Shanda H. Blackmon · Min P. Kim
Karen J. Dickinson *Editors*

Atlas of Esophageal Disease and Intervention

A Multidisciplinary Approach

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This book is dedicated to my husband, Matt Blackmon, my partners in practice, and my esophageal support group; for the years of dedication, support, and love. Without such teams, caring for these patients would be impossible.

Preface

This atlas began when I was in my first year of clinical practice. As I began to develop my skills in endoluminal technology, I realized there was no single resource to guide me. There were several moments through these years when it became clear that one specialty may not always understand important facts from another specialty regarding the disease they both treat. I distinctly remember speaking to a patient after an esophagectomy for cancer and having the patient tell me his gastroenterologist told him I may have resected the vagal nerve, thus giving him a dumping syndrome. I responded by stating "I certainly hope I resected it, because that is part of the surgery!" I started a multidisciplinary tumor board to enhance learning and communication between the specialties, focusing on the diseases rather than keeping it specialty-specific. I made every attempt to learn all aspects of caring for patients with esophageal disease.

This book is meant to be a single reference for anyone caring for patients with esophageal disease. When separate specialties learn to think like the other, patients benefit. Surgery today is becoming less invasive and more endoluminal. Most procedures I perform today were not performed when I was a resident 10 years ago. Learning new technology is difficult especially when the new skill requires a specialist to move toward another specialty or "cross a line." A common language, understanding, philosophy, and terminology can enhance communication, thus improving patient care.

Rochester, MN, USA — Shanda H. Blackmon, MD, MPH, FACS

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Chapter 1
Gross Anatomy

Shanda H. Blackmon

The anatomy of the esophagus is one of the more complicated subjects in medicine because the esophagus traverses the neck, chest, and abdomen. Surgeons, endoscopists, pathologists, radiologists, and other practitioners who care for patients with disease of this organ require an intricate knowledge of not just the location of the esophagus in relation to adjacent structures, but also its function and pathologic conditions. This chapter focuses on the anatomy of the esophagus from a multidisciplinary perspective.

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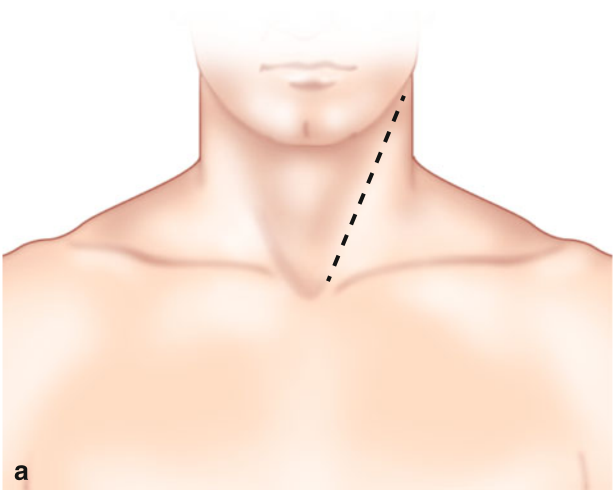
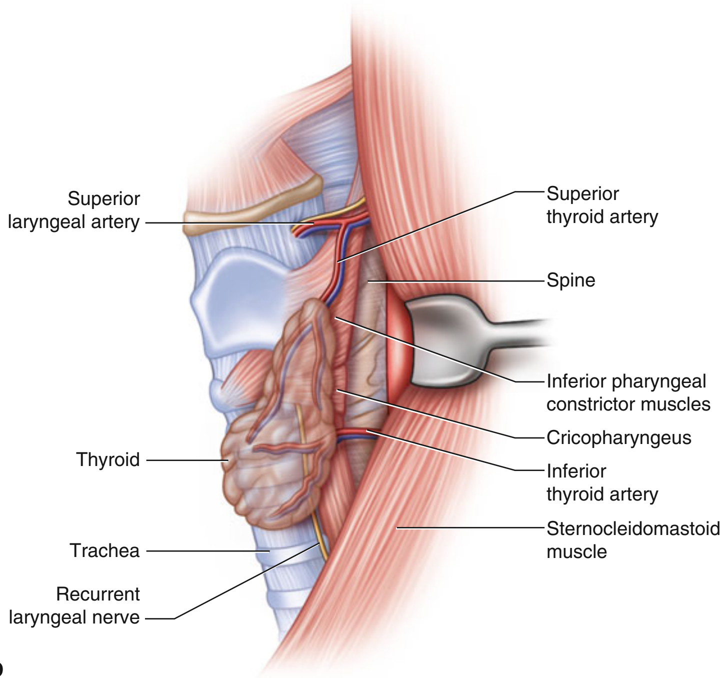


Fig. 1.1 Cervical esophagus. (**a**) The upper esophagus is best exposed through a left oblique incision on the neck. (**b**) From this incision, the anterior border of the sternocleidomastoid muscle is retracted laterally and, with careful dissection, the structures in this figure may be exposed. The left recurrent laryngeal nerve typically is identified in the tracheoesophageal groove, inferior to the inferior thyroid artery. Posterior to the esophagus, the spine and prevertebral fascia allow easy passage of a finger during dissection to begin mobilization of the esophagus. (**c**) The omohyoid muscle, also referred to as the “doorway to the esophagus,” typically is divided to gain access to the esophagus during dissection. (**d**) The upper esophagus from a posterior view. The relationship of the cervical esophagus to the cricoid cartilage, the superior laryngeal and recurrent nerves, and adjacent structures may be seen more clearly from a posterior view. This view is more commonly seen when performing endoscopy and looking for the esophageal lumen. It is important to be aware of adjacent structures and to see how an esophageal diverticulum may develop when the cricopharyngeus muscle is too tight. Learning to distinguish between cricopharyngeus, strap muscles of the neck, and omohyoid is critical to successfully performing surgery of the cervical esphagus



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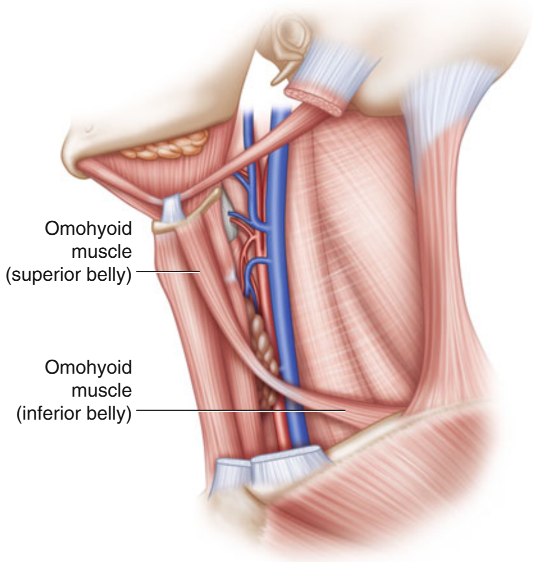

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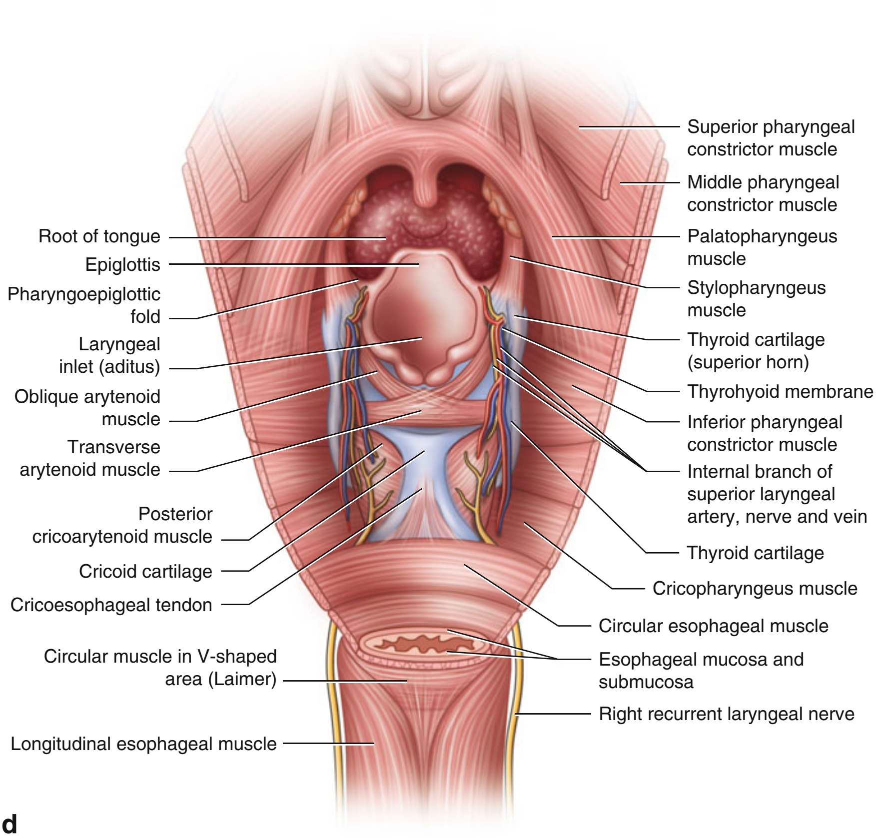

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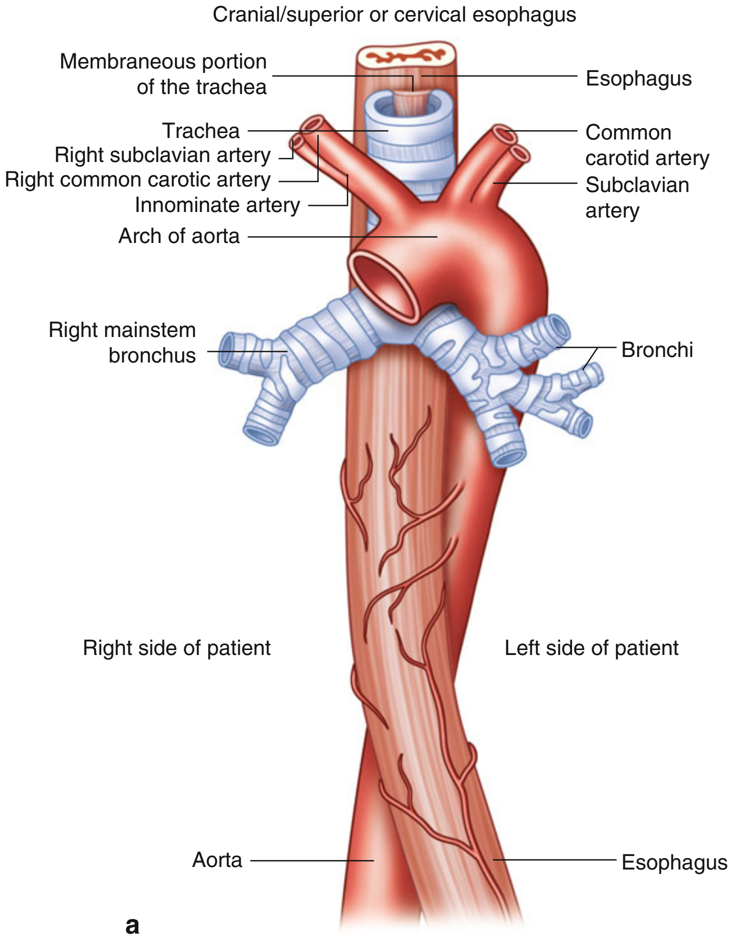
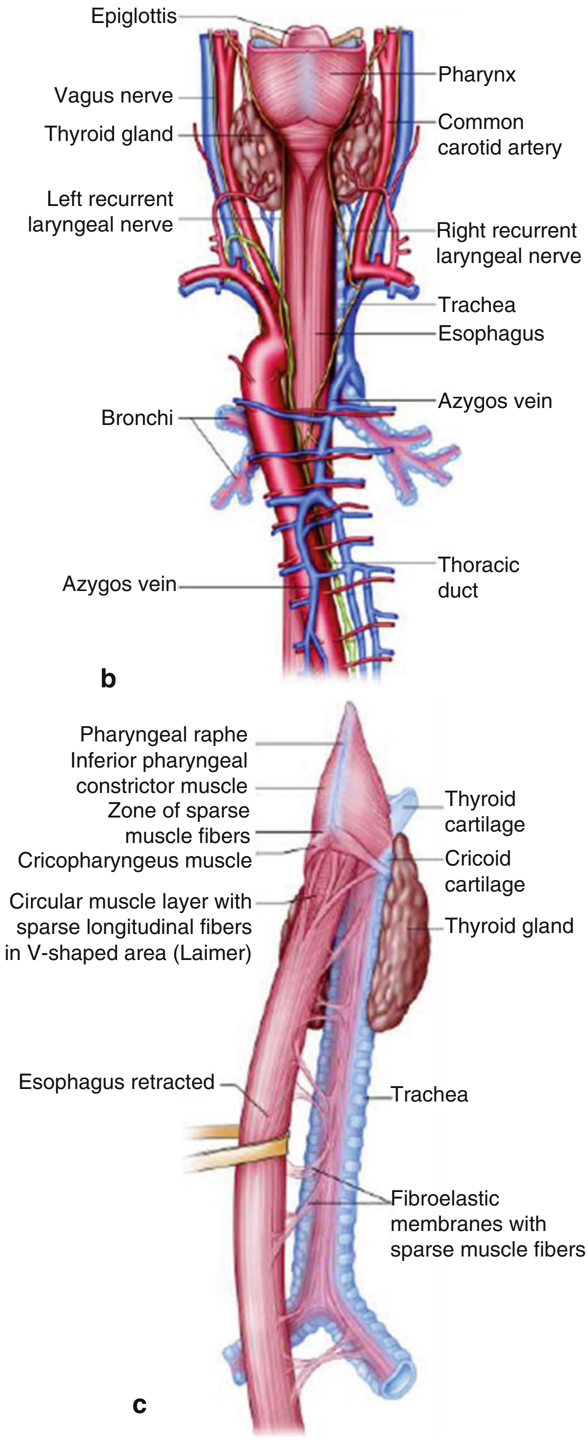


Fig. 1.2 Thoracic esophagus. The upper thoracic esophagus is best exposed through either a right thoracoscopic approach or a right posterolateral thoracotomy. The esophagus lies behind the trachea and the left atrium of the heart. The azygos vein arches over the esophagus just above the tracheal bifurcation and descends along the side of the esophagus on the right side of the chest, parallel to the course of the esophagus. An unnamed vein that runs directly into the esophagus from the azygos vein may be a source of bleeding when blunt dissection is used. On either side of the esophagus, the vagus nerves are found, with branches exiting their parallel pathway, extending to the bronchial branches of the lungs. In most circumstances, the aorta descends parallel to the esophagus in the left chest but may be identified easily when dissecting the esophagus from the right. The close relationship of the aorta and esophagus is best appreciated with esophageal ultrasound. The thoracic duct courses between the aorta, esophagus, and azygos vein. During esophageal dissection, special attention should be paid to the lymphatics low in the chest and to the close proximity of the left and right bronchi. The lower thoracic esophagus is best approached from the left chest, as the esophagus courses to the left in the lower thorax. A left thoracotomy also gives a good view of the esophageal hiatus from above. (**a**) Anterior view. (**b**) Posterior view. (**c**) Relationship of the thoracic esophagus to the trachea



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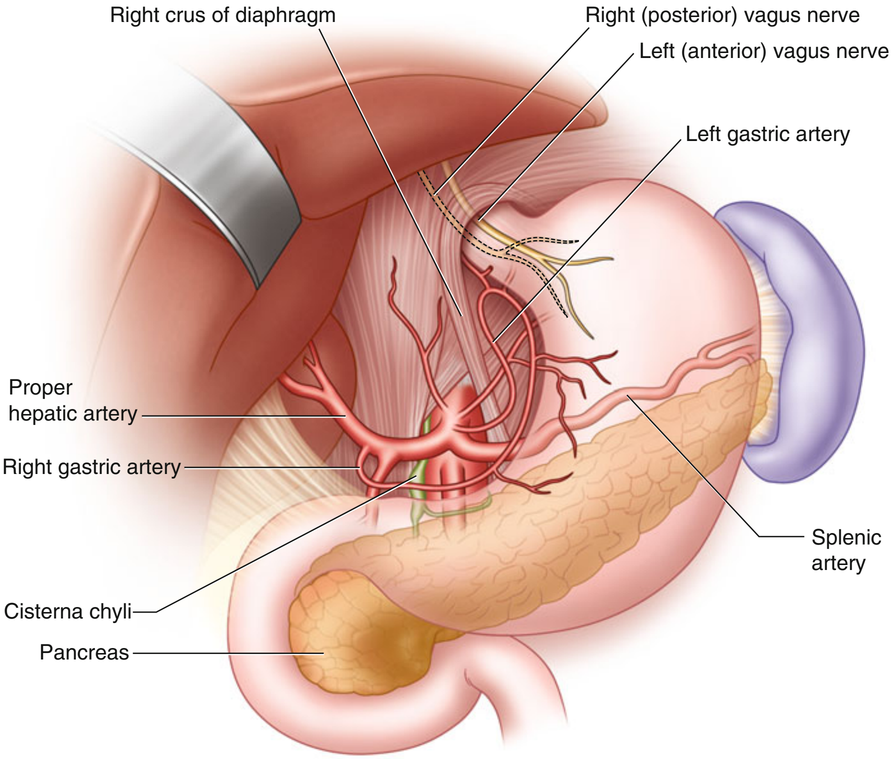


Fig. 1.3 Abdominal esophagus. The abdominal esophagus is best exposed from either a chevron, laparoscopic, or upper midline abdominal incision. With the left lateral lobe of the liver retracted, the phrenoesophageal membrane, hepatogastric ligament, and crura are seen. The aorta is located behind the crural decussation, and just to the right of the aorta, in front of the crura, lies the cisterna chyli. The left vagus nerve takes an anterior course, and the right vagus nerve travels posteriorly as it descends and innervates the stomach. The celiac trunk and its branches are exposed. The pancreas lies just posterior to the stomach and in front of the splenic vessels

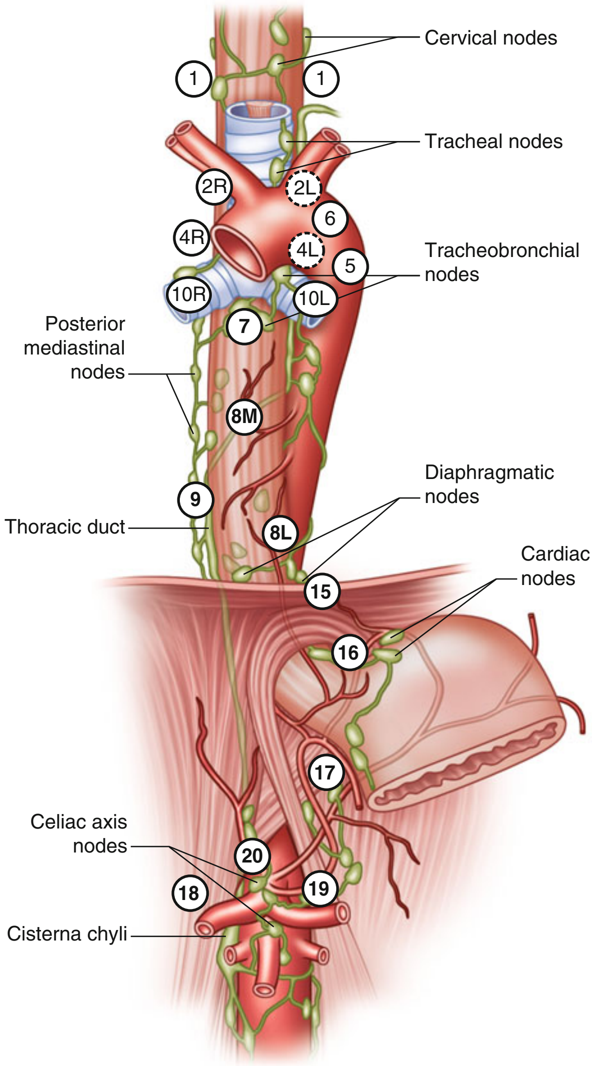


Fig. 1.4 Lymphatic drainage. The lymphatic drainage of the esophagus is primarily through the thoracic duct. Accounting for tumor that may spread to the lymph nodes of the abdomen, chest, or neck is essential for staging esophageal tumors accurately. The numbering system for nodal drainage of the esophagus is illustrated. *1* supraclavicular, *2L* left paratracheal, *2R* right paratracheal, *3P* posterior mediastinal, *4L* left tracheobronchial angle, *4R* right tracheobronchial angle, *5* aortopulmonary, *6* anterior mediastinal, *7* subcarinal, *8L* lower paraesophageal, *8M* middle paraesophageal, *9* inferior pulmonary ligament, *10L* left hilar, *10R* right hilar, *15* diaphragmatic, *16* paracardial, *17* left gastric, *18* common hepatic, *19* splenic, *20* celiac

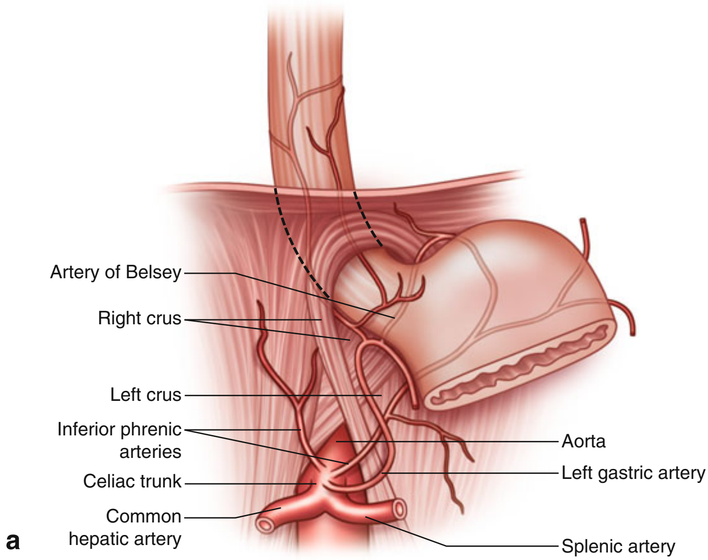
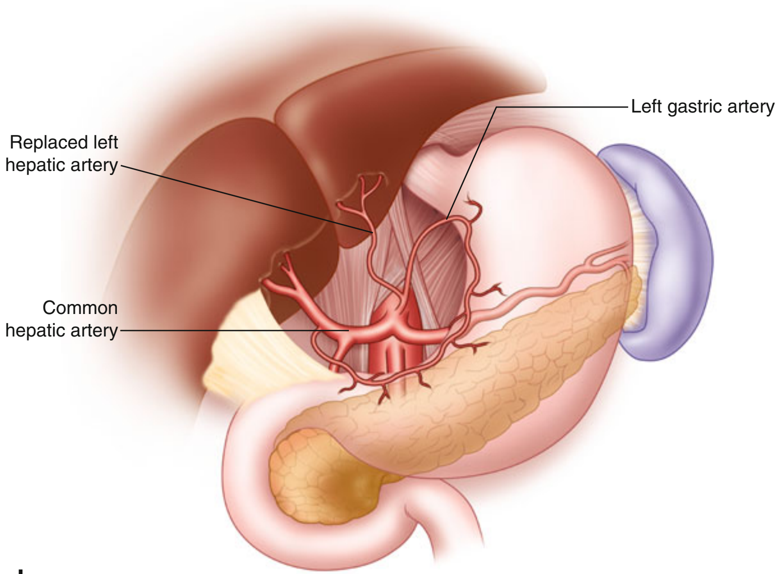


Fig. 1.5 Arterial blood supply. (**a**) The blood supply to the lower esophagus is delivered primarily through branches of the left gastric artery. Inferior phrenic branches, short gastric vessels or branches off the splenic artery, and a direct supply from the aorta constitute the remainder of the blood flow to the lower esophagus. (**b**) Aberrant blood supply to the liver from the left gastric artery. This figure represents a replaced left hepatic artery; Doppler examination of the portal collateral flow should be performed before ligating such an artery during esophagectomy. If portal blood flow is inadequate, or if obvious liver ischemia occurs on clamping of the replaced left hepatic artery, this vessel should be preserved. The level at which the left gastric artery is ligated is tailored to achieve preservation of this replaced left hepatic artery. This anatomic detail also may be detected by CT scan or endoscopic ultrasound. (**c**) Aberrant blood supply to the liver from the left gastric artery. This figure represents an accessory left hepatic artery, which typically can be divided without consequence to a normal liver during esophagectomy. This anatomic detail also may be detected by CT scan or endoscopic ultrasound. (**d**) Blood supply to the cervical and thoracic esophagus



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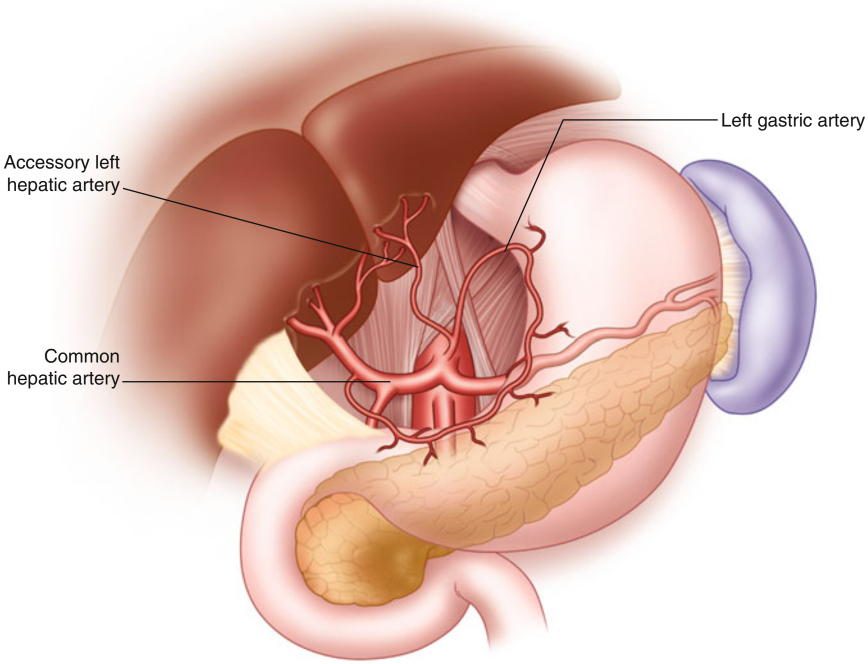

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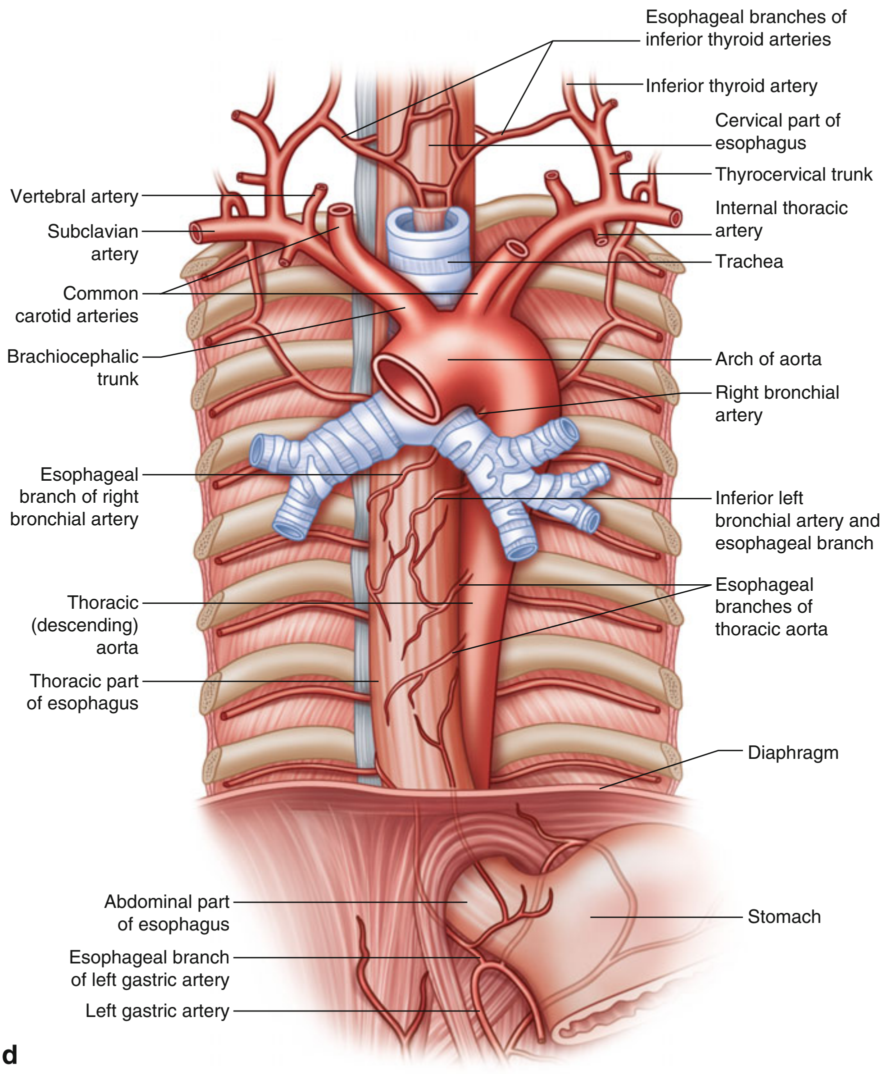

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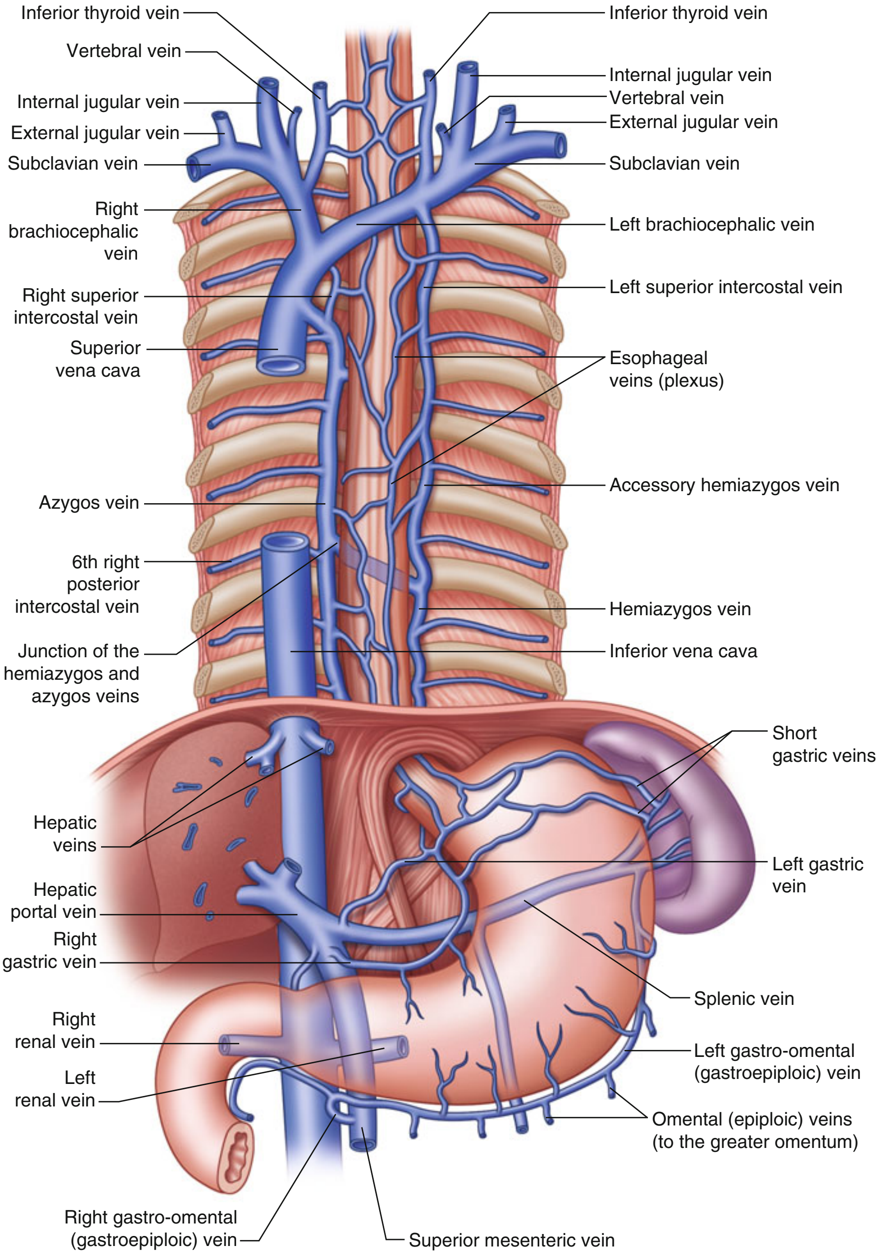

Fig. 1.6 Venous drainage of the stomach and esophagus. The larger veins include the left gastric vein (also called the coronary vein)—an important collateral when portal hypertension causes esophageal varices—and the collaterals draining into the azygos. It is important to control the left gastric vein during dissection of the left gastric pedicle during esophagectomy. Injury can cause bleeding that is difficult to control, particularly if the injury is close to the portal vein. The inferior vena cava is seen easily by lifting the caudate lobe of the liver during esophagectomy (heart and most of the liver have been removed in this illustration to facilitate visualization of the venous anatomy)

