by patients and may result in substantial debility.

Transhiatal Esophagectomy

Transhiatal esophagectomy is used for treatment of tumors involving the lower third of the esophagus and gastric cardia, as well as for many benign diagnoses. The major advantage of the transhiatal technique is the potential to diminish respiratory complications by avoiding a thoracotomy and an intrathoracic anastomosis with a possible intrathoracic anastomotic leak (8,14). The disadvantages are an increased rate of anastomotic leak for a cervical anastomosis, increased risk for subsequent stricture formation, and higher risk for recurrent laryngeal nerve injury (14).

The procedure is performed in three phases. The first step involves a supraumbilical incision, which allows distal esophageal dissection. The second step, the cervical phase, involves an incision parallel to the left sternocleidomastoid muscle for dissection of the proximal esophagus (Fig 3a, 3b). The third phase consists of careful blunt dissection of the esophagus in the mediastinum transhiatally by insertion of the surgeon's hand through the abdominal incision. Once the entire esophagus is mobilized, the cervical esophagus is transected. Next, a partial gastrectomy is

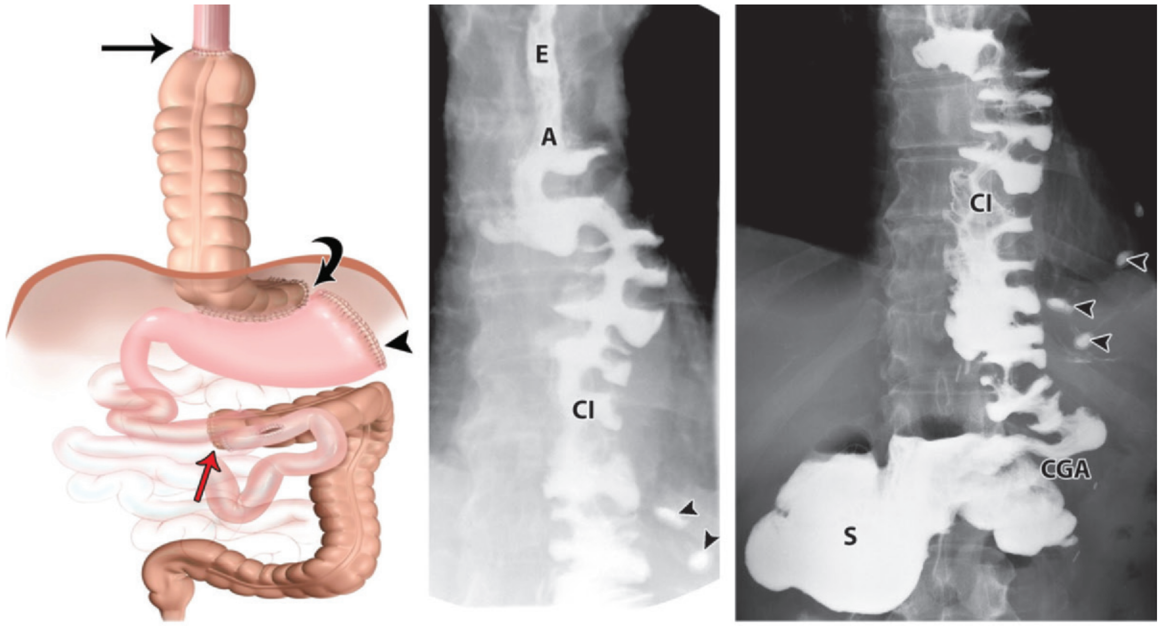

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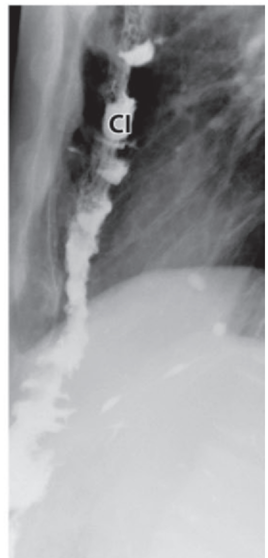
Figure 4. Retrosternal colonic interposition. **(a)** Drawing of the anatomy after esophagectomy with colonic interposition shows the esophagocolonic anastomosis (straight black arrow), cologastric anastomosis (curved black arrow), gastric staple line (arrowhead), and ileocolonic anastomosis (red arrow). **(b–d)** Frontal esophagrams of the upper **(b)** and lower **(c)** thorax and lateral esophagram of the lower thorax **(d)** in a 61-year-old man show the anatomy after an esophagectomy with retrosternal colonic interposition for a gastrointestinal stromal tumor of the lesser curvature. The arrowheads indicate spilled contrast agent extraneous to the patient. *A* = esophagocolonic anastomosis, *CGA* = cologastric anastomosis, *CI* = interposed colon, *E* = remnant esophagus, *S* = remnant stomach.



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performed, and the esophagus is removed via the abdominal incision. The gastric conduit is then brought up to the neck through the posterior mediastinum to create a cervical esophagogastric anastomosis (Fig 3c–3e) (13).

