Esophageal Resection: Indications, Techniques, and Radiologic Assessment[1]

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CME FEATURE

See accompanying test at http://www.rsna.org/education/rg_cme.html

LEARNING OBJECTIVES FOR TEST 2

After reading this article and taking the test, the reader will be able to:

- Discuss various surgical techniques for benign and malignant esophageal lesions.
- List the indications for each surgical technique.
- Discuss the anatomic changes and complications that may accompany esophageal surgery.

Various surgical procedures are performed for benign and malignant esophageal lesions. These procedures include transthoracic esophageal resection through a right or left thoracotomy and transhiatal blunt esophageal resection (esophagectomy) without thoracotomy. The whole stomach, colon, gastric tube, jejunum, and free revascularized grafts may be used as substitutes for the resected esophagus. Bypass procedures including substernal stomach bypass surgery and substernal or subcutaneous colon bypass surgery are performed for tracheoesophageal fistula, previous esophagectomy without reconstruction, or obstruction due to lye ingestion. The mortality rate for esophageal resection depends on the stage of the tumor, the patient's condition, and the surgeon's skill and is quite low when the procedure is performed by a highly skilled surgeon. The most frequent sources of morbidity related to esophageal surgery include pneumothorax, pleural effusion, pneumonia, and respiratory failure. Mediastinitis and sepsis due to disruption at an anastomosis site cause serious postoperative morbidity and mortality; therefore, thoracic anastomotic leaks require aggressive surgical treatment. Familiarity with these surgical options, the resultant anatomic changes associated with each option, and the expected findings at postoperative imaging is essential for evaluating the effectiveness of surgical procedures and for the early detection and management of surgery-related complications.

Index terms: Esophagus, CT, 71.1211 • Esophagus, diseases • Esophagus, neoplasms, 71.31, 71.32 • Esophagus, surgery, 71.451, 71.458 • Gastrointestinal tract, 70.92

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See the commentary by Aquino.

Table 1
Indications, Surgical Mortality Rates, and Complication Rates for Various Types of Esophagectomy

Procedure	Indications	Surgical Mortality Rate	Complication Rate
Transthoracic esophagectomy through a right thoracotomy	Carcinoma involving the upper two-thirds of the esophagus, high-grade dysplasia in Barrett esophagus, destruction of the lower two-thirds of the esophagus by caustic ingestion, complications of reflux esophagitis failed with other reflux procedures	16 (range, 5–27)*	Overall, 45%; anastomotic leak, up to 14%; respiratory complication, up to 38%†
Transhiatal esophagectomy without thoracotomy	Curative or palliative resection of thoracic-cervicothoracic esophageal carcinoma, removal of thoracic esophagus after pharyngectomy or pharyngolaryngectomy for esophageal carcinoma, esophageal stricture, neuromotor dysfunction (achalasia, spasm, scleroderma), recurrent gastroesophageal reflux, perforation, caustic injury	11 (range, 3–19)*	Overall, 62%; anastomotic leak, up to 26%; respiratory complication, up to 54%‡
Transthoracic esophagectomy through a left thoracotomy	Benign and malignant lesions of the distal esophagus, gastroesophageal junction, and gastric cardia	17 (range, 1–33)*	Overall, 44%; anastomotic leak, up to 12%; respiratory complication, up to 34%§
Radical en bloc esophagectomy	Potentially curable tumor in pre- and intraoperative staging	8 (range, 2.4–11)‖	Overall, 59%; anastomotic leak, up to 6%; respiratory complication, up to 27%‖

*Source.—Reference 9.
†Sources.—References 1, 3, 7–9, 13–16.
‡Sources.—References 1, 3, 9, 11–16.
§Sources.—References 3, 5, 9, 16, 18.
‖Sources.—References 21–24.

Introduction

Various surgical procedures are used in esophageal resection. The surgical option is chosen on the basis of the benign or malignant condition of the lesion, the extent of the lesion, and the presence of complications (Table 1) (2,3,18).

The morbidity and mortality rates for esophagectomy are significant, and sometimes the associated risks are high enough to prohibit surgery. However, meticulous surgical techniques and improved postoperative care have reduced the complications and death rates associated with this surgical procedure (19). Because of lack of familiarity with the diversity of surgical procedures, the normal postoperative radiographic findings, and the most common potential complications, radiologists may encounter difficulties in postoperative radiologic interpretation.

In this article, we discuss and illustrate the indications for and results of various techniques of esophageal surgery. In addition, we demonstrate the imaging manifestations of postoperative anatomic changes and complications associated with each surgical option in various esophageal diseases.

Esophageal Resection

Transthoracic Esophagectomy through a Right Thoracotomy

In transthoracic esophagectomy through a right thoracotomy (Fig 1), the thoracic cavity is usually entered through the fifth intercostal space. With this approach, the aortic arch does not limit access to the esophagus. The stomach is mobilized through an abdominal incision or through the esophageal hiatus without such an incision. Most often, a high intrathoracic anastomosis is created (Fig 1c), although a cervical esophagogastric anastomosis may also be created (Figs 1d, 2).

Ivor Lewis esophagectomy (separate laparotomy and right thoracotomy incisions) is the

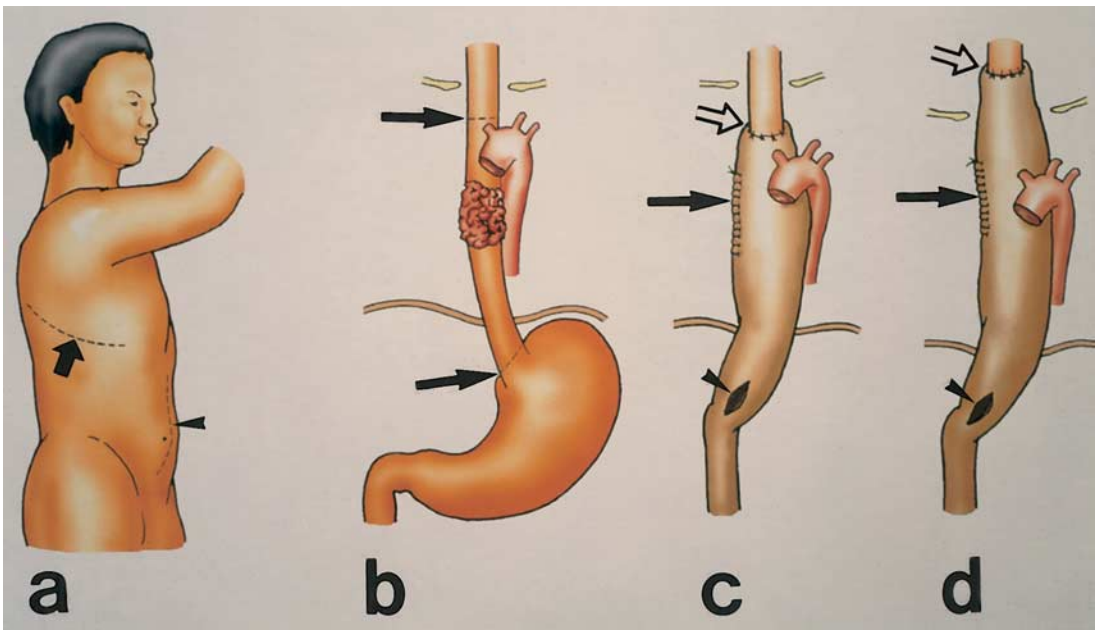


Figure 1. Drawings illustrate transthoracic esophagectomy through a right thoracotomy. Drawing *a* shows how tumors of the upper thoracic esophagus are assessed through a right thoracotomy (arrow) and upper abdominal incision (arrowhead). Drawing *b* demonstrates how the esophagus is partially resected through the right thoracotomy. Arrows indicate resection lines. Drawings *c* and *d* show how an intrathoracic (*c*) or cervical (*d*) anastomosis is created between the remaining esophagus and the esophageal substitute. Open arrows indicate the anastomosis site, solid arrows indicate the original cardioesophageal junction, and arrowheads indicate pyloromyotomy.

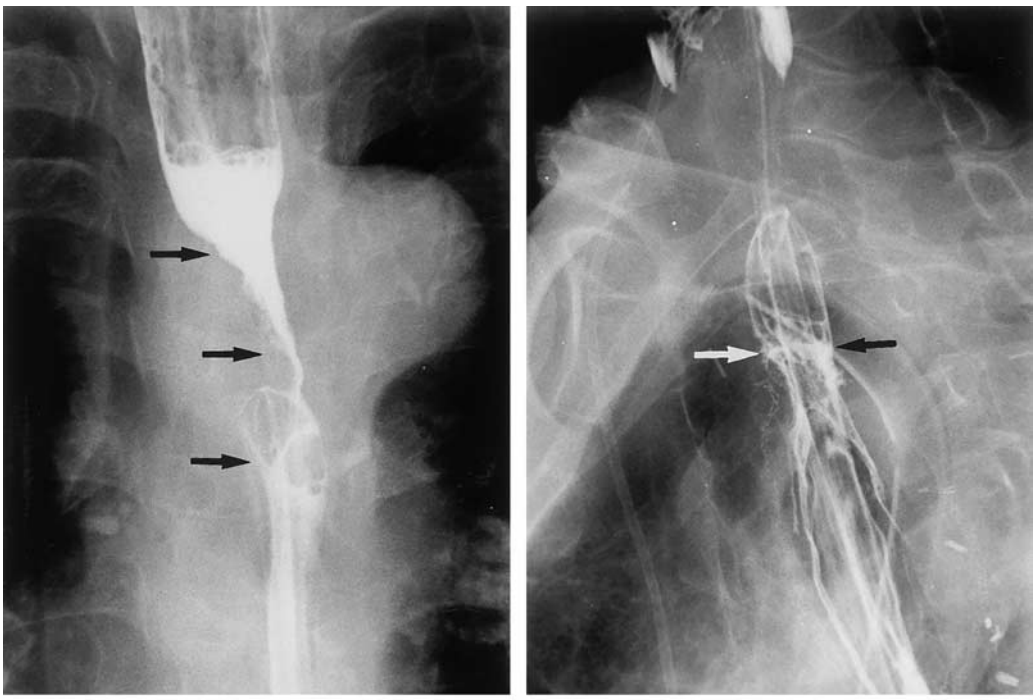
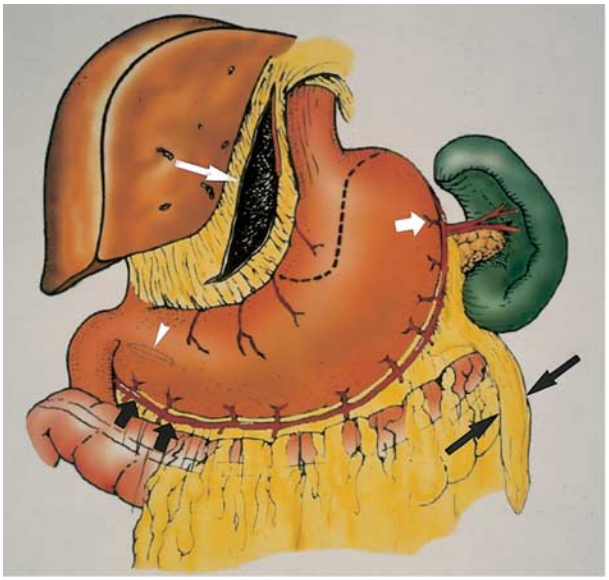


Figure 2. Transthoracic esophagectomy and cervical esophagogastrostomy through a right thoracotomy in a 69-year-old man with squamous cell carcinoma of the upper thoracic esophagus. **(a)** Preoperative esophagogram shows a 4-cm segment of an esophageal mass with luminal narrowing (arrows) and mucosal irregularity at the level of the aortic arch. **(b)** Barium esophagogram obtained 7 days after surgery shows a cervical esophagogastric anastomosis (arrows).