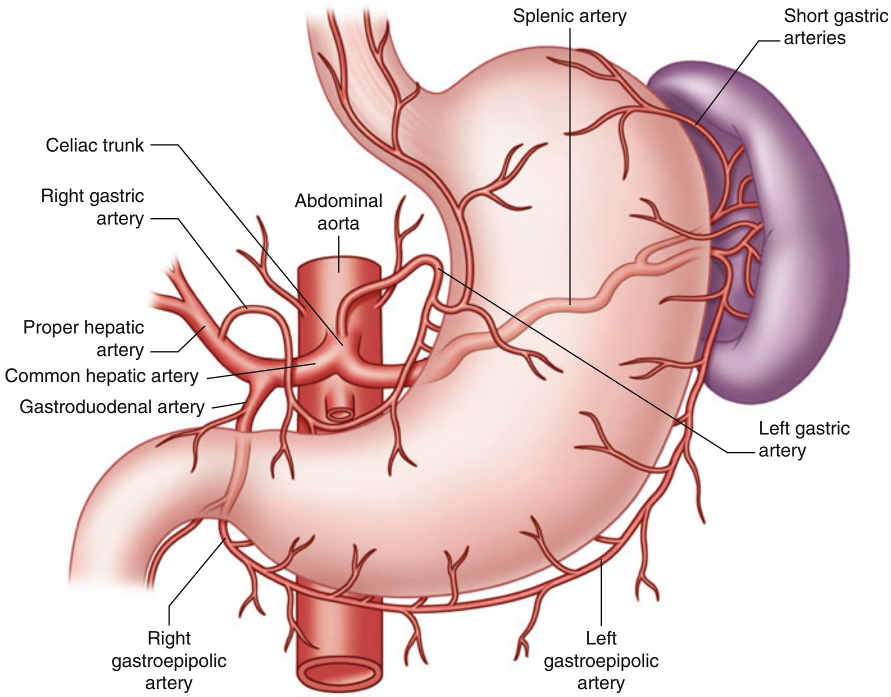

Fig. 1.7 The arterial supply of the stomach. This anatomy is important to understand as preservation of adequate arterial supply to the gastric conduit, specifically the right gastroepiploic artery, is essential for a good outcome. When performing esophagectomy and creating a neo-esophagus from the stapled stomach the short gastric arteries, left gastric artery, and branches of the right gastric artery are divided to create the gastric conduit

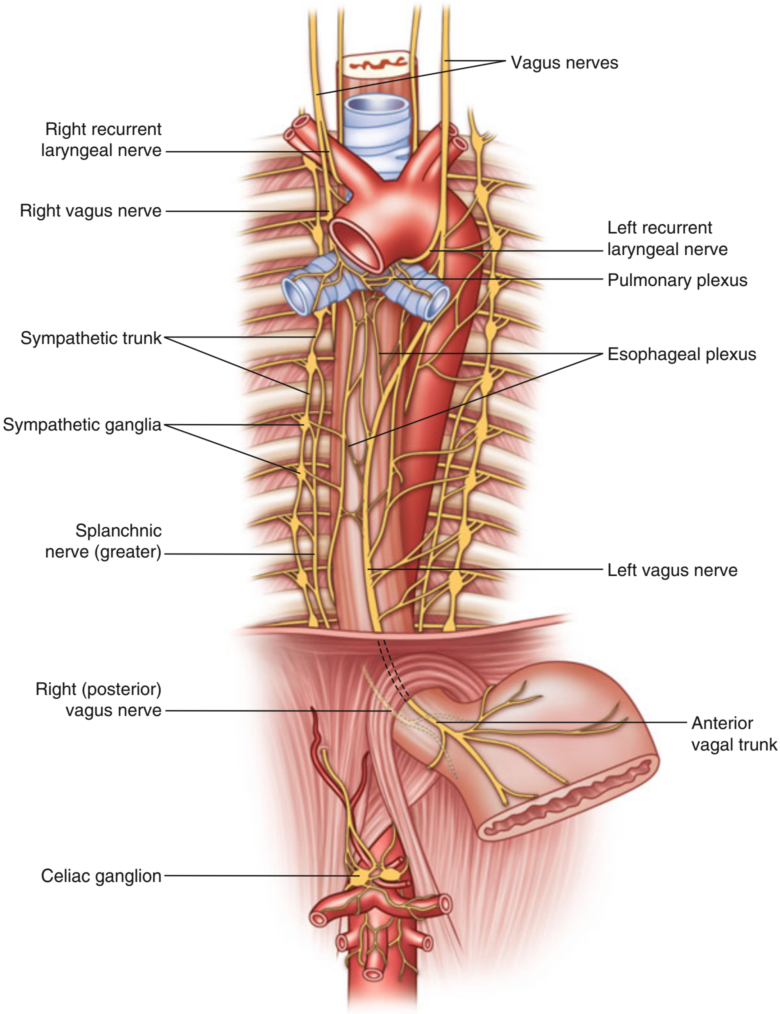

Fig. 1.8 Nerve supply to the esophagus. The nerves that innervate the esophagus include Auerbach's plexus (which is related to achalasia) and the vagal nerves. Knowing where these are located and how they travel along the esophagus is important for almost every type of esophageal surgery. Vagal injury during esophageal surgery when the stomach is preserved can cause devastating symptoms for the patient. The sympathetic ganglia are depicted

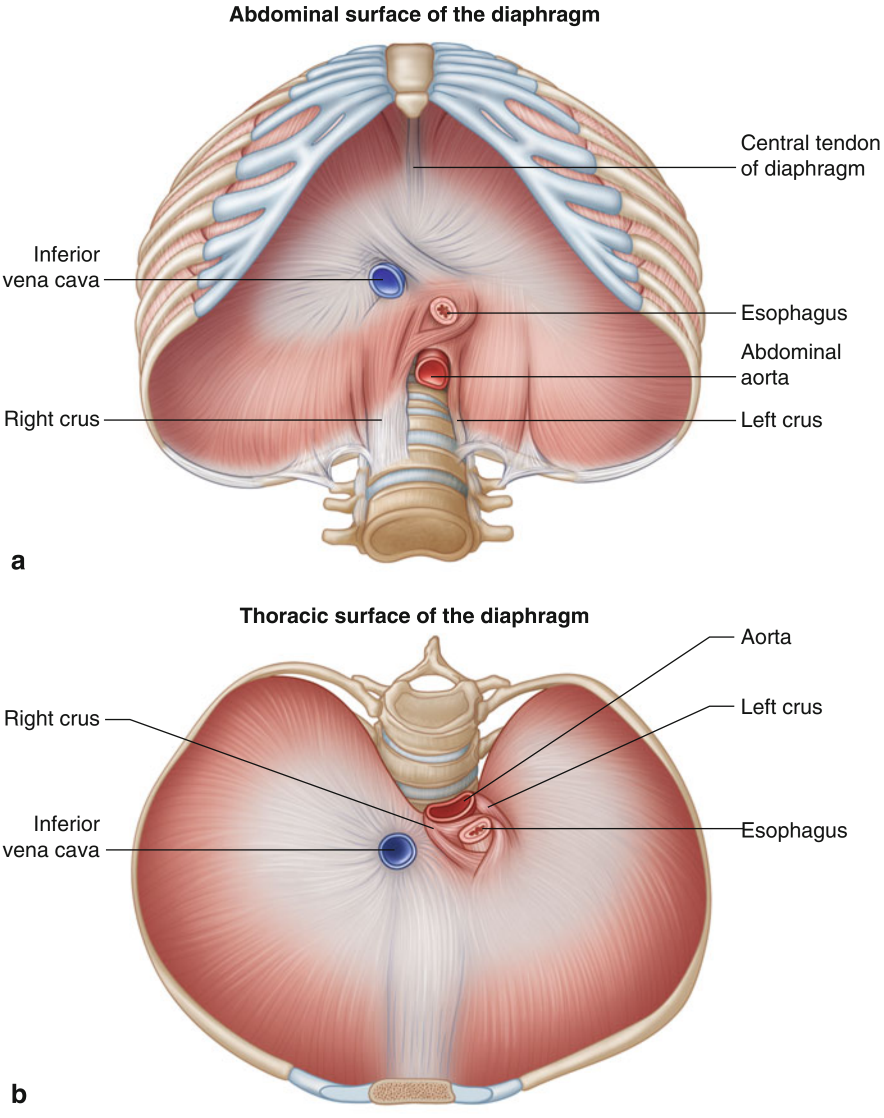

Fig. 1.9 Relationship of the diaphragm and esophagus. The location of the aorta, inferior vena cava, and spine, as well as their relationship to the diaphragmatic structures, is shown. (**a**) Abdominal surface. (**b**) thoracic surface

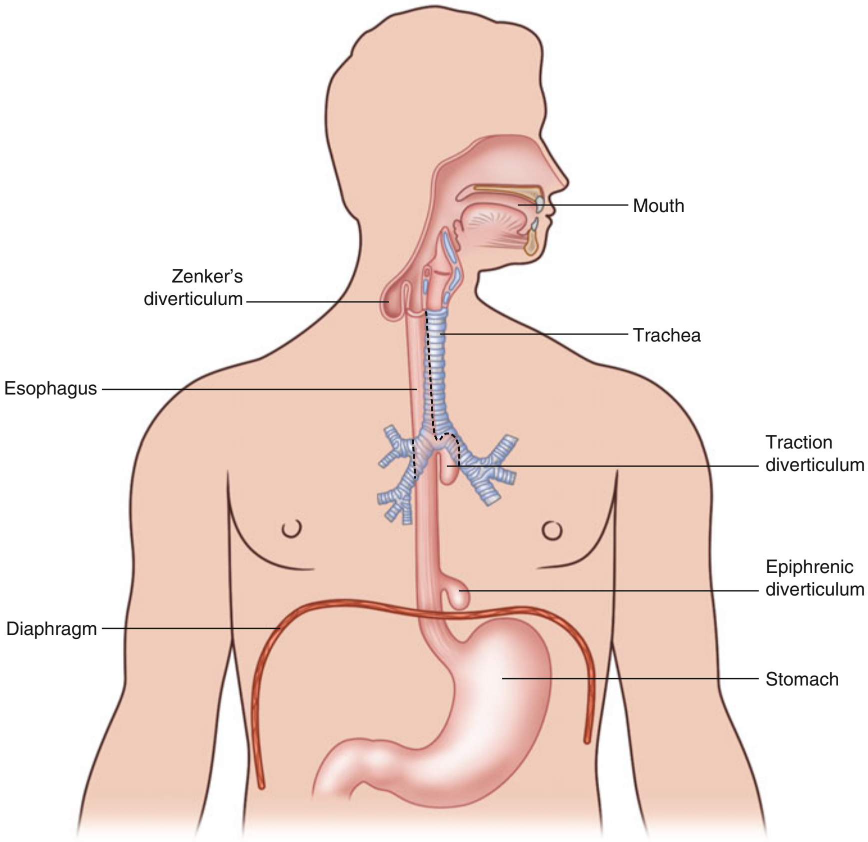

Fig. 1.10 Esophageal diverticula. There are multiple opportunities for the esophagus to form diverticula. If the cricopharyngeus muscle is too tight, then a pulsion Zenker's diverticulum forms. If there is unusual traction from an adherent lymph node in the subcarinal region below the tracheal bifurcation, a traction diverticulum may form. When there is unusual pulsion or pressure at the lower esophagus, then a lower esophageal diverticulum forms and is named *epiphrenic diverticulum*. In the case of pulsion diverticula, a myotomy typically is performed to prevent recurrence at the time of diverticulectomy

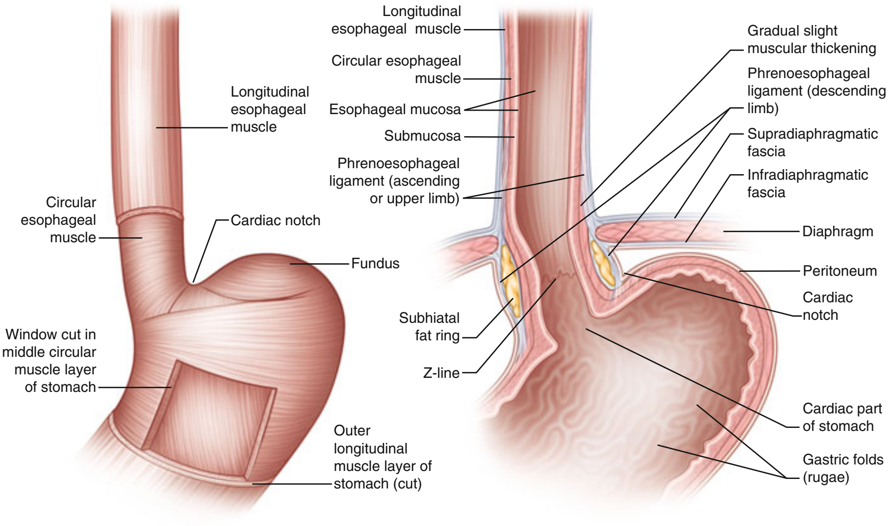

Fig. 1.11 Musculature of the lower esophagus and upper stomach. The gastroesophageal junction and diaphragm are important landmarks for both endoscopic and surgical interventions, such as peroral endoscopic myotomy (POEM) and modified Heller myotomy

Suggested Reading

Clemente CD. Anatomy: a regional atlas of the human body. 6th ed. Philadelphia: Wolters Kluver/Lippincott/Williams & Wilkins; 2010.

Standring S. Gray's anatomy: the anatomical basis of clinical practice. 40th ed. Philadelphia: Elsevier; 2009.

Netter FH. Atlas of human anatomy. Philadelphia: Elsevier; 2014.

Chapter 2
Histologic Anatomy

Blythe Gorman

Esophageal Pathology

Cytologic sampling and tissue biopsy of the esophagus should be considered in the context of the patient's history and endoscopic findings. The location of the lesion in the esophagus, the endoscopic appearance of the lesion, and any other clinical or endoscopic findings are all valuable data points to the pathologist.

Some lesions are better sampled by cytologic brushing rather than with biopsy forceps. Brush cytology, for example, is far more sensitive for the detection of *Candida* than tissue biopsy. Tissue biopsy is usually superior to cytologic brushing in the case of suspected carcinoma, as the depth of invasion and presence or absence of a desmoplastic stromal response cannot be assessed by cytologic sampling alone. Cytologic sampling of esophageal and gastroesophageal lesions is complementary to tissue biopsy.

This chapter covers the basic gross features as well as the cyto- and histopathology of commonly encountered esophageal lesions.

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Normal Esophagus

The innermost layer of the normal esophagus is composed of epithelium bounded by a basement membrane (Figs. 2.1, 2.2, and 2.3). The epithelium rests on top of the lamina propria, which contains lymphatic channels. The muscularis mucosa is the deepest layer of the mucosa, beneath which is the submucosa. The submucosa also contains submucosal glands, ducts and lymphatic channels. The muscularis propria consists of an inner circular layer and an outer longitudinal layer of smooth muscle. The adventitia is the outermost lining of the esophagus, which lacks a serosal surface [1].

Fig. 2.1 Normal distal esophagus, gastroesophageal (GE) junction, and stomach after formalin fixation. The squamous mucosa is pinkish white, the GE junction is well demarcated, and the stomach shows normal darker pink columnar mucosa with rugae

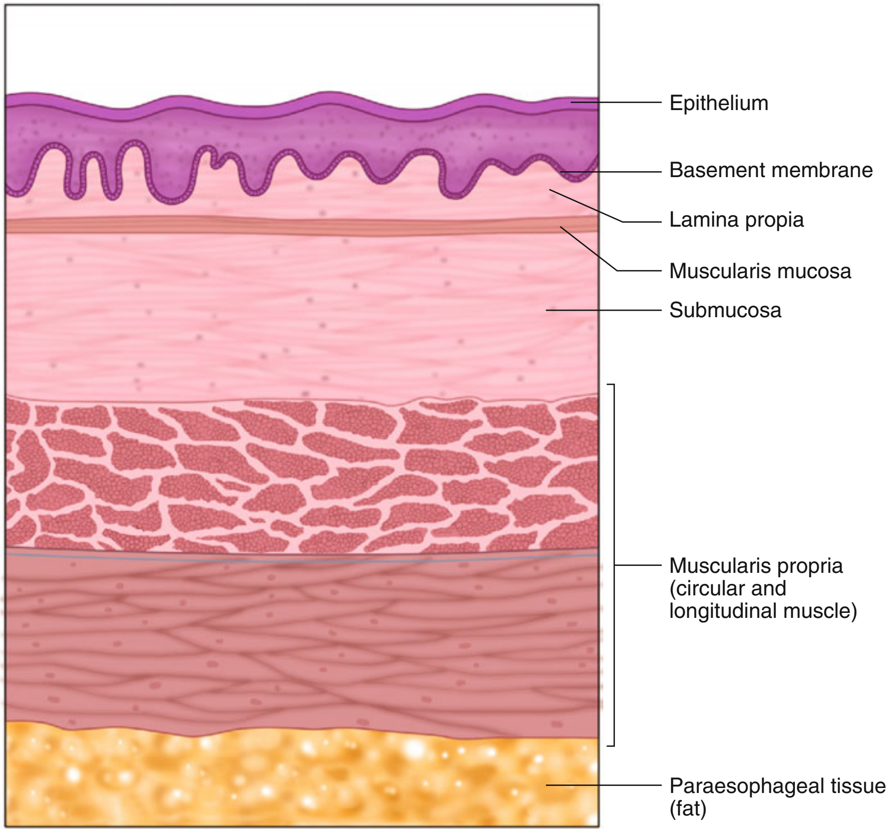


Fig. 2.2 Schematic view of a normal full-thickness section of esophagus

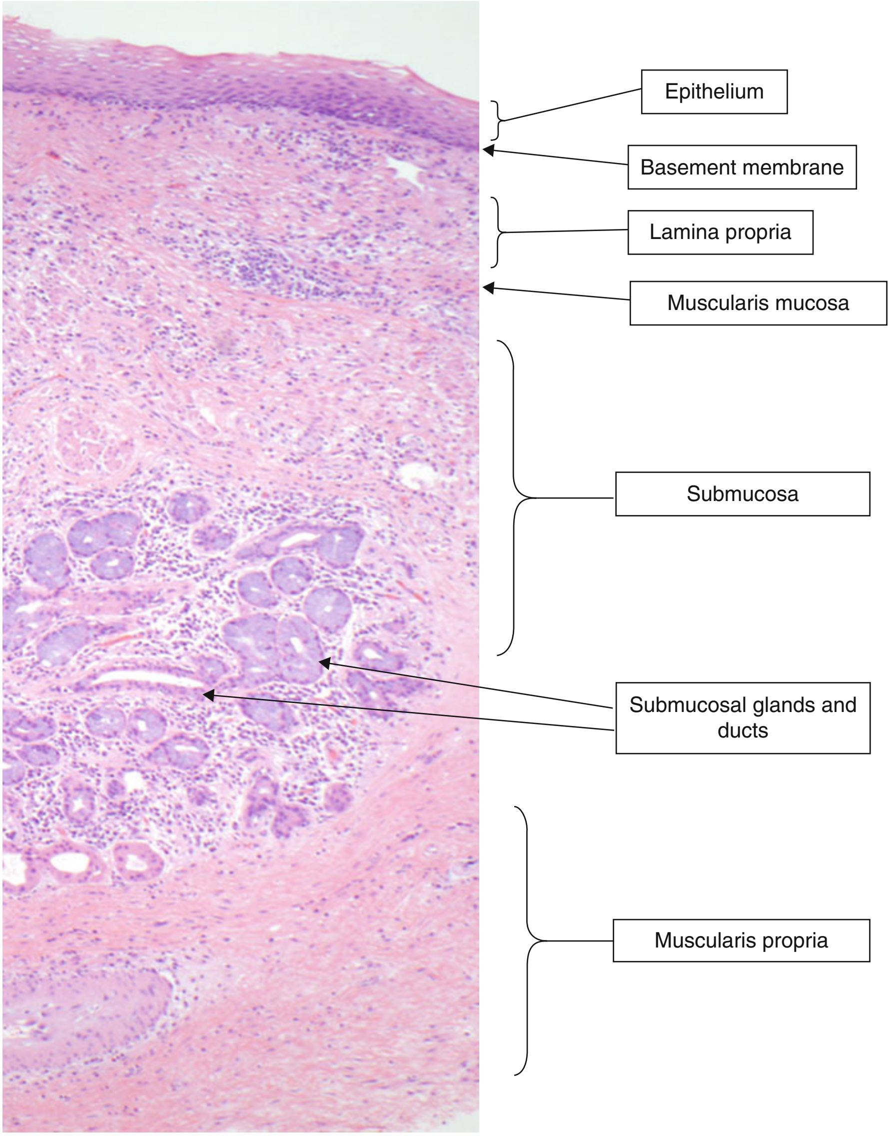


Fig. 2.3 Normal histology of a full-thickness section of esophagus (hematoxylin-eosin [H & E], ×20)

Esophagitis

Changes of reflux esophagitis include thickening/proliferation of the epithelial basal cell layer with dilated intracellular spaces, elongated lamina propria papillae, and intraepithelial eosinophils (Fig. 2.4a).

Increased lymphocytes may be seen in the epithelium and lamina propria (Fig. 2.4b) [2]. Note the dilated intercellular spaces (spongiosis), reflective of intercellular edema. The nuclei have reactive changes including enlargement and prominent nucleoli with retention of smooth nuclear and nucleolar contours.

Multilayered epithelium (Fig. 2.4c) is characterized by the presence of columnar glandular cells overlying squamous cells. This change is associated with reflux esophagitis, but also may be seen in biopsy specimens taken from patients who go on to develop Barrett's esophagus, as reflux is often seen in these patients as well [3].

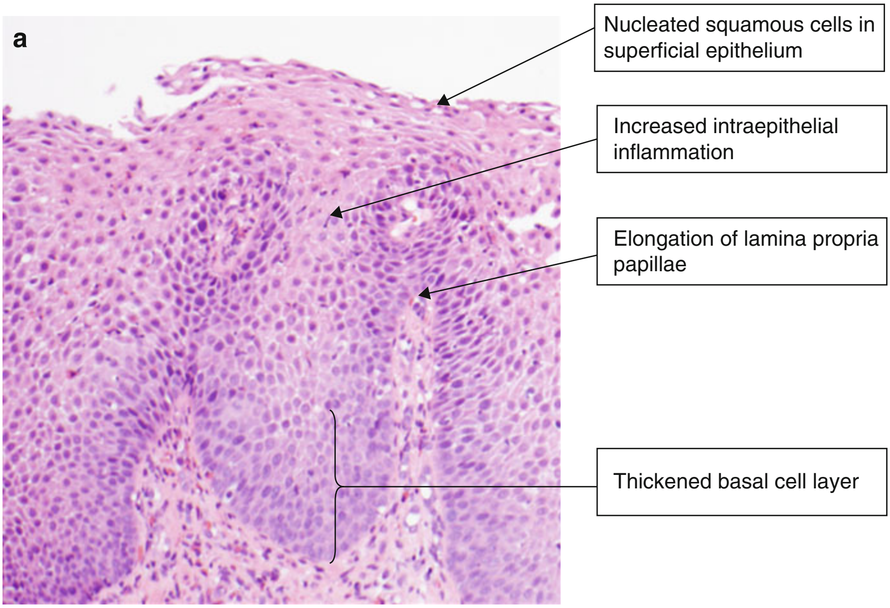


Fig. 2.4 Histology of esophagitis. (**a**) Reflux esophagitis (H & E, ×100). (**b**) Reflux esophagitis, basal layer of epithelium (H & E, ×400). (**c**) Gastroesophageal junction with multilayered epithelium (H & E, ×400)

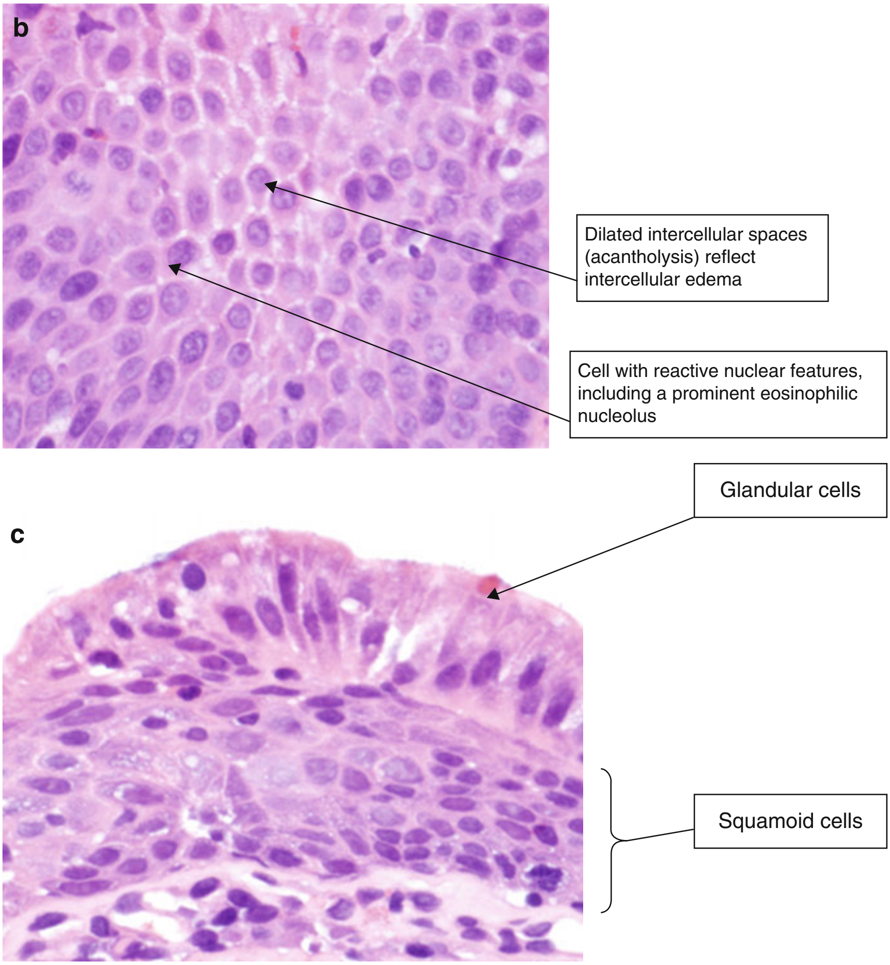


Fig. 2.4 (continued)

Barrett's Esophagus

The squamocolumnar junction is composed of squamous epithelium and glandular epithelium (Figs. 2.5 and 2.6a). In the United States, Barrett's metaplasia is defined by the presence of columnar epithelium with goblet cells. The metaplastic epithelium must be located in the tubular esophagus. The goblet cells are distended by blue-hued acid mucin. Note that the epithelium is mature at the surface, as the cells have abundant cytoplasm and small nuclei that are oriented toward the basement membrane. No dysplasia is seen Fig. 2.6a.

Another feature of Barrett's esophagus is duplication of the muscularis mucosa (Fig. 2.6b). The original muscularis mucosa is located deeper than the new layer that is associated with Barrett's esophagus. The new layer is closer to the lumen of the esophagus and is composed of thinner, frayed smooth muscle fibers. There may be edematous lamina propria between the two layers.

A diagnosis of Barrett's esophagus indefinite for dysplasia may be rendered under several circumstances. In Fig. 2.7a, for example, glands lined by atypical, metaplastic epithelium are seen beneath squamous epithelium; they are "buried." This neoepithelialization may occur after radiofrequency ablation treatment of Barrett's esophagus. The glandular cells have nuclear hyperchromasia and enlargement, some stratification, and increased mitotic activity. The degree of surface maturation of the glandular epithelium cannot be assessed in this sample because of the overgrowth of squamous epithelium. As a definitive diagnosis of dysplasia cannot be rendered, the diagnosis of "indefinite for dysplasia" is felt most appropriate. However, the mere presence of buried metaplastic epithelium is insufficient to warrant a diagnosis of indefinite for dysplasia.

Other situations that may warrant a diagnosis of indefinite for dysplasia include: (1) the presence of marked reactive atypia in the setting of ulceration or inflammation; (2) atypia limited to the bases of the glands (not extending to involve the surface epithelium); (3) tangential sectioning, absence of surface epithelium, or other artifactual changes; and (4) cytologic and architectural changes that are worrisome for, but not diagnostic of, dysplasia (Fig. 2.7b) [3].

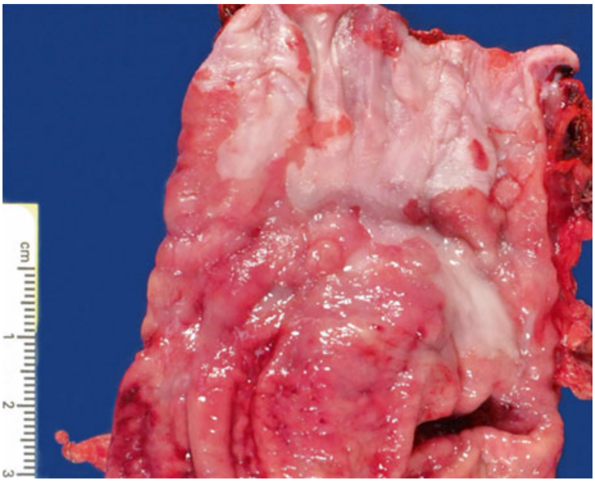


Fig. 2.5 Gross photo of gastroesophageal junction with Barrett's esophagus (fresh specimen)

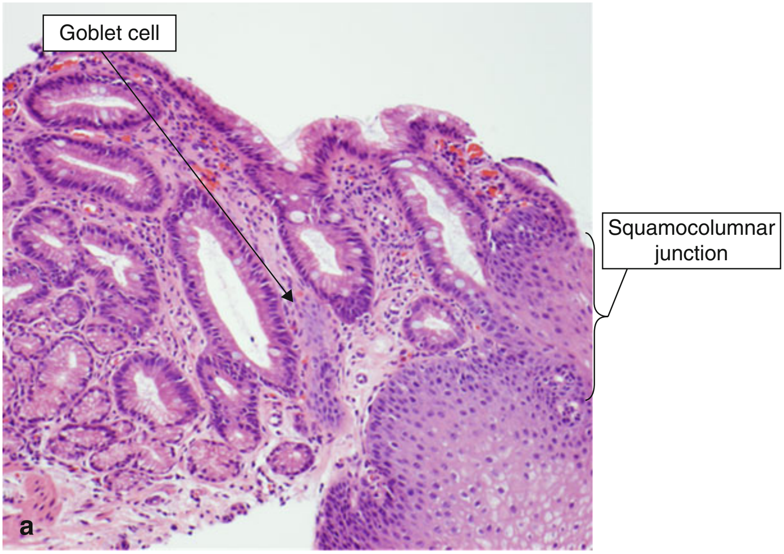
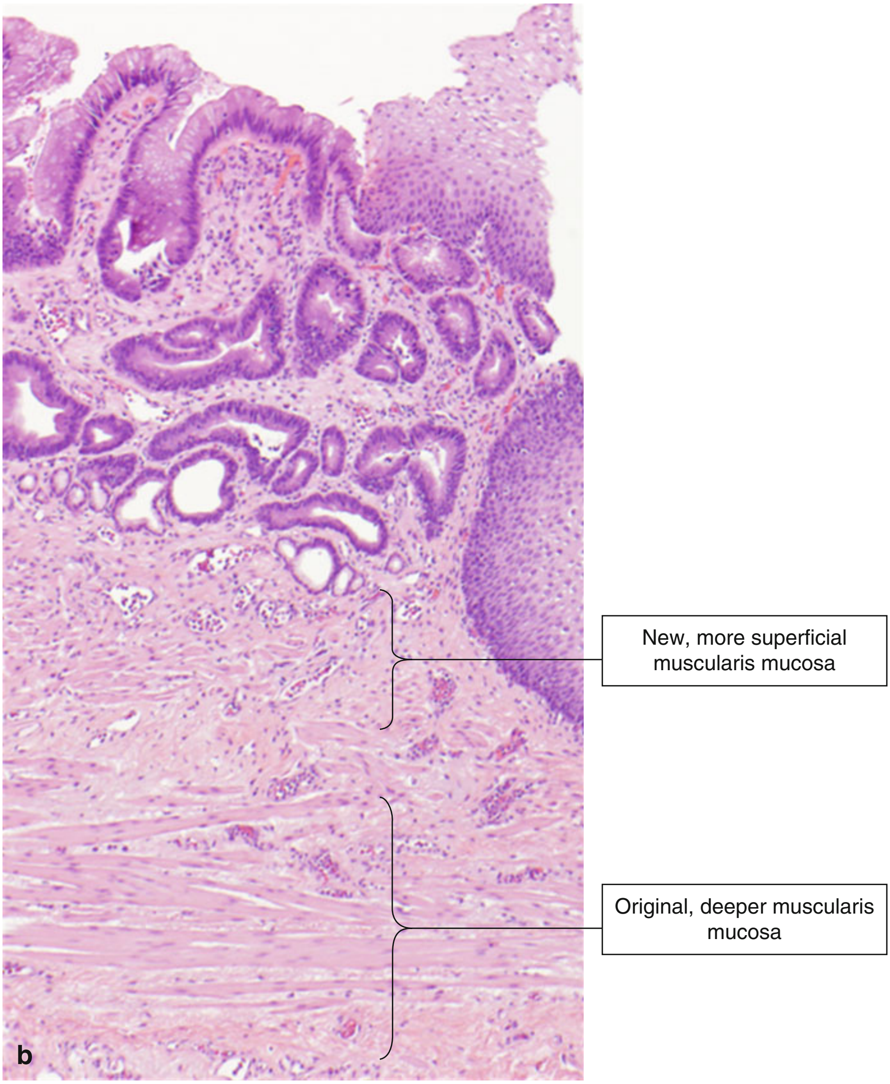


Fig. 2.6 Barrett's esophagus, histology. (**a**) Barrett's esophagus (H & E, ×100). (**b**) Barrett's esophagus (H & E, ×40)



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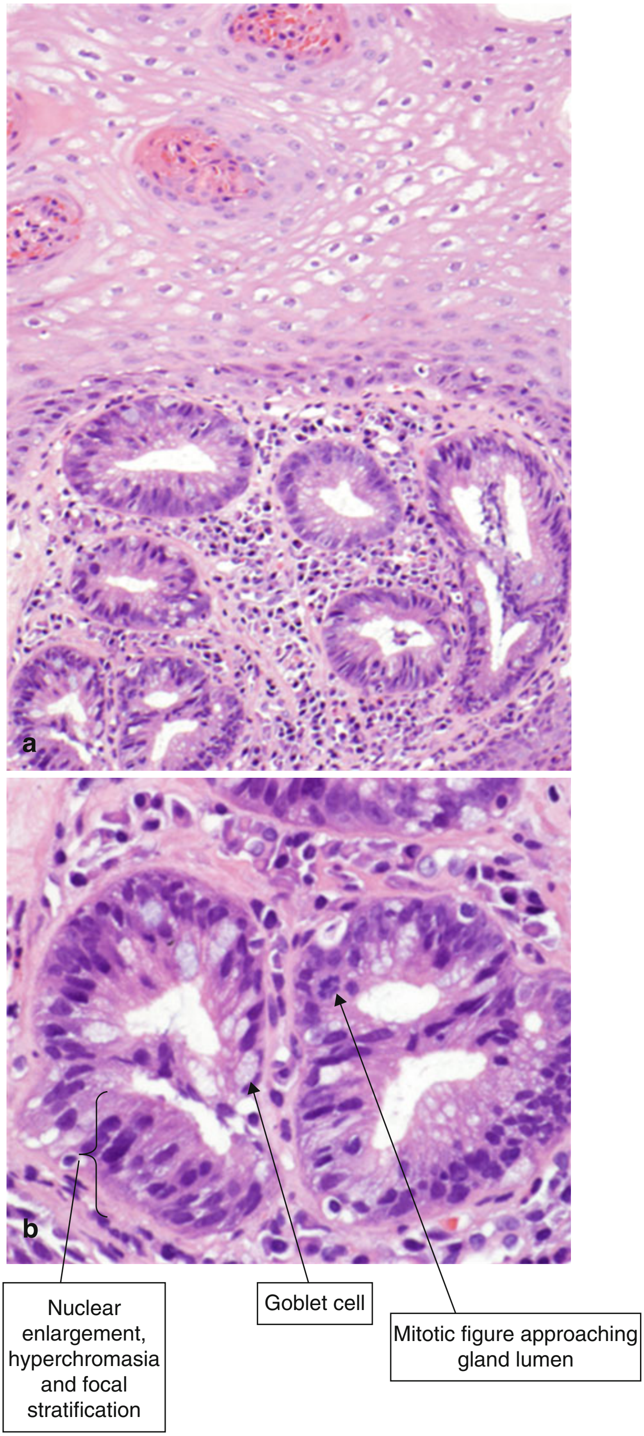


Fig. 2.7 (**a**) Barrett's esophagus, indefinite for dysplasia (H & E, ×100). (**b**) Barrett's esophagus, indefinite for dysplasia (H & E, ×400). The cells show cytologic features of dysplasia that include nuclear enlargement, hyperchromasia, and some nuclear stratification. Diagnostic features of high-grade dysplasia are not seen

Barrett's Esophagus, Low-Grade Dysplasia

Low-grade dysplasia is characterized by nuclear crowding, stratification, atypia, and increased mitotic figures (Fig. 2.8). The atypical nuclei extend beyond the crypt epithelium to involve the superficial epithelium. Focal goblet-cell depletion may also occur. The contours of the dysplastic glands are more irregular than those without dysplasia. In contrast to high-grade dysplasia, low-grade dysplasia retains some nuclear polarity (most nuclei are oriented toward the basal aspect of the cell, away from the luminal surface) and the nuclei remain elongated or cigar-shaped.