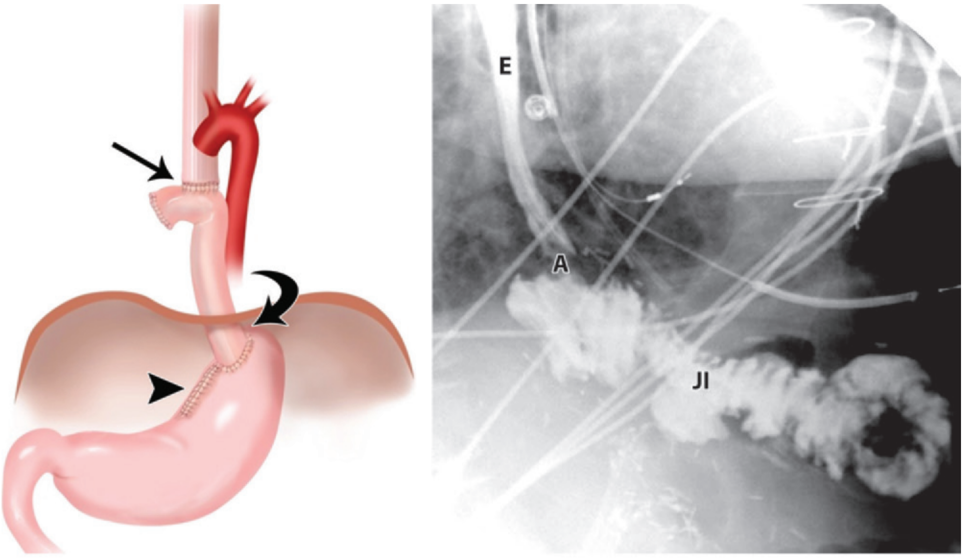
Bowel Interposition

When the stomach is unavailable because of previous or synchronous partial or total gastrectomy, reconstruction can be performed by using the colon or jejunum.

Colon.—The colon is considered a well-functioning and durable esophageal substitute. Colonic interposition is most often used in patients with benign disease and a long life expectancy (15). Indications include caustic or peptic strictures that are unable to be dilated, Barrett esophagus, advanced functional disorders, congenital atresia, achalasia, scleroderma, and esophageal varices (8,13,15). Although the right, transverse, and left colon have been used for esophageal replacements, the left colon is preferred because of its smaller diameter, resistance to chronic dilation, more reliable blood supply, adequate length, potential for less reflux, and ability to propel a solid bolus (8,16,17).

After esophagectomy, the colon is transected and elevated to the neck through one of three routes: subcutaneous, substernal, or posterior mediastinal (8). The substernal route is often the route of choice and is performed without pleural penetration (16). Once the colon is brought up to the neck, a cervical esophagocolonic anastomosis is created just below the level of the upper esophageal sphincter (16). When a portion of the stomach is available, the distal anastomosis is created in the posterior aspect of the gastric antrum. In the absence of the stomach, coloduodenostomy or colojejunostomy can be performed, although colojejunostomy is preferred. Continuity of the distal bowel is achieved with ileocolostomy or colocolostomy (Fig 4).

Disadvantages of using the colon as an interposition include a technically demanding procedure



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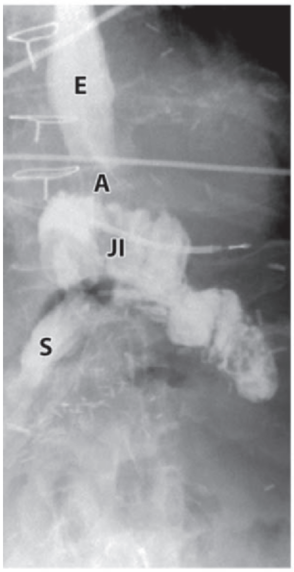

c.

Figure 5. Jejunal interposition. **(a)** Drawing of the anatomy after esophagectomy with jejunal interposition shows the intrathoracic esophagojejunal anastomosis (straight arrow), jejunogastric anastomosis (curved arrow), and gastric staple line (arrowhead). **(b, c)** Left posterior oblique **(b)** and frontal **(c)** esophagrams of the lower thorax in a 76-year-old man with adenocarcinoma of the gastroesophageal junction show the anatomy after an esophagectomy with jejunal interposition. *A* = intrathoracic esophagojejunal anastomosis, *E* = remnant esophagus, *JI* = interposed jejunum, *S* = remnant stomach.

with higher morbidity and mortality compared with a gastric conduit, longer operating times, the creation of additional anastomoses (each with their own rates of leak and stricture formation), and increased postoperative pulmonary complications (18,19).

Jejunum.—When the stomach and colon are unavailable, the jejunum can be a suitable choice for esophageal reconstruction. After esophagectomy, the jejunal segment is selected according to the quality of vascularization. While the mesenteric blood supply is maintained, the jejunum is transected and brought into the thoracic cavity in a retrogastric position. More recently, studies have shown that the jejunal interposition blood supply can be "supercharged" by creating a microvascular anastomosis in the portion of the jejunal mesenteric vessels farthest from the abdominal mesentery to the internal mammary vessels or neck vessels (20). The esophagojejunal anastomosis may be to the intrathoracic or (in the case of the "supercharged" interposition) cervical esophagus. Jejunogastric and jejunojejunal anastomoses are then created to establish intestinal continuity (Fig 5), as is done in gastric pull-up procedures (21). The pylorus may or may not be altered with a pyloroplasty, pyloromyotomy, or pyloromyomectomy to assist in gastric emptying.