Figure 3. Drawings illustrate an Ivor Lewis esophagectomy. **(a)** During the abdominal stage of the procedure, the stomach is elevated by grasping its greater curve (external to the right gastroepiploic artery), and the short gastric arteries (thick white arrow) are clamped and tied. The greater omentum is dissected distally near the pylorus with care to avoid injuring the right gastroepiploic artery (thick black arrows). The gastrohepatic ligament (thin white arrow) is then carefully divided to preserve the right gastric artery. The esophageal hiatus and distal esophagus are dissected free, and a pyloromyotomy (arrowhead) is performed. Note the tongue of the omentum (thin black arrows) attached to the greater curvature of the stomach; it will be used to wrap the anastomosis. Dotted lines indicate resection lines. **(b)** Following right thoracotomy, the azygos vein is divided and the esophagus is dissected out of its bed. Dissection is continued up to the apex of the thorax. The stomach is then pulled up into the chest and divided. Dotted line represents proposed resection line for gastric division. **(c)** An anastomosis is created between the end of the esophagus and the fundus of the stomach. The remaining (tumor-containing) esophagus is divided and removed. The omentum that was preserved with the stomach is wrapped around the anastomosis (arrows). Arrowheads indicate the original cardioesophageal junction.



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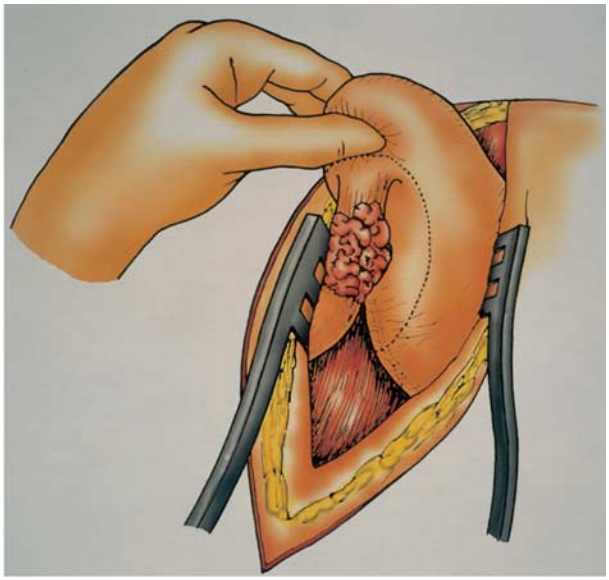

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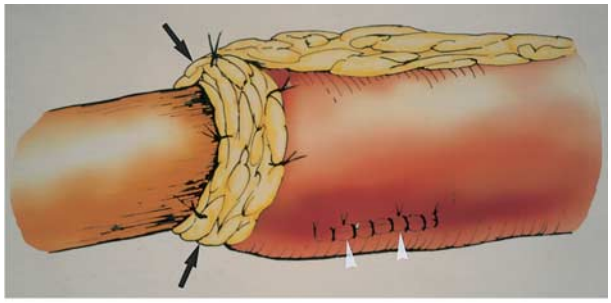


c.

most frequently performed procedure for resection of the thoracic esophagus (Fig 3). An upper midline abdominal incision is made, and the abdomen is explored to mobilize the stomach (Fig 3a). Thereafter, a standard posterolateral right thoracotomy is performed. The esophagus is dissected out of its bed. The stomach is pulled up into the thorax through the esophageal hiatus and is divided at its cardiac portion to allow creation of an anastomosis between the distal end of the esophagus and the fundus of the stomach (Fig 3b). Then, the esophageal segment containing the mass is removed (Fig 3c) (1,4,5,12,20).

Right thoracotomy for esophagectomy is preferred for lesions of the upper two-thirds of the esophagus to avoid interference caused by the aortic arch. The aortic arch limits access to lesions of the upper two-thirds of the esophagus in left thoracotomy.

The Ivor Lewis procedure is an excellent surgical technique for patients with midesophageal carcinomas (Fig 4). In addition to esophageal cancer, indications for this procedure include high-grade dysplasia in Barrett esophagus, destruction of the distal two-thirds of the esophagus

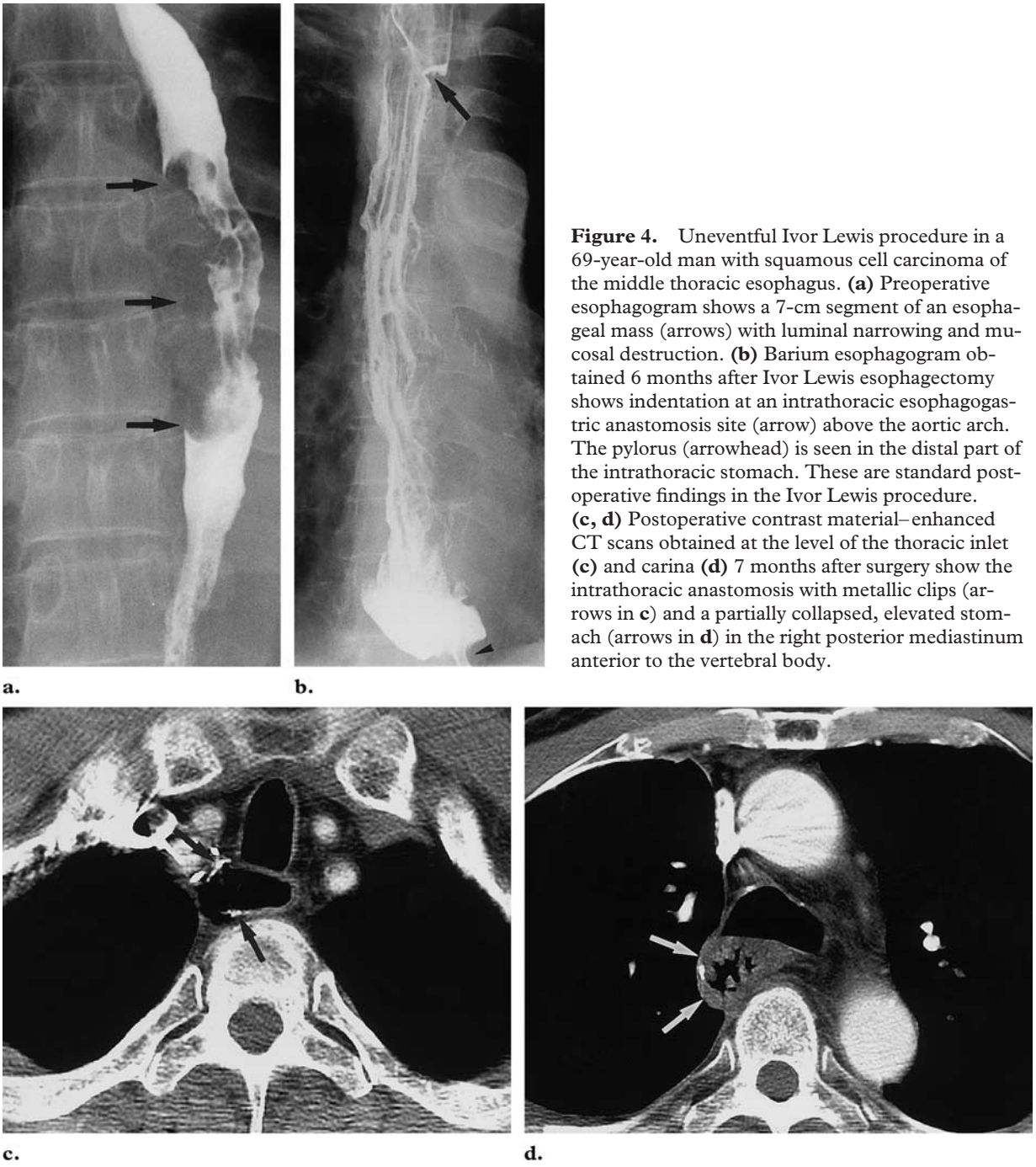


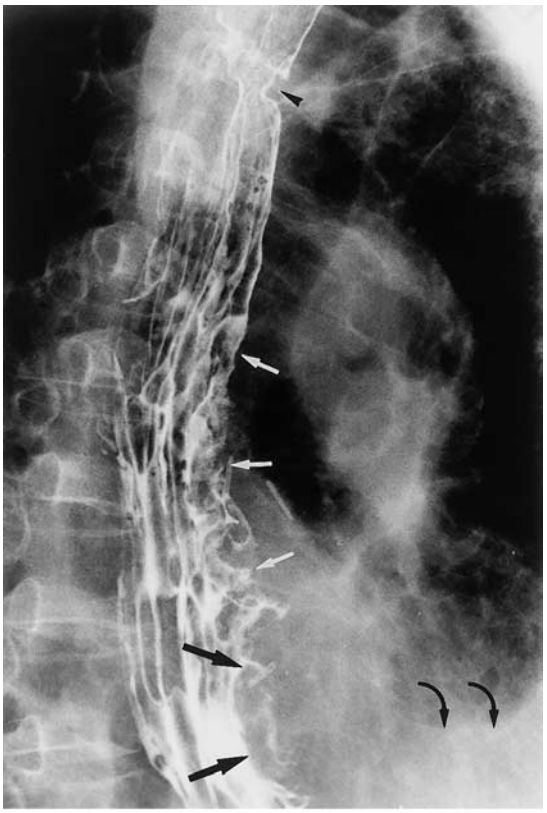
Figure 4. Uneventful Ivor Lewis procedure in a 69-year-old man with squamous cell carcinoma of the middle thoracic esophagus. **(a)** Preoperative esophagogram shows a 7-cm segment of an esophageal mass (arrows) with luminal narrowing and mucosal destruction. **(b)** Barium esophagogram obtained 6 months after Ivor Lewis esophagectomy shows indentation at an intrathoracic esophagogastric anastomosis site (arrow) above the aortic arch. The pylorus (arrowhead) is seen in the distal part of the intrathoracic stomach. These are standard postoperative findings in the Ivor Lewis procedure. **(c, d)** Postoperative contrast material–enhanced CT scans obtained at the level of the thoracic inlet **(c)** and carina **(d)** 7 months after surgery show the intrathoracic anastomosis with metallic clips (arrows in **c**) and a partially collapsed, elevated stomach (arrows in **d**) in the right posterior mediastinum anterior to the vertebral body.

by caustic ingestion, peptic stricture and ulcer, persistent reflux esophagitis causing pulmonary complications that fail to respond to antireflux procedures, and, rarely, perforation of the mid- to distal esophagus (20). The Ivor Lewis procedure is not indicated for high esophageal carcinomas located within 20 cm of the incisors. The procedure is relatively contraindicated in patients who have undergone a previous right thoracotomy due to postoperative adhesion (20).