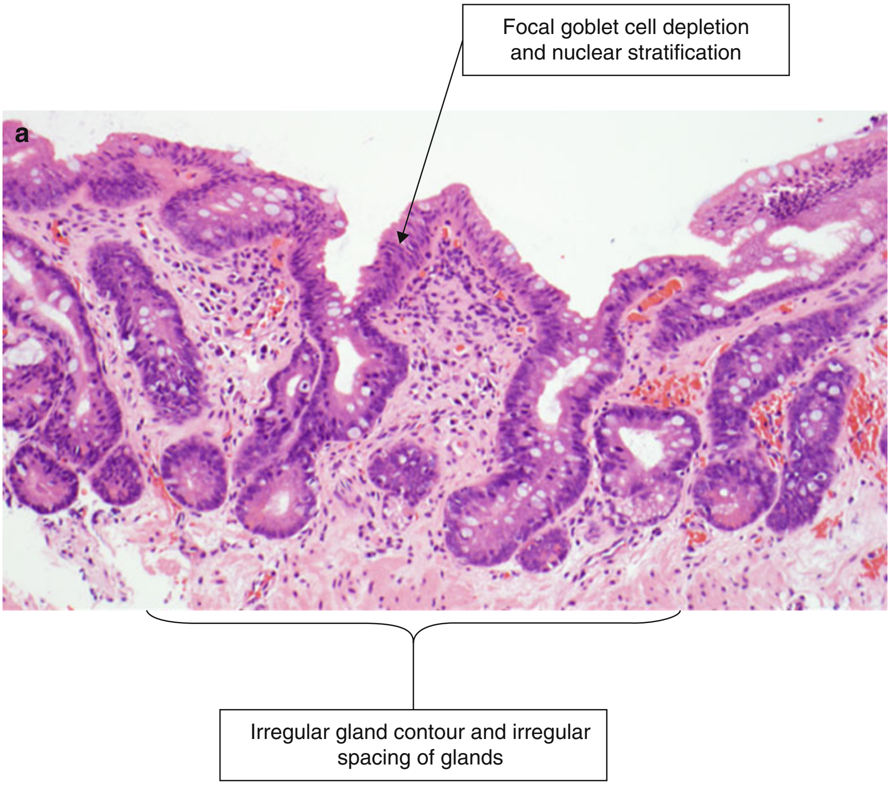


Fig. 2.8 (**a**) Barrett's esophagus, low-grade dysplasia (H & E, ×100). (**b**) Barrett's esophagus, low grade dysplasia (H & E, ×200). Review of the histological specimen by two histopathologists is recommended to diagnose and characterize dysplasia in Barrett's esophagus

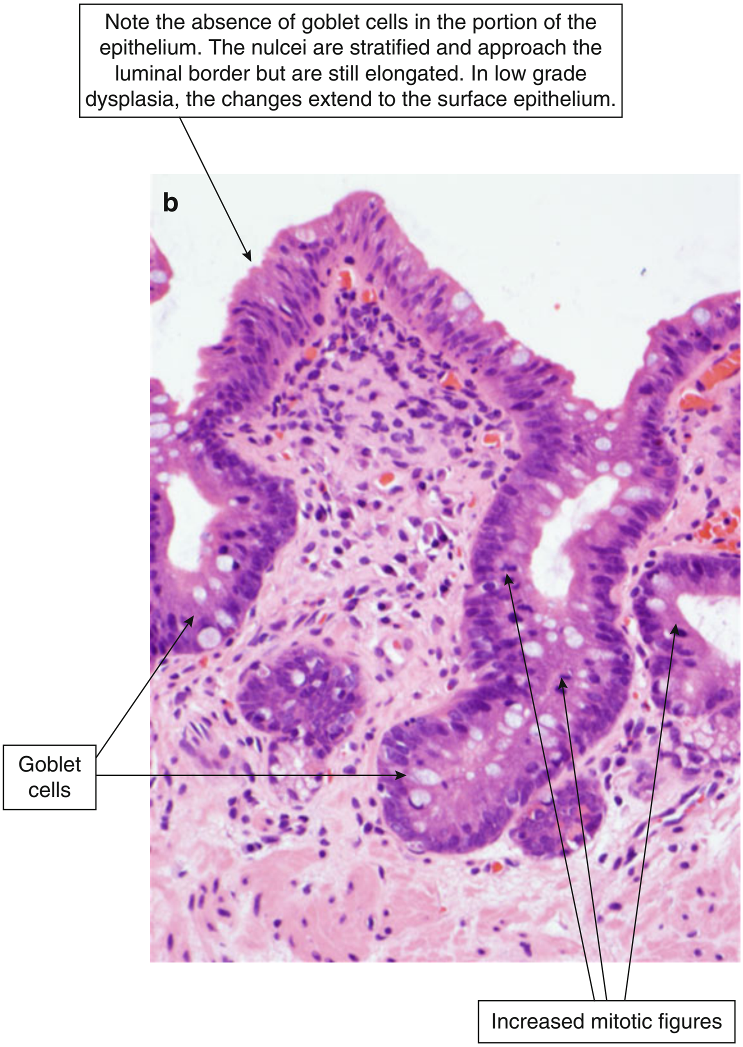


Fig. 2.8 (continued)

Barrett's Esophagus, High-Grade Dysplasia

High-grade dysplasia shows more marked nuclear atypia, which extends to the superficial epithelium (Fig. 2.9). The nuclei are hyperchromatic, enlarged, and rounded, often with irregular nuclear contours. There is loss of nuclear polarity, often with full-thickness nuclear stratification. Increased mitotic figures (including atypical forms) are seen, and goblet cells are notably decreased. Some features, when present in biopsy specimens showing Barrett's esophagus with high-grade dysplasia, are predictive of invasive carcinoma upon surgical resection. These features include gland cribriforming, dilated glands with necrotic material, ulceration of high-grade dysplasia, invasion of dysplastic glands into the overlying squamous epithelium and the presence of many neutrophils within the epithelium with high grade dysplasia [4].

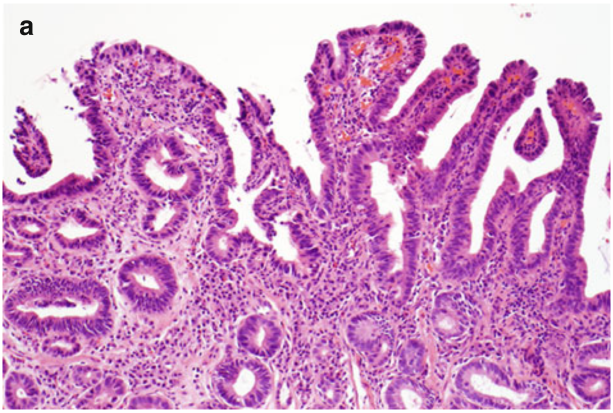


Fig. 2.9 (**a**) Barrett's esophagus, high-grade dysplasia (H & E, ×100). (**b**) Barrett's esophagus, high-grade dysplasia (H & E, ×200). (**c**) Barrett's esophagus, high-grade dysplasia (H & E, ×400)

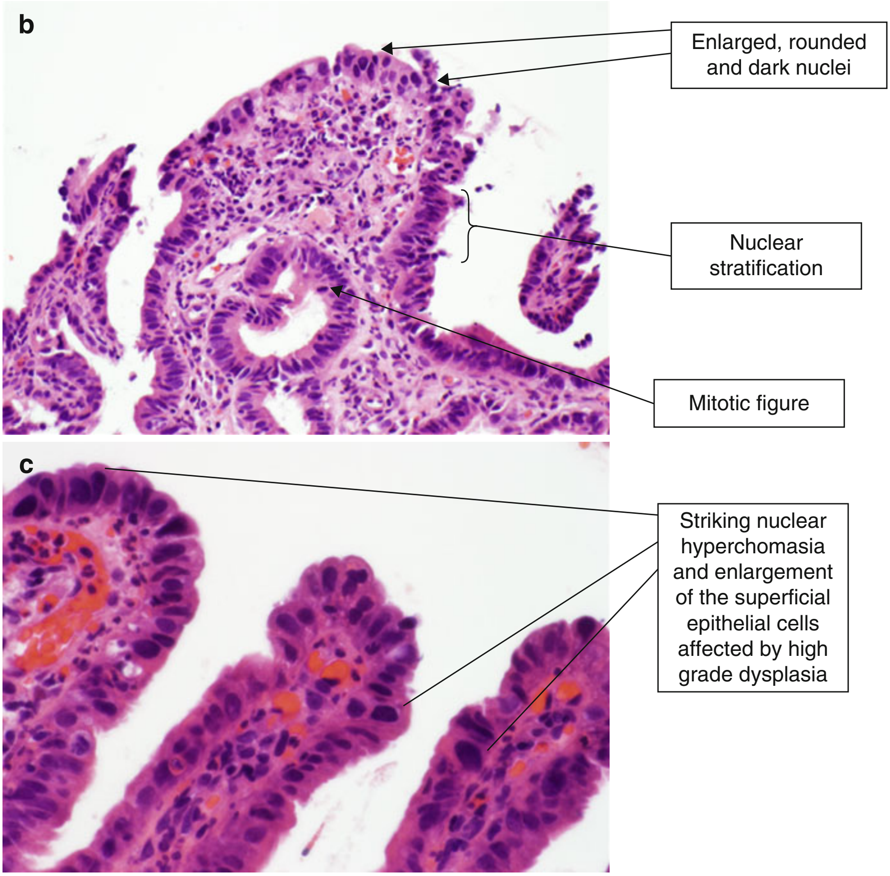


Fig. 2.9 (continued)

Adenocarcinoma

The presence of dysplastic glands beyond the epithelial basement membrane and within the lamina propria or duplicated muscularis mucosa defines intramucosal adenocarcinoma (Fig. 2.10). Invasion through the true muscularis mucosa and into the submucosa is not identified. The nuclear morphology is similar to that seen in high-grade dysplasia. The gland architecture is complex and crowded, with back-to-back glands lacking intervening stroma. Angular gland contours, intraluminal necrosis, and dilatation of gland lumina may also be seen. In addition, single malignant cells may be present within the lamina propria. As lymphatics are present in the lamina propria of the esophagus, there is a small risk of metastasis [5]. The histological diagnosis of intramucosal adenocarcinoma corresponds to T1a disease, with invasion into the lamina propria or muscularis mucosa. This finding is important, as the 15–20 % rate of lymph node metastases with submucosal tumors (T1b disease) is higher than the rate for T1a disease (5–7 %).

Adenocarcinoma of gastroesophageal junction is a bulky, nodular, and exophytic tumor. The surrounding gastric mucosa may be hemorrhagic (Fig. 2.11).

With esophageal adenocarcinoma, malignant glands invade deep into the muscularis propria (Fig. 2.12). Cribriform architecture and areas of necrosis are present. The overlying epithelium is dysplastic. Invasion into the muscularis propria defines this tumor as pT2 (seventh edition AJCC Cancer Staging Manual) [6].

Due to the large amount of extracellular mucin, mucinous adenocarcinoma is relatively less cellular than the other types (Fig. 2.13). Clusters of tumor cells are afloat in a sea of mucin. The overlying squamous epithelium is essentially normal. By definition, a diagnosis of mucinous carcinoma is rendered when more than 50 % of the lesion consists of mucin [7].

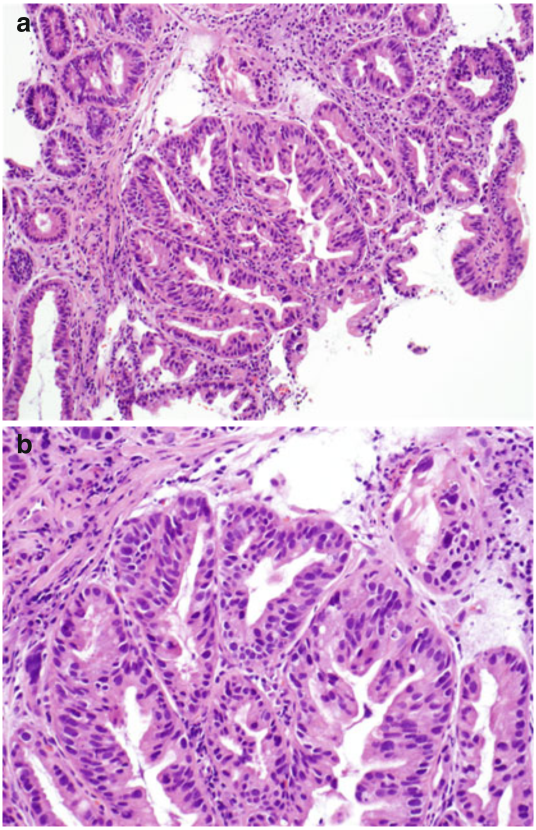


Fig. 2.10 (**a**) Intramucosal adenocarcinoma (H & E, ×100). (**b**) Intramucosal adenocarcinoma (H & E, ×200)

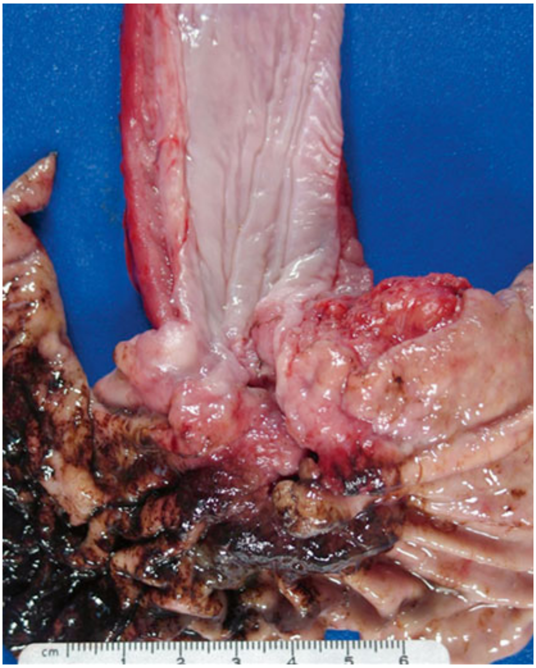


Fig. 2.11 Untreated adenocarcinoma at the gastroesophageal junction (fresh specimen)

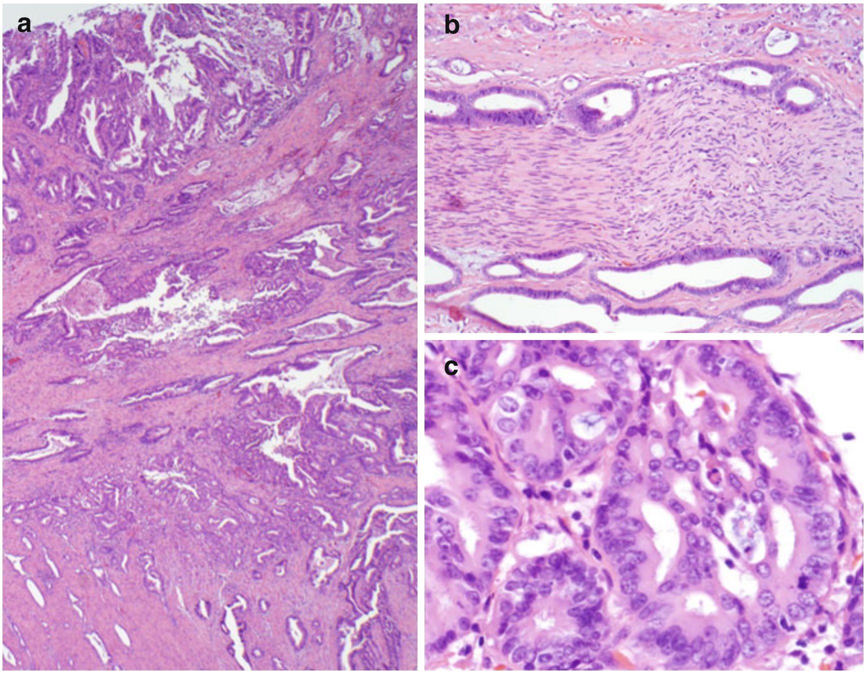


Fig. 2.12 Esophageal adenocarcinoma. (**a**) Adenocarcinoma (H & E, ×20). (**b**) Adenocarcinoma showing perineural invasion (H & E, ×100). (**c**) Adenocarcinoma with complex, cribriform architecture (H & E, ×400). Note the irregular size and shape of gland lumina with intraluminal necrosis. The tumor cell nuclei are large, with prominent nucleoli

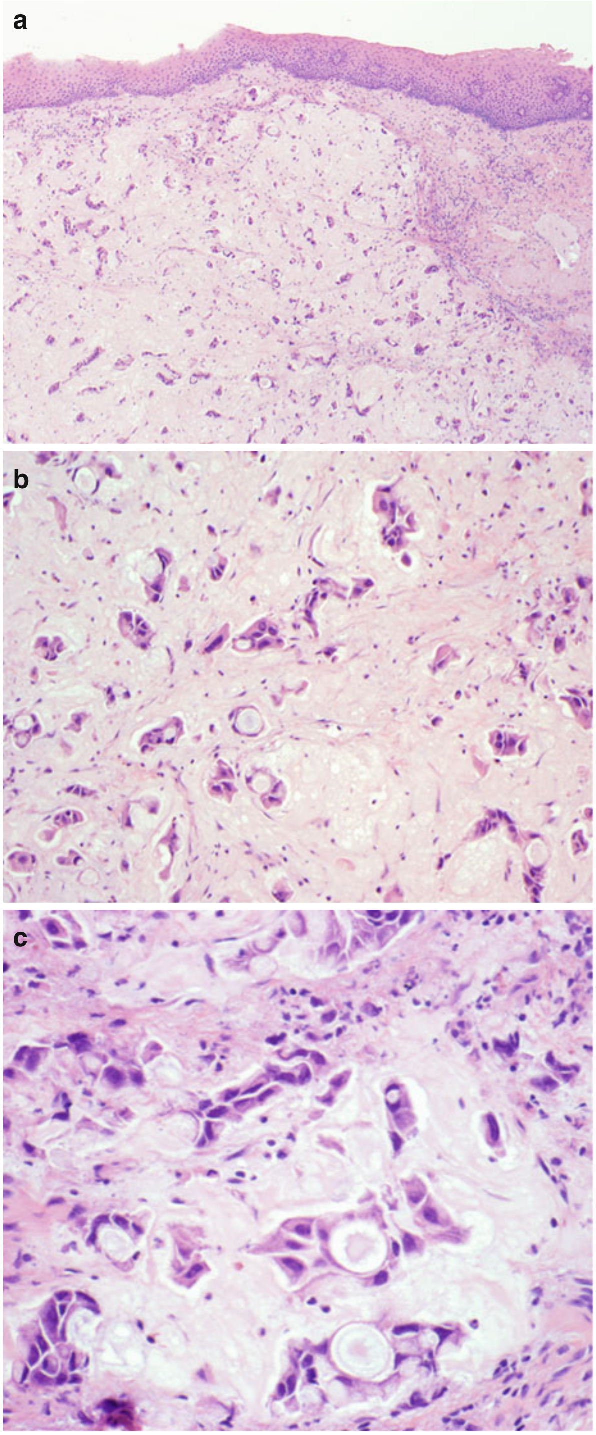
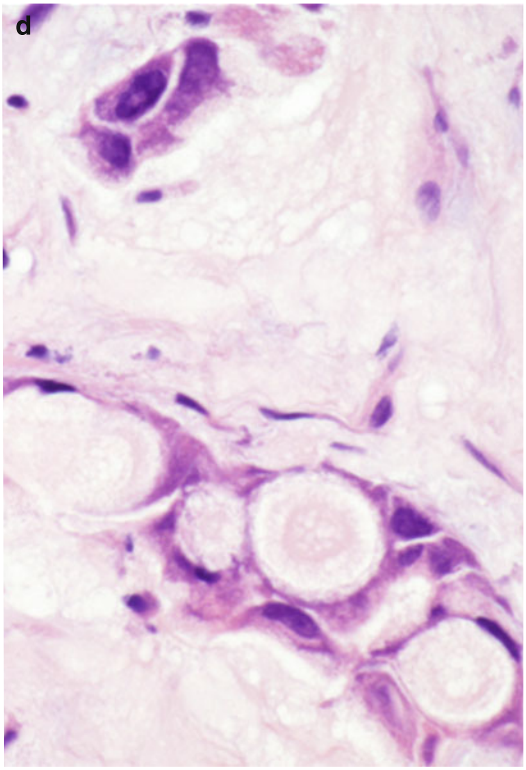


Fig. 2.13 Mucinous adenocarcinoma (a recurrence). (**a**) H & E, ×40. Squamous epithelium overlies tumor cells in a background of mucin. (**b**) H & E, ×100. Irregular nests of tumor cells infiltrate the stroma. (**c**) H & E, ×200. (**d**) H & E, ×400. Note the signet ring appearance of several tumor cells. This is due to intracytoplasmic mucin. Although some of the tumor cell nuclei are small, they are hyperchromatic, angular, and displaced by the mucin vacuoles

Fig. 2.13 (continued)



Esophageal Squamous Cell Carcinoma

The squamous cell carcinoma shown in Figs. 2.14 and 2.15 is ulcerative and infiltrates the wall of the esophagus. Note the thickening of the wall. The surface of the tumor is irregular and somewhat nodular but is well demarcated from the normal esophageal mucosa.

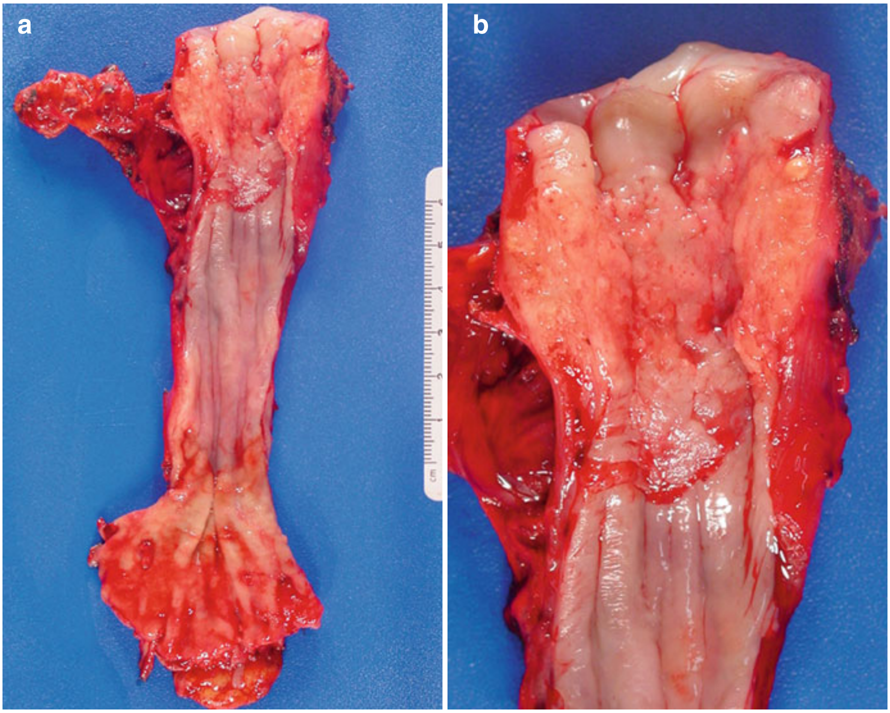


Fig. 2.14 (**a**, **b**) Esophageal squamous cell carcinoma, gross photos

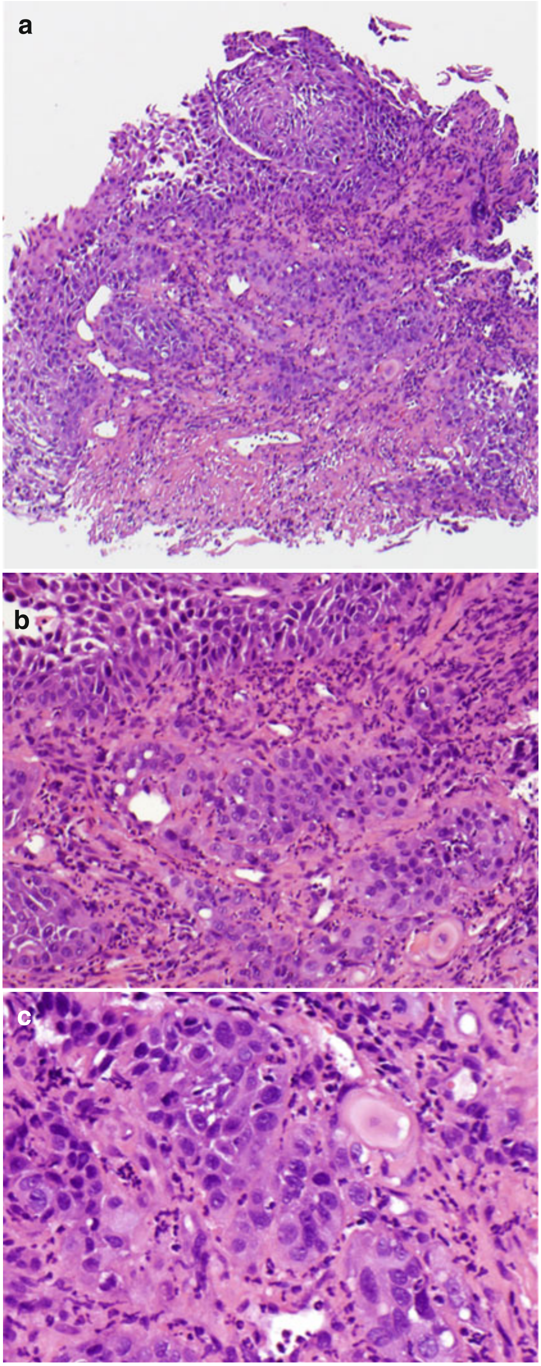


Fig. 2.15 (**a**) Squamous cell carcinoma (H & E, ×40). This moderately differentiated squamous cell carcinoma involves the full thickness of the biopsy specimen. Tumor necrosis is prominent. (**b**) Squamous cell carcinoma (H & E, ×200). The tumor cells have enlarged hyperchromatic nuclei and infiltrate the stroma in irregular nests. (**c**) Squamous cell carcinoma (H & E, ×400). The presence of intercellular bridges (delicate filaments seen between the tumor cells) indicates squamous differentiation, as does keratin production

Candida

The esophageal brushing specimen in Figs. 2.16 and 2.17 shows numerous *Candida* yeast and pseudohyphae. The pseudohyphae are said to skewer the squamous cells, giving a characteristic "shish kebab" appearance. The squamous cells show reactive changes that include nuclear enlargement and mild hyperchromasia. Cytologic specimens are often of higher yield than biopsies for detecting *Candida*, as the brush samples a larger surface area. Special stains are frequently employed to aid in the detection of organisms in both histologic and cytologic samples. Two of the more commonly used special stains for fungus are Gomori methenamine silver (GMS) and periodic acid–Schiff with diastase (PAS-D).

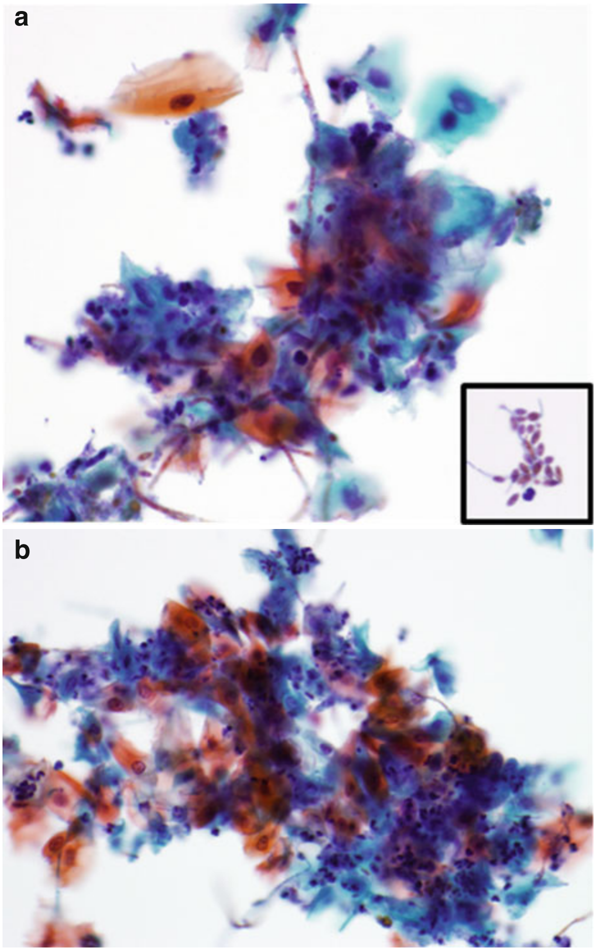


Fig. 2.16 *Candida* in an esophageal brushing specimen. (**a**) *Candida* species (ThinPrep, Papanicolaou stain, ×200; inset ×400). The inset panel shows a high-power view of the fungal yeast. (**b**) *Candida* species (100×, ThinPrep, Papanicolaou stain, ×100)

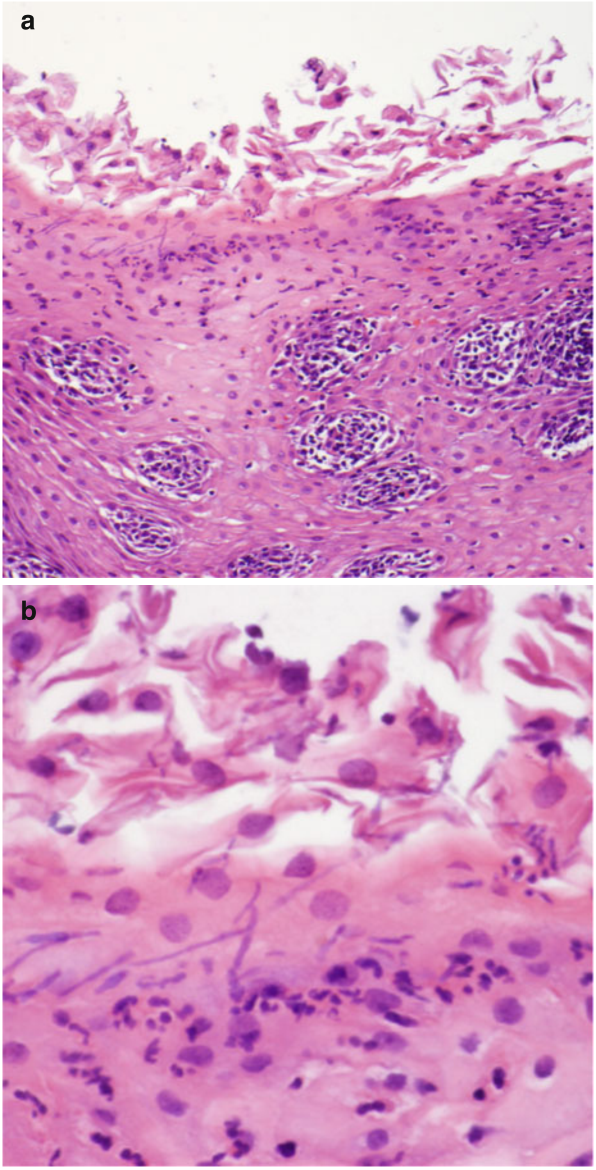


Fig. 2.17 (**a**) Candida esophagitis (H & E, ×100). This biopsy specimen shows squamous epithelium with increased intraepithelial acute and chronic inflammation. The presence of neutrophils in the epithelium is a clue to search for fungi. When numerous, the fungi are easily visible on H & E–stained sections. (**b**) Candida esophagitis (H & E, ×400)

Eosinophilic Esophagitis

In eosinophilic esophagitis, a myriad of eosinophils infiltrates the epithelium and the lamina propria (Fig. 2.18). Intraepithelial clusters of eosinophils (eosinophilic abscesses) and degranulation are characteristic. Features of reflux esophagitis are also seen (basal cell hyperplasia, dilated intercellular spaces, and elongation of the lamina propria papillae) [8]. Scattered eosinophils may be present in reflux esophagitis, but the amount seen in eosinophilic esophagitis is far greater. Some authors use a cutoff of at least 20 eosinophils per high-power field, but the exact number of eosinophils required for the diagnosis is debated and requires additional study [9].