The jejunum as an esophageal replacement is more resistant to bile and acid. Use of the jejunum has also been shown to reduce the occurrence of intrinsic disease, increase peristalsis, contribute to superior postoperative body weight maintenance, and decrease the incidence of gastroparesis (21,22). The major disadvantage is that at least three anastomoses are created, each with its own risk factors (21).

Minimally Invasive Esophagectomy

The esophagectomy methods that have been described can be performed by using minimally invasive surgical techniques. Although the mortality rate for open techniques has decreased from 25% to 5% in the past 2 decades, minimally invasive surgical techniques appear to have superior outcomes because they reduce pulmonary complications, shorten hospital stays, and allow faster postoperative recovery (23,24). In addition, minimally invasive surgery can be performed with a laparoscope or thoracoscope (in minimally invasive esophagectomy) and/or completely robotically. Robotically assisted esophagectomy is the method most often performed at our facility. Minimally invasive esophagectomy is indicated in the same patients as the open techniques, with a few exceptions (24). Stage T4 cancers are a relative contraindication (25).

Although many retrospective studies have demonstrated that minimally invasive techniques are a safe alternative to open esophagectomies, the definite benefit is still debatable. There remains a lack of long-term data on recurrence rates and overall survival to adequately compare the two approaches (26). More importantly, the literature suggests that surgeon experience and hospital case volume are some of the most important, if not the most important, factors to reduce morbidity and mortality, rather than surgical approach (25,26).

Postoperative Complications

Regardless of the surgical technique used, esophagectomy continues to carry risk for severe complications. Among all elective gastrointestinal surgical interventions, esophagectomy has the highest mortality rate, ranging from 3%–22% (3,5). Early detection of complications is critical to improve patient outcomes after esophagectomy. Chest radiographs, esophagrams, and chest CT images aid in early detection of complications, which allows early intervention.

Postoperative complications can be broadly grouped into pulmonary problems, anastomotic leaks, and technical, functional, or delayed complications.

Pulmonary Complications

Pulmonary complications are the most common postoperative complications, accounting for almost two-thirds of postoperative deaths (5). Risk for pulmonary complications is highest with use of thoracotomy (7,27). Complications include pneumonia, aspiration, acute respiratory distress syndrome, prolonged ventilator dependence, reintubation, pulmonary edema, pleural effusion, pneumothorax, tracheobronchial injury, and pulmonary embolism.

Anastomotic Leaks

Anastomotic leaks occur in 10%–44% of postoperative patients and account for as much as 40% of postoperative patient mortality (3,5). Anastomotic leaks often occur within the first 10 days after surgery and can be attributed to inappropriate tension (excessive or insufficient) at the anastomosis, with insufficient tension leading to poor tissue apposition with extravasation and delayed healing, and excessive tension leading to ischemia and necrosis (28). Ischemia, if severe, can lead to the most feared complication, which is conduit necrosis. Most leaks occur at the anastomosis, but leaks can develop at any of the resection sites, including the gastric staple line (the site where the anastomotic stapler is introduced to create the esophagogastric anastomosis), the site of a pyloric drainage procedure, and bowel harvest sites. Anastomotic leaks are more commonly seen with gastric conduits than with colon interposition and occur more often with a cervical anastomosis because of the higher possibility of tension and ischemia at the anastomosis (28–30). Anastomotic leaks also lead to increased risk for subsequent development of anastomotic strictures.

Patients can be asymptomatic, show signs of shock, or demonstrate other life-threatening symptoms. Gross anastomotic leaks can be diagnosed clinically on the basis of physical findings, including saliva exiting the neck incision or gastric fluids exiting the chest tubes. A leak at the cervical anastomosis is less serious and easier to treat (by reopening the neck incision) than an intrathoracic leak, which could lead to mediastinitis (28).

Esophagography is part of routine postoperative evaluation at most centers (31,32). We routinely obtain a single-contrast esophagram between postoperative days 6 and 10, depending on how the conduit looked at the time of surgery, the overall health of the patient postoperatively, and postoperative progress. However, postoperative esophagrams have been reported to be insensitive for detection of postsurgical leaks, and the clinical relevance of detecting an occult leak has been questioned (33,34). A report by Tomaszek et al (35) suggests increased pulmonary complications from aspiration during postoperative swallow studies. However, all patients in that study received diatrizoate meglumine (Gastrografin; E-Z-EM Canada, Anjou, Quebec, Canada), a hyperosmolar ionic contrast agent known to cause pulmonary edema and chemical pneumonitis. In the following paragraph, we describe an esophagographic technique performed with use of a low-osmolar nonionic contrast agent that is hand injected via a nasogastric tube to evaluate the conduit under pressure and detect leaks that may otherwise be missed at a passive swallow test. After esophagectomy, patients are at increased risk for aspiration because of possible recurrent laryngeal nerve injury. Using a low-osmolar, nonionic, water-soluble contrast agent, keeping the head of the table elevated, closely watching for aspiration throughout the study, and being prepared to suction should aspiration occur