The overall hospital mortality rate for the right transthoracic approach is about 16% (5%–27%) (1). According to several reports, the surgical mortality rate for Ivor Lewis esophagogastrectomy is 3%–4% (4,5). The causes of mortality are respiratory failure and sepsis (Table 1). Sixty percent of patients with esophageal squamous cell

Figure 5. Tumor recurrence in a 60-year-old man with squamous cell carcinoma of the esophagus who had undergone the Ivor Lewis procedure. **(a)** Contrast-enhanced CT scan (7-mm collimation) obtained at the level of the inferior pulmonary vein 7 months after surgery shows a heterogeneous soft-tissue mass (arrows) with aortic invasion and smooth indentation of the left atrium (*). Note also the nodular thickening of the left parietal pleura (arrowheads) with effusion, a finding that suggests malignant effusion. **(b)** Barium esophagogram shows tethering and thickening of the mucosal folds due to tumor infiltration in the left side of the elevated stomach below the carina (white arrows). Note the extraluminal mass (straight black arrows) and left pleural effusion (curved arrows). An intrathoracic anastomosis is also identified (arrowhead).

a.



b.

carcinoma who underwent Ivor Lewis esophagectomy have recurrent tumor (Fig 5) at 2.3-year follow-up (4). These recurrent tumors include (in decreasing order of frequency) distant metastasis (29% of cases), simultaneous regional and distant metastasis (12%), regional metastasis (11%), and tumor at the anastomosis site (5%) (4). The overall 5-year survival rate is 22.8%–33.3% (4,21).

Transhiatal Esophagectomy without Thoracotomy

Transhiatal esophagectomy has recently been proposed as a viable alternative to traditional transthoracic esophagectomy and has been used frequently since that time. This is mainly because recent reports suggest that this surgical procedure has morbidity and mortality rates comparable to those of esophagectomy with thoracotomy (6–11).

In transhiatal esophagectomy, a cervical incision is made, the esophagus is mobilized inferiorly down to the azygos arch, and the stomach is dissected through an abdominal incision (Fig 6a). The lower part of the esophagus is mobilized through the esophageal hiatus (Fig 6b), and the cervical esophagus is transected at an appropriate level. The esophagus distal to the transection is brought down through the posterior mediastinum into the abdomen. The esophagus is transected at the gastroesophageal junction, and the stomach is brought into the neck through the posterior mediastinum for esophagogastrostomy (Fig 6c) (10, 11).

Transhiatal esophagectomy has been used for curative or palliative resection of thoracic and cervicothoracic esophageal malignancy (Fig 7) and for benign esophageal conditions. The latter include esophageal stricture, neuromotor dysfunction (achalasia, spasm, scleroderma), recurrent gastroesophageal reflux, perforation, caustic

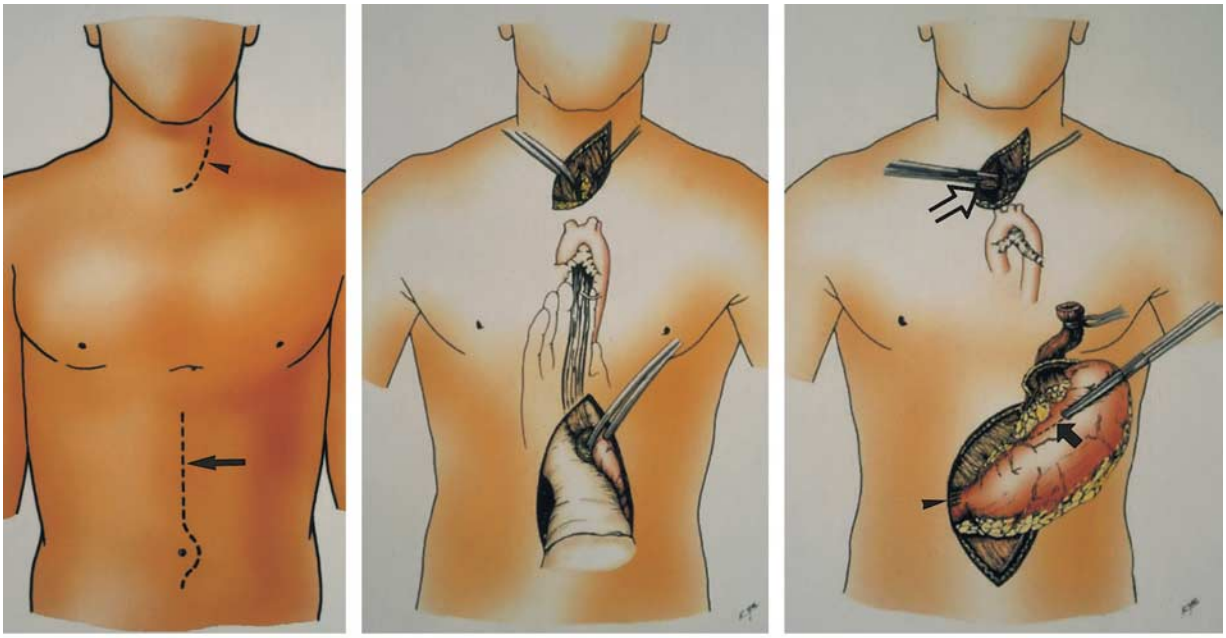


Figure 6. Drawings illustrate transhiatal esophagectomy without thoracotomy. **(a)** Cervical (arrowhead) and upper abdominal midline (arrow) incisions are made. **(b)** Mobilization of the stomach for esophageal replacement is performed through a laparotomy with pyloroplasty. The right gastric and gastroepiploic arteries are preserved. The esophagus is mobilized from the back wall of the trachea through the cervical incision. From below, the surgeon's hand passes through the widened hiatus. Any remaining attachments of the muscular esophageal tube are avulsed from the esophageal wall. **(c)** The cervical esophagus is clamped, leaving adequate length for reconstruction by preserving 3–4 cm of peristaltic esophagus (open arrow). The esophagus is then extracted from the mediastinum. The stomach is divided at the proximal region with a stapler or clamp (solid arrow). Pyloromyotomy is performed at the distal portion with a suture technique (arrowhead). Finally, the remaining portion of the stomach is advanced to the neck for esophagogastric anastomosis.

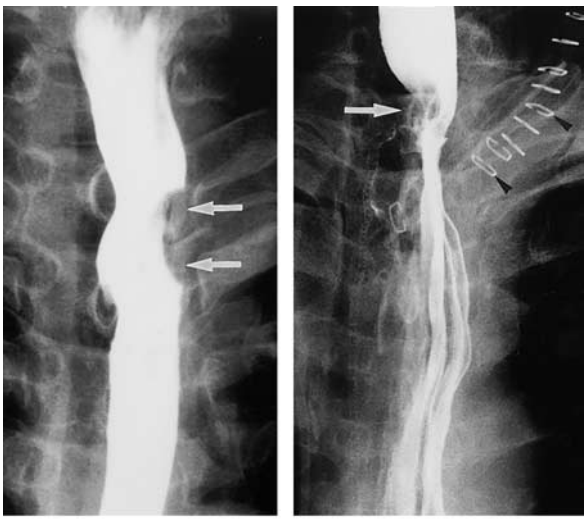
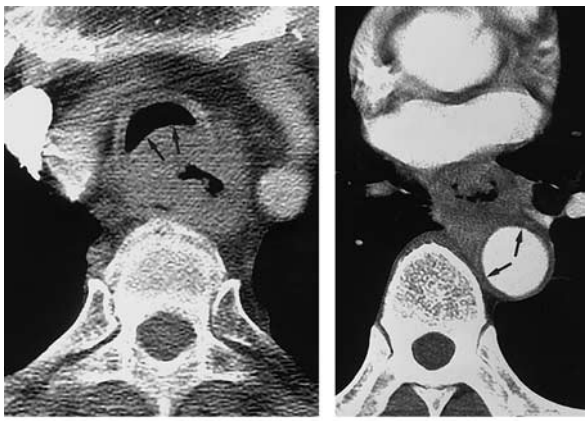


Figure 7. Transhiatal esophagectomy with cervical esophagogastrostomy in a 52-year-old man with squamous cell carcinoma of the cervicothoracic esophagus. **(a)** Preoperative esophagogram shows a focal filling defect (arrows), a finding that suggests esophageal cancer at the level of the thoracic inlet. **(b)** Barium esophagogram obtained 5 months after surgery shows a cervical esophagogastric anastomosis (arrow). Metallic clips are also noted (arrowheads).

injury, and removal of the thoracic esophagus after pharyngectomy or pharyngolaryngectomy for carcinoma (2). Close adhesion between the tumor and mediastinal structures such as the airways and aorta constitute a major risk during surgery. At this level, accidental laceration resulting from sharp or forced blunt surgical dissection of the trachea, main-stem bronchi, or aorta is difficult to repair without thoracotomy. Therefore, transhiatal esophagectomy is considered a safe procedure only when tracheobronchial (Fig 8) or aortic (Fig 9) involvement is not suggested at CT (22).