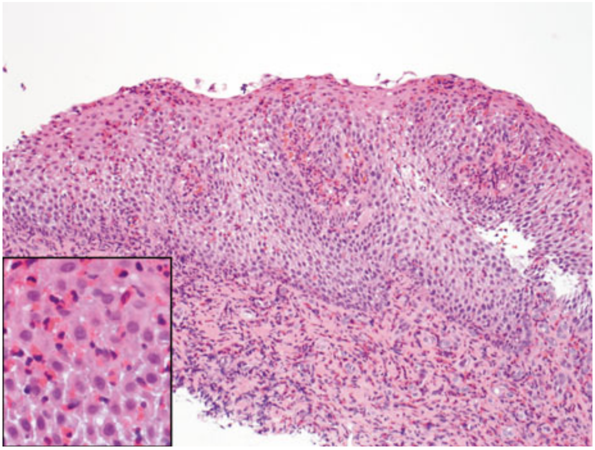


Fig. 2.18 Eosinophilic esophagitis (H & E, ×100; inset ×400)

Stricture

In stricture of the esophagus, the esophageal wall is thickened and fibrotic. Visualizing the mucosal surface may require using forceps to hold the specimen open (Fig. 2.19), unlike the specimens pictured in the other gross photographs.

Histology shows marked thickening and fibrosis of the lamina propria, submucosa, and muscularis propria (Fig. 2.20). (Compare the normal histology in Fig. 2.3, shown at the same magnification.)

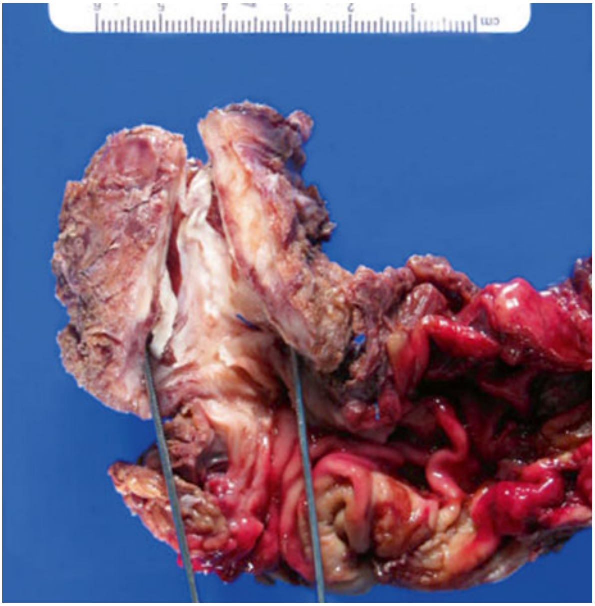


Fig. 2.19 Stricture of the esophagus, fresh specimen

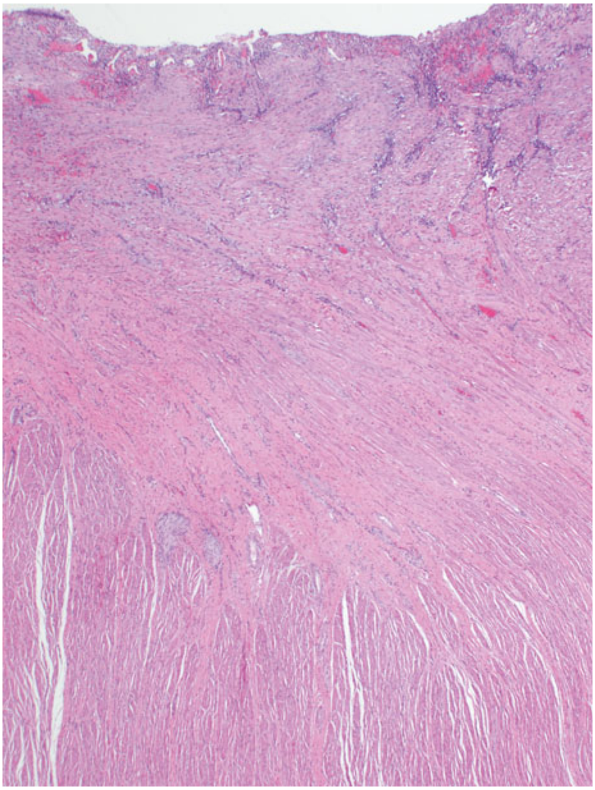


Fig. 2.20 Histology of stricture (H & E, ×20)

Inlet Patch

The inlet patch is characterized by ectopic gastric mucosa that is surrounded by normal squamous mucosa (Fig. 2.21). Inlet patches are most frequently seen in biopsy specimens taken from the upper third of the esophagus.

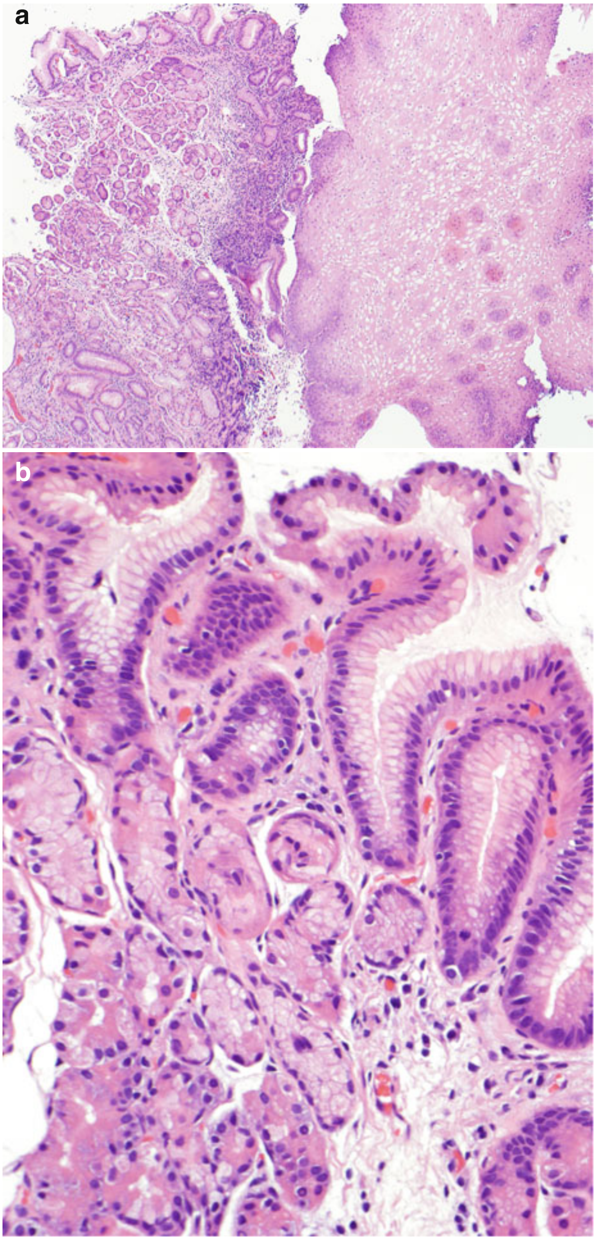


Fig. 2.21 (**a**) Inlet patch (H & E, ×40). The mucosa on the left side of this photomicrograph shows essentially normal gastric mucosa with foveolar and glandular epithelium. The mucosa on the right shows normal esophageal squamous epithelium. (**b**) Inlet patch (H & E, ×200). On higher power, the gastric mucosa of the inlet patch is identical to that seen in the stomach, with foveolar epithelium overlying gastric glands composed of mucus neck cells, parietal cells, and chief cells. Oxyntic-type gastric mucosa is most common, although antral and mixed type are also seen [10]

Achalasia

Achalasia, the failure of smooth muscle fibers (usually in the esophagus and lower esophageal sphincter) to relax, can cause dilatation of the distal esophagus. The examples of achalasia in Figs. 2.22 and 2.23 show dilatation of the distal esophagus with an area of ulceration at the gastroesophageal junction.

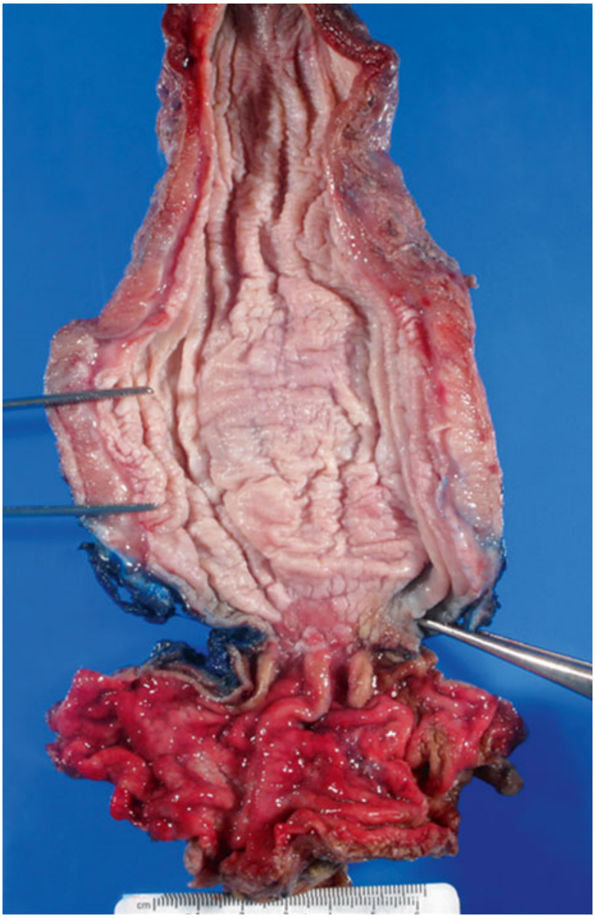


Fig. 2.22 Esophagogastrectomy specimen with achalasia, unfixed

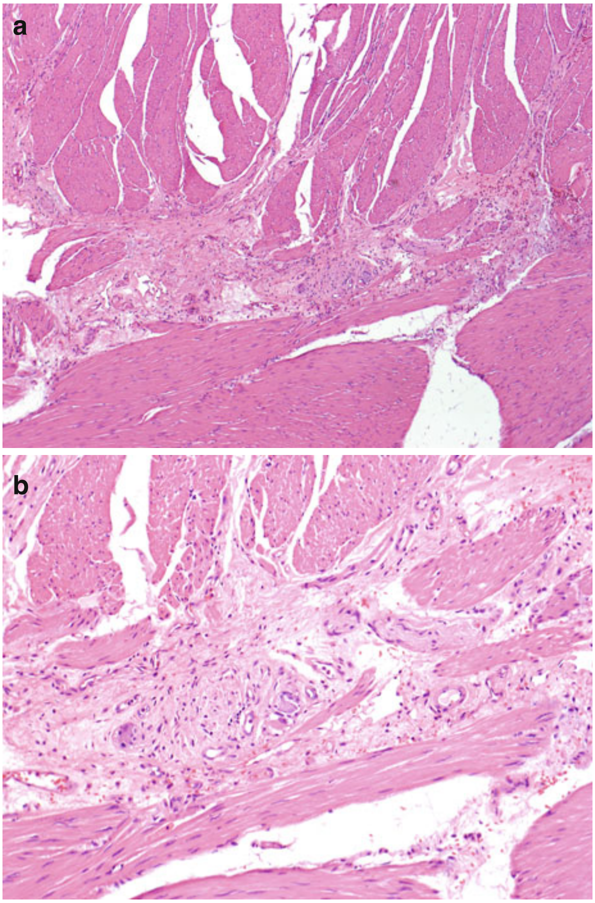


Fig. 2.23 (**a**) Achalasia (H & E, ×40). Features of achalasia include fibrosis of the myenteric plexus and decreased numbers of ganglion cells. Smooth muscle hypertrophy and lymphoplasmacytic infiltration of the myenteric plexus may also be seen. (**b**) Achalasia (H & E, ×100). A minimal lymphoplasmacytic infiltrate surrounds a small nerve in the myenteric plexus, located between the inner circular and outer longitudinal layers of the muscularis propria. The degree of inflammation depends in part upon the age of the lesion

Glycogen Accumulation

Glycogen accumulation creates cytoplasmic clearing in squamous cells (Fig. 2.24). This finding may mimic the perinuclear halo seen with the human papillomavirus cytopathic effect. The absence of characteristic nuclear changes supports a diagnosis of glycogen accumulation.

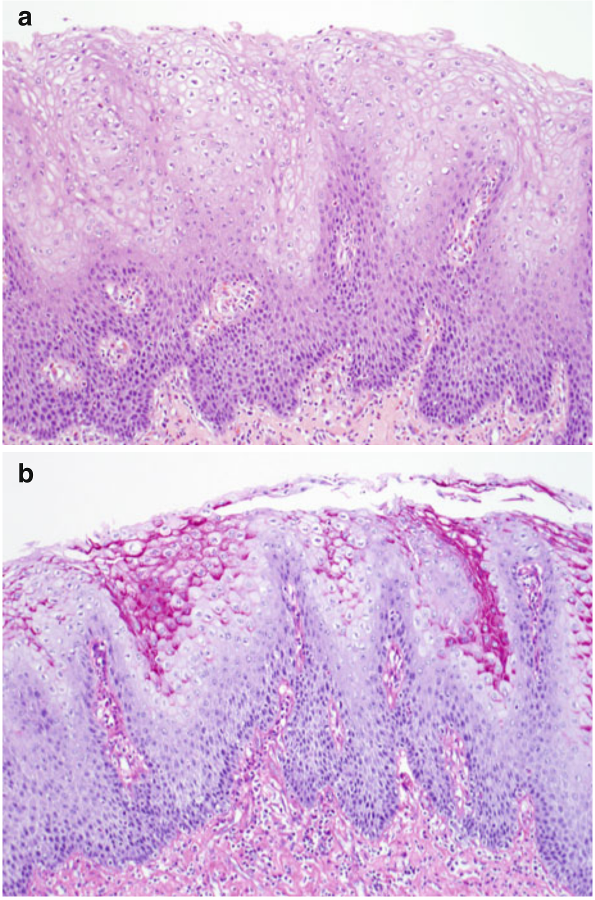


Fig. 2.24 (**a**) Glycogen accumulation (H & E, ×100). (**b**) Glycogen accumulation (PAS without diastase, ×100). The PAS stain highlights the cytoplasmic glycogen

Herpes Esophagitis

Herpesvirus infects the squamous epithelium of the esophagus, leading to ulceration (Fig. 2.25). The ulcer has a purulent base and well-demarcated edges. The characteristic cells with the viral cytopathic effect are usually located at the lateral borders of the ulcer. Infected cells and the cells surrounding the ulcer can be markedly reactive, occasionally mimicking dysplasia or malignancy.

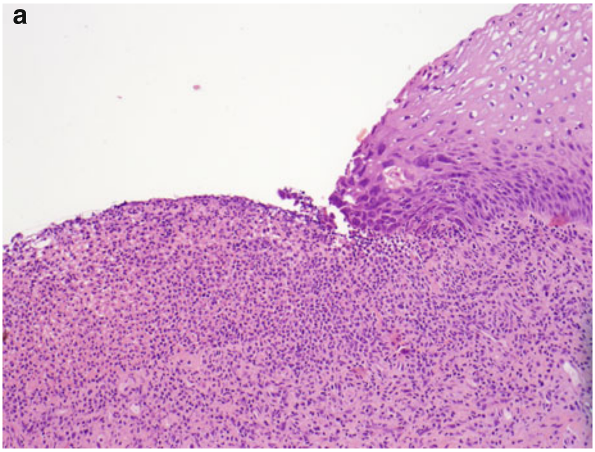
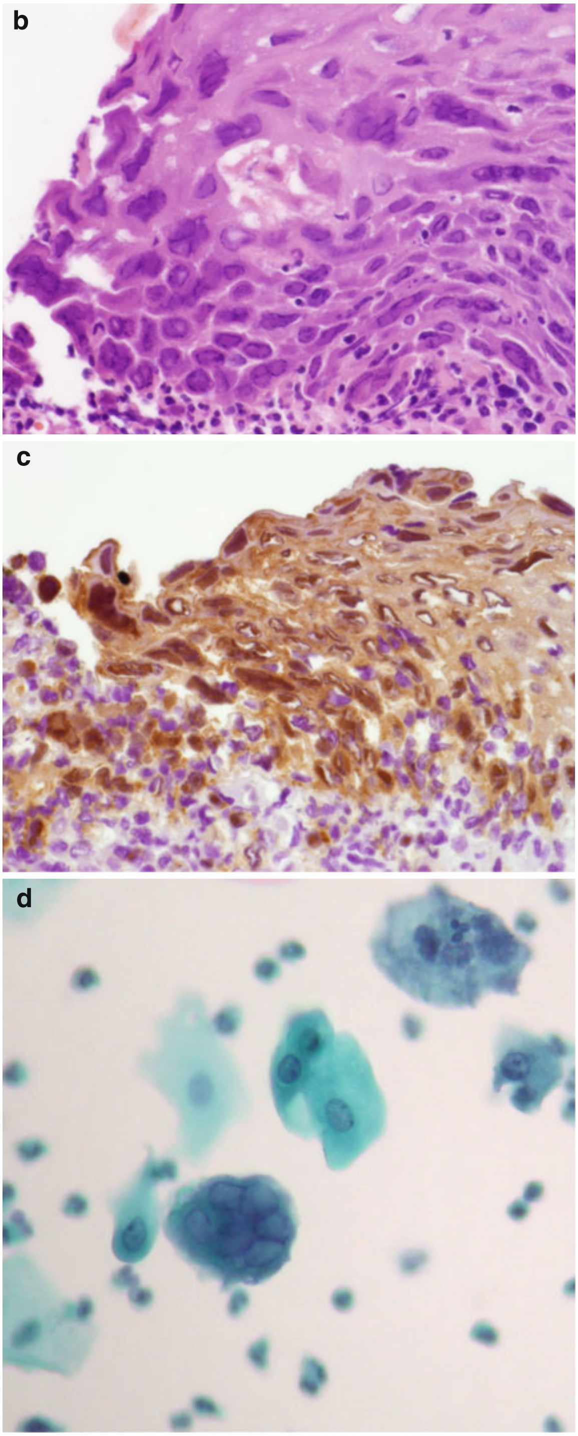


Fig. 2.25 (**a**) Herpes esophagitis (H & E, ×100). (**b**) Herpes esophagitis (H & E, ×400). Infected cells are enlarged, with nuclear molding, multinucleation, and margination of chromatin (the "three Ms" of herpesvirus infections). The nuclear membranes appear thickened because of the margination of chromatin. The nuclei have homogeneous, smooth chromatin, often referred to as having a "ground-glass" appearance. Some infected cells are mononuclear but still show ground-glass nuclei with chromatin margination. (**c**) Herpes esophagitis (immunohistochemical stain for HSV I and II, ×400). The infected cells show dark brown nuclear staining. Immunohistochemistry helps highlight the characteristic cells in cases with relatively few cells or those lacking morphologically classic cells. (**d**) Herpesvirus cytopathic effect in esophageal brushing (ThinPrep, Papanicolaou stain, ×400). Infected cells have a striking appearance in cytologic specimens, as seen in this esophageal brushing. The Papanicolaou stain demonstrates excellent nuclear detail. Note the prominent nuclear molding and fine homogeneous chromatin with margination

Fig. 2.25 (continued)



Squamous Papilloma

Exophytic squamous papilloma is characterized by papillary architecture, dilated vessels in the lamina propria, and elongation of the lamina propria papillae (Fig. 2.26) [11].

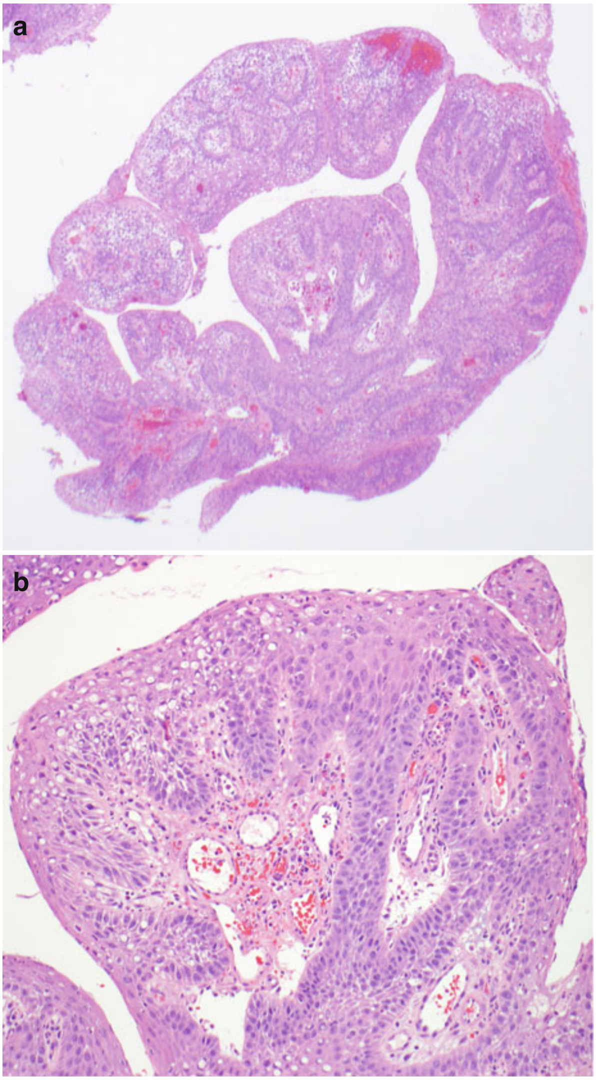


Fig. 2.26 Squamous papilloma. (**a**) H & E, ×20. (**b**) H & E, ×100. The squamous epithelial cells show reactive features including nuclear enlargement and hyperchromasia. Although many squamous papillomas are associated with HPV, diagnostic nuclear features are not seen in this example

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Chapter 3
Esophageal Anatomy as Seen During Endoscopy and Basic Endoscopic Orientation

Puja Gaur and Karen J. Dickinson

The art of surgical endoscopy has revolutionized the diagnosis and treatment of gastrointestinal disorders. Gastroenterologists and esophageal surgeons must familiarize themselves with the proper technique of examining a patient for upper gastrointestinal endoscopy.

Current endoscopic instrumentation includes a modern video high-definition endoscope, illustrated in Fig. 3.1. The video camera is connected to a control panel that can capture images, adjust lighting, and change views. At the terminal end of the insertion tube are an air or water nozzle, an objective lens, a biopsy and suction channel, and an illuminating lens. The biopsy channel allows the passage of biopsy forceps or instrumentation for cytologic testing as well as therapeutic maneuvers. The flexible end of the tube allows for atraumatic insertion, manipulation, and guidance within the esophageal lumen. A deflection control knob with a locking switch makes it possible to look up and down and right and left. Other parts of the system include an instrument port; suction, air, and water valves; suction, video, and water container connectors; and a universal cord that connects the handheld instrument to the processor.

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The newer versions of endoscopes are equipped with a tiny camera at the distal end of the instrument, which transmits the digitalized image to an external television monitor for viewing. Typically, most are high definition. Carbon dioxide can be insufflated to minimize air entrapment. Developments in this technology have added special lenses to the tip of the instrument for magnification, and diagnostic ultrasound has been adapted to the instrument to facilitate the elucidation of cardiac and gastrointestinal disorders.

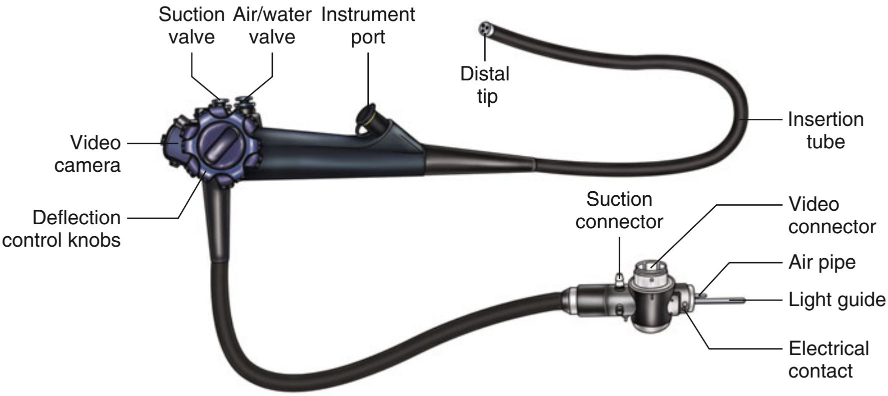


Fig. 3.1 The parts of a standard Olympus endoscope (Olympus America, Center Valley, PA)

Esophagogastroduodenoscopy (EGD)

Indications

There are several indications for EGD examination of the upper gastrointestinal (GI) tract:

- Investigations of symptoms such as dysphagia, odynophagia, persistent pyrosis, hematemesis, or melena
- Retrieval of a foreign body
- Evaluation of unremitting upper abdominal pain with a normal upper GI barium examination, or suspicious abnormalities identified on a barium upper GI series

Endoscopy Procedure

A patient being considered for any esophageal surgery should undergo endoscopic examination prior to their operation, to ensure that there have been no pathologic changes since the last endoscopy and to ensure that the tumor or abnormality is as described when the patient was initially referred. Additionally, a patient with a previous surgery should undergo surveillance endoscopy to evaluate the anastomosis for recurrence and the pylorus for patency; this endoscopy ideally should be performed by the surgeon who best understands the patient's reconstructed anatomy.

Preparing for the Endoscopy

The patient should not be fed for 6–8 h prior to an upper endoscopy. Antireflux medication may be administered prior to the exam. In an emergency, rapid-sequence intubation may protect the airway of a patient who has recently consumed a meal.

Technique

- The posterior pharynx is anesthetized with topical anesthetic spray or gargle, unless the procedure is being performed under general anesthesia.
- Intravenous sedation is administered slowly until the patient is comfortable. For more complicated endoscopic procedures, we advocate the use of general anesthesia and intubation to avoid aspiration.

- A patient who is intubated may be left in the supine position. Otherwise, with the patient in the left lateral decubitus position, the endoscope may be passed in one of two ways:
  - A mouth guard is positioned between the patient's teeth, and the scope is advanced under direct vision (Fig. 3.2). The epiglottis and vocal cords are visualized and the instrument is passed posteriorly into the esophageal orifice. This technique allows visualization of the hypopharynx and may be particularly useful in patients with suspected lesions high in the esophagus or pharynx, or in relatively uncooperative patients.
  - In an alternative method, the instrument is passed by feel of the operator. The endoscopist does not attempt to observe the lumen until the scope is in the esophagus. Observation of the upper pharynx and vocal cord are performed after removal of the scope. The index and middle fingers of the endoscopist are placed over the tongue to the posterior pharynx; the scope is then placed on top of the fingers and manipulated downward to the esophageal orifice. The guiding fingers ensure that the scope glides along the wall of the pharynx and is centered.

- As the patient swallows, the instrument is advanced into the esophagus. Undue force is never applied and the scope is advanced only when the lumen can be visualized, to avoid perforation of the pharynx. (Perforation of the pharynx most likely would involve the piriform sinus, and the result would be massive injection of subcutaneous air throughout the neck and mediastinum when the endoscope is insufflating the hypopharynx.)
- The esophagus is inflated with air and inspection is begun. The normal esophagus demonstrates a long, round, tubular lumen with a pale, smooth mucosa.
- Careful inspection of the mucosal surfaces is important to detect subtle irregularities that may herald underlying pathology. When an irregularity of the mucosa is encountered, a biopsy specimen and brushings can be obtained for cytologic examination, after ensuring (using the Doppler flow tool) that the abnormality is not a vascular structure. If there is concern about the structure and depth, then an ultrasound may be used to determine the characteristics of the lesion.
- At the most distal end of the normal esophagus, about 40 cm from the incisors, there is a sharp transition from the pale esophageal (squamous) mucosa to the deeper orange gastric (columnar) mucosa (Fig. 3.3a, b). This junction is called the Z-line and is usually somewhat irregular. An abnormal mucosal tongue of columnar mucosa is representative of Barrett's island, and biopsies must be performed to confirm metaplasia (Fig. 3.3c). Large extensions of gastric-type mucosa above this point may represent Barrett's esophagus (columnar metaplasia of the esophagus). A biopsy specimen should be obtained from such an area, as dysplasia and malignancy may arise within a Barrett's epithelium.
- The esophagus frequently veers slightly to the left as it traverses the diaphragm. The gastroscope should be advanced under direct vision into the stomach; it should never be advanced when a lumen cannot be identified.
- As the gastroscope is advanced into the stomach, the endoscopist must become oriented to the gastric anatomy. The lesser curvature of the stomach occupies the 12 o'clock position and the field of observation. The mucosa in this area is

usually smooth. Careful observation in the lesser curvature is warranted, as this is frequently the site of gastric ulceration or malignancy.

- The greater curvature occupies the 6 o'clock position. This area is characterized by prominent parallel rugae folds, which do not totally flatten with insufflation of air. The 9 o'clock position represents the anterior wall of the stomach, and the posterior wall is at the 3 o'clock position.
- As the instrument is advanced further into the body of the stomach, the gastric incisura, or angularis, becomes visible on the lesser curvature. The smooth, arching fold separates the body from the antrum of the stomach. Alteration of the smooth contour of this fold may indicate previous ulcer disease or an infiltrative process.
- Beyond the angularis lies the antrum of the stomach. The scope should be advanced into the antrum after careful observation of all the features of the gastric corpus. Typically, there are no rugal folds in this region. The pylorus lies at the distal extent of the antrum. It is worth waiting a moment after entering the antrum to watch the peristaltic waves pass the pylorus. The peristaltic activity is useful in unfolding all areas of the antrum for observation; and watching it also ensures that there is no infiltrative process limiting motility.
- Once positioned at the angle of the stomach, the tip of the endoscope may be turned to view the gastric cardia and fundus (Fig. 3.3d, e). This retroflexed view is useful in identifying and treating lesions of the proximal stomach and distal esophagus. It is useful to twist the insertion tube of the instrument into this position to bring the area surrounding the scope into view. Subtle lesions of the fundus and cardia are best identified in this manner, so this maneuver must be part of every endoscopic examination of the stomach.
- When examining a patient with esophageal cancer, one must ensure that the tumor does not extend into the gastric lumen. If cardia involvement is detected, the patient may not be able to have a gastric conduit and may instead require an alternate conduit such as colon or small bowel [1, 2].
- As the scope is advanced, the characteristics of the pylorus should be carefully observed. A normal pylorus is typically round and opens and closes in response to peristaltic activity (Fig. 3.3f). Irregularities in the shape of the pyloric aperture may suggest past or present ulcer disease. Lack of motility may indicate scarring or an infiltrative process.
- After passing the tip of the endoscope through the pylorus, the examiner should pause briefly to observe the duodenal bulb. Not infrequently, the scope may advance beyond the bulb after passing the pylorus; it should be pulled back so that the first portion of the duodenum can be carefully examined. The bulb has no folds. Its mucosa is usually smooth and fine. Submucosal vessels are often visible. Some granularity occasionally may be present as a result of ectopic gastric mucosa. Ulcers are the most common lesions identified in this area, although other lesions such as adenomas of Brunner's gland, heterotopic pancreas, and even malignancy occasionally may be identified. The distal extent of the duodenal bulb is marked by the first duodenal fold and the superior duodenal fold, which marks the posterior turn of the duodenal lumen into its second portion (Fig. 3.3g).

Once the surgeon has become familiar with basic endoscopic techniques, particular procedures that are performed through an endoscope may then be employed. Some of these endoscopic procedures are discussed in Chaps. 5 and 6.