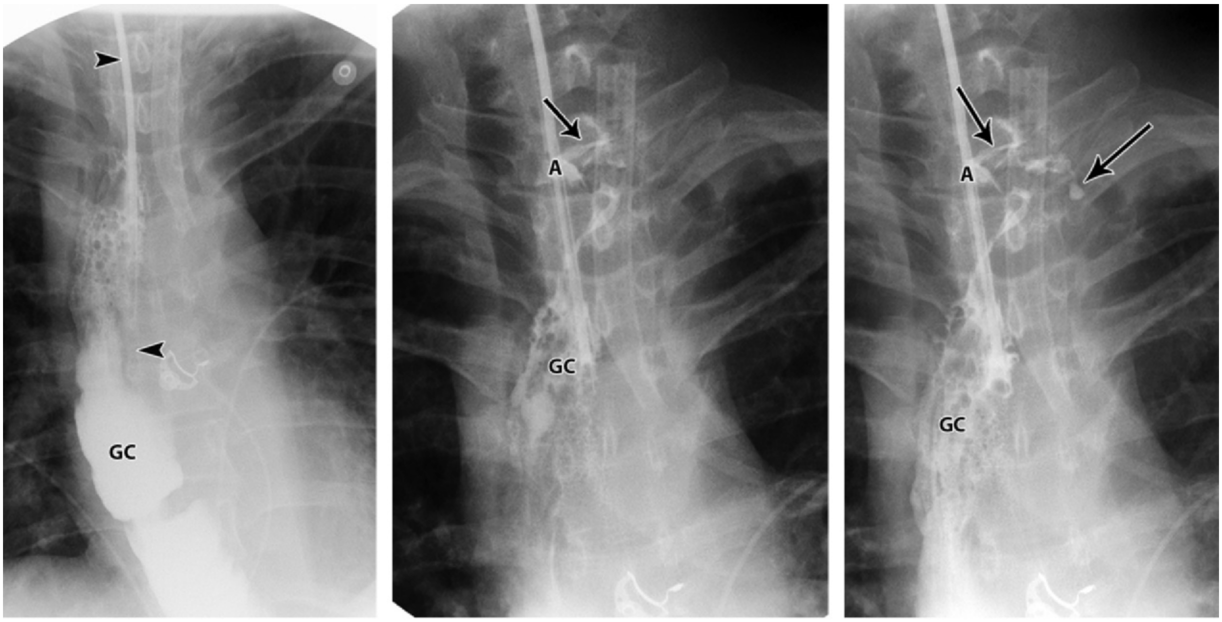

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Figure 6. Cervical anastomotic leak. Esophagrams of the upper thorax were obtained in a 32-year-old man 8 days after a transhiatal esophagectomy for end-stage achalasia. *GC* = gastric conduit. **(a)** Frontal view shows water-soluble contrast agent (hand injected via an indwelling nasogastric tube [arrowheads]) opacifying the gastric conduit. **(b, c)** Frontal views (obtained as the nasogastric tube was slowly retracted) show a small anastomotic leak (arrows) along the left paraspinous region at the level of the cervical esophagogastric anastomosis *(A)*.

will help minimize risk for pulmonary complications from aspiration (36).

At our institution, the patient arrives in the radiology department with an intraoperatively placed nasogastric tube, with the tip positioned just above or at the diaphragm. Knowledge of the location and type of anastomosis (ie, end-to-end, end-to-side, or side-to-side) is critical for more accurate imaging evaluation after esophagectomy. Obtaining a magnified scout view at the level of the anastomosis is important because surgical suture material can confound detection of a leak. The head of the fluoroscopy table is elevated to approximately 30° to minimize reflux aspiration. Low-osmolar, nonionic, water-soluble contrast material is hand injected through the indwelling nasogastric tube, with the side hole of the nasogastric tube positioned at different levels: below, at, and above the anastomosis. Contrast material is injected at low pressure (10 mL) and then at high pressure (20 mL), with anteroposterior, oblique, and/or lateral fluoroscopic images obtained at each level. It is important to know the location of the nasogastric tube side hole at all times during injection, especially in patients with a cervical anastomosis, because injecting contrast material too high in the cervical esophagus could put the patient at risk for aspiration.

If the conduit appears intact with use of a low-osmolar, nonionic, water-soluble contrast agent, the nasogastric tube is removed, and the study is repeated with the patient swallowing thin barium. Use of a water-soluble contrast agent alone can fail to depict small leaks (36,37). Barium has a higher density than water-soluble contrast agents and may adhere more strongly to the site of leakage. If a leak is observed when using a water-soluble contrast agent, the nasogastric tube is taped into place and the surgical team is notified immediately. Advancing the nasogastric tube in the presence of a leak could result in further damage at the site of the dehiscence.

When there is no nasogastric tube in place, imaging is performed as described previously, with the patient taking small sips of a water-soluble contrast agent (5 mL) and progressing to small mouthfuls of thin barium (10 mL) if no leak is seen. Irrespective of the technique used, postoperative esophagrams are obtained to evaluate for leaks, obstruction, and delayed gastric emptying (Figs 6, 7). If a leak is observed, it is important to note the location and size and whether it is contained or allows contrast material to freely extravasate into the mediastinum or pleural space (Figs 8, 9). Including drainage catheters in the field of view can help depict subtle leaks, which can be seen as areas of increased density within the drainage tubing. If there is high suspicion for a leak (eg, in patients with fever or sepsis), the contrast agent should be diluted with sterile water rather than tap water. Imaging performed with the patient