The overall hospital mortality rate for transhiatal esophagectomy is about 11% (3%–19%) (1). Orringer et al (2) reported the hospital mortality rate for transhiatal esophagectomy as low as 5% for benign and malignant esophageal diseases. The leading causes of death are pulmonary problems such as pneumonia and respiratory insufficiency. Other causes of mortality may include cardiac problems, hemorrhage, mediastinal or retroperitoneal abscess, renal failure, and sepsis (2). Transhiatal esophagectomy with cervical esophagogastric anastomosis avoids the morbidity associated with thoracotomy and removes the potential for sepsis from an intrathoracic leak.

According to several reports, no statistically significant difference in the surgical mortality rates for transhiatal and transthoracic approaches has been shown (6–8). The overall morbidity rates for the two approaches, although variable, are also not significantly different. No statistically significant differences in survival for patients who underwent transthoracic versus transhiatal esophagectomy for esophageal carcinoma have been demonstrated (Table 1) (1,9). Tumor stage at the time of surgery is the only significant determinant of long-term outcome. No significant differences in survival based on the extent or type of surgery performed have been shown.



8. 9.

Figures 8, 9. **(8)** CT contraindication for transhiatal esophagectomy (tracheal invasion) in a 66-year-old man with squamous cell carcinoma of the esophagus. Contrast-enhanced CT scan obtained at the level of the thoracic inlet shows tracheal displacement and indentation in the posterior wall (arrows) due to an upper thoracic esophageal mass. Total esophagectomy through a right thoracotomy and cervical esophagogastrostomy revealed tracheal invasion. Careful dissection was performed between the posterior tracheal wall and the esophageal cancer. **(9)** CT contraindication for transhiatal esophagectomy (aortic invasion) in a 65-year-old man with squamous cell carcinoma of the esophagus. Contrast-enhanced CT scan (7-mm collimation) obtained at the level of the left atrium shows an esophageal tumor abutting the descending thoracic aorta with a contact area of more than 90° (arrows). The Ivor Lewis procedure was performed and revealed direct invasion of the aorta. Adhesiolysis was performed for the severe adhesion between the aortic wall and the esophageal cancer.

Transthoracic Esophagectomy through a Left Thoracotomy

Esophageal resection through a left thoracotomy (Fig 10) is less commonly used than the Ivor Lewis procedure or transhiatal esophagectomy. When esophagectomy is performed through a left thoracotomy, either posterolateral thoracotomy (Fig 10a) or a thoracoabdominal incision may be used. After mobilization and resection of the lower half of the thoracic esophagus (Fig 10b), reconstruction is performed in the mediastinum (Fig 10c) or, preferably, in the neck between the remaining portion of the esophagus and the gastric fundus (13).

A left thoracotomy provides free access to the esophagus from the level of the aortic arch to the hiatus. This procedure is usually performed for distal esophageal and gastroesophageal lesions (Fig 11). Although less popular than either the Ivor Lewis approach or transhiatal esophagectomy, it continues to be useful in the treatment of esophageal or gastric tumors near the gastroesophageal junction (12,13). The overall hospital mortality rate for the left transthoracic approach is about 17% (1%–33%) (1). Postsurgical results are the same as those seen with esophagogastrectomy performed with other incisional techniques (Table 1) (12).

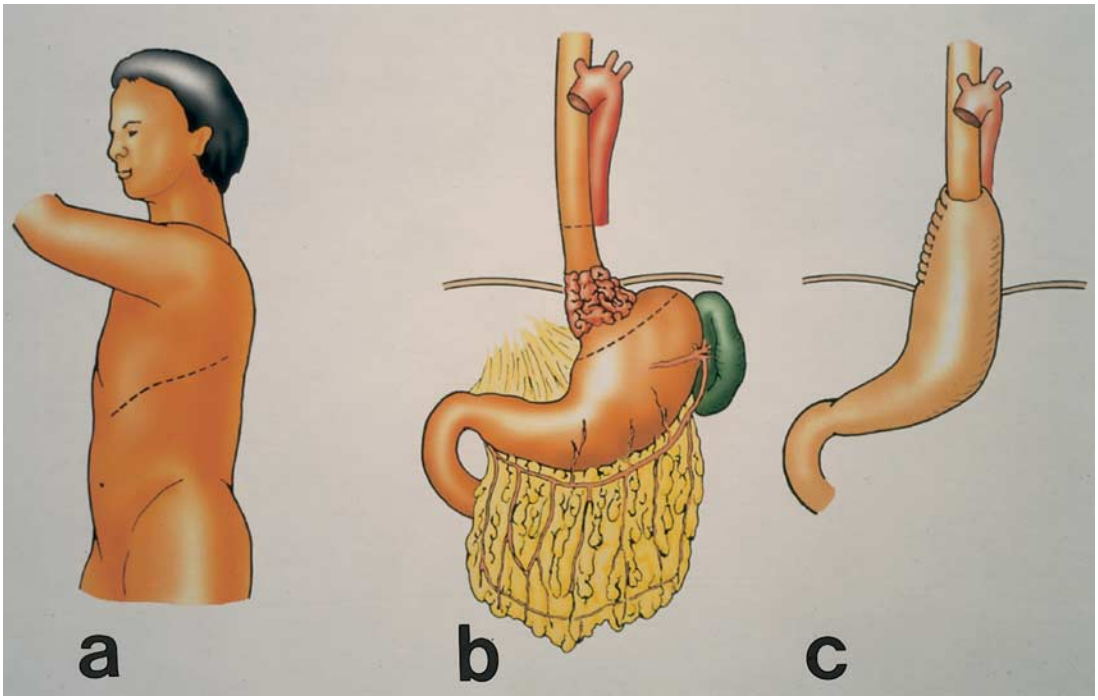
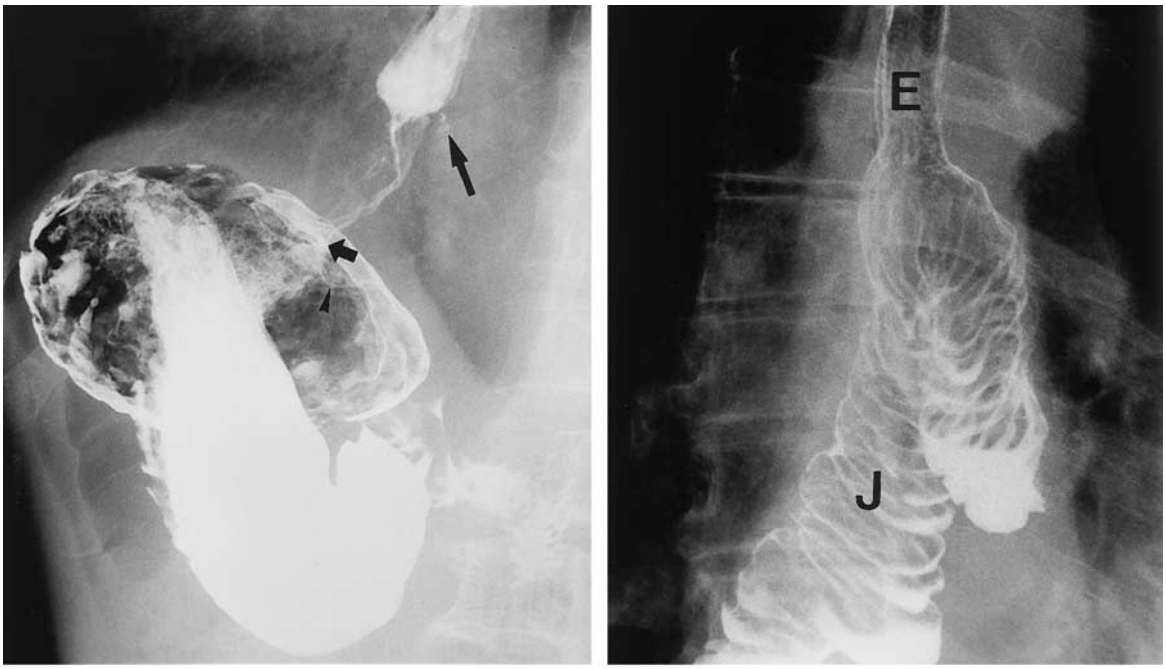


Figure 10. Drawings illustrate transthoracic esophagectomy through a left thoracotomy. Drawing *a* shows how the thorax is usually entered through the left sixth intercostal space. To further expose the esophagus, the incision may be extended posteriorly (as in posterolateral thoracotomy). The incision may be extended anteriorly across midline or inferiorly as a midline incision. Drawings *b* and *c* show how resection of the lower esophagus and cardia is performed with end-to-side esophagogastrostomy.



a. **b.**

Figure 11. Transthoracic esophagectomy with left thoracotomy in a 65-year-old man with squamous cell carcinoma of the distal esophagus with extension to the gastroesophageal junction and gastric cardia. **(a)** Preoperative barium esophagogram shows a 4-cm segment of luminal narrowing with ulceration (long arrow) and with extension to the gastroesophageal junction (short arrow) and gastric cardia (arrowhead). **(b)** Barium esophagogram obtained 19 months after surgery shows an intrathoracic end-to-side esophagojejunostomy after total gastrectomy performed through a laparotomy and distal esophagectomy through a left thoracotomy. *E* = esophagus, *J* = jejunum.