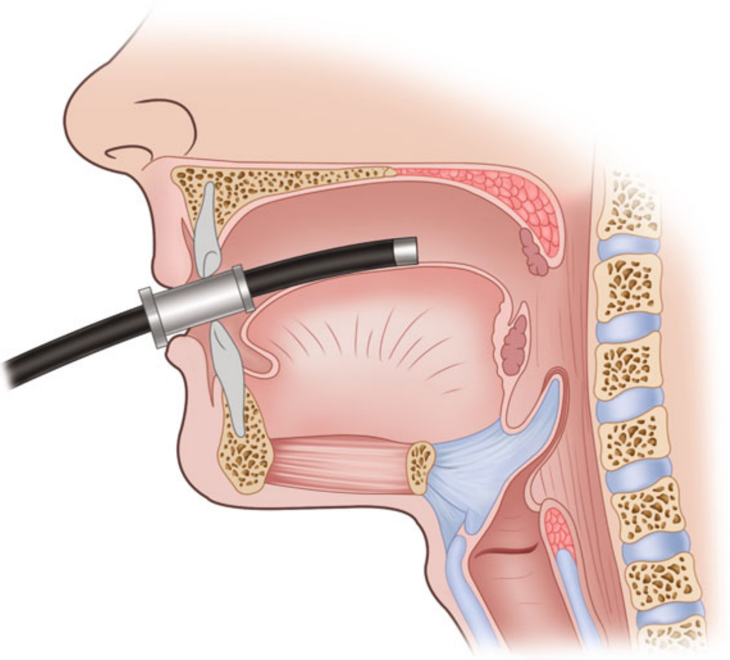
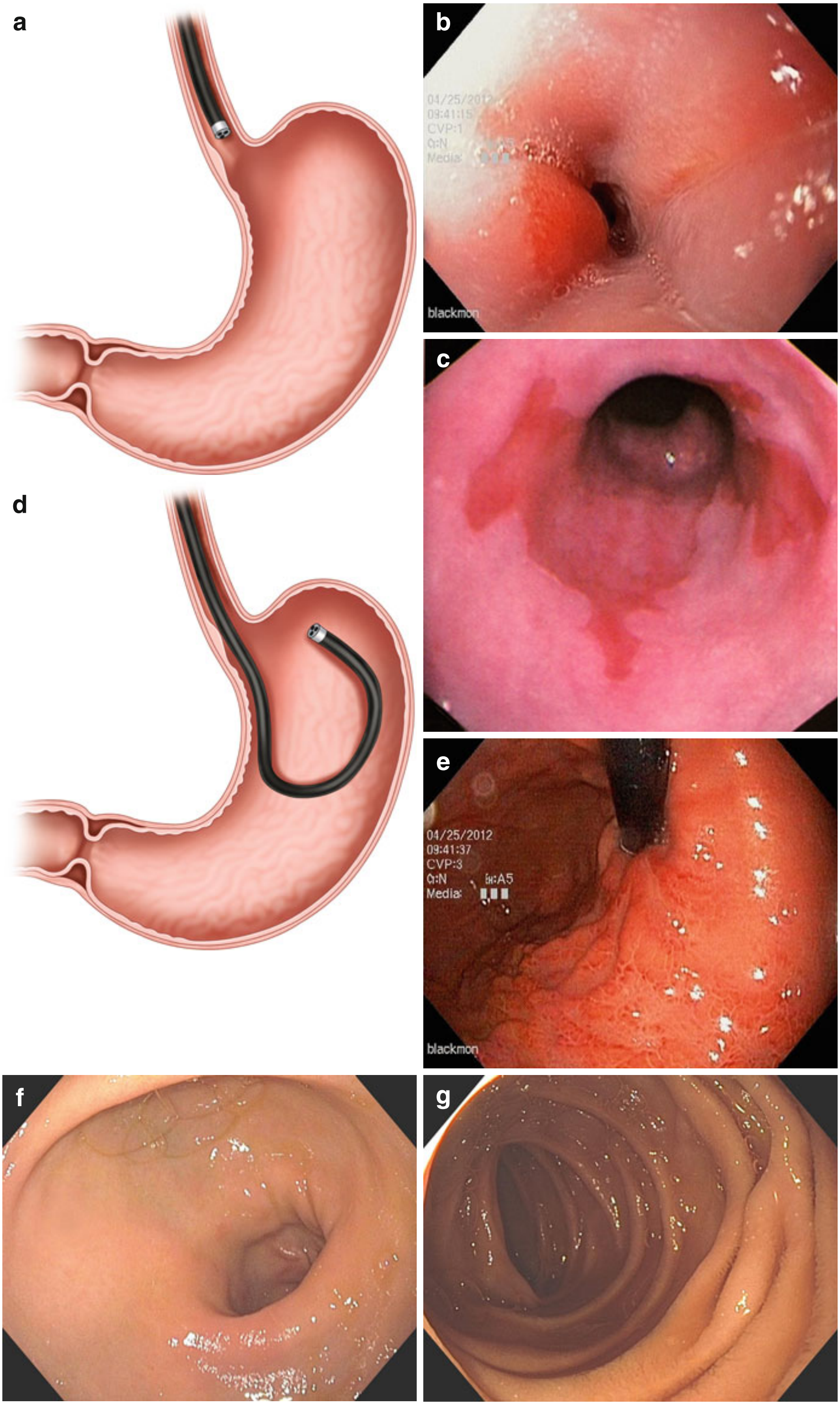


Fig. 3.2 A mouthguard is typically used for insertion of the endoscope, to avoid damage to the patient's dentition and the endoscope

Fig. 3.3 The gastroesophageal junction is easily identified where the squamous esophagus lining transitions over to the columnar gastric mucosa (**a**, **b**). When this Z-line undergoes metaplasia, biopsies must be performed to confirm Barrett's esophagus and rule out dysplasia (**c**). The gastroesophageal junction is visualized on retroview of the endoscope (**d**, **e**). The pyloric sphincter (**f**) and its intubation into the duodenum (**g**) must also be visualized and documented on every routine endoscopy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Endoscopic Imaging of Barrett's Esophagus

The importance of Barrett's esophagus is based on the recognition that it is often a precursor of esophageal adenocarcinoma. This histologic progression from metaplasia to low-grade dysplasia to high-grade dysplasia and then to adenocarcinoma is the rationale for endoscopic screening and surveillance programs. Current surveillance protocols call for periodic endoscopic exams for mucosal abnormalities and four-quadrant random biopsies every 2 cm within the segment of Barrett's esophagus (referred to as the Seattle protocol). The limitations of such protocols include sampling error (they sample less than 1 % of affected esophageal surface) and the effort and time required to perform each biopsy and place it into a separate cytologic cup at every level [3].

The development of endoscopic imaging modalities that identify intestinal metaplasia and facilitate differentiation of bland Barrett's epithelium from low-grade and high-grade dysplasia and early adenocarcinoma simultaneously has been the focus of intense research. The potential merit of such imaging modalities is the possibility of complete examination of a Barrett's esophagus segment for dysplasia without the need for biopsy or with the ability to perform focused biopsies in areas most likely to contain dysplastic epithelium. A number of endoscopic imaging methods have been developed for this purpose over the past several decades. The rest of this section focuses on the basis for each method and the technique, interpretation, and evidence for these imaging modalities.

One of the difficulties in identifying dysplastic foci and Barrett's esophagus is the large esophageal surface area that must be examined. In general, it is difficult to apply imaging methods with high resolution, which provide greater tissue detail or histologic information, when it is necessary to scan a large segment of Barrett's esophagus. Lower-resolution methods can be used to image a larger area of esophagus, but they are less reliable in distinguishing dysplasia from nondysplasia.

An ideal imaging technique would have several characteristics [4]:

- High sensitivity for dysplasia
- Moderate specificity not affected by inflammation
- The ability to scan a wide area in real time
- High interim server agreement
- The ability to localize dysplastic areas for biopsy
- Cost that is not prohibitive

Techniques that can assist an endoscopist in identifying suspicious areas within the esophagus include (but are not limited to) chromoendoscopy, narrow band imaging, autofluorescence, optical coherence tomography, endoscopic ultrasound, and confocal microscopy, as discussed below.

Chromoendoscopy

Chromoendoscopy refers to the application of contrast stains to mucosa at endoscopy, so that surface patterns are highlighted [5–7]. The use of various contrast agents such as methylene blue, acetic acid, Lugol solution, and indigo carmine has been described extensively in the literature.

- Methylene blue is absorbed by intestinal-type epithelium. In the setting of Barrett's esophagus, Barrett's epithelium is stained, and nonintestinal columnar and squamous epithelium is spared. Furthermore, dysplastic Barrett's epithelium stains less than Barrett's epithelium without dysplasia because of the paucity of goblet cells in the setting of dysplasia. Therefore, areas of Barrett's epithelium with dysplasia may be more evident on chromoendoscopy using methylene blue. The technique of chromoendoscopy using methylene blue involves clearance of surface mucous in the esophagus by flushing with 10 % N-acetylcysteine (Mucomyst). Subsequently, 0.5 % methylene blue is applied to the esophageal mucosa using an endoscopic spray catheter. After a 2-min standing period, excess methylene blue is cleared by flushing with sterile water.
- Indigo carmine, unlike methylene blue, is simply a contrast agent that accentuates mucosal surface patterns. Indigo carmine is applied during endoscopy using a typical endoscopic spray catheter after the surface has been cleared of mucous with water saline or Mucomyst flush. The use of a cap fitted at the endoscopic tip has been described to stabilize high-magnification images in image areas of interest. A ridged or villous pattern with a cribriform appearance, or a circular pattern with a uniform circular or oval appearance, is typically seen in nondysplastic Barrett's esophagus and in low-grade dysplasia. In high-grade dysplasia, on the other hand, the pattern seen is irregular and distorted.

Narrow Band Imaging

Conventional video endoscope transmits a white light from a xenon lamp, but in narrow band imaging (NBI), the light passes through a special, rotating red-green-blue filter that has been incorporated into the endoscope. The transmitted light, composed of alternating pulses of red, green, and blue light, illuminates the imaged area. Waves are absorbed or reflected by the image area and are detected by a charge-coupled device (CCD) at the endoscope tip. The light waves detected by the CCD are transmitted to the video processor unit, where superimposed red, green, and blue light images are integrated to create a final video endoscopic image that is can be seen by the human eye.

- In NBI, an additional special filter has been incorporated into the endoscope
- The light is preferentially absorbed by hemoglobin, so hemoglobin-containing structures such as capillaries and luminal blood are accentuated in the presence of blue light (Fig. 3.4a).
- The red light, on the other hand, has a wavelength of 650 nm and penetrates tissue more deeply than blue light, with a wavelength of 475 nm.
- Three distinct mucosal patterns in patients with Barrett's esophagus can be identified on NBI: the ridged/villous pattern, the circular pattern, and the irregular, distorted pattern (Fig. 3.4b, c). The ridged/villous pattern is characterized by

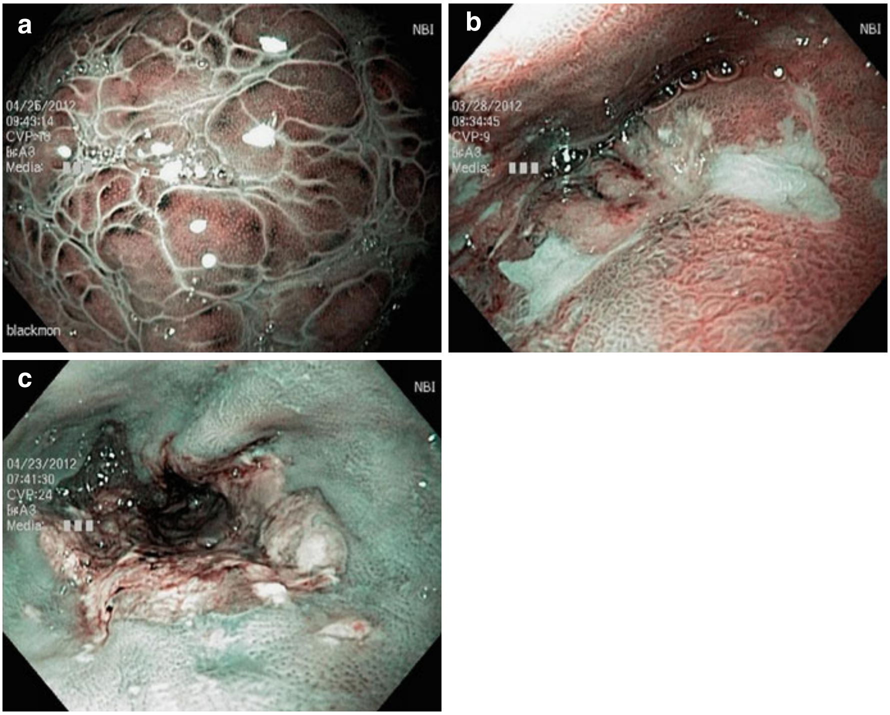

Fig. 3.4 Narrow band imaging (NBI) endoscopic images. (**a**) The narrow esophageal mucosa demonstrates the fine vascular network in NBI mode. (**b**, **c**) Abnormal mucosa is seen as white patches

uniformly aligned ridges alternating with a villiform pattern. This pattern is seen on NBI as alternating dark and white lines. The circular pattern is characterized by a uniformly arranged, circular mucosal pattern. The irregular, distorted pattern demonstrates the ridged and villous pattern with significant irregularity and distortion, suggestive of an inflammatory or malignant change.

- Vascular patterns on NBI are characterized as normal (thin, uniformly branching vessels) or abnormal (dilated, corkscrew vessels and nonuniform branching patterns).
- The positive predictive value, sensitivity, and specificity of NBI for an abnormal vascular pattern and high-grade dysplasia is relatively high. False positives for abnormal vascular pattern do occur, but the rate is low.

Autofluorescence Imaging

In autofluorescence, certain molecules, termed fluorophores, absorb light energy and reach an excited state. From the excited state, fluorophores reach the ground state, and in that process, they emit light of a longer wavelength than produced in the excited state. Emitted light within the visible light spectrum accounts for the obstacle phenomenon of fluorescence.

The use of fluorescence for imaging may be based on endogenous fluorophores such as nicotinamide adenine dinucleotide (NADH) or collagen, or on the use of exogenously supplied fluorophores such as porfimer sodium or fluorescein, a fluorescent dye. Autofluorescence is the term denoting the exploitation of endogenous fluorophores and biological tissue for imaging. Variations in molecular composition and tissue microstructure lead to differences in fluorescence, thereby creating the potential for distinguishing neoplastic tissue from nonneoplastic tissue. Prototypic endoscopes that make use of this technology have been developed in recent years. The additional use of confocal microscopy including the injection of fluorescein can allow endoscopists to identify areas of dysplastic Barrett's epithelium and target these areas for focused biopsy, but the role of this technique has been questioned [8].

Confocal Microscopy

Confocal microscopy is an optical imaging technique used to increase the optical resolution and contrast of a micrograft by using point elimination and a special pinhole to eliminate out-of-focus light and specimens that are thicker than the focal plane. It enables the reconstruction of three-dimensional structures from the obtained images. This technique has gained popularity and is now commonly used in some Barrett's screening programs. A compilation of several scanned images can be made to provide a larger photograph of the dysplastic epithelium, which represents a map larger than that of the tip of the confocal microscope [9].

Optical Coherence Tomography

Optical coherence tomography (OCT) is a method of producing high-resolution, cross-sectional imaging of the esophagus. It is similar to ultrasound but uses light to produce the images, rather than sound waves. Real-time images of the esophagus can be obtained during endoscopy. Its particular use in the setting of esophageal pathology is in the surveillance of Barrett's esophagus [10–12]. The planar images created can allow detection of "buried" Barrett's epithelium that may otherwise be missed on routine EGD. This technology may be useful in the surveillance of Barrett's after treatment such as radiofrequency ablation.

Endoscopic Ultrasound

This technique will be discussed further in Chaps. 5 and 6.

Endoscopic Abnormalities

Any mucosal ulceration or mass noted in the esophageal or gastric lumen during endoscopy can be cultured, biopsied, or both. A number of abnormalities may be seen:

- Typically, a dysplastic lesion will present as linear erosions, irregular mucosa, or small nodularities (Fig. 3.5a).
- If the mass is noted to involve the esophageal wall (Fig. 3.5b), then a primary tumor is most likely the diagnosis; an ultrasound of the lesion is warranted to determine its depth and associated lymphadenopathy (*see* Chap. 5).
- A finding on endoscopy of a classic ringed esophagus, sometimes termed "trachealization of the esophagus" (Fig. 3.6), can be diagnostic of eosinophilic esophagitis. This diagnosis typically cannot be made from any other, noninvasive imaging. The endoscopy also can be used to obtain a definitive diagnosis by allowing the performance of an esophageal biopsy.
- Another uncommon clinical entity that can be visualized on endoscopy is "black esophagus," which usually has an ischemic etiology.
- Various fungal infections such as esophageal candidiasis can be seen as linear growths in immunocompromised patients such as those undergoing neoadjuvant chemotherapy prior to surgical resection.
- Patients presenting with dysphagia can be worked up for a Schatzki's ring (Fig. 3.7a), benign (Fig. 3.7b) or malignant stricture, epiphrenic or Zenker's diverticulum, or to identify classic radiological features of achalasia such as megaesophagus or bird's beak esophagus.
- Although diffuse esophageal spasm and scleroderma are connective tissue disorders and are slightly difficult to diagnose on endoscopy, characteristics such as tertiary contractions can be noted on endoscopy (Fig. 3.8).

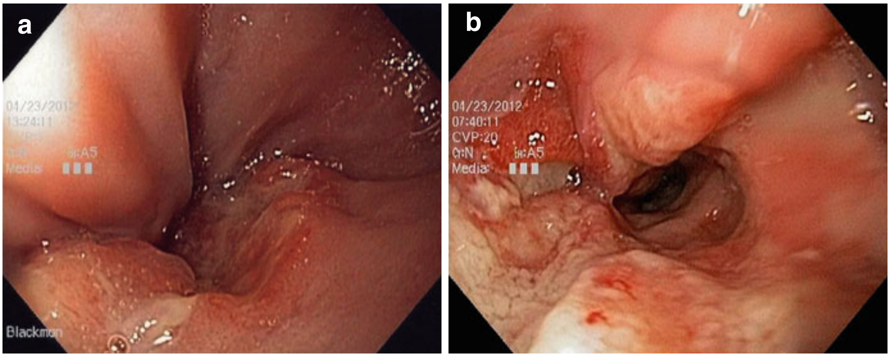

Fig. 3.5 Esophageal cancer can be identified as small, abnormal nodularities (**a**) or a discrete mass (**b**)

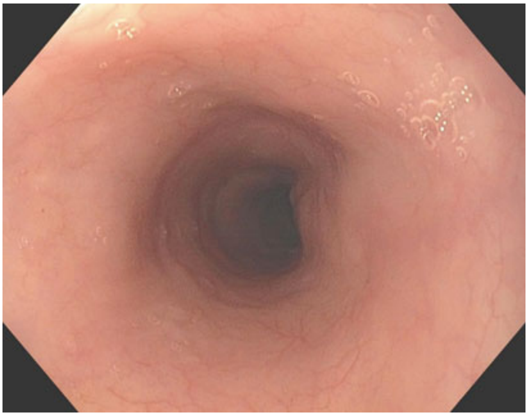

Fig. 3.6 Eosinophilic esophagitis can be seen on endoscopy as ringed esophagus (trachealization). A biopsy of the mucosa would determine infiltration of the esophagus with eosinophils

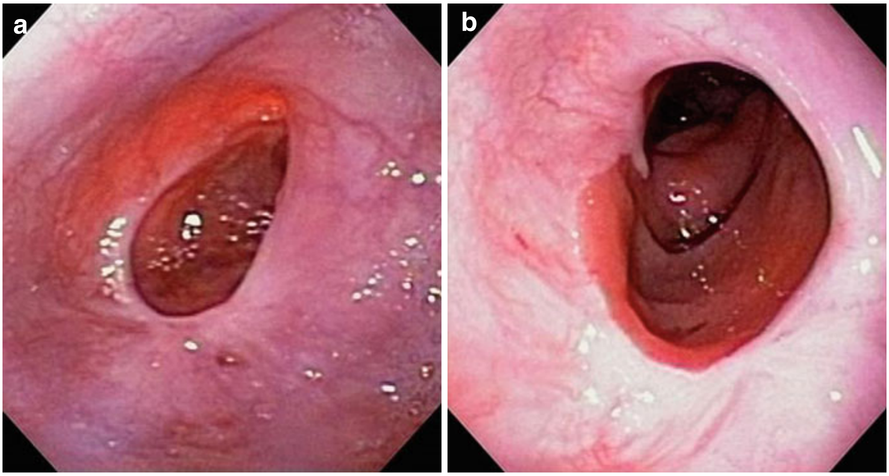

Fig. 3.7 Other diagnoses that can be identified on endoscopy include Schatzki's ring (**a**) or stricture (**b**)

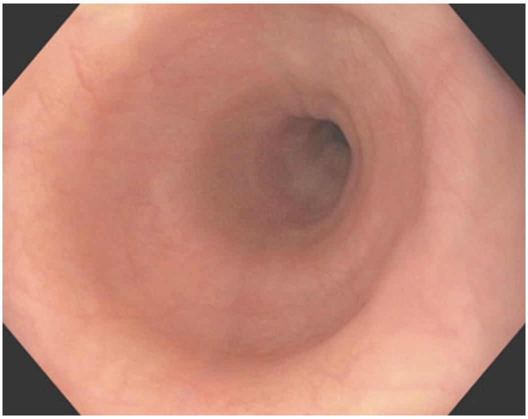

Fig. 3.8 Tertiary contractions noted on endoscopy in a patient with dysphagia can be suggestive of diffuse esophageal spasm (DES) or scleroderma. Esophageal manometry can be used to confirm the diagnosis

Complications of Endoscopy

Endoscopy does have pitfalls that require care.

- Perforation may occur if the endoscope is advanced blindly into a pouch or the sidewall of the esophagus, especially in a previously radiated tumor bed (Fig. 3.9).
- In patients with esophageal or gastric varices, extreme caution must be used to avoid pushing the endoscopic probe too vigorously. One approach to these patients would be to decompress their portal hypertension before proceeding to elective endoscopy. The endoscopist should be familiar with a Sengstaken-Blakemore tube and be prepared to tamponade the bleeding with it if necessary.

Fig. 3.9 Complications of endoscopy can include iatrogenic perforation. This image demonstrates a chronic iatrogenic perforation secondary to endoscopy

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Chapter 4
Radiographic Anatomy

Karen J. Dickinson and Shanda H. Blackmon

Imaging of the esophagus is best approached in a multidisciplinary fashion. The surgeon and radiologist bring different attributes to the interpretation of the images, and a dialogue between all members of the team caring for the patient is essential. Preoperative discussion of a patient's images can allow appropriate staging of any tumor and allow selection of the most appropriate neoadjuvant therapy and operative approach. Further discussion regarding postoperative anatomy is essential for accurate interpretation of the images; it is especially important for those patients in whom a complication such as an anastomotic leak or obstruction is encountered. This chapter focuses on imaging the esophagus using a variety of techniques to image benign and malignant pathology. The upper gastrointestinal (GI) contrast swallow examination, plain x-ray, CT imaging, MR imaging, and positron emission tomography (PET) imaging are reviewed (Figs. 4.1–4.21). Ultrasound imaging of the esophagus is reviewed in Chap. 5.

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Upper Gastrointestinal Contrast Swallow Examination

Barium swallow, esophagram, or upper GI study involves the patient swallowing a contrast agent to identify structural and functional abnormalities of the esophagus. In the postoperative setting, if a leak is suspected, the test will start with a water-soluble agent like iohexol (Omnipaque™) or diatrizoic acid (Gastrografin®); if no leak is detected, barium may be used. The ordering practitioner should be aware of the densities of materials used for upper GI studies. Barium will preclude good imaging if a CT scan of the chest to view the esophagus is required later or if a leak is present, as extravasation of the barium remains within the leak. Adequate CT images cannot be obtained until enough time has passed for the contrast to leave the esophagus or the cavity formed by the leak, so it is common to image first with a CT scan and later with a swallow if a leak is suspected. Gastrografin pneumonitis and pneumonia can be fatal, and many institutions have changed to using vascular contrast agents like Omnipaque or iodixanol (Visipaque™). Omnipaque dissolves quickly after extravasation, is less caustic if aspirated, and is less expensive than Visipaque, which was originally developed for patients with renal failure. Barium remains the gold standard for imaging subtle mucosal changes and anatomic abnormalities of the esophagus. The individual images that are recorded during these swallow examinations are only a representative selection of the study obtained, however. It is best for the surgeon to attend the examination and watch the real-time pictures of the study, to correlate his or her understanding of the postoperative anatomy with the images obtained.

Thick barium (high density and high viscosity) and thin barium (lower density, low viscosity) may be used for examinations. Thick barium is useful when evaluating for aspiration during a modified barium swallow evaluation performed by a radiologist and speech pathologist. Other densities of food (e.g., applesauce, marshmallows, or pudding) may also be mixed with barium to assess swallowing with different textures. In the outpatient setting, barium swallows may be used to assess strictures (benign or malignant) in patients with dysphagia. A barium tablet also may be swallowed to see if there is any delay in passage through the esophagus, indicating a stricture.

CT Scans

CT images of the esophagus are usually obtained in order to assess esophageal perforation and local contamination and for the staging of esophageal tumors. For tumor staging, CT will not reliably determine T stage, but it sometimes can help to determine whether there is a fat plane between the esophageal lesion and local structures. If there is doubt with regard to invasion of local structures, endoscopic ultrasound (EUS), intravascular ultrasound (IVUS), and MRI may help to differentiate which lesions are growing into the aorta, lung, mediastinal structures, or other great vessels. CT images are also important for determining evidence of metastatic spread. If esophageal perforation has occurred, pneumomediastinum, free fluid or fluid collections, and a left pleural effusion may commonly be seen on CT scans.

When evaluating the esophagus using CT scanning, if no lumen can be seen, half of the maximum thickness of the esophagus is a surrogate for the diameter of the esophagus. More recently, three-dimensional CT models can be printed from two-dimensional CT images, and with the administration of an oral effervescent agent, the esophagus can be distended and relationships to other mediastinal structures can be accurately delineated. A positive enteric contrast agent is given to the patient prior to administration of effervescent granules. Positive contrast agents used in our practice include an iso-osmotic iodinated agent diluted with water for postoperative patients (Omnipaque 300; GE Healthcare, Cork, Ireland; 15 mL added to a 500-mL bottle of water) or barium sulfate suspension for preoperative patients (Berry Smoothie Readi-Cat two barium sulfate suspension 2.1 % w/v; E-Z-EM Inc., Lake Success, NY). The patient is then given a packet of effervescent granules containing sodium bicarbonate (E-Z-GAS II; E-Z-EM Inc., Lake Success, NY) to release carbon dioxide within the esophagus. The effervescent granules are mixed with approximately 20 mL of water and swallowed, or injected via a tube if the patient cannot swallow. After the patient is placed in the decubitus position on the scanner table, several more swallows or injections of positive enteric contrast agent are given to fill a redundant or patulous esophagus. Images are generally acquired in two positions using automatic exposure control (AEC) to ensure similar image noise across the acquired volume. Standard low-dose techniques such as kV selection, AEC, and iterative reconstruction are used to create high contrast differences between the esophageal wall, air, periesophageal fat, and positive enteric contrast. Routine multiplanar images used for diagnostic purposes are obtained. From these data, additional thin (1-mm) images are reconstructed in order to minimize stair-step artifacts in 3D printing. The imaging data, stored in Digital Imaging and Communication in Medicine (DICOM) format, is imported into proprietary software (Materialise, Belgium). The imaging data are then segmented using Hounsfield units (as well as hand segmented) to provide greater accuracy of the critical structures involved. (Hounsfield units are an indicator of radiodensity on CT scanning [air, −1000; water, 0; blood, 30–40; soft tissue, 100–300] and may help to determine if duplication cysts near the esophagus are hemorrhagic or are filled with thin fluid.) The segmented data are converted into a virtual 3D anatomic model, which is then exported into an STL (STereoLithography) file format. The final STL file is reimported into the source imaging data to ensure that its outline accurately matches what was initially segmented. The STL files are imported into Mimics software (Materialise, Belgium) for printing (Objet350 Connex multi-material 3D printer; Stratasys, Rehovot, Israel). Using the 3D printing software, different colors are assigned to the various anatomic structures, and several materials, both rigid and flexible, are selected. Life-size models are then printed using liquid photopolymers on the polyjet 3D printer. The material is printed with surrounding support material, which is washed off after the model is created. These life-size anatomic models can be used for multidisciplinary preoperative discussions, surgical planning, and as part of the patient education and consent process.

PET Imaging

PET imaging in patients with esophageal disease is used primarily for staging esophageal cancer. PET scanning utilizes fluorodeoxyglucose (FDG) to determine the metabolic activity, expressed in standardized uptake value (SUV) of tissues. It is important to note that disease smaller than 8 mm typically is not detected by PET scanning. Additionally, other pathology such as reflux can cause mild PET activity in the lower esophagus, and mucin-producing tumors typically are not FDG-avid. EUS is better for staging local disease. Invasion into the thoracic aorta is not imaged well with PET, which can show false positives. Diffusion-weighted MRI may be superior to PET when evaluating patients after neoadjuvant therapy. PET is good at detecting synchronous primary lesions, however—especially unsuspected metastasis outside the esophagus.

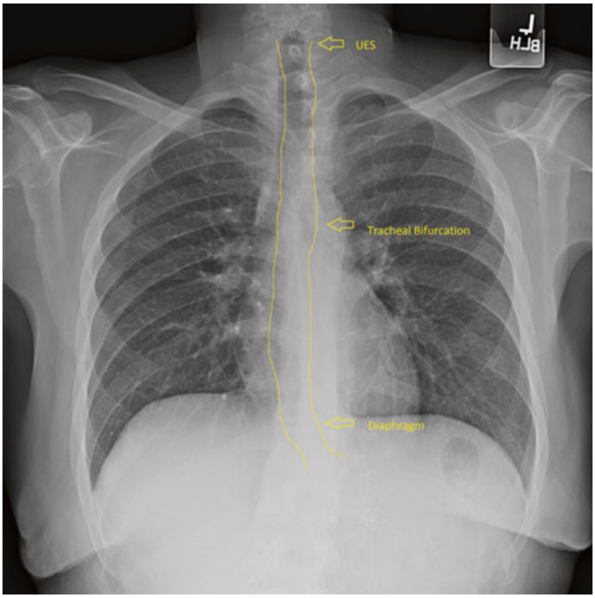


Fig. 4.1 Normal esophageal images seen on plain film. In this normal chest x-ray, the esophagus has been highlighted for better identification. The esophagus extends from C6 to T10 and is approximately 25–30 cm long. Cephalad, the esophagus is posterior to the trachea and subsequently is posterior to the left atrium. The esophagus deviates to the left of the midline caudad to the left mainstem bronchus. UES—upper esophageal sphincter

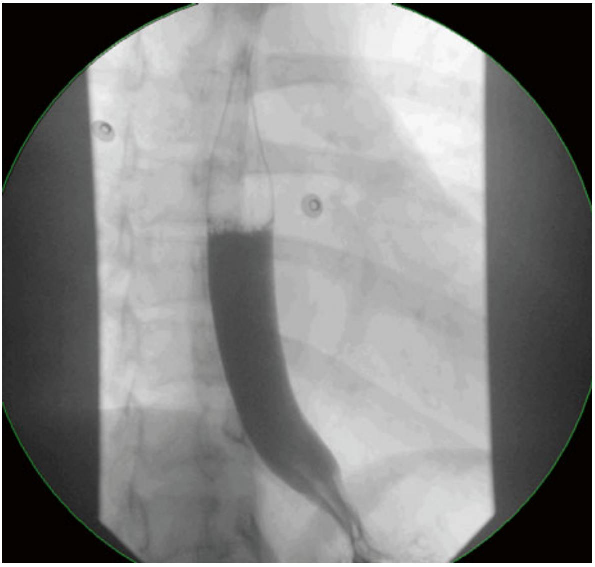


Fig. 4.2 Normal esophagram; the upper esophagus begins just below the larynx progressing through the upper esophagus, enters the thoracic inlet, passes behind the trachea, traverses the diaphragm anterior to the aorta, and enters the stomach in the abdomen

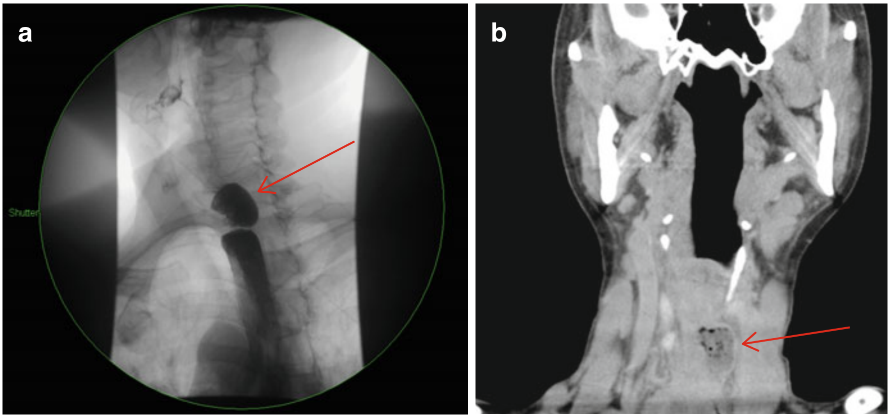


Fig. 4.3 Upper esophageal (Zenker's) diverticulum, often caused by a hypertonic cricopharyngeus muscle. (**a**) Contrast esophagram. (**b**) CT scan. *Arrows* denote the diverticulum

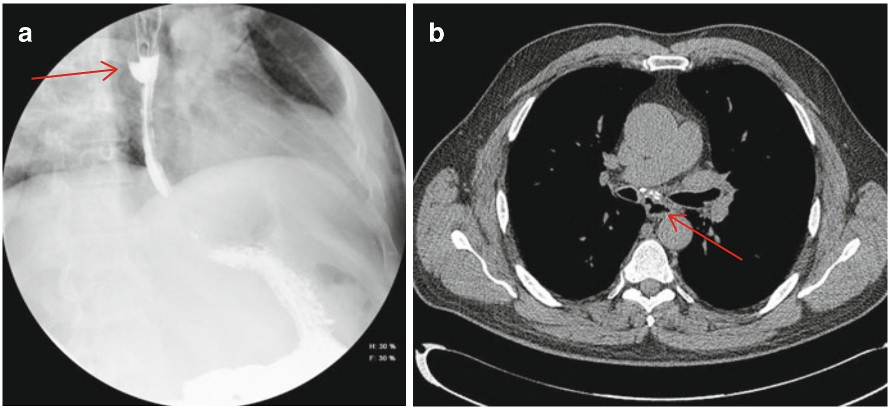


Fig. 4.4 Midesophageal diverticulum, often caused by traction from tuberculosis or an inflamed lymph node. (**a**) Contrast esophagram. (**b**) CT scan. *Arrows* denote the traction diverticulum

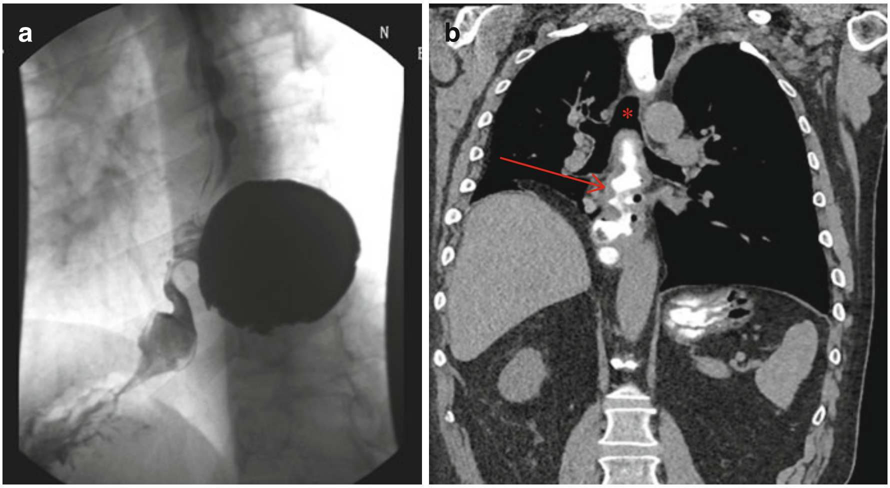


Fig. 4.5 Lower esophageal diverticulum, often caused by pulsion from a wall defect and a hypertonic lower esophageal sphincter. (**a**) Contrast esophagram. (**b**) CT scan of a complex multi-site lower esophageal diverticular disease extending from the carina to the diaphragm. * denotes trachea and *arrow* shows the esophagus with multiple diverticula