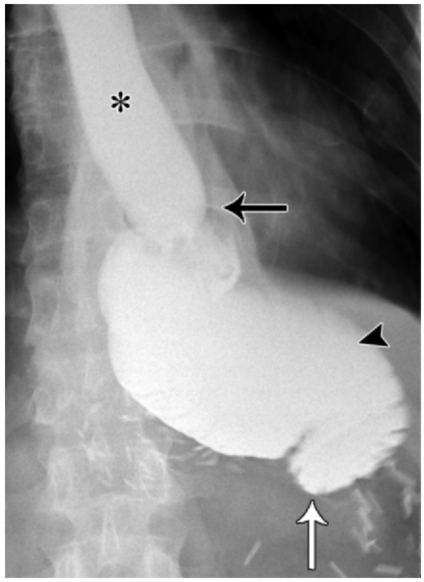
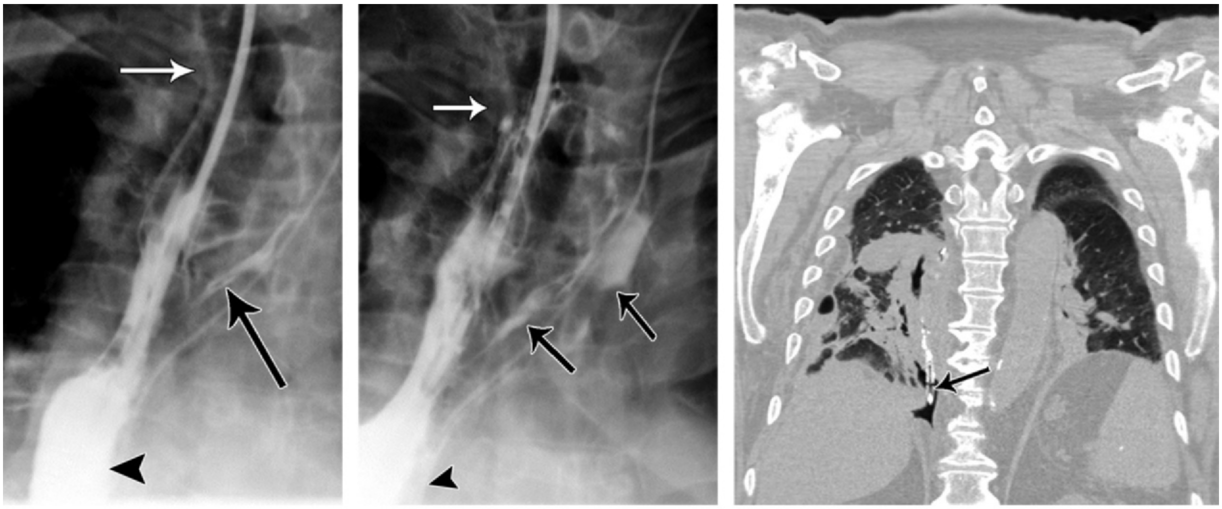


Figure 7. Jejunogastric anastomotic obstruction in a 43-year-old man after a transhiatal esophagectomy with jejunal interposition for adenocarcinoma of the gastroesophageal junction. Frontal esophagram of the lower chest obtained on postoperative day 10 shows an obstruction at the level of the jejunogastric anastomosis (white arrow). Arrowhead = dilated interposed jejunum, black arrow = esophagojejunal anastomosis, * = remnant esophagus.

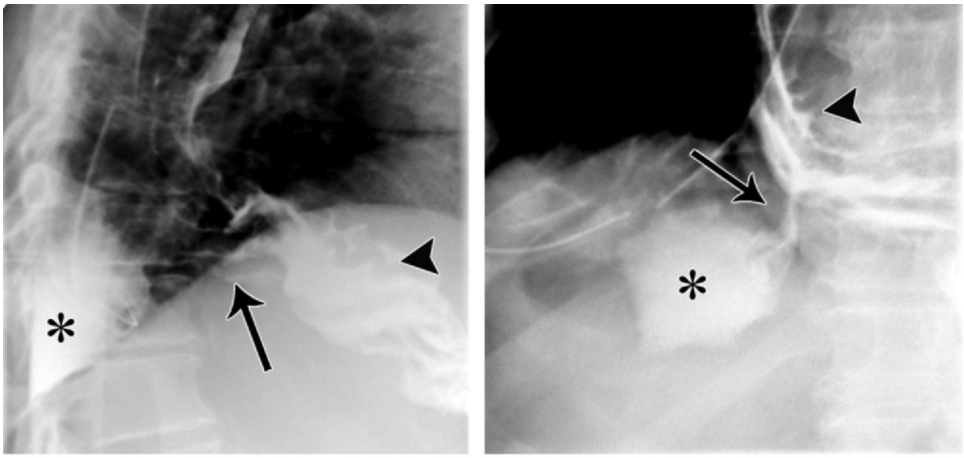


a. b. c.

Figure 8. Gastric conduit leak in a 70-year-old man after a transhiatal esophagectomy for adenocarcinoma of the gastroesophageal junction. **(a, b)** Left posterior oblique esophagrams of the upper thorax obtained on postoperative day 8 show extraluminal contrast agent extravasation (black arrows) from the left portion of the gastric conduit (arrowhead) tracking along the left mediastinal drain. White arrow = cervical anastomosis. **(c)** Coronal computed tomographic (CT) image (lung window) obtained when the nasogastric tube was advanced shows the tube (arrow) perforating the gastric conduit at a lower level and terminating in the right pleural space. The air surrounding the tip of the nasogastric tube indicates a pneumothorax.