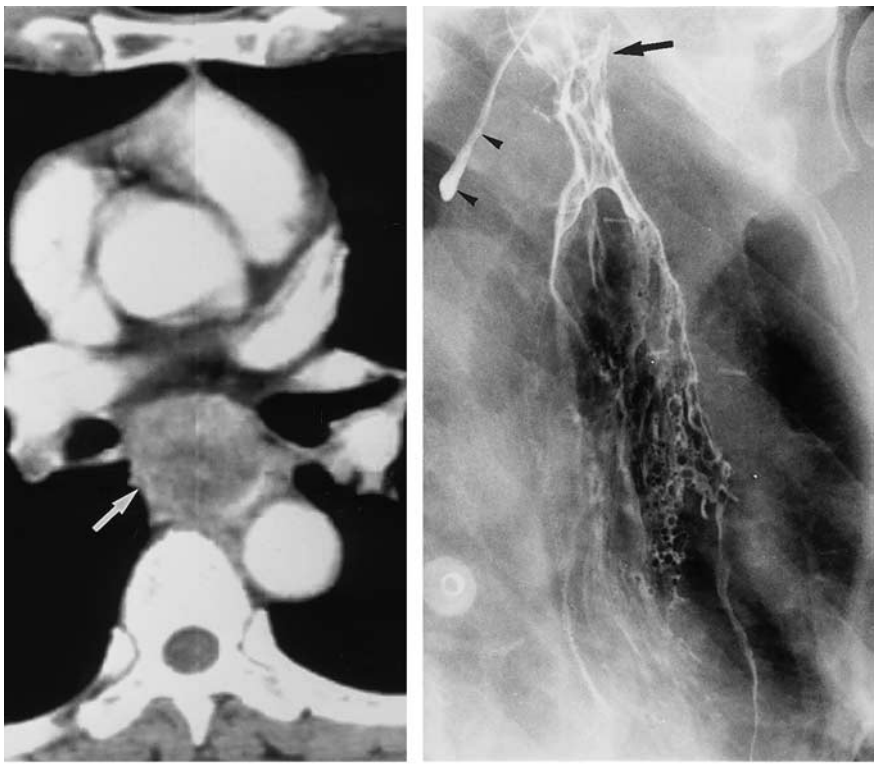


Figure 12. Radical en bloc resection with cervical esophagogastrostomy in a 65-year-old man with squamous cell carcinoma of the midesophagus. **(a)** Preoperative contrast-enhanced CT scan (10-mm collimation) obtained at the subcarinal level shows an esophageal mass in the midesophagus (arrow). Radical en bloc resection of the tumor-bearing segment of the esophagus, azygos vein, thoracic duct, adjacent lung parenchyma and mediastinal pleura was performed through a right thoracotomy. **(b)** Barium esophagogram obtained 7 days after right transthoracic esophagectomy and cervical esophagogastrostomy shows indentation at the cervical esophagus (arrow) due to an esophagogastric anastomosis. Tracheal aspiration is also seen (arrowheads).

Radical En Bloc Resection versus Standard Esophagectomy

The extent of resection, whether limited or more radical, depends primarily on the expertise and preference of the surgeon. Standard esophagectomy involves dissection of the esophagus and removal of any obviously enlarged lymph nodes (23). Unlike with radical en bloc resection, no effort is usually made to remove the pleura, pericardium, thoracic duct, dorsal mesoesophagus, or azygos vein in standard esophagectomy (14, 23,24).

Radical en bloc resection is performed when pre- and intraoperative staging indicate that the tumor is potentially curable. A potentially curable tumor is defined as one in which the disease is limited to the esophageal wall, with locoregional involvement within the limits of the proposed resection and without evidence of hematogenous spread (Fig 12) (15,16).

The goal of en bloc resection is to completely remove the digestive tract, including the normal hollow viscera up to 10 cm on either side of the tumor, along with an upper abdominal lymphadenectomy and posterior mediastinectomy. An en bloc esophagectomy includes the tumor-bearing segment of the esophagus, with a wide envelope of tissue that includes both pleural surfaces laterally, the pericardium anteriorly, and all lymphatic and vascular tissue between the prevertebral fascia and the esophagus (14,15).

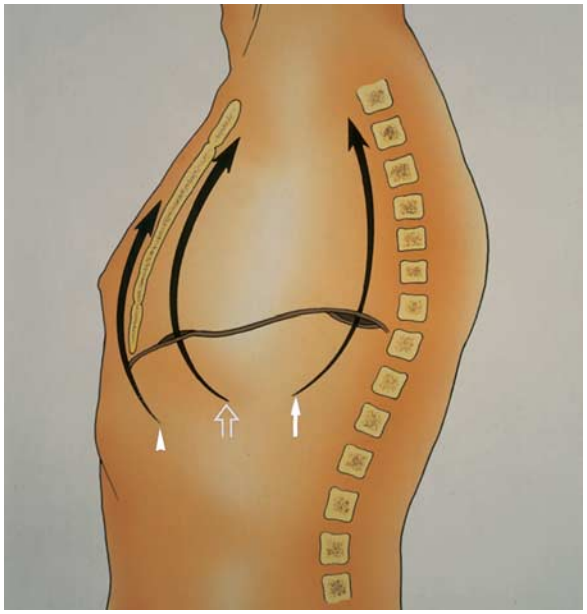
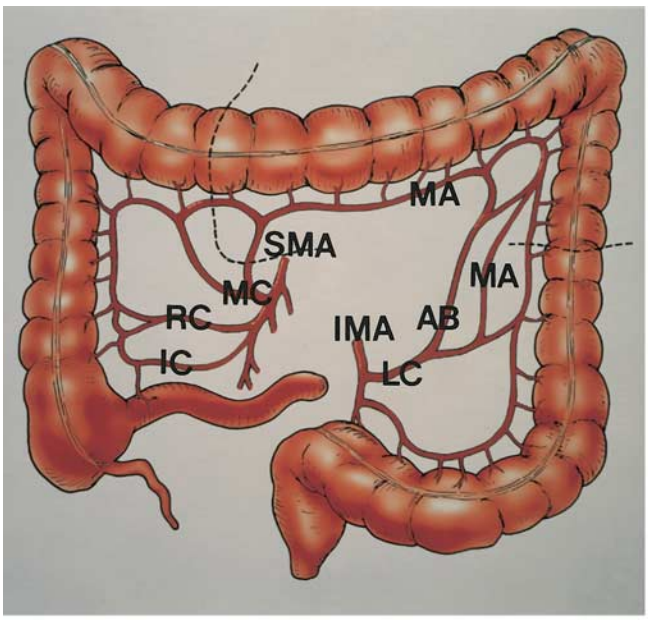


Figure 13. Drawing illustrates different types of bypass surgery. The three potential routes of neoesophageal passage during esophageal bypass surgery are the transthoracic (solid arrow), substernal (open arrow), and subcutaneous routes (arrowhead). The substernal route is most often used, followed by the transthoracic route and, rarely, the subcutaneous route.



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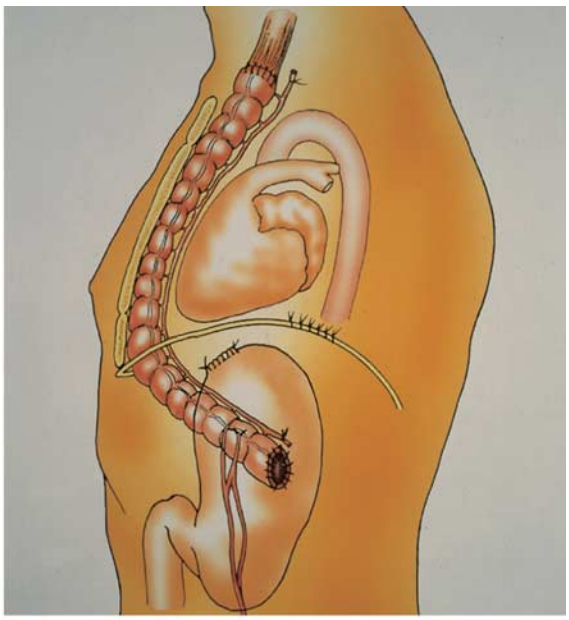

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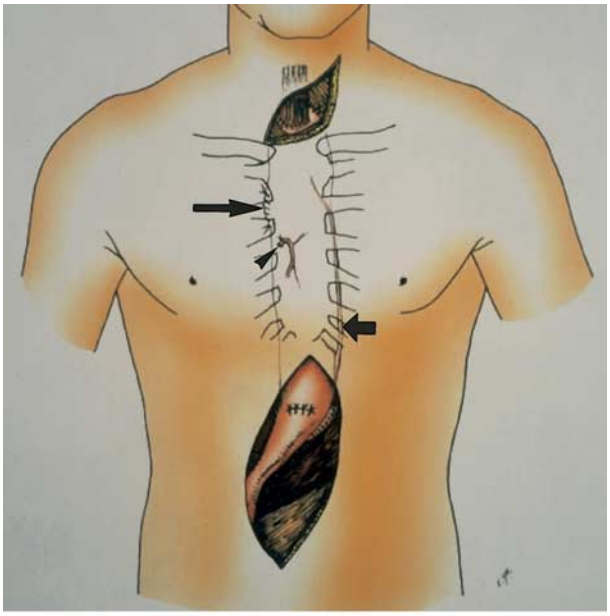


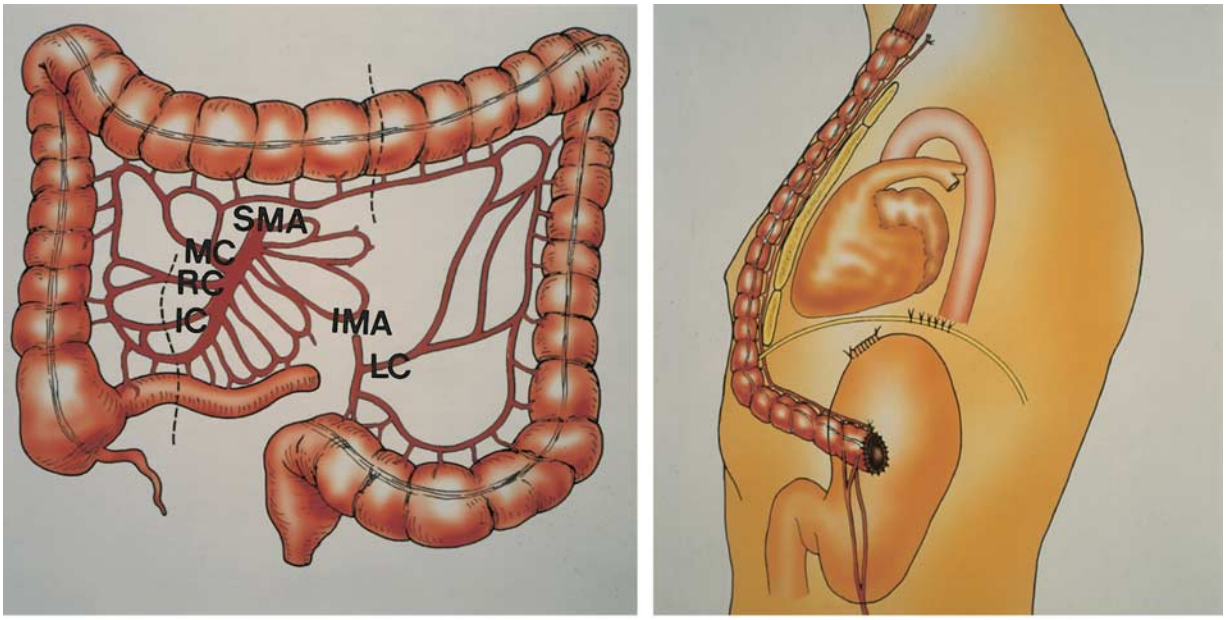
c.