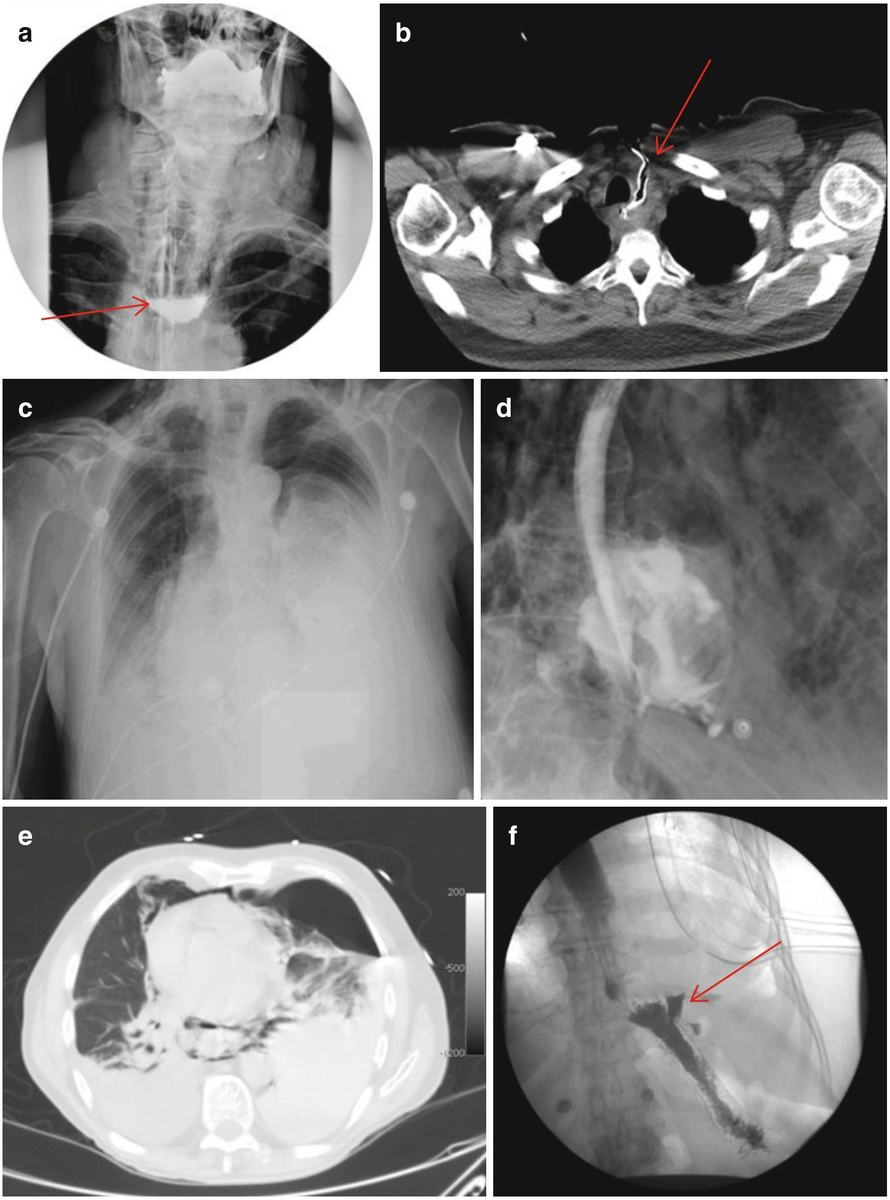


Fig. 4.6 Esophageal leaks: (**a**) Esophageal leak in the neck: contrast esophagram. *Arrow* denotes the pooling of contrast extra-luminally from cervical esophageal perforation; (**b**) Esophageal leak in the neck: CT scan. *Arrow* denotes extra-luminal contrast leaking from the esophagus. (**c**) Esophageal leakage in the chest: chest radiograph; (**d**) Esophageal leak in the chest: contrast esophagram; (**e**) Esophageal leak in the chest: CT scan. (**f**) Esophageal leakage in the abdomen above a deployed esophageal stent, demonstrated on a contrast esophagram. *Arrow* denotes leakage of contrast from proximal aspect of esophageal stent. This is a type I leak. Stephens et al. [1]

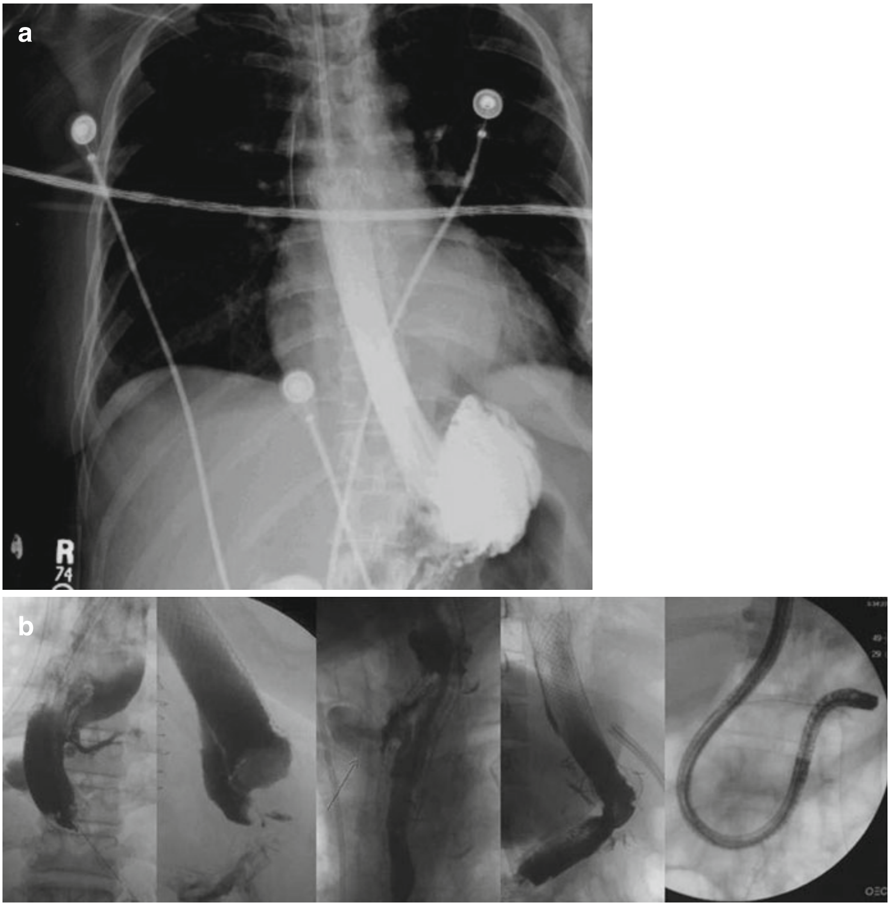


Fig. 4.7 (**a**) Esophageal stent deployed to seal a leak that was located at the gastro-esophageal junction. (**b**) Persistent esophageal leakage after esophageal stenting using a leak classification system (*left to right*): Type I (proximal leak), Type II (distal leak), Type III (leak in the stent lining), Type IV (leak between the stents), Type V (leak from a migrated stent) (Reprinted from Stephens et al. [1]; with permission from Elsevier)

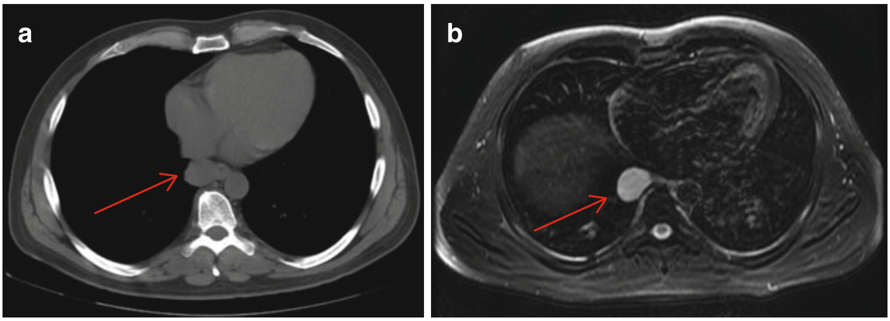


Fig. 4.8 Esophageal duplications cyst. (**a**) CT scan; (**b**) MRI. The *arrows* denote the position of the cyst

Fig. 4.9 Contrast esophagram demonstrating a distal esophageal malignant stricture

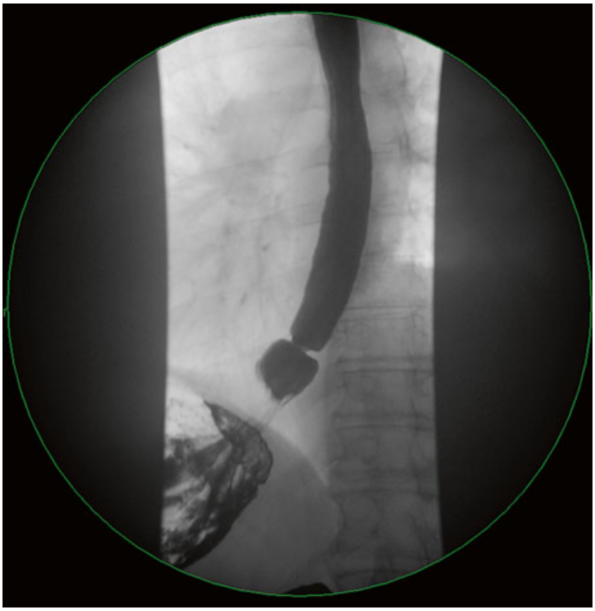


Fig. 4.10 Contrast esophagram demonstrating an esophageal web

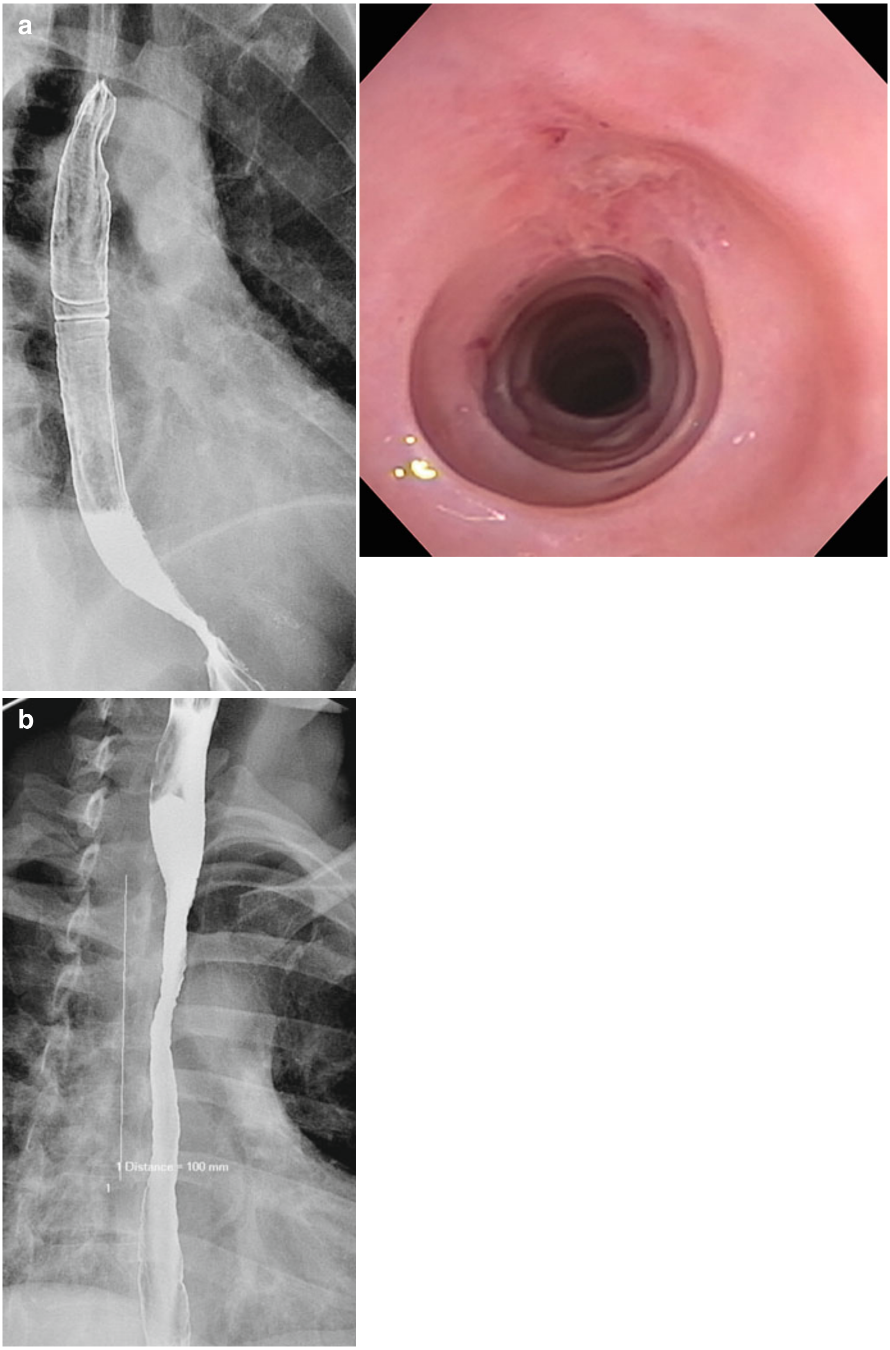
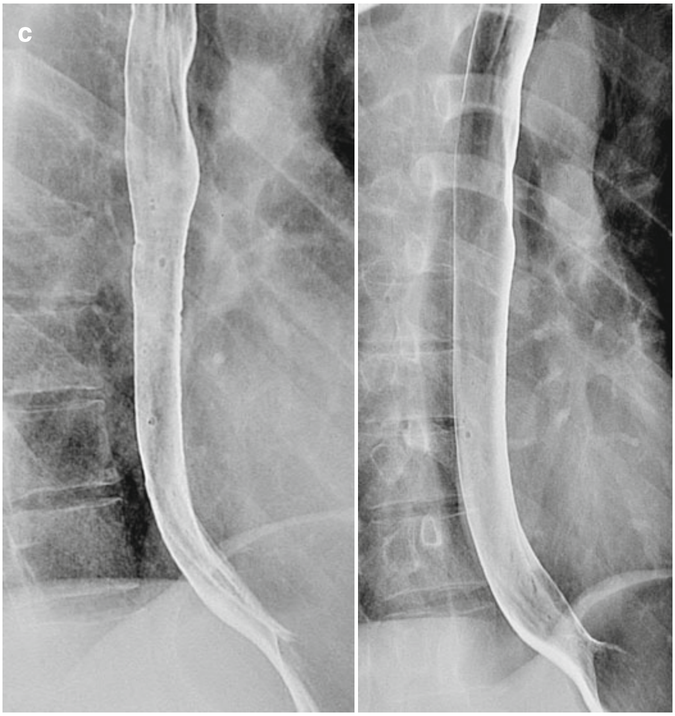


Fig. 4.11 (**a**) Contrast esophagram (*left*) and upper gastrointestinal endoscopy (*right*) demonstrating ringed esophagus seen in a patient with eosinophilic esophagitis. (**b**) Contrast esophagram demonstrating a long stricture in a patient with eosinophilic esophagitis and dysphagia. (**c**) Constrast esophagram from a patient with eosinophilic esophagitis demonstrating esophageal rings (*left*) and appearances following proton pump inhibitor treatment (*right*)



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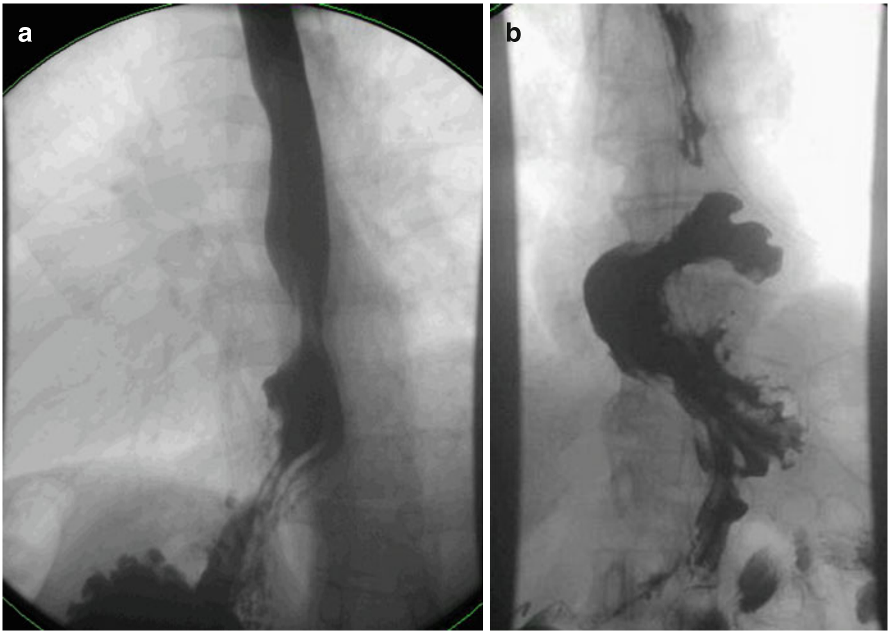
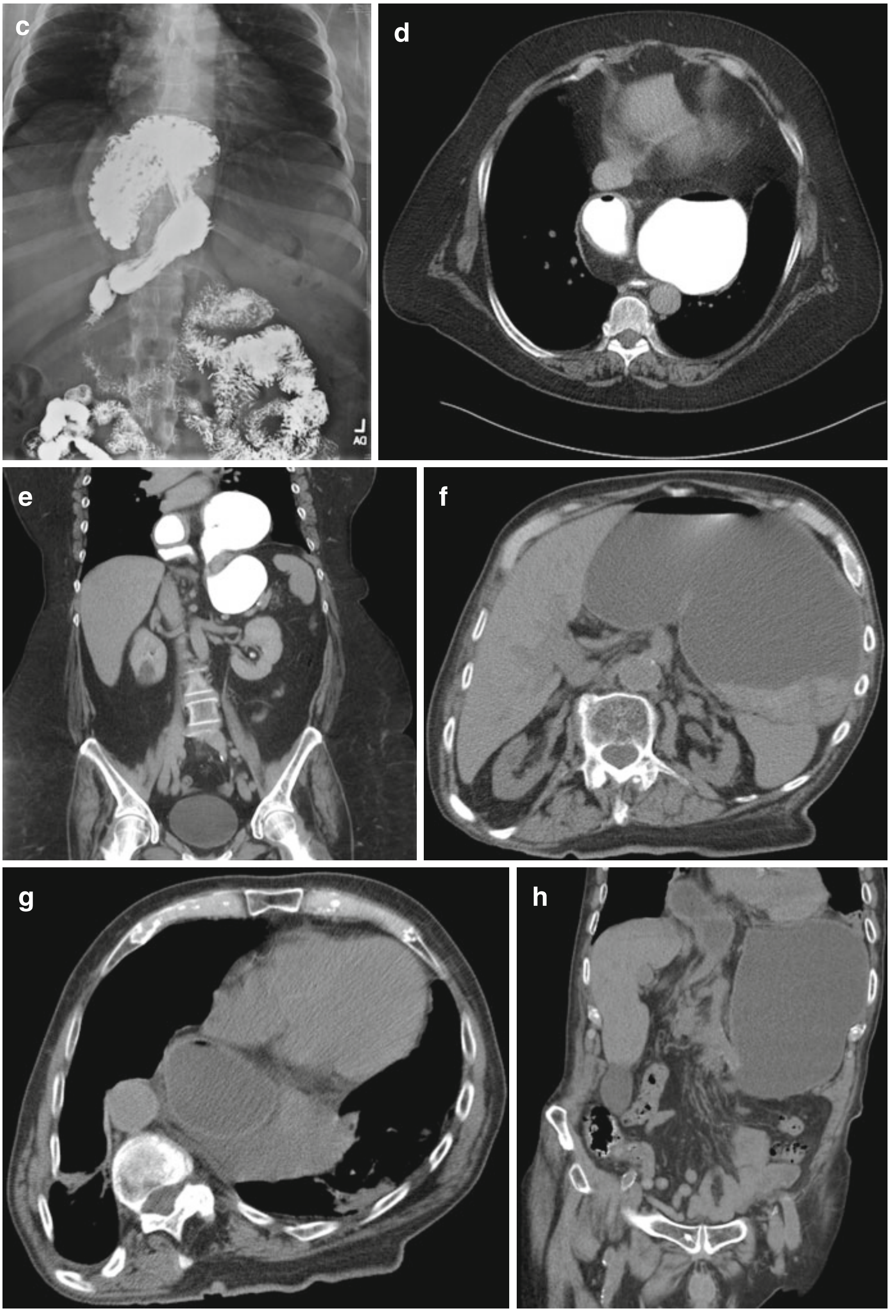


Fig. 4.12 Paraesophageal hernias (type I–IV). (**a**) Type 1. (**b**) Type II. (**c**) Type III: contrast esophagram; (**d**) Type III: CT in axial section demonstrating a type III hernia with organoaxial volvulus; (**e**) CT scan of the same patient with organoaxial volvulus in coronal section. (**f**) Type IV: axial CT scan showing a dilated stomach in a man with a type IV hernia causing gastric outlet obstruction secondary to the hernia containing duodenum; (**g**) Axial CT of the same patient demonstrating intrathoracic duodenum; (**h**) Coronal CT image from the same patient demonstrating the type IV paraesophageal hernia



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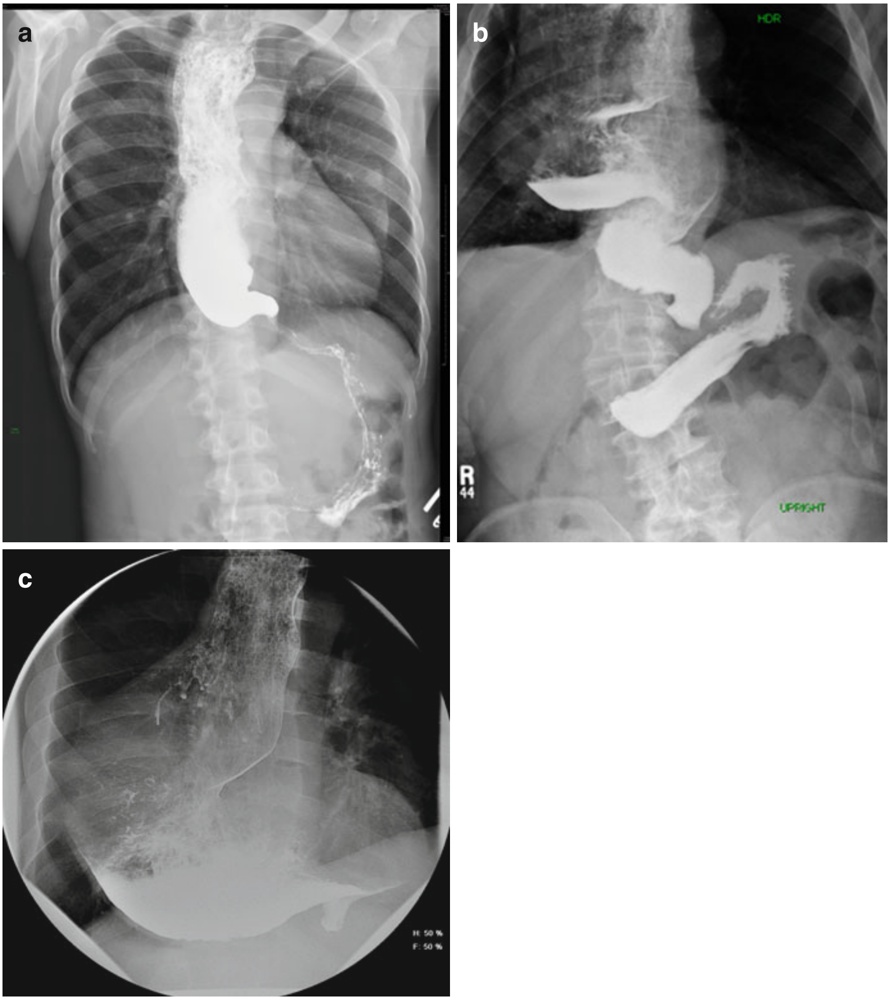

Fig. 4.13 Achalasia of the esophagus. (**a**) Contrast esophagram showing achalasia. (**b**) Contrast esophagram with sigmoid achalasia. (**c**) Contrast esophagram of achalasia with megaesophagus

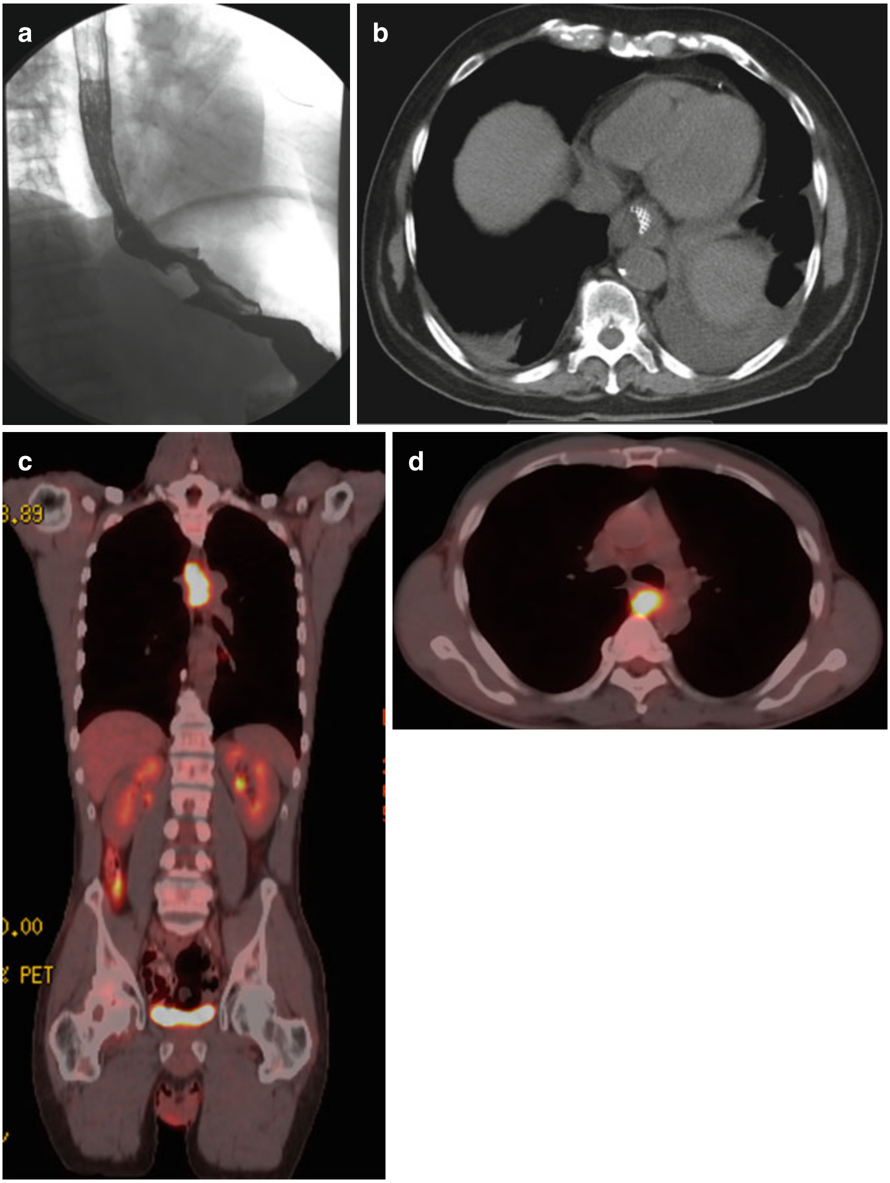

Fig. 4.14 Esophageal cancer. (**a**) Esophagram demonstrating a distal esophageal carcinoma. (**b**) CT scan demonstrating aortic invasion by an esophageal carcinoma that has been stented. PET-CT imaging demonstrating a squamous esophageal cancer: coronal view (**c**); axial view (**d**)

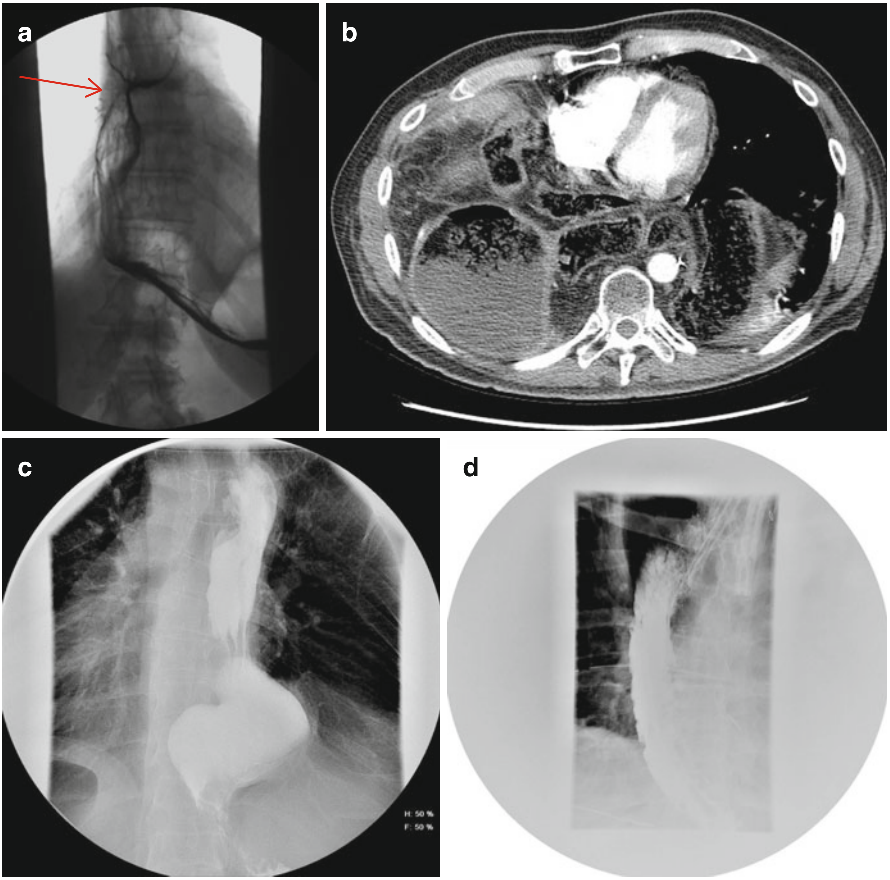

Fig. 4.15 Images seen after esophagectomy. (**a**) Esophagram of anastomotic stricture after Ivor Lewis esophagectomy. *Arrow* denotes the stricture. (**b**) Axial CT scan showing diaphragmatic hernia after Ivor Lewis esophagectomy. (**c**) Postoperative conduit dilatation after Ivor Lewis esophagectomy. (**d**) Esophagectomy with the anastomosis in the chest

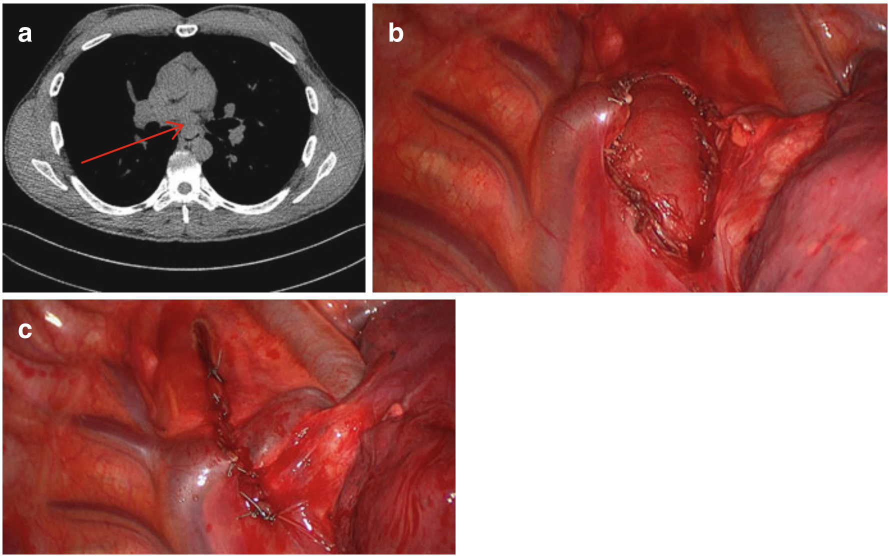

Fig. 4.16 Esophageal leiomyoma: (**a**) CT images showing esophageal mass, *Arrow* shows the location of the esophageal leiomyoma causing intraluminal narrowing; (**b**) intraoperative appearances following resection of the leiomyoma; (**c**) pleural repair over the oesophageal mucosa