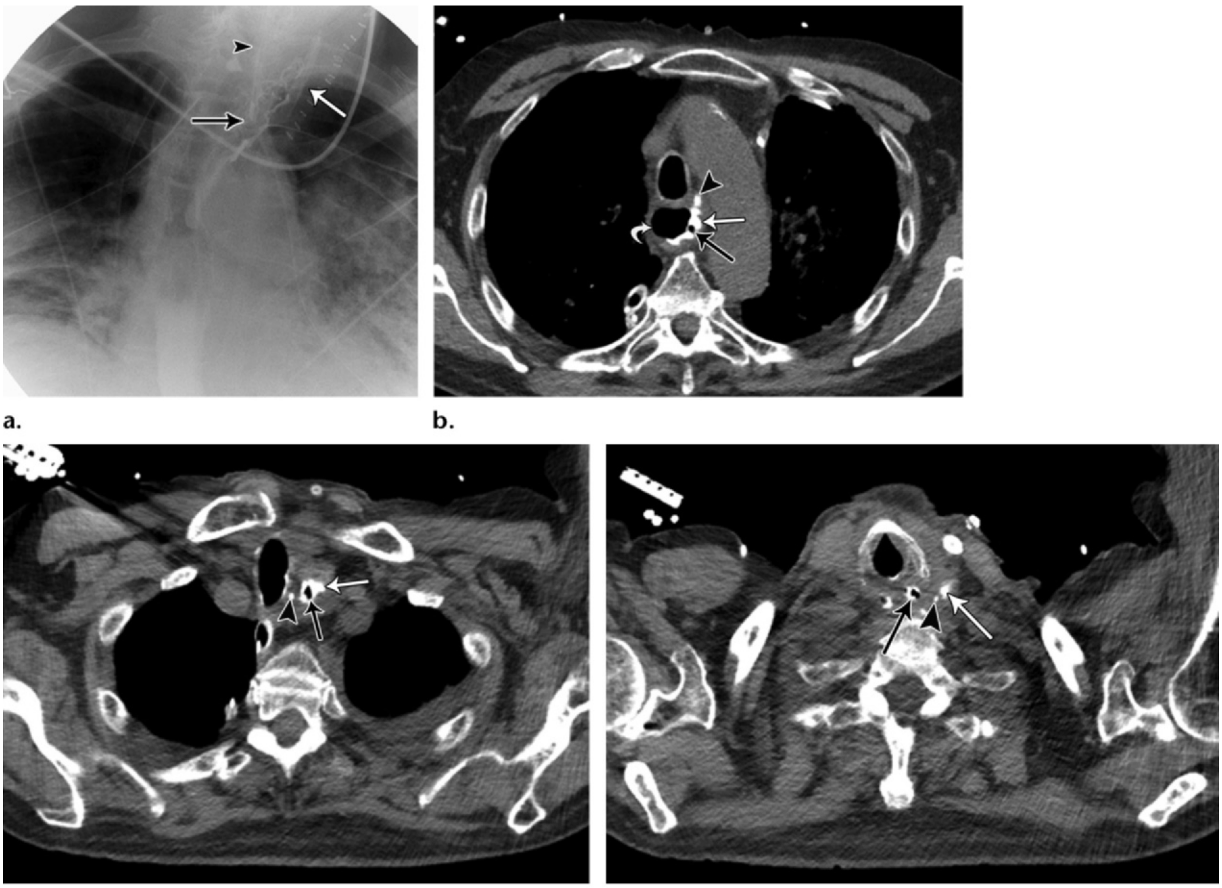
in multiple positions is necessary because the contrast agent may "shoot through" the anastomosis, especially in patulous areas, if imaging is performed with the patient in only one position. Imaging in multiple positions, including delayed phase imaging with the patient upright, also is valuable in evaluating obstruction and delayed gastric emptying because hypomotility is common after esophagectomy, and gravity plays an important role in conduit emptying.

Chest CT can be used to evaluate unstable postoperative patients. CT images are complementary to esophagrams and can help in evaluation of patients with challenging conditions, such as redundant fundal tissue at the esophagogastric anastomosis, side-to-side anastomosis, revision surgeries, and contained extravasations (Fig 10). Although we do not routinely use oral contrast agent for early postesophagectomy chest CT, use of diluted nonionic oral contrast agent may be considered for some clinical conditions and indications. If a leak is present, extravasation of contrast agent into the mediastinum or pleural space can easily be identified. Evaluation for a leak without use of oral contrast agent may be difficult because of expected air and fat stranding in the postsurgical mediastinum (31). Abscesses are readily identifiable at



a. b.

Figure 9. Gastropleural fistula in a 70-year-old man after a transhiatal esophagectomy for adenocarcinoma of the gastroesophageal junction (same patient as in Fig 8). Lateral **(a)** and frontal **(b)** esophagrams of the lower thorax obtained 30 days after surgery show a persistent gastropleural fistula (arrow) arising from the right posterior aspect of the gastric conduit (arrowhead) with communication to the right pleural space (*).



a. b. c. d.