Figure 14. Drawings illustrate substernal approaches to esophageal bypass surgery. **(a)** Interposition of a long segment of the colon is prepared based on ascending branches (*AB*) of the left colic artery (*LC*) to reach the neck and the division of the midcolic artery (*MC*). *IC* = ileocolic artery, *IMA* = inferior mesenteric artery, *MA* = marginal artery, *RC* = right colic artery, *SMA* = superior mesenteric artery. **(b)** Substernal left colon bypass surgery. **(c)** Substernal stomach bypass surgery. Long arrow indicates the stump of the cardia, arrowhead indicates the (divided) left gastric artery, short arrow indicates the (intact) gastroepiploic artery.

The overall hospital mortality rate is about 8% (2.4%–11%) (14–17). The causes of hospital mortality include myocardial infarction, pulmonary complications, hemorrhage, and intrathoracic anastomotic leak. Despite the theoretical advantages of en bloc resection and full lymphadenectomy, studies comparing these procedures with transhiatal esophagectomy show no difference in the overall survival rate for patients who undergo one or the other approach for esophageal cancer. There is also no statistically significant difference in mortality and morbidity rates between radical en bloc resection and standard esophagectomy (1,9,23).

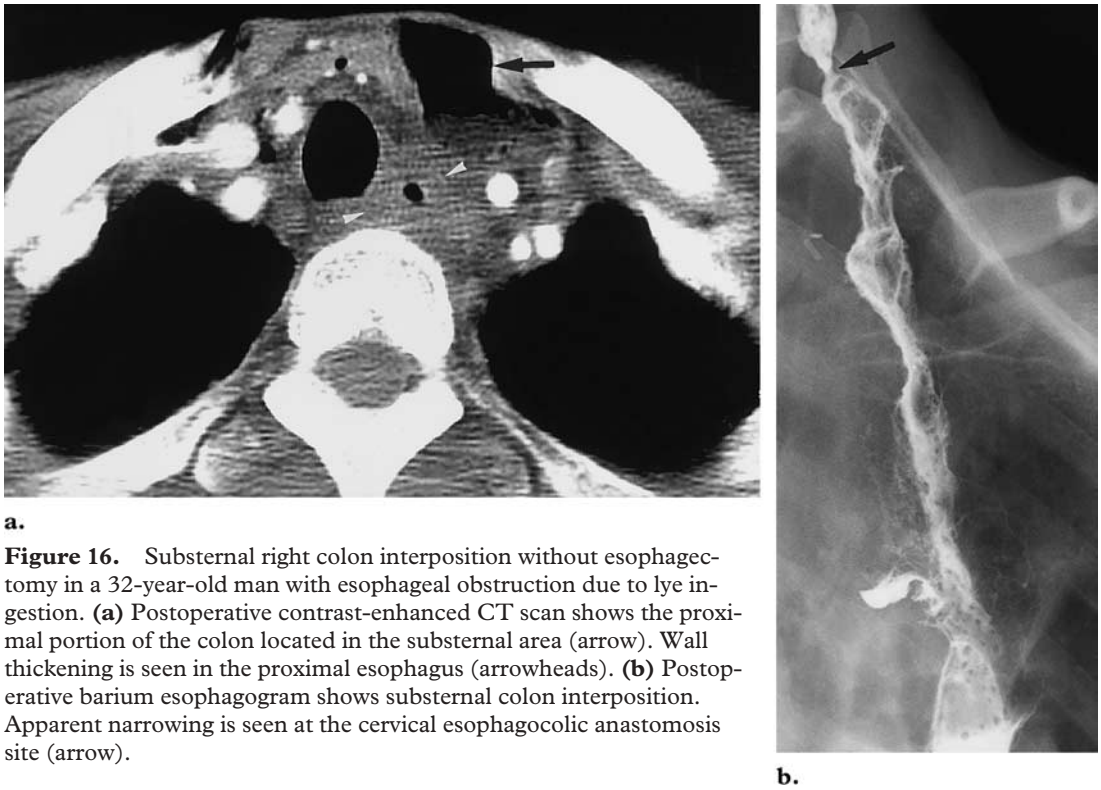
Palliative Resection or Bypass Surgery

Potentially curative surgical resection may be performed in only 25% of patients with esophageal carcinoma (25). The remaining patients, who cannot undergo curative surgery, may undergo palliative resection or bypass surgery to decrease local recurrence or to produce good symptomatic results. This procedure is most commonly performed substernally but may be performed transthoracically or, rarely, subcutaneously (Figs 13–15) (25–27). The transthoracic route may allow better maintenance of an esophageal substitute over time. This approach utilizes the shortest and most direct route between the neck and the abdominal cavity. However, it requires excision of the segment of the native esophagus involved by primary tumor. With residual tumor in the mediastinum, this approach may impose the risk of recurrent obstruction of the esophageal substitute (26). The substernal route offers the best direct conduit to the neck when the primary tumor is



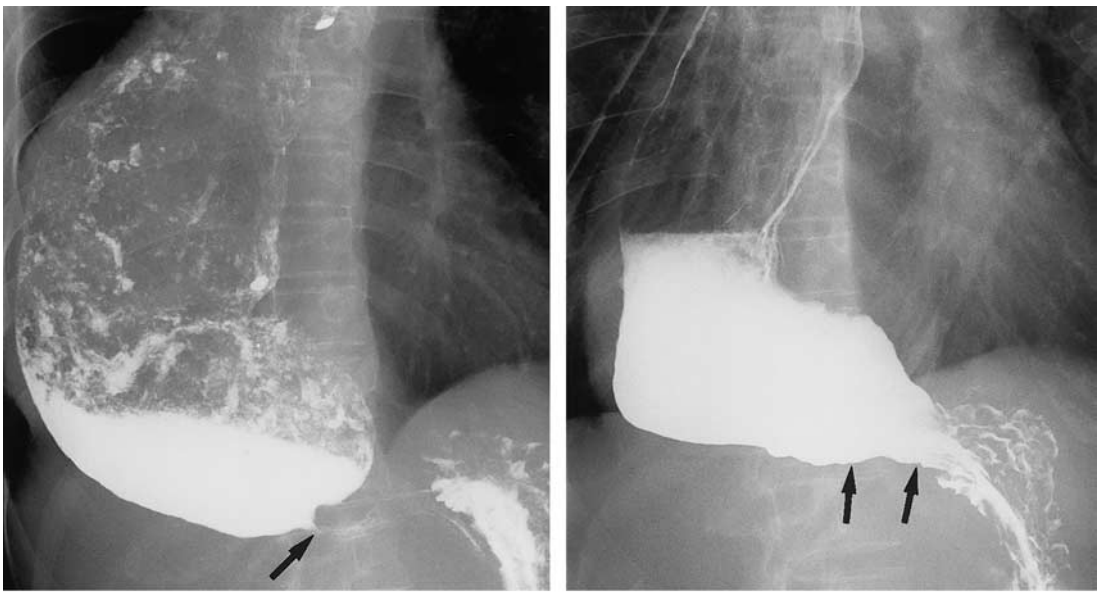
a. b.

Figure 15. Drawings illustrate the subcutaneous approach to esophageal bypass surgery. **(a)** The transverse colon, mesocolon, ileum, and mesentery are divided (dotted lines) based on the midcolic artery (*MC*). *IC* = ileocolic artery, *IMA* = inferior mesenteric artery, *LC* = left colic artery, *RC* = right colic artery, *SMA* = superior mesenteric artery. **(b)** Subcutaneous right colon bypass surgery. If the ascending colon and a portion of the transverse colon provide proper colonic length for the esophageal substitute, the cecum and terminal ileum may be amputated.



a. b.

Figure 16. Substernal right colon interposition without esophagectomy in a 32-year-old man with esophageal obstruction due to lye ingestion. **(a)** Postoperative contrast-enhanced CT scan shows the proximal portion of the colon located in the substernal area (arrow). Wall thickening is seen in the proximal esophagus (arrowheads). **(b)** Postoperative barium esophagogram shows substernal colon interposition. Apparent narrowing is seen at the cervical esophagocolic anastomosis site (arrow).



a. b.

Figure 17. Esophagomyotomy through a right thoracotomy in a 42-year-old woman with achalasia who presented with progressive dysphagia. **(a)** Preoperative barium esophagogram shows a markedly dilated esophageal lumen proximal to an abruptly narrowed distal esophagus and gastroesophageal junction with terminal beaking (arrow). **(b)** Follow-up esophagogram obtained after an esophagomyotomy approximately 3 cm in length and including the gastroesophageal junction (arrows) shows a decrease in both esophageal dilatation and passage disturbance.

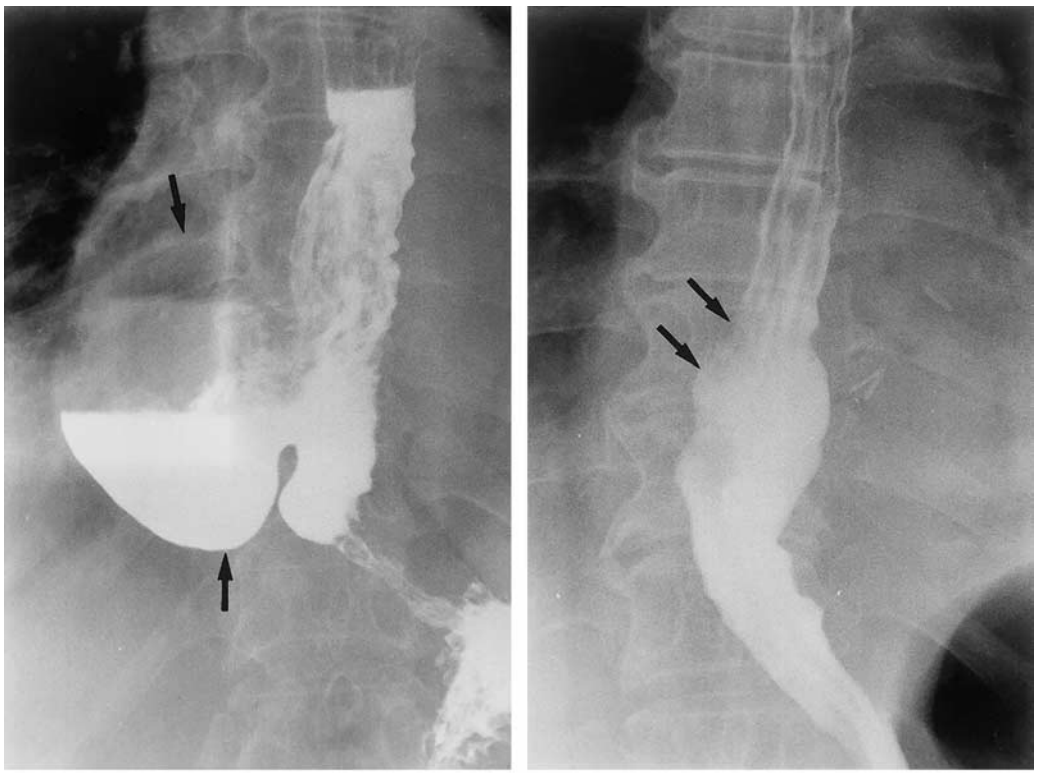
left in situ due to involvement of mediastinal structures or a fistula (25). This route reduces the possibility of recurrent malignant dysphagia or malignant fistulization and allows creation of a portal for palliative radiation therapy that avoids the esophageal substitute. However, the substernal route requires a more tortuous and hazardous course for the substitute than does the transthoracic route. Therefore, along its course, the substitute may be compressed at the areas of the xiphoid, substernal tunnel, and narrow superior thoracic outlet, leading to obstruction of venous drainage and loss of the transplant. The subcutaneous or presternal route is safer. Any leakage will be superficial, and if the bypass should demonstrate infarction, this can be recognized quickly and the bypass easily removed (27). It also allows creation of a portal for palliative radiation therapy. However, it is reserved for rare situations in which the substernal route is unavailable due to previous cardiac or mediastinal surgery.