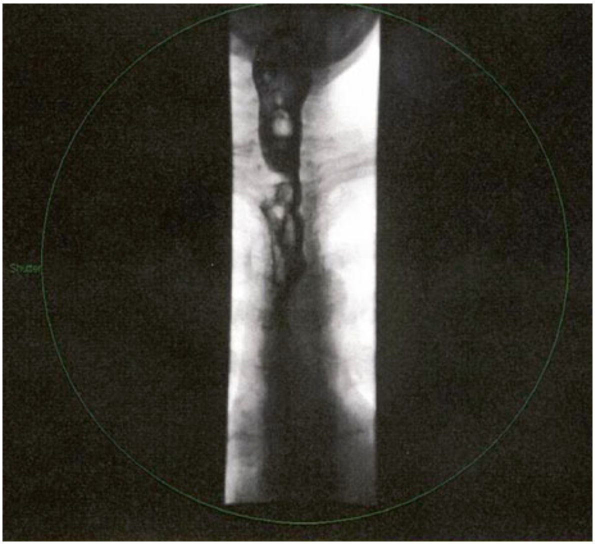

Fig. 4.17 Radiation stricture after mantle radiation for lymphoma

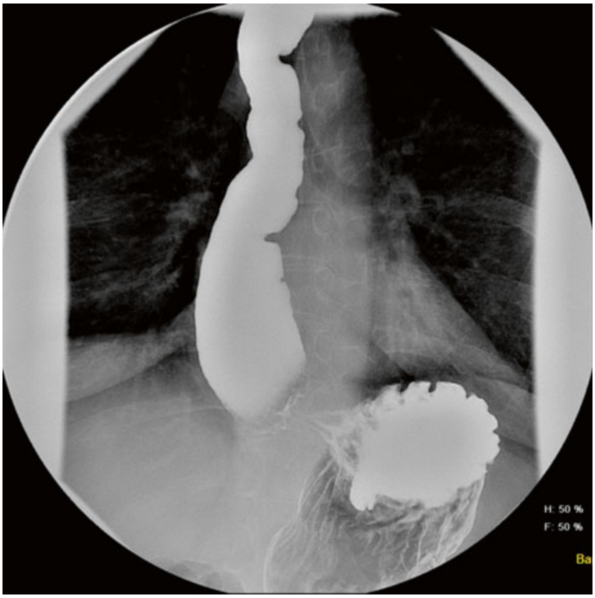

Fig. 4.18 Contrast swallow demonstrating scleroderma esophagus

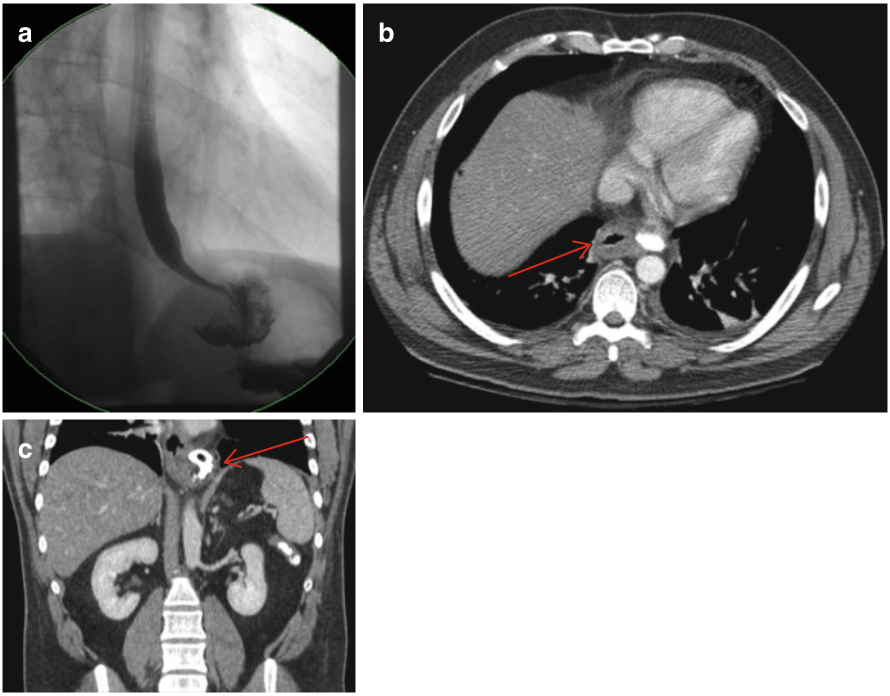

Fig. 4.19 Esophageal images after antireflux surgery. (**a**) Normal appearance of esophagram after a laparoscopic Nissen fundoplication. (**b**, **c**) CT images of slipped Toupet fundoplication following prolonged postoperative vomiting: axial section (**b**) showing wrap herniation above the diaphragm; coronal section (**c**). *Arrows* show the wrap herniation above the diaphragm

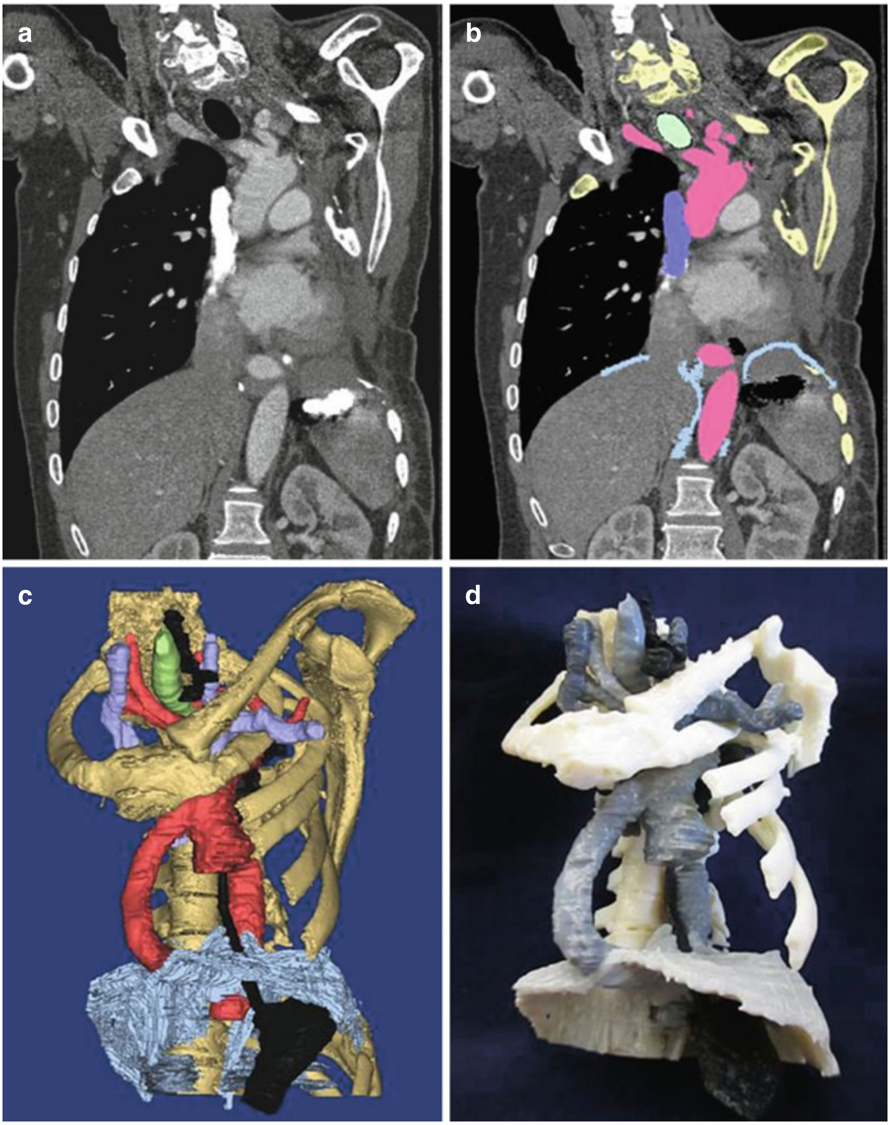

Fig. 4.20 Development of a three-dimensional anatomic model for a patient with an aorto-esophageal fistula, to allow a combined approach of surgical and endoscopic management. (**a**) The coronal CT scan images, (**b**) the segmentation process of selecting which anatomic features will be printed, (**c**) the three-dimensional computerized model that is used to create the .stl file and (**d**) the three-dimensional model after printing (From Dickinson et al. [2]; with permission)

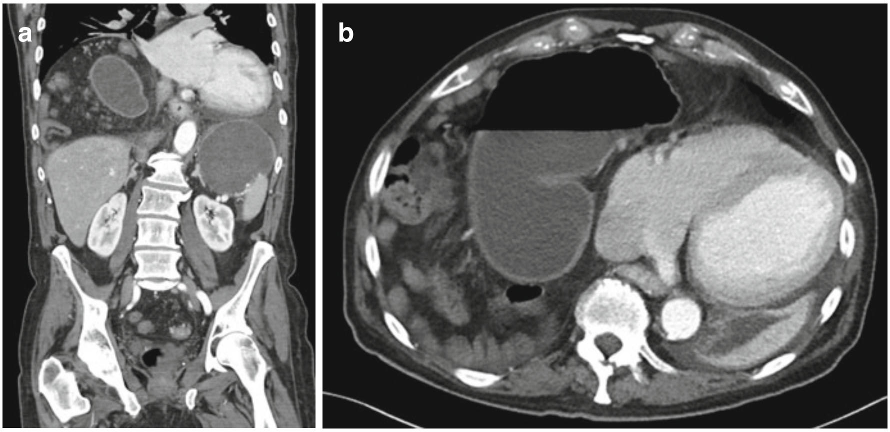

Fig. 4.21 Morgagni hernia: (**a**) sagittal CT scan demonstrating the anterior diaphragmatic defect containing stomach; (**b**) axial CT scan of the same patient, demonstrating gastric distension secondary to this hernia

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Chapter 5
Mapping Esophageal Disease with Endoscopic Ultrasound

Shanda H. Blackmon

The gold standard for staging of esophageal cancer involves the use of a linear endoscope, linear and radial endoscopic ultrasound. To assess for occult adenocarcinoma in patients with gastroesophageal reflux disease (GERD) and Barrett's esophagus, an endoscope is used to identify the location of a suspicious nodule, a radial ultrasound endoscope is used to assess the depth of invasion and invasion into neighboring structures, and the linear ultrasound endoscope is used to biopsy lymph nodes adjacent to the esophagus (Fig. 5.1).

This assessment serves to guide the biopsy of the lesion in question and esophageal brushings, which are performed through the linear echoendoscope. These instruments also have a role in management, as tumors of early cancer (T1a or below) are amenable to endoscopic ablative therapy, submucosal dissection, and endoscopic mucosal resection (EMR).

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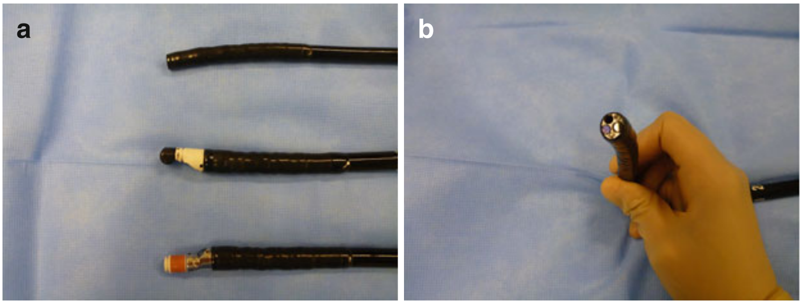


Fig. 5.1 A linear endoscopic probe (**a**, *top*; **b**) is typically used as the initial diagnostic tool to evaluate the upper gastrointestinal (GI) tract. A linear endoscopic ultrasound (EUS) scope (**a**, *middle*) and radial ultrasound scope (**a**, *bottom*) are used to visualize structures in the wall of the esophagus

Tumors Amenable to Endoscopic Treatment

In the classification of esophageal tumors [1], T1a cancers, with a known 5–7 % chance of harboring lymphatic spread of tumor, are considered amenable to endoluminal therapy. On the other hand, T1b lesions, which have spread to the submucosa or beyond, have a 15–20 % chance of nodal involvement. These tumors are not amenable to endoluminal therapy [2].

Setting Up the Ultrasound Probe

The scope itself is larger than the linear probe. A balloon is placed on the tip using a plastic installing device (Fig. 5.2a). Before the probe is introduced into the patient, the balloon is insufflated with saline (Fig. 5.2b), and any air is expelled to allow a clear probe-tissue interface.

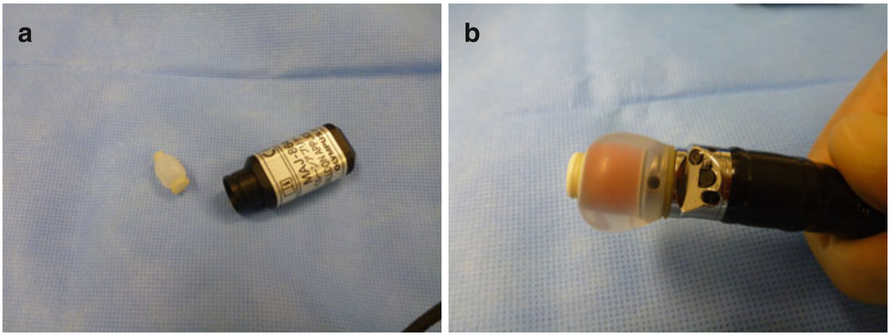


Fig. 5.2 The EUS scope is typically set up with a balloon, using a loading device (**a**) at the terminal end of the scope. All air is expelled from the balloon before it is inflated with water (**b**) to allow a scope-tissue interface to optimally assess the layers of the esophagus—the mucosa, submucosa, muscle layer

Technique

Assessment

Step 1. Visualize abnormalities

A regular endoscope is used to first visualize the tumor and any other associated esophageal and gastric wall abnormalities. Distance from the incisors, total tumor length, and length of any Barrett's esophagus is noted by the endoscopist. The pylorus is investigated and intubated to visualize the duodenum.

Step 2. Assess the tumor

The radial probe is then advanced into the esophagus to the most proximal extent of the tumor as measured from the incisors previously. Tumor depth is then measured to define the T-stage

The ultrasound probe is positioned for universal interpretation (Fig. 5.3a, b):

- Left atrium anteriorly
- Aorta at 5 o'clock position
- Azygos vein and left gastric artery posteriorly
- Look for the thoracic duct between the aorta and azygos vein

Once the tumor is visualized on the monitor, the balloon is insufflated. All the layers of the esophageal wall are then seen (Fig. 5.3c, d). Any abnormal wall thickening should be documented. The T-stage of the tumor should be determined by adjusting the depth on the monitor (Fig. 5.3e). Invasion into neighboring structures also can be determined (Fig. 5.3f).

Step 3. Investigate the nodal beds

Nodal beds should be investigated next (refer to Chap. 1 figure that labels the lymph nodes of the esophagus):

- Upper esophagus
- Subcarinal station
- Lower esophagus and along the inferior pulmonary ligament
- Celiac and gastric nodes

Any other pathological lymph nodes (Fig. 5.3g, h) and nonpathological nodes (Fig. 5.3i) should also be documented.

On EUS, benign lymph nodes are usually oval, measure less than 1 cm in the smallest axis, and have regular borders. Nodes suspicious for malignancy are round, more than 1 cm in the smallest axis, and homogenous without a germinal center.

Step 4. Evaluate other structures

Other vital structures also can and should be evaluated with the ultrasound probe:

- Left atrium
- Thoracic duct and azygos vein
- Aorta: Any aortic invasion should be excluded to determine resectability; an esophageal-aortic fat plane should be evaluated for violation
- Left gastric artery (Fig. 5.3j)
- Caudate lobe of the liver and the inferior vena cava (Fig. 5.3k)

Endoscopic Mucosal Resection

Using a linear endoscope, EMR can be performed for therapeutic resection of T1a tumors or more superficial lesions. This resection also helps to make the pathologic diagnosis by allowing histologic evaluation of the deeper margin.

In the most common technique, the nodule in question is identified. Using methylene blue, a submucosal wheal is then created, which allows the depth of the tumor to be assessed (Fig. 5.4). If the tumor invades the submucosa, typically the wheal is unable to develop uniformly and the lesion in question is not lifted away from the muscle.

If it appears that the lesion can be excised, it is suctioned into the endoscope, and a band mounted onto the end of the endoscope is deployed, being placed on the base of the lesion. Using a snare technique, the lesion is slowly cauterized and excised either below the band or above the band with an intent to excise the lesion.

Multiple biopsies can be performed in this fashion, involving up to 50 % of the circumference of the esophageal wall.

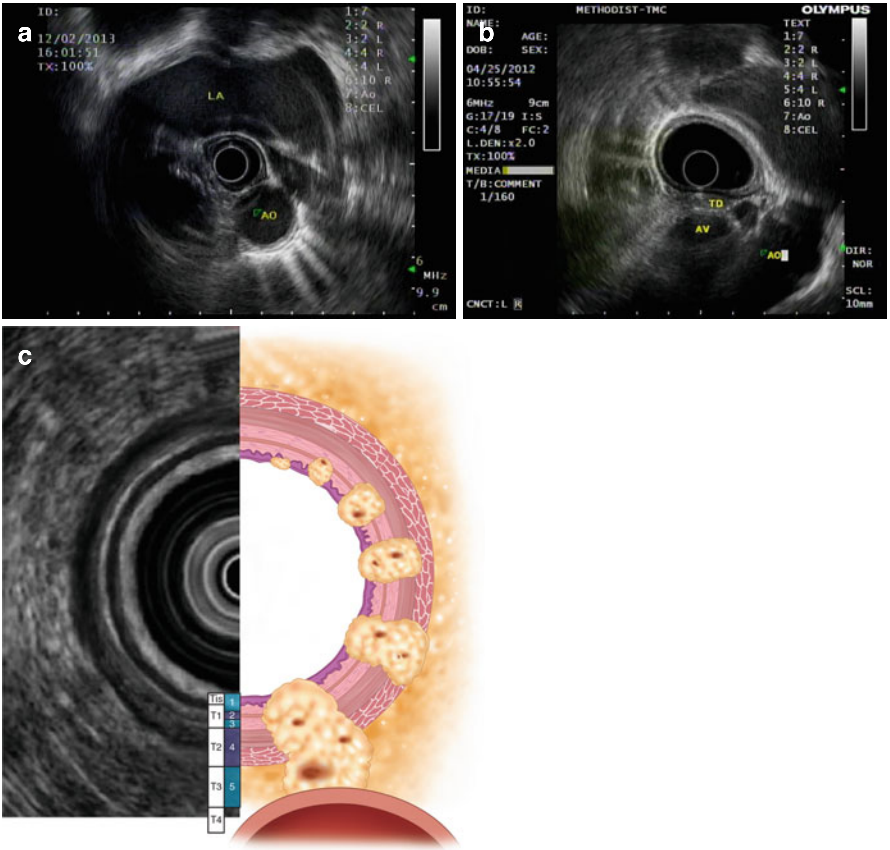
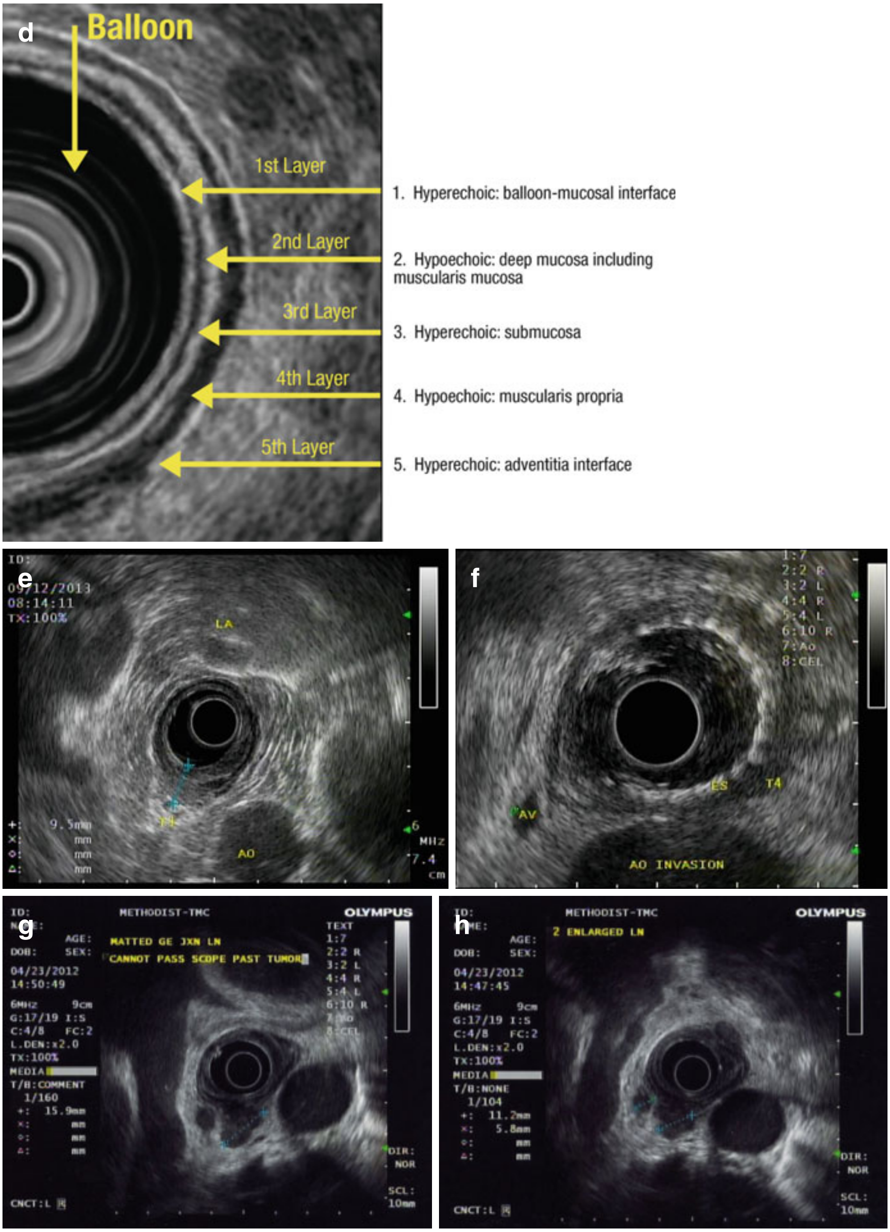


Fig. 5.3 When the endoscope is advanced into the esophagus, most surgeons use a standard image setup for interpretation of tumor involvement: The aorta (*AO*) is set at the 5 o'clock position, and the left atrium (*LA*) is anterior (**a**). The thoracic duct (*TD*) and azygos vein (*AV*) can also be seen posterior to the esophagus, more superiorly (**b**). The EUS allows analysis of the different esophageal layers: mucosa, submucosa, muscularis propria and adventitia (**c**, **d**) and to determine the depth of a lesion (**e**). EUS also allows assessment of any involvement of adjacent structures, such as aortic invasion (**f**) (*Es*—esophagus). Besides tumor depth, pathological matted nodes (**g**, **h**) as well as nonpathological lymph nodes (**i**) should also be noted and documented during EUS. If the endoscope can advance beyond the tumor, the left gastric artery (*LGA*) can be assessed (**j**); the presence of any abnormal gastrohepatic lymph nodes warrants documentation. EUS also allows visualization of the caudate lobe of the liver and the inferior vena cava (*IVC*) with the balloon (*BAL*) inflated (**k**)



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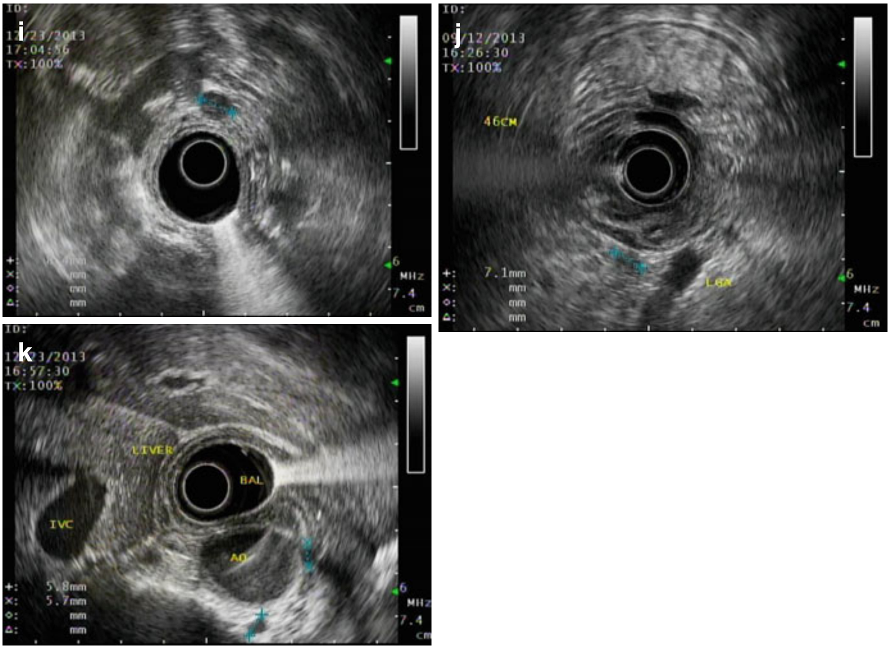

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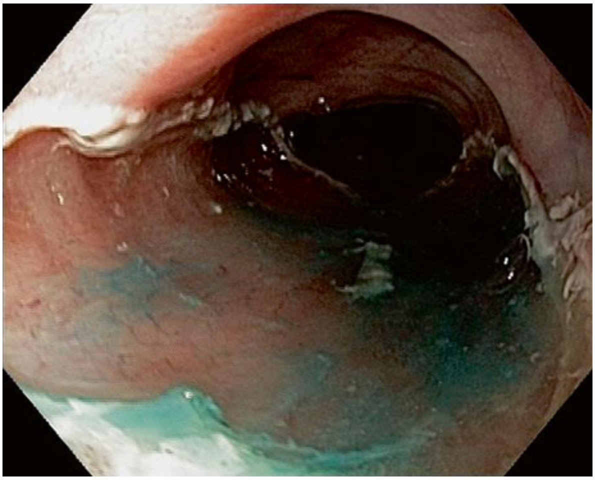

Fig. 5.4 EUS can be used to identify low-grade tumors (T1a) that would be amenable to endoscopic mucosal resection (EMR). The submucosa is injected with methylene blue solution, and if the tumor lifts, it can be resected endoscopically. This photo shows a large area of mucosa that has been removed to resect a T1a esophageal cancer, with residual methylene blue at the base of the submucosal layer, and the mucosal defect can be seen in the 9:00 and 3:00 position. When the resection is larger than half of the circumference, one must watch for severe stricture formation

Other Uses of the Endoscope and Esophageal Ultrasound

- Identification of submucosal tumors such as leiomyomas and gastrointestinal stromal tumors (Fig. 5.5), helping to differentiate them from esophageal cancers and mediastinal tumors
- Identification of duplication cysts and foregut cysts; because they may not communicate with the esophageal lumen, diagnosis and visualization can be difficult
- Assessment for any vascular rings by evaluating for blood flow, using the Doppler mode

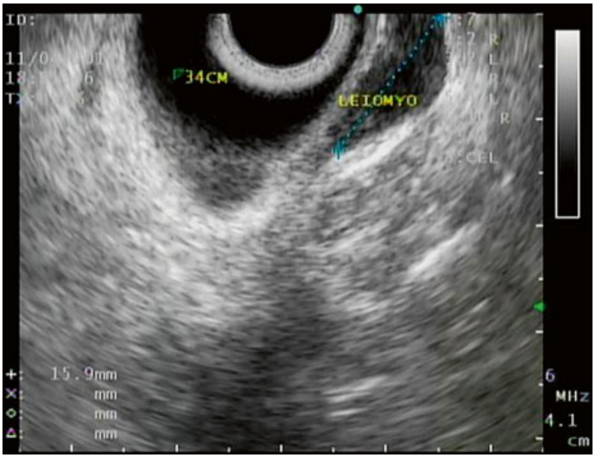

Fig. 5.5 When an upper GI study demonstrates an esophageal mass but the endoscopy does not demonstrate any mucosal abnormality, a submucosal mass such as a benign leiomyoma or a gastrointestinal tumor is suspected. These can be visualized and confirmed on endoscopy using EUS. A leiomyoma is typically found as a separate homogenous mass located in either the inner circular muscular layer or the outer longitudinal muscle layer of the esophagus

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Chapter 6
Endoluminal Interventions

Karen J. Dickinson and Shanda H. Blackmon

This chapter reviews task lists for the following procedures:

- Rigid esophagoscopy
- Esophageal biopsy
- Balloon and Savary dilation of esophageal strictures
- Endoscopic esophageal stenting
- Endoscopic suturing
- Endoscopic mucosal resection
- Botox injection
- Radiofrequency ablation
- Peroral endoscopic myotomy (POEM)
- Endoscopic drainage for esophageal perforations or anastomotic leaks

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Rigid Esophagoscopy

Rigid esophagoscopy (Fig. 6.1), though not often performed in the modern era, is an important skill to acquire. Its indications include foreign body impaction in the esophagus or bleeding from an esophageal mass that is difficult to control. In both of these situations, it may not be possible to perform the interventions required using a flexible endoscope. For an impacted foreign body, larger instruments such as graspers can be passed down a rigid esophagoscope. In the situation of severe bleeding, topical therapies such as epinephrine-soaked swabs may be more easily employed via a rigid scope.

Fig. 6.1 Rigid esophagoscopy. The rigid esophagoscope is carefully inserted, taking care to protect the patient's teeth. This procedure allows therapeutic endoscopy of the esophagus with larger instruments than with a flexible endoscope

Endoscopic Biopsy of the Esophagus

Esophageal biopsies are taken when pathology is seen. A number of forceps are available for these biopsies, and the use of cautery usually is not recommended for a diagnostic esophageal biopsy. The Prague classification (Fig. 6.2 and Table 6.1) is used to describe the Barrett's segment macroscopically. With regard to esophageal biopsies for Barrett's surveillance, the Seattle protocol of four-quadrant biopsies must be observed. This allows histological assessment of any Barrett's segment (Fig. 6.3).

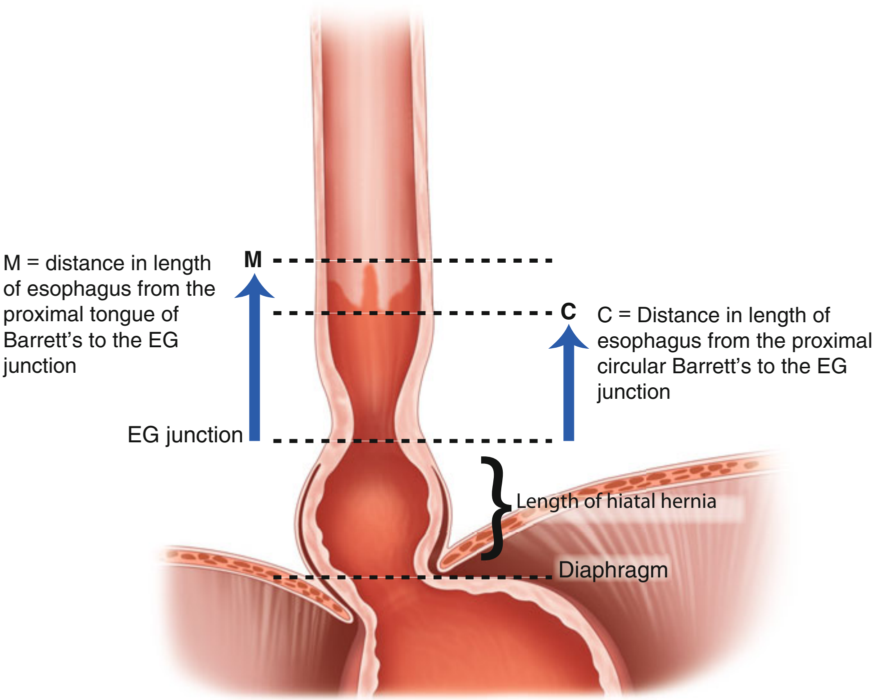

Fig. 6.2 The Prague classification of Barrett's esophagus. This schematic describes the steps for performing an esophagogastroduodenoscopy and assessing the Barrett's epithelium according to the Prague criteria [2] (Adapted from Sharma et al. [2]; with permission from Elsevier.) Table 6.1 further outlines the six numbered steps shown in this figure

Table 6.1 Steps of the esophagogastroduodenoscopy (EGD) examination in a patient with Barrett's esophagus

Steps	Action points
1	Full EGD examination. Particularly note the presence of any hiatus hernia. Observe the position of the gastroesophageal junction (GEJ) in relation to the hiatal impression of the diaphragm
2	Note the location (in centimeters from the incisors) of the GEJ. Anatomical clues: Top of gastric mucosal folds The "pinch" of the lower esophageal sphincter
3	Note whether the squamocolumnar junction (or Z line) is above the GEJ
4	Note the location (in centimeters from the incisors) of the most proximal **C**ircumferential extent of the suspected Barrett's epithelium. This measurement = **C**
5	Note the location (in centimeters from the incisors) at the **M**aximum extent (i.e., most proximal extension) of suspected Barrett's epithelium. This measurement = **M**
6	Subtract the **C** and **M** values noted in Step 4 and Step 5 from the depth of endoscope insertion noted in Step 2 (i.e., the GEJ). This is the relative position of the circumferential and maximal Barrett's in relation to the GEJ
7	Report these values as Prague C and M [2]. For example, e.g., Barrett's with a circumferential length of 4 cm but a maximum length of 8 cm would be C4M8

Adapted from Sharma et al. [2]; with permission from Elsevier

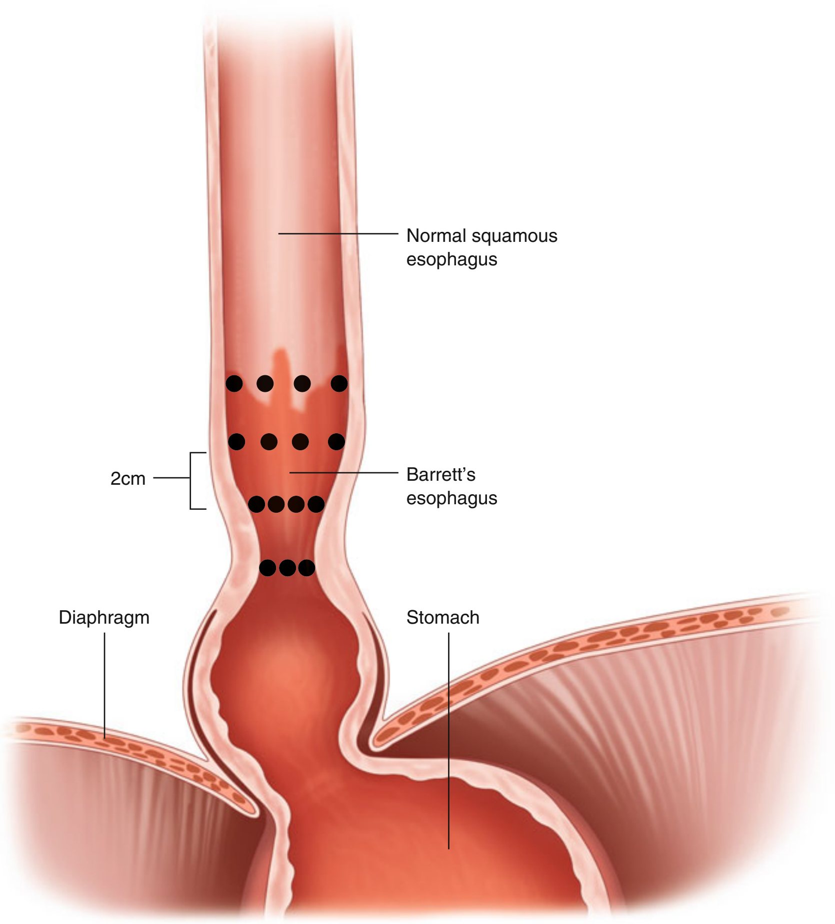

Fig. 6.3 The Seattle protocol of four-quadrant biopsies for histologic assessment of Barrett's epithelium. When Barrett's esophagus is seen, or at surveillance endoscopy, biopsies from all four quadrants of the circumference of the esophagus should be performed every 2 cm to clearly document the length of the Barrett's epithelium

Dilation of Esophageal Strictures

Esophageal strictures may be benign or malignant. At times, the distinction is unclear, so biopsy should be performed on all strictures of the esophagus. Dilation of the stricture will frequently facilitate biopsy and cytologic brushings and will also relieve dysphagia. Dilation should be undertaken with caution because of the risk of esophageal perforation.