Figure 10. Redundant fundal tissue mimicking an anastomotic leak in a 74-year-old man after a McKeown esophagectomy for adenocarcinoma of the gastroesophageal junction. **(a)** Left posterior oblique esophagram of the upper thorax obtained on postoperative day 8 shows contrast agent tracking superolaterally toward the left neck incision and left neck surgical drain (white arrow), a finding suspicious for an anastomotic leak. Arrowhead = nasogastric tube, black arrow = cervical anastomosis. **(b)** Axial CT image (soft-tissue window) below the level of the esophagogastric anastomosis shows the gastric conduit (curved white arrow), nasogastric tube (black arrow), contrast agent (straight white arrow) surrounding the nasogastric tube, and suture line (arrowhead). **(c)** Axial CT image (soft-tissue window) at the level of the anastomosis shows the nasogastric tube (black arrow), suture line (arrowhead), and contrast agent (white arrow) surrounding the nasogastric tube within the conduit. **(d)** Axial CT image (soft-tissue window) above the level of the anastomosis shows contrast agent (white arrow) lateral to the nasogastric tube (black arrow) on the left within redundant fundal tissue, as evidenced by the suture line (arrowhead) alongside the redundant fundus.

Figure 11. Diaphragmatic hernia in a 60-year-old man 13 months after an esophagectomy with a gastric conduit for squamous cell carcinoma of the distal esophagus. The patient presented with acute abdominal pain, nausea, and vomiting. Axial **(a)**, coronal **(b)**, and sagittal **(c)** abdominal CT images (soft-tissue window) obtained with oral and intravenous contrast agents show a large diaphragmatic defect containing multiple dilated, fluid-filled, intrathoracic small bowel loops (black arrows), with stranding of the mesentery and normal-caliber intra-abdominal small bowel loops. The findings are consistent with a closed-loop small bowel obstruction. Arrowheads = diaphragm remnant, white arrow = gastric conduit, * = herniated intrathoracic spleen.

CT, tend to develop adjacent to staple lines, and predispose the patient to fistula development.

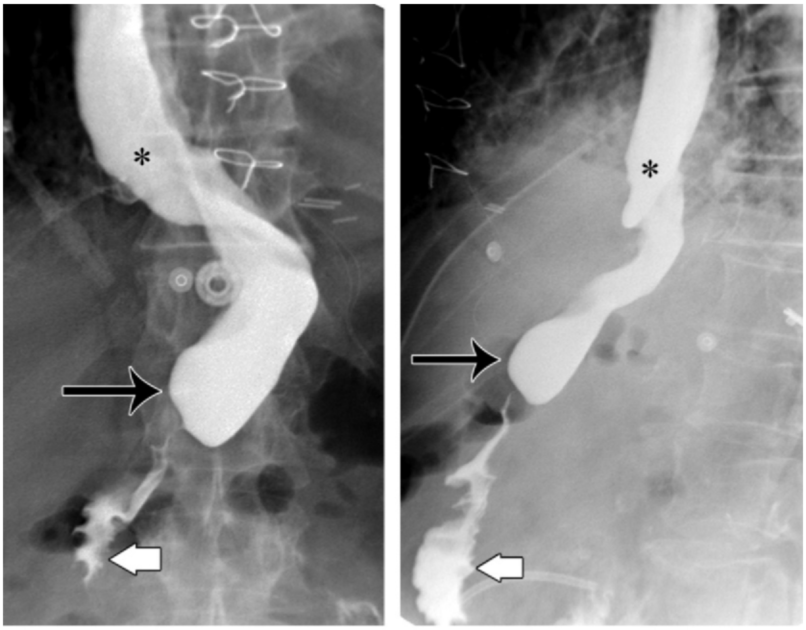
According to the Lerut classification for grading and management of leaks, a small leak seen only on a radiographic study without clinical suspicion in an asymptomatic patient (grade 1) does not require treatment. A small contained leak with minor clinical symptoms (grade 2) can be treated conservatively with wound drainage, delayed oral intake, and antibiotics. Larger leaks with major clinical manifestions (grade 3) and conduit necrosis (grade 4) require immediate surgical intervention (32,38).

CT-guided drainage of an intrathoracic leak or abscess may be used to temporarily allow decompression of the abscess cavity and clinical stabilization before surgical repair (39). CT- guided drainage can also be used for management of additional complications, including pleural effusion and pneumothorax (40).

Technical Complications

Technical complications include recurrent laryngeal nerve injury, chylothorax, hemorrhage, tracheobronchial injury, and diaphragmatic hernia. Recurrent laryngeal nerve injury usually occurs during cervical dissection and has an incidence of 10%–20% when a cervical anastomosis is created (28). This can affect the patient's voice as well as put the patient at risk for aspiration. If there is concern for aspiration, a modified barium swallow study can be used.

Chylothorax is a rare complication that results from injury to the thoracic duct and has an occurrence rate of 1%–5% (28). Persistent loss of chyle causes a decrease in lymphocytes, nutritional deficiencies, and reduced immunity and can eventually lead to systemic infections (41). Hemorrhage often occurs because of injury to the spleen, azygos vein, intercostal vessels, right gastric artery, and lung parenchyma during



a. b.