There are a variety of indications for bypass surgery. Reconstructive bypass surgery with or without concurrent esophagectomy may be performed in tracheoesophageal fistula, previous esophagectomy without reconstruction, and, in some cases, obstruction due to lye ingestion (Fig 16). Bypass surgery is also performed in cases of unresectable esophageal cancer (25–27).

Miscellaneous Surgical Procedures

Antireflux repairs are performed through a thoracotomy (Belsey Mark IV operation) or laparotomy (Nissen, Hill, and Guarner procedures). The basic underlying principle of antireflux repair is to restore and maintain the function of the intraabdominal segment of the esophagus as a lower esophageal sphincter. For this purpose, the intraabdominal segment of the esophagus is wrapped with a portion of the gastric cardia or the fundus. Antireflux repair has been shown to control reflux in approximately 85%–90% of cases with variable follow-up lasting up to 10 years (28,29).

In patients with esophageal strictures that are difficult to dilate or that have recurred after previous antireflux surgery, resection of the esophagus may be necessary. Motor disorders such as achalasia (Fig 17) and diffuse esophageal spasm are characterized by muscular dysfunction; consequently, myotomy is included in the treatment. Zenker diverticulum, a protrusion of mucosa cephalad to the cricopharyngeal sphincter, is the most common diverticulum of the pharynx and esophagus. In diverticular disease such as Zenker



a. b.

Figure 18. Diverticulectomy for epiphrenic diverticulum of the distal esophagus in a 64-year-old woman. **(a)** Preoperative barium esophagogram shows a large diverticulum (arrows) containing air-fluid–contrast material levels and protruding to the right of the distal esophagus. **(b)** Barium esophagogram obtained after diverticulectomy through a left thoracotomy shows slight mucosal rigidity at the diverticulectomy site (arrows).

diverticulum, myotomy with or without diverticulectomy aids in treatment (Fig 18) (30).

Leiomyoma is the most common nonmalignant tumor of the esophagus. The surgical approach is chosen on the basis of the tumor level as determined at endoscopy. If the tumor is in the distal esophagus, a left thoracotomy is preferred, whereas a leiomyoma in the middle or upper third is approached through a right thoracotomy. The muscularis overlying the lesion is incised longitudinally, and the mass is enucleated by means of blunt or sharp dissection, usually without injuring the mucosa, after which the incision in the muscularis is closed (Fig 19).

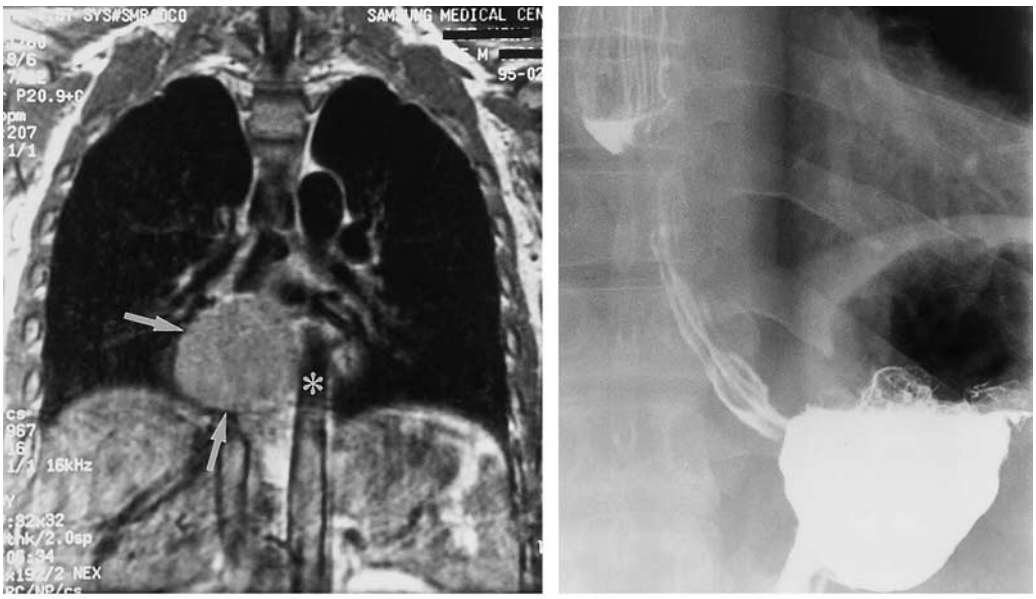
There are a number of causes of esophageal rupture. The esophagus may rupture spontaneously, after instrumentation, with penetrating trauma, or with an underlying disease process such as Barrett ulcer or neoplasm. In esophageal rupture related to Barrett ulcer or neoplasm, esophageal resection and reconstruction may be necessary. For perforation of an esophagus that had no specific abnormality prior to the rupture, treatment options include primary repair, esophageal diversion, and, rarely (if the injury is extensive), resection (Fig 20).

Selection of Esophageal Substitutes

Several anatomic structures may be used to reconstruct the resected esophagus, including the whole stomach, gastric tube, left or right colon (Figs 14b, 16), jejunum (Fig 11b), and free revascularized grafts.

The stomach is the most convenient esophageal substitute and is the most widely used because it has a reliable blood supply and is easily connected to the remaining esophagus with a single anastomosis (Figs 2b, 4b, 7b, 12b) (31,32). The right gastric and right gastroepiploic arteries are preserved when the stomach is used as an esophageal substitute. However, the stomach may be inappropriate as a substitute because it incurs high morbidity in cases of anastomotic failure, shows a tendency to dilate and cause defective propulsion, and may frequently be related to late complications (recurrent esophagitis and stenosis, gastric ulceration, hemorrhage) (32,33).

The use of the colon for esophageal replacement is indicated when long-term patient survival is confidently expected. Indications for colonic substitutions include types IB and II congenital esophageal atresia, complications related to resection of benign strictures or tumors, advanced



a. b.

Figure 19. Enucleation of an esophageal leiomyoma through a right thoracotomy in a 35-year-old man. **(a)** Preoperative coronal T1-weighted MR image (repetition time msec/echo time msec = 967/16) shows a large, pear-shaped soft-tissue mass (arrows) that is isointense relative to surrounding tissue in the right aspect of the descending thoracic aorta (*). **(b)** Barium esophagogram obtained 2 days after enucleation shows no evidence of mucosal injury.

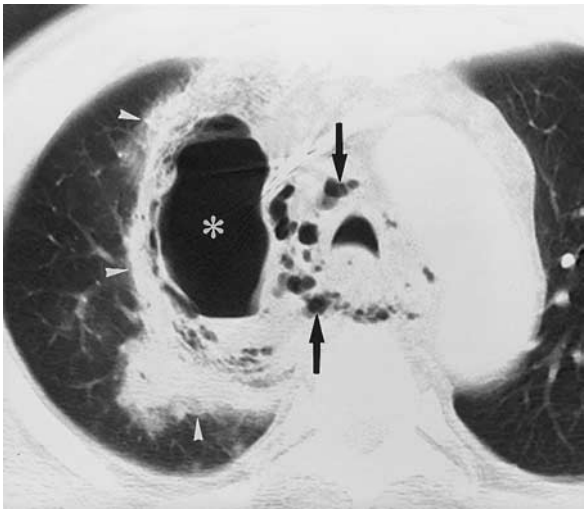


Figure 20. Esophageal perforation due to ingestion of a fish bone in a 56-year-old man. CT scan (7-mm collimation, lung windowing) obtained at the level of the aortic arch shows pneumomediastinum around the trachea and esophagus (arrows), an air-containing abscess cavity in the right paramediastinal area (*), and necrotizing pneumonia in the right upper lobe (arrowheads). The patient was successfully treated with esophageal diversion and total esophagectomy with cervical esophagocologastrostomy.

functional disorders following multiple previously failed antireflux procedures, and certain cases of malignant obstruction with an apparently good prognosis following radical surgery (34). The left colon is preferred to the right due to its smaller diameter, more constant and reliable blood supply (from the left colic artery), adequate length for total esophageal replacement, and superior ability to propel a solid bolus (34,35). The interposition of colonic substitutes that are isoperistaltic relative to the unidirectional pulsation of the colon is mandatory because there is little chance of functional obstruction or reflux and the procedure prohibits aspiration.

Jejunal interposition is indicated for reconstruction of the pharyngeal and cervical esophagus after radical resection (36). Pre- or postoperative irradiation is used in many patients who have undergone partial or complete pharyngolaryngectomy for supraglottic, glottic, or subglottic cancer. The stricture associated with the irradiation can be very difficult to alleviate with dilation alone. In this setting, free jejunal replacement is performed after resection of the irradiated and scarred tissue. Jejunal transposition can also be used for the treatment of benign, isolated, cervical esophageal strictures that have not responded to dilation (36). If a stricture due to caustic ingestion is limited to the upper portion of the esophagus, a free jejunal graft can adequately replace the diseased segment. If, on the other hand, caustic ingestion has produced a diffuse stricture involving more than a 25-cm length of the esophagus,

Table 2
Complications of Esophageal Resection and Reconstruction

Intraoperative complications
Hemorrhage
Injury to the tracheobronchial tree
Recurrent laryngeal nerve injury
Pneumothorax
Postoperative complications
Delayed hemorrhage
Anastomotic leak
Mediastinitis
Pulmonary complications (atelectasis, pneumonia, adult respiratory distress syndrome, aspiration bronchiolitis)
Arrhythmia, myocardial infarction, pericardial tamponade
Delayed gastric emptying
Chylothorax
Herniation of abdominal viscera through the hiatus
Functional complications of esophageal replacement
Anastomotic stricture
Redundancy and impaired emptying
Obstruction at the upper thoracic inlet or diaphragmatic hiatus
Reflux esophagitis
Ulceration of the esophageal substitute
Postvagotomy dumping

21. 22.

Figures 21, 22. **(21)** Fistula between the intrathoracic stomach and upper trachea in a 66-year-old man with squamous cell carcinoma of the upper thoracic esophagus. The patient had undergone right transthoracic esophagectomy and cervical esophagogastrostomy. Barium esophagogram obtained 19 days after surgery demonstrates a fistula (arrows) between the elevated stomach and upper trachea during barium swallowing. A wide fistulous tract is seen at the cervical anastomosis site (arrowhead) and was confirmed at surgery. The patient subsequently underwent focal tracheal resection with end-to-end anastomosis followed by transposition flap with the pectoralis major muscle for closure of the gastric fistula. **(22)** Anastomotic leak in a 66-year-old man with squamous cell carcinoma of the upper thoracic esophagus. The patient had undergone total esophagectomy through a right thoracotomy and cervical esophagogastrostomy. Barium esophagogram obtained 9 days after surgery shows a small amount of leakage at the cervical esophagogastric anastomosis site (arrows). Stoppage of the leak was achieved with conservative treatment.

the stomach or colon should be used. The suitability of organs for reconstruction varies among patients (31–36).

Complications of Esophageal Resection and Reconstruction

Various complications may occur intra- and postoperatively with esophageal resection and reconstruction (Table 2) (1,2,37,38). Intraoperative complications include hemorrhage, injury to the tracheobronchial tree (Fig 21), recurrent laryngeal nerve injury, and pneumothorax. Postoperative complications include delayed hemorrhage, anastomotic leak (Fig 22), mediastinitis, atelecta-

a. b.

Figure 24. Diaphragmatic hernia in a 65-year-old man with distal esophageal cancer. The patient had undergone esophagojejunostomy with distal esophagectomy and total gastrectomy 1 year earlier. The procedure had been performed through a left thoracotomy and laparotomy. **(a)** Chest radiograph shows opacity in the right hemithorax, which contains dilated and gas-filled bowel loops with pleural effusion. **(b)** Unenhanced CT scan (7-mm collimation) obtained at the level of the cardiac chamber shows herniation of proximal jejunal loops with edematous wall thickening (arrows). Herniation of engorged mesenteric vessels (arrowheads) and mesenteric fat are also seen. Note the large amount of right pleural effusion with mediastinal shifting to the left. Herniation through the esophageal hiatus was seen at surgery, and the hiatus was repaired.

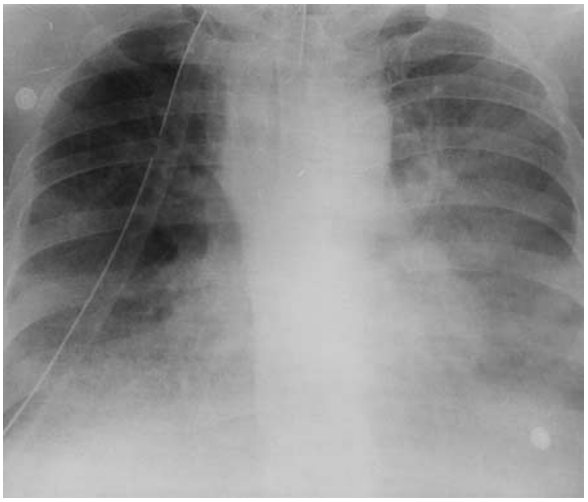


Figure 23. Adult respiratory distress syndrome in a 50-year-old man with middle thoracic esophageal carcinoma who had undergone the Ivor Lewis procedure. Conventional chest radiograph obtained 9 days after surgery shows increased opacity in both lower lung zones and in the left upper lung zone, findings that suggest pulmonary edema.

sis, pneumonia, adult respiratory distress syndrome (Fig 23), arrhythmia, myocardial infarction, pericardial tamponade, delayed gastric emptying, chylothorax, herniation of abdominal viscera through the hiatus (Fig 24), and functional disturbance of the esophageal substitute (eg, anastomotic stricture [Fig 25], obstruction, reflux esophagitis, ulceration [37,38]).

The most common complications are thoracic or pulmonary and include pneumothorax, pleural effusion, pneumonia, aspiration bronchiolitis, empyema, and respiratory failure. These complications are the most frequent cause of morbidity in patients undergoing esophagectomy and occur in almost 50% of cases (38).

Mediastinitis and sepsis due to disruption at the anastomosis site are the most dreaded complications and cause serious postoperative morbidity

and mortality (Fig 26). Ischemia around the anastomosis site and error in surgical technique are major etiologic factors in anastomotic leaks. Cervical anastomoses have consistently higher leak rates (10%–25% of cases) than do intrathoracic anastomoses (<10%). Leaks from thoracic anastomoses require aggressive surgical treatment (Fig 26) because mediastinitis and shock caused by intrathoracic leak have a mortality rate of 60%–90% (39,40).

Conclusions

Various surgical procedures are performed for benign or malignant esophageal lesions. Radiologists should be familiar with these surgical options, the resultant anatomic changes associated with each option, and the expected findings at postoperative imaging. Such information is essential for evaluating the effectiveness of surgical procedures and for the early detection and management of surgery-related complications.

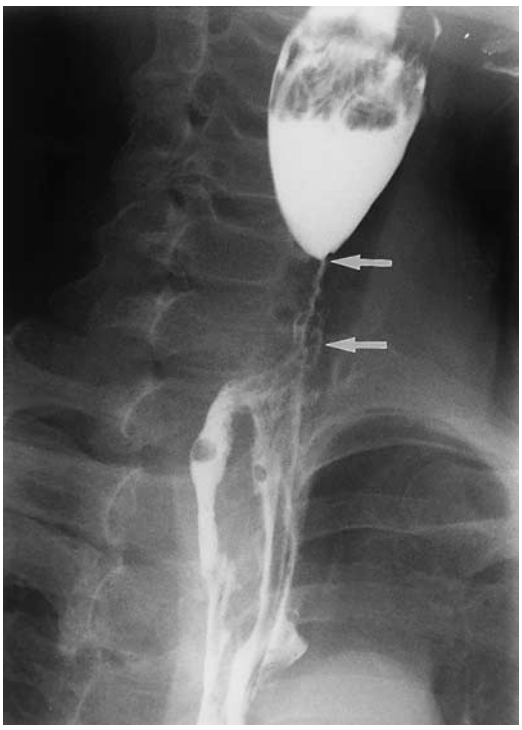


Figure 25. Anastomotic stenosis in a 61-year-old woman with squamous cell carcinoma of the middle thoracic esophagus. The patient had undergone transhiatal esophagectomy and cervical esophagogastrostomy. Barium esophagogram obtained 3 months after surgery shows an area of marked narrowing 2 cm in length (arrows) at the anastomosis site with proximal esophageal dilatation. The patient was treated with esophageal balloon dilation and stent placement.

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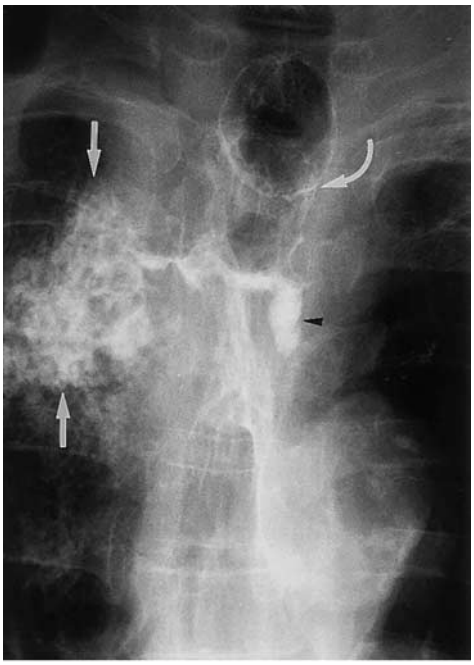
Figure 26. Intrathoracic leak and mediastinitis due to graft (elevated stomach) necrosis in a 71-year-old man with squamous cell carcinoma of the esophagus. The patient had undergone the Ivor Lewis procedure. **(a)** Radiograph obtained with water-soluble contrast material 15 days after surgery shows leakage of contrast material (straight arrows) from the right side of the elevated stomach distal to the anastomosis site (curved arrow). Note also the leakage from the left side of the elevated stomach (arrowhead). **(b)** CT scan obtained 2 cm distal to the anastomosis site shows communication between the mediastinum and elevated stomach (arrow) due to gastric perforation. Intrathoracic leakage with perforation due to ischemic necrosis of an elevated stomach was noted at surgery 2 cm below the anastomosis site. Primary closure of the perforated stomach was achieved with a pericardiopleural patch.



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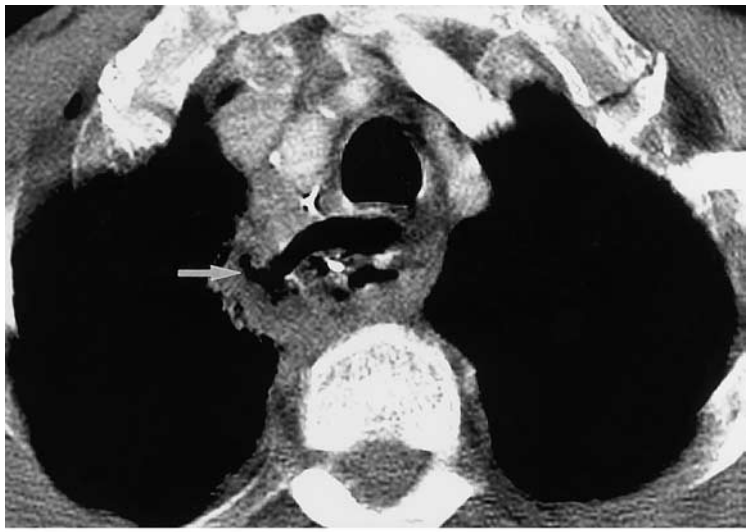

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