Strictures vary in their diameter and in their response to dilation. Some are treated easily by the passage of the scope itself or by a single balloon dilation. Other strictures, such as those resulting from caustic ingestion, are inelastic, demonstrate great resistance to dilation, and frequently are long. The endoscopist should assess the most likely etiology for the stricture and proceed with caution. The use of intraoperative fluoroscopy is often advisable, and excessive force should be avoided. If the patient complains of pain, the procedure should be promptly terminated and a contrast study should be performed to rule out esophageal perforation.

Strictures following operations such as esophagectomy are usually very amenable to endoscopic dilation. Early dilation may result in a more effective and long-lasting result. The gastroscope is positioned immediately above the narrowing and the characteristics of the stricture are noted. Biopsy and cytologic specimens of the edges of the stricture may be obtained at this time and again after dilation.

Strictures of the esophagus may present initially with bolus obstruction. Urgent endoscopy must be undertaken to remove the bolus, usually with a snare or grasping forceps, but the endoscopist must not ignore the stricture that caused the event. It may be dealt with shortly after removal of the food bolus.

Balloon Dilation

To perform a balloon dilation of an esophageal stricture, the endoscope is positioned above the stricture and an appropriate balloon is selected. The normal human esophagus is 2 cm wide, and a 20-mm balloon is usually the maximum dilation that would be attempted. The flaccid balloon is passed through the biopsy channel of the scope and positioned within the stricture. If the stricture is complex and the lumen is narrow, contrast can be injected to allow fluoroscopic guidance of a wire over which the balloon is passed. This technique prevents inadvertent perforation and allows safe passage of the sheathed balloon into the lumen. The balloon should be long enough to traverse the entire length of the stricture. After positioning, the balloon is inflated using radiopaque contrast material under fluoroscopic monitoring. This step may be accomplished without fluoroscopic guidance, using saline to fill the balloon, but without fluoroscopy there can be no assurance that the maximum diameter of the balloon has been achieved.

Using fluoroscopic guidance and a manometer, the balloon is insufflated with contrast agent until the waist is obliterated (Fig. 6.4a–c). The manometer prevents balloon rupture. The balloon should be inflated for a minute to ensure adequate dilation. After the balloon is deflated and removed, the scope may be passed through the stricture, or a larger dilator may be used if necessary. Once the scope is passed through the narrowing, it is important to obtain tissue samples from the stricture's lower extent.

Balloon dilation of esophageal strictures allows rapid clinical improvement in a patient's dysphagia, but the strictures often recur and require repeated dilations.

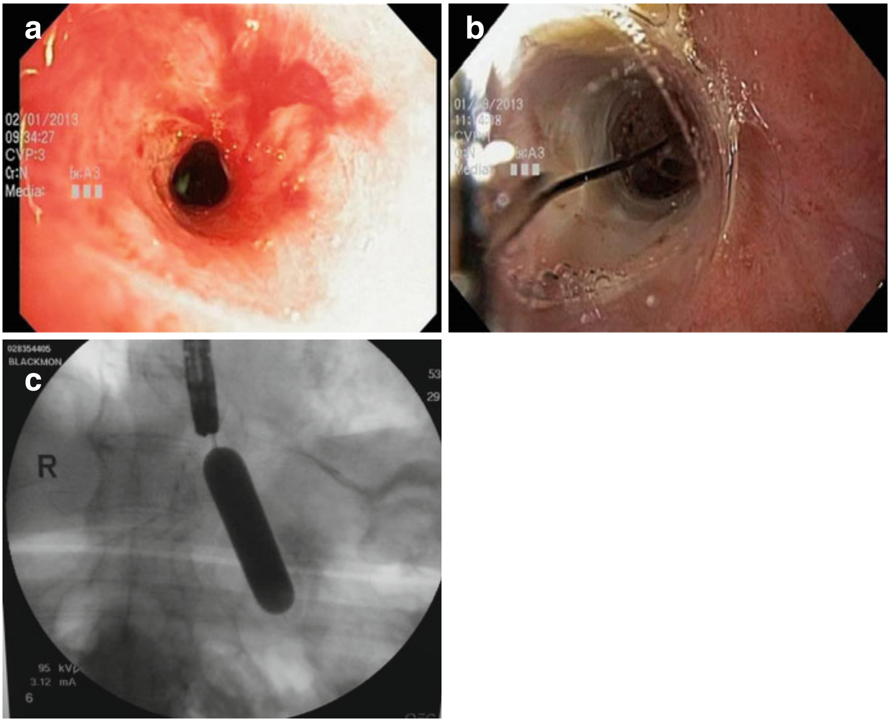

Fig. 6.4 (**a**) Endoscopic appearances of a benign esophageal stricture, pre-balloon dilatation. (**b**) Endoscopic appearances during balloon dilatation of a benign esophageal stricture. (**c**) Fluoroscopy demonstrating balloon dilation of an esophageal stricture. The balloon is filled with contrast to enable the endoscopist to observe adequate dilation of the stricture and obliteration of the "waist."

Savary Dilation

An alternative to using balloon dilation is wire-guided rigid Savary dilation of esophageal strictures. The Savary dilators are usually more successful in dilating recalcitrant strictures but are often more uncomfortable for the patient. One must use fluoroscopy when using these dilators. Savary dilators, which range in size from 15 Fr to 60 Fr (5–20 mm) in diameter, are passed over a guidewire in progressive size increments to dilate the stricture safely (Fig. 6.5). The endoscope should always be passed back into the esophagus after dilation to assess the esophageal mucosa.

Kenalog Injection

Injecting Kenalog (triamcinolone acetonide), a topical steroid, into the esophageal stricture may increase the length of time between necessary dilations. Our experience is that repeat dilations are still needed with the use of steroids, but the interval between dilations is increased in selected patients.

Fig. 6.5 Savary esophageal dilators. (**a**) Savary esophageal dilators have a narrow tip inserted over a guidewire that has been placed endoscopically. This wire allows the dilator to be passed safely even though the endoscope is removed during dilation. (**b**) Savary dilators are available in a range of sizes from 15 to 60 Fr (5–20 mm) and are passed sequentially to dilate the stricture

Esophageal Stenting

Patients who present with esophageal strictures, spontaneous esophageal perforation, or esophageal anastomotic leak may require the placement of an esophageal stent. We advocate the use of a partially covered, self-expanding metal stent such as those shown in Fig. 6.6 [1]. The uncovered portion of the stent will encourage tissue growth and help to reduce the risk of distal migration. Other stents are available, however, including fully covered, silicone, and uncovered stents. An uncovered stent must not be used for a benign stricture.

Indications

- Esophageal perforation
- Esophageal stricture
- Esophageal fistula

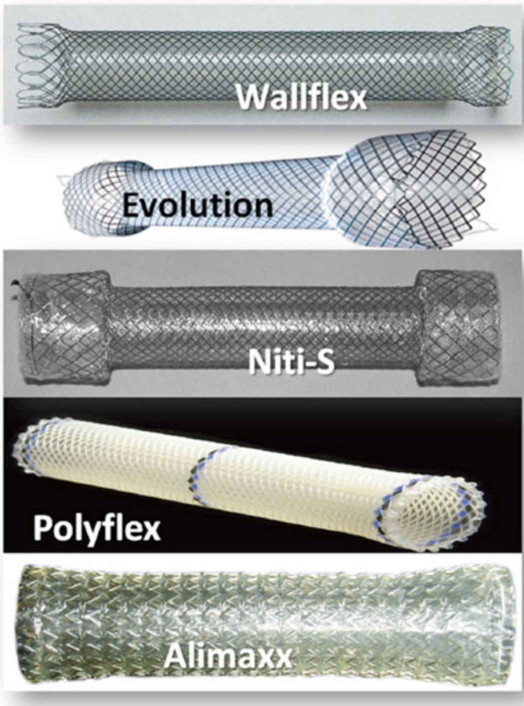

Fig. 6.6 Esophageal stents. A number of stents are available for the treatment of benign and malignant esophageal strictures. These may be metal or plastic and uncovered or covered. With uncovered stents or plastic stents, the risk of migration is increased and precautions should be taken, such as endoluminal suturing to secure the stent in place (Reprinted from Carrott and Low [1]; with permission from Elsevier)

Contraindications

- Uncovered aorta nearby
- Unsalvageable esophagus
- Aspiration risk
- Tracheoesophageal fistula with poor landing zone or large fistula
- Foreign body present within the fistula
- Spine hardware present adjacent to leak

Partially covered, self-expanding metal stents are available on a delivery device with a graded tip, allowing easy introduction into the pharynx and esophagus. We recommend placing a very stiff wire into the lumen of the stomach prior to stent placement and using fluoroscopy to guide the stent over the guidewire. If fluoroscopy is not available, it is possible to deploy the stent under endoscopic visualization. If a stricture is not involved and there is high risk for distal migration of the stent, it is possible to bridle the stent into place by placing an umbilical tape around the proximal interstices of the wire of the stent and bringing the tape out of each nostril, fastening it in place. This bridling technique will prevent the patient from swallowing the stent. Other fixation techniques, including endoscopic suturing of the stent, have been presented to prevent migration of a stent, especially when it is placed around the upper pharynx, where swallowing of the stent is common. We believe the Apollo OverStitch™ device (Apollo Endosurgery, Austin, TX), the tool currently used to fix stents into place, will be used in the future to secure stents and prevent migration in most cases, although this use currently is off-label with the US Food and Drug Administration (FDA).

To prevent impaction of the stent with food, a postoperative stent diet should be employed. When nitinol stents are used, it is important to educate the patient to avoid extremely cold food, which causes shrinkage and migration of the stent, and extremely hot food, which causes degradation of the stent's covering. Each patient should have an upper GI contrast evaluation performed after the deployment of a stent to ensure that the stent's position is satisfactory and that there is no leak or residual stricture.

Endoscopic Suturing

Endoscopic suturing is useful in a number of situations, including esophageal perforation (to close small defects) and the deployment of esophageal stents (to avoid distal migration).

Endoscopic suturing devices such as the Apollo OverStitch™ device use pre-loaded sutures to close defects or anchor stents in place (Fig. 6.7). Other methods of anchoring or closing defects include over-the-scope clips (OTSC®; Ovesco Endoscopy, Tübingen, Germany). Resolution® Clips (Boston Scientific, Natick, MA), however, are not effective in securing stents to prevent migration. Newer applications of these suturing devices include endoscopic sleeve gastrectomy.

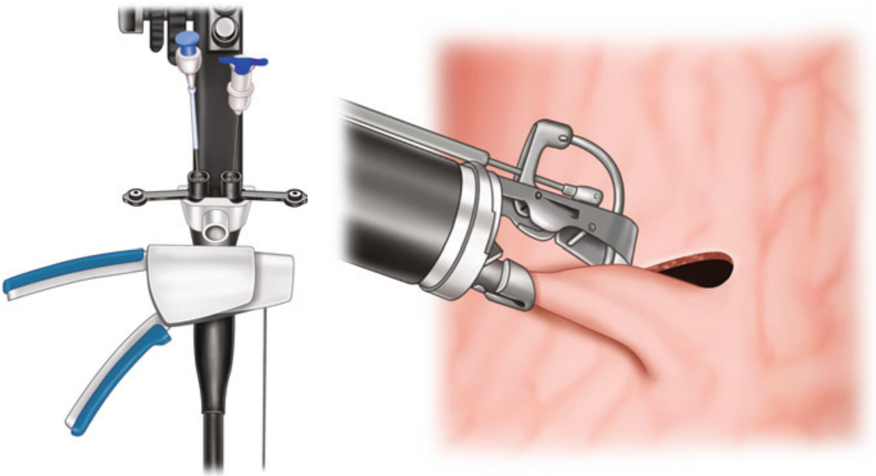

Fig. 6.7 The Apollo OverStitch™ device (Apollo Endosurgery, Austin, TX). This endoluminal suturing device can be used to suture esophageal perforations and to secure stents in place (Reprinted with permission from Apollo Endosurgery)

The endoluminal suturing device is placed on the tip of the gastroscope and passed through an overtube to prevent damaging the lining of the esophagus. The suture is preloaded, and a dual-channel scope is necessary. Through the second channel, a drill is passed to embed into the esophageal wall and pull tissue into the suture as it is passed through the wall. Full-thickness bites of the esophageal wall are typically taken. Once the suturing is finished, the suture is “cinched” with a plastic fixation tip (resembling a T fastener) that is passed through the working channel to tighten the stitch. This process then allows the operator to cut the end of the suture after tightening, completing the process of placing either a figure-of-eight or simple stitch (Fig. 6.8).

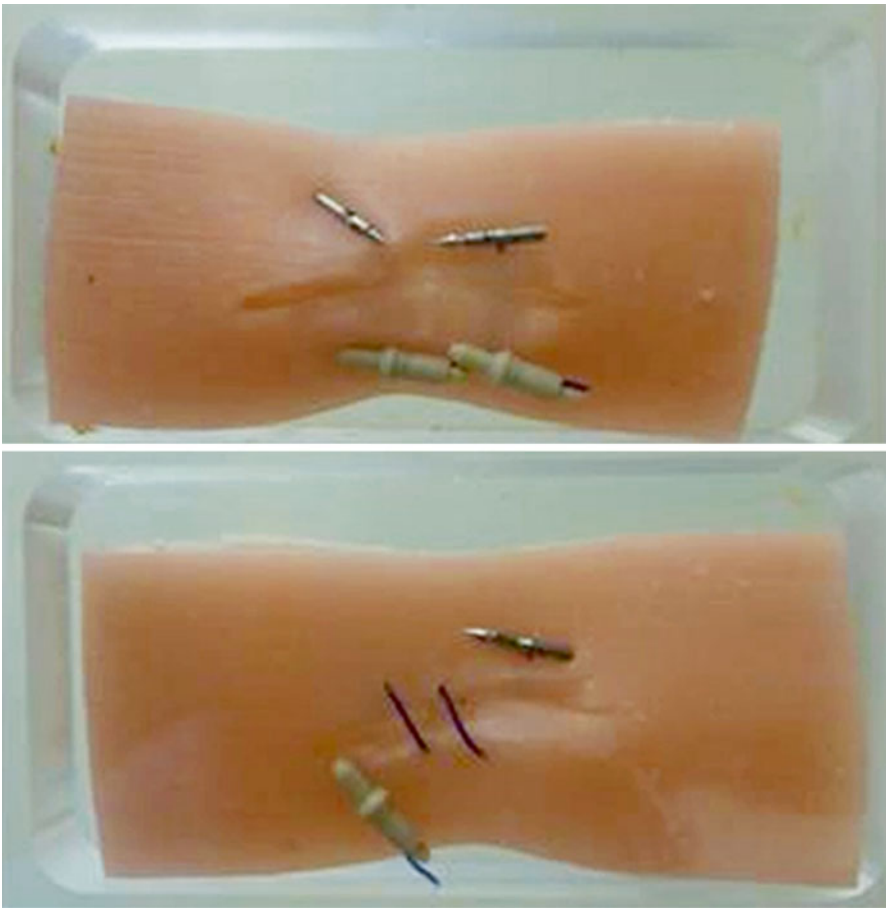

Fig. 6.8 The Apollo OverStitch™ device can be used to suture tissue in an interrupted fashion (*top*) or a continuous fashion (*bottom*)

Endoscopic Mucosal Resection

Endoscopic mucosal resection (EMR) can be performed with several different techniques, as illustrated in Figs. 6.9, 6.10 (ligation device), and 6.11 (cap and snare).

The loose connective tissue attaching the muscle and mucosal layers of the esophagus enable EMR to be performed easily. It is possible to resect the mucosa and submucosa without injury to the muscle layer, but the wall of the esophagus is only 4 mm thick, so precautions must be taken to avoid perforation. Correct lifting of the mucosa is extremely important. Injecting saline or other liquids into the submucosal layer, or mechanical lifting using special instruments like a ligation device, is the easiest and most effective way to avoid muscle involvement. After lifting the mucosa, including the target lesion, the lesion can be safely captured, grasped with a narrow wire, and resected by electrocauterization. When removing the specimen from the scope, it is extremely important to orient it accurately so that the locations of any positive margins are correctly identified (Fig. 6.12).

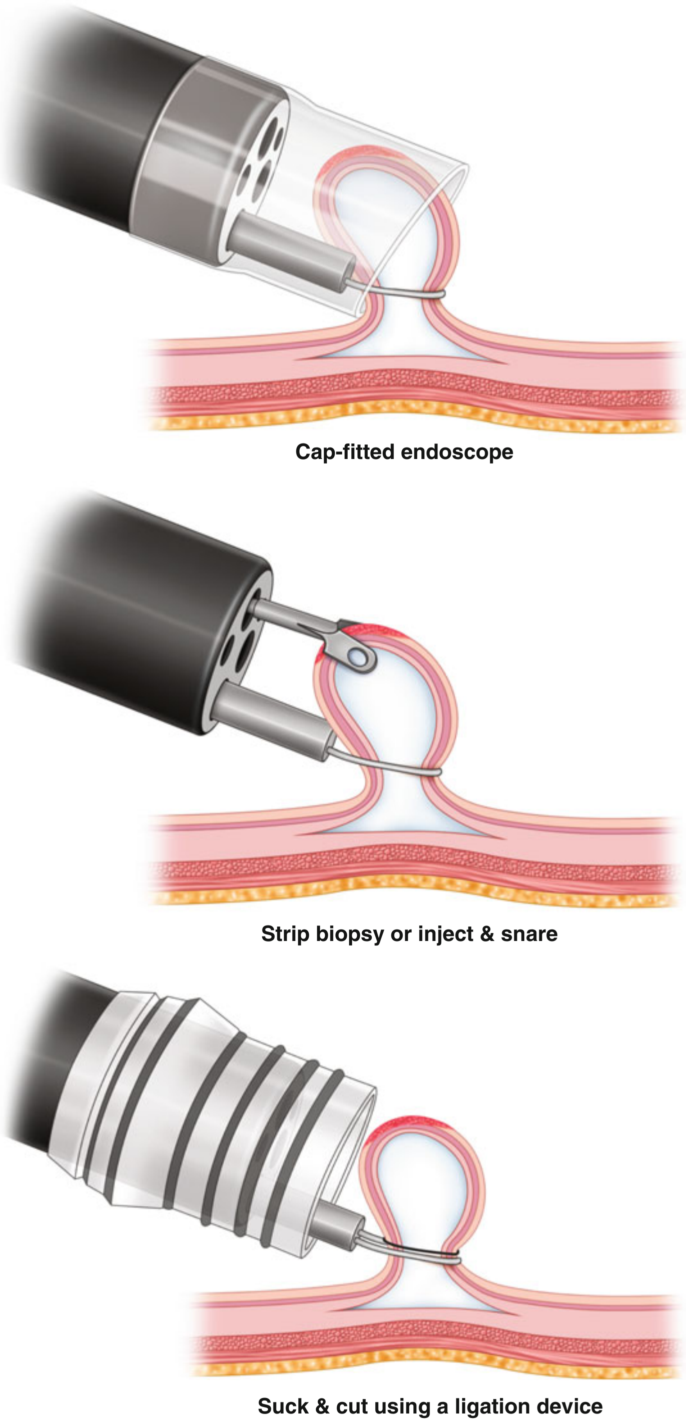

Fig. 6.9 Endoscopic mucosal resection (EMR) techniques include using a cap-fitted endoscope, strip biopsy (inject and snare), or "suck and cut" using a ligation device

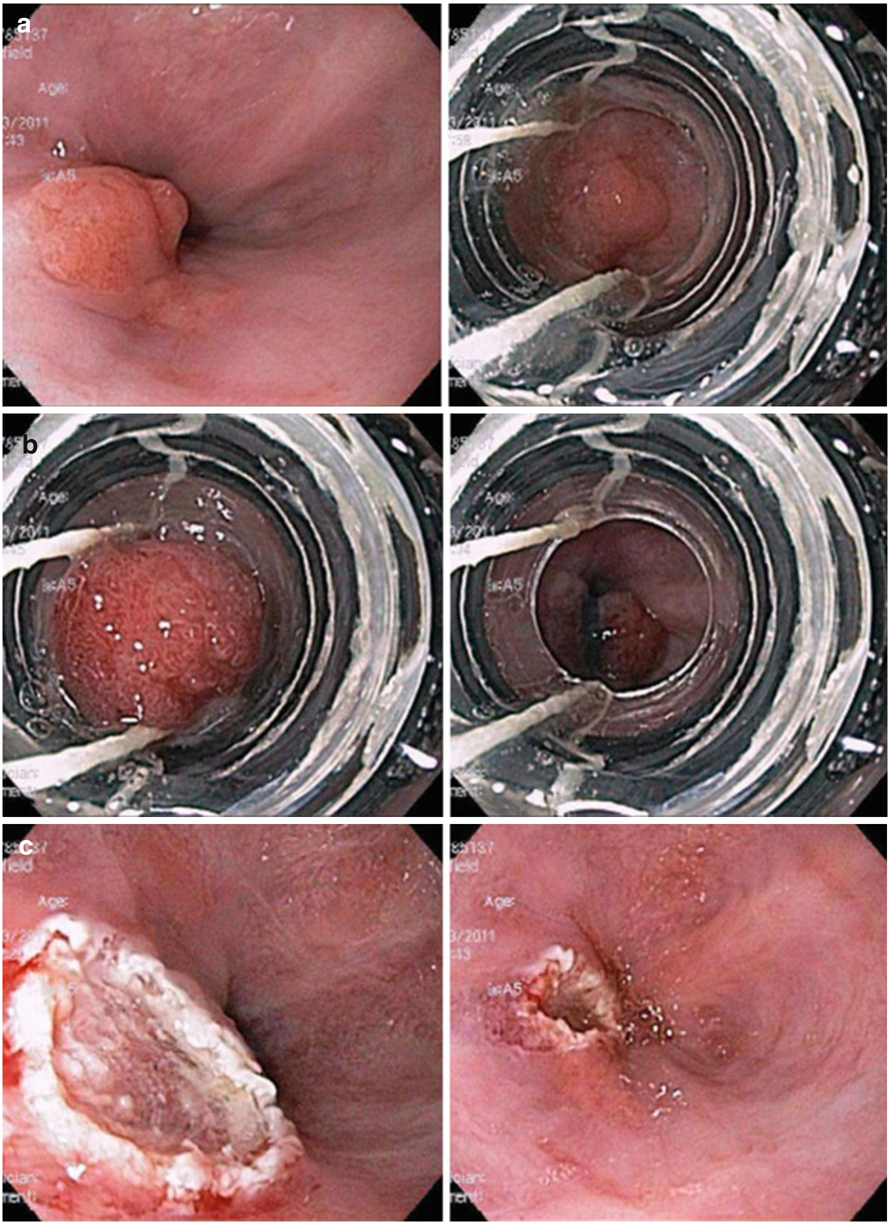

Fig. 6.10 EMR performed using the ligation device. (**a**) The lesion for EMR is identified (*left*) and the endoscope with the ligation device fitted is brought into position to perform the EMR (*right*). (**b**) The endoscope is positioned directly over the lesion and suction is applied to bring the lesion into the scope (*left*). The band device is deployed whilst maintaining suction to allow band ligation of the lesion to facilitate subsequent EMR (*right*). (**c**) A snare is passed through the scope and positioned beneath the band. Electrocautery is carefully applied and the EMR completed. The base of the EMR site is carefully inspected to identify any perforation. If there is any concern regarding perforation, then endoclips (e.g., Resolution® Clips; Boston Scientific, Natick, MA) should be applied

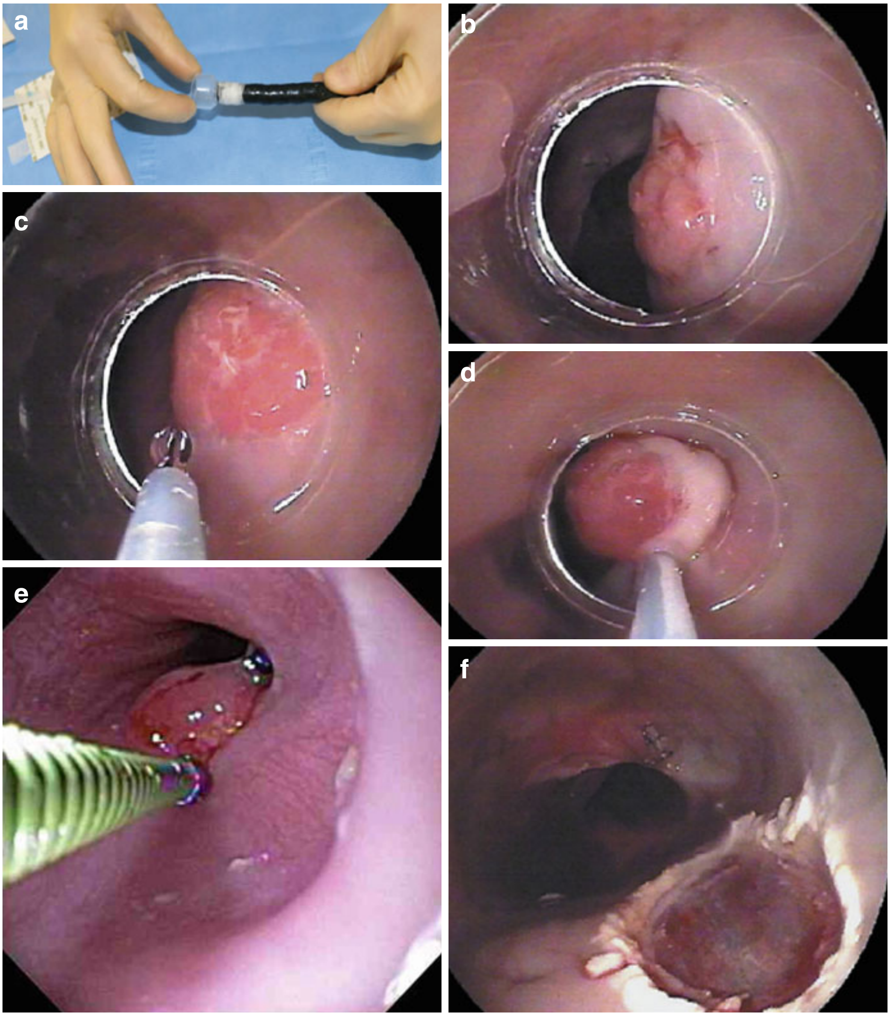

Fig. 6.11 EMR performed with a cap-fitted device and snare. (**a**) The cap is fitted to the endoscope. (**b**) The endoscope is passed orally and the lesion is identified through the cap. (**c**) The lesion may be elevated with a submucosal bleb of solution (saline-diluted methylene blue with or without epinephrine), and a snare is passed through the scope. (**d**) The lesion is snared. In this picture, normal mucosa can be seen beyond the target mucosa, important in ensuring adequate resection. (**e**) Electrocautery is applied to the snare and gentle upward traction is applied to complete the EMR. (**f**) The base of the lesion is inspected to rule out any perforation. If perforation is suspected, clips are applied through the scope

Fig. 6.12 Orienting the EMR specimen. (**a**) The EMR specimen is retrieved carefully from the snare. (**b**) The specimen is pinned and oriented on a cork board to allow both the pathologist and the surgeon to understand which borders are involved or are clear of dysplasia or intramucosal carcinoma

Botox Injection

The injection of botulinum toxin (Botox) is useful in esophageal pathology in two situations. The first is in the treatment of achalasia, when Botox is injected into the lower esophageal sphincter (LES) in order to improve symptoms. Usually 100 units are injected into the LES quadrantically. Future surgical myotomy may be made more difficult but is not a contraindication. The second clinical application is the injection of Botox into the pylorus as treatment for established gastroparesis or during esophagectomy. Botox is injected into the pyloric sphincter at a dose of 25 units to each quadrant. The effects of Botox are temporary and usually last up to 4–6 months.

Radiofrequency Ablation

Radiofrequency ablation (RFA) is used in the treatment of Barrett's esophagus, usually in the setting of dysplasia (Fig. 6.13). The most commonly used device is Barrx™Ablation System (Covidien GI Solutions, Sunnyvale, CA), formerly known as HALO. A 360° device (Barrx™ 360 RFA Balloon Catheter) can be used for circumferential lesions, or 90- or 60° focal catheters can be used for localized treatment (Barrx™ 90/60 RFA Focal Catheter). Previously a sizing balloon was required before treatment was instituted for circumferential lesions, but a new device that can size and treat will soon be available. The thickness of Barrett's esophagus is usually less than 500 µm and the ablation from these devices is 500–1000 µm. At this time, the American Gastroenterological Association recommends endoscopic ablative therapy for Barrett's with high-grade dysplasia (Fig. 6.14), rather than surveillance or proceeding to esophagectomy.

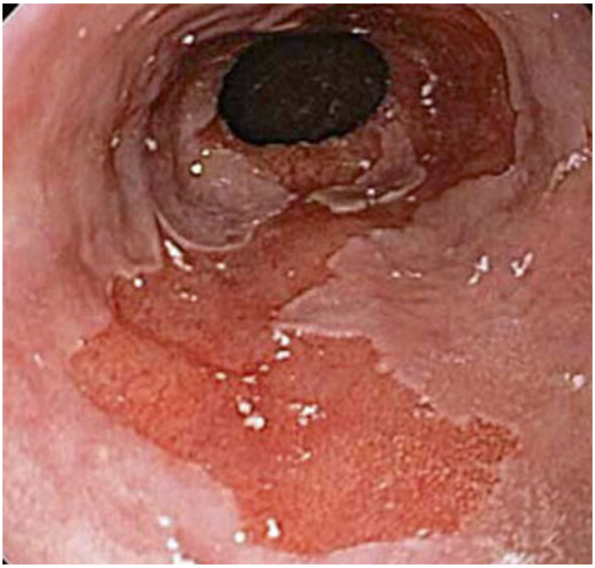

Fig. 6.13 The endoscopic appearance of Barrett's esophagus

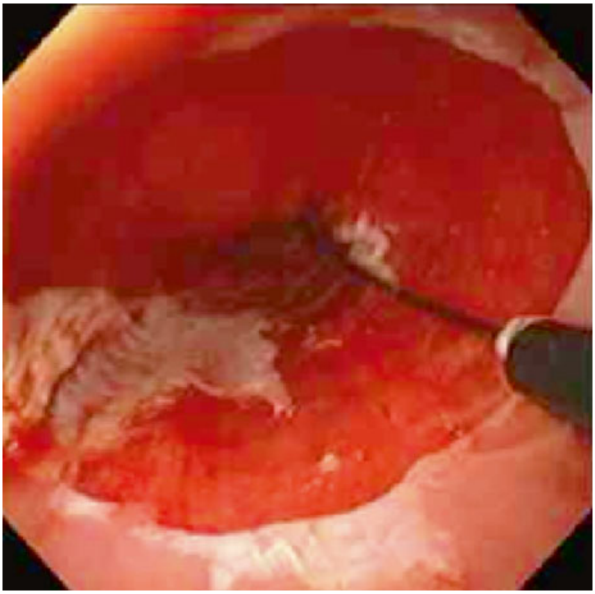

Fig. 6.14 The endoscopic appearance of Barrett's esophagus following radiofrequency ablation with the Barrx device

Peroral Endoscopic Myotomy

The use of peroral endoscopic myotomy (POEM) in the treatment of achalasia began in Japan and has been increasing in the West. This technique involves endoscopic myotomy of circular or circular and longitudinal muscle fibers over the lower esophagus and proximal stomach. The use of the POEM technique is still in the early years of development, and long-term results are awaited.

A dual-channel or single-channel endoscope is used; the dual channels allow two instruments to be passed. A cap on the endoscope is desirable for optimal visualization, and a high-pressure water pump (ERBEJET® 2; ERBE, Tübingen, Germany) allows waterjet dissection. The submucosal layer may be injected with methylene blue and dextrose or hyaluronic acid to facilitate dissection. The ERBE VIO 300 D waterjet dissector is used in conjunction with a cautery device. The endoscope is passed into the esophagus and a diagnostic esophagoscopy is performed, with irrigation of the esophagus using débridement antibiotic (DAB) solution. After injection of the submucosa with methylene blue and dextrose, an incision is made in the mucosal lining of the esophagus proximal to the LES (Fig. 6.15a). This mucosal incision facilitates entry of the scope into the submucosal plane. Once the endoscope is passed into the submucosal plane, dissection continues caudad, with attention directed to controlling with cautery the blood vessels passing the submucosal space (Fig. 6