Figure 12. Delayed gastric emptying in a 67-year-old man after an Ivor Lewis esophagectomy for adenocarcinoma of the gastroesophageal junction. Frontal **(a)** and delayed right posterior oblique **(b)** upper abdominal esophagrams obtained on postoperative day 7 show slow passage of contrast material into the duodenum. Black arrow = pylorus, white arrow = contrast material in the duodenum, * = gastric conduit.

retraction or dissection (28). Traction injuries to the heart and pericardium can lead to cardiac tamponade. Loosening of the diaphragmatic hiatus during surgery predisposes to herniation of the abdominal contents into the chest. Patients can develop hernia-related complications such as bowel obstruction (Fig 11). Generally, all hernias are repaired unless the hernia is small and the patient is asymptomatic. Hernias can manifest in the immediate or late postoperative period and may be difficult to identify clinically but can easily be identified at cross-sectional imaging (42).

Functional Complications

One of the challenges after esophagectomy is restoration of function. Functional complications include delayed gastric emptying, dumping syndrome, and esophageal reflux. Delayed gastric emptying and gastric outlet obstruction occur in 10% of patients and are usually due to vagotomy and anatomic rearrangement (Fig 12) (28). Vagotomy leads to decreased gastric peristalsis and impairs relaxation of the pyloric sphincter. For these reasons, a pyloric drainage procedure often is performed concurrently. Delayed gastric empting is more prominent with the Ivor Lewis procedure, likely because of redundant stomach above the diaphragm (3). Delayed gastric emptying can lead to gastric distention and excessive tension at the anastomosis. The use of pyloric drainage procedures during esophagectomy, including pyloroplasty and pyloromyotomy, has been long debated. Advocates believe that these procedures help prevent gastric outlet obstruction, therefore reducing risk for aspiration and pneumonia, and improve early postoperative recovery. Others argue that only a small number of patients will develop gastric outlet obstruction and that pyloric drainage procedures could lead to dumping syndrome and bile reflux (10).

At our institution, 100 U of botulinum toxin is injected into four quadrants of the pylorus to temporarily disrupt normal basal tone, allowing the sphincter to relax. This decreases intraluminal pressure of the antrum and reduces pressure on the newly created gastric conduit, esophagogastric anastomosis, and gastric staple line, thus reducing the likelihood of leaks. The temporary disruption from botulinum toxin lasts 3–6 months, after which normal function resumes, potentially reducing the likelihood of bile reflux.

Dumping syndrome is reported to occur in as many as 50% of patients because of rapid transit of hyperosmolar gastric contents into the small bowel. Patients present with vasomotor and gastrointestinal symptoms (33). Hypoglycemia secondary to increased insulin response also causes delayed symptoms. It is managed medically, along with dietary alterations. Reflux of gastric and duodenal contents is an expected complication, with increased occurrence after pyloroplasty, and can cause ulceration and stricture (33).

Delayed Complications

Delayed complications generally are anastomotic strictures or disease recurrence, with the most common symptom of both being dysphagia. In the early postoperative period, dysphagia is commonly due to anastomotic stricture; however, in the late postoperative period, disease recurrence becomes an increasing concern. Other

a. b. c. d.

Figure 13. Anastomotic strictures. **(a)** Esophagram in a 65-year-old man 8 years after an Ivor Lewis esophagectomy for achalasia shows an intrathoracic esophagogastric anastomotic stricture (black arrow) with an associated pulsion diverticulum (white arrow). Arrowhead = gastric conduit, * = remnant esophagus. **(b)** Left posterior oblique esophagram in a 54-year-old man 5 years after an Ivor Lewis esophagectomy for adenocarcinoma in the distal esophagus shows an intrathoracic anastomotic stricture (black arrow). Arrowhead = gastric conduit, white arrow = anastomosis, * = remnant esophagus. **(c)** Right posterior oblique esophagram in a 50-year-old woman 17 years after a transhiatal esophagectomy and partial gastrectomy with colonic interposition for lye ingestion shows a cologastric anastomotic stricture (black arrow). Black arrowhead = interposed colon, white arrow = cologastric anastomosis, white arrowhead = remnant stomach. **(d)** Right posterior oblique esophagram in a 54-year-old man 2 months after a transhiatal esophagectomy and partial gastrectomy with jejunal interposition for adenocarcinoma of the gastroesophageal junction shows an esophagojejunal anastomotic stricture (black arrow). Black arrowhead = interposed jejunum, white arrow = esophagojejunal anastomosis, white arrowhead = remnant stomach, * = remnant esophagus.

complications discussed earlier, including functional complications, postoperative leaks, fistulas, and diaphragmatic hernias, may occur in the delayed postoperative period as well (43).

Anastomotic strictures have a reported prevalence of 9%–48% (34). Postoperative anastomotic leaks predispose to development of anastomotic strictures and therefore occur more commonly when a cervical anastomosis is created (Fig 13). Other risk factors include use of a stapled rather than hand-sewn technique, a poorly vascularized gastric conduit, and preoperative cardiac disease or diabetes. Diagnosis is often made at endoscopy; however, single- or double-contrast esophagography and CT may also be useful. Patients are usually treated with endoscopic dilatation because stent placement is not preferred.

Conclusion

Esophagectomy and restoration of gastrointestinal continuity are complex and challenging procedures. Understanding the different surgical techniques and recognizing their postoperative appearances is imperative to evaluate postoperative patients. Radiologists should review the operative report with specific attention to the type of conduit used and the location of the anastomosis. Pulmonary complications and anastomotic leaks are the leading causes of postoperative mortality after esophagectomy. Chest radiographs, esophagrams, and CT images are commonly obtained in postoperative patients. Knowledge of the potential complications is critical for radiologists to provide effective postoperative patient care.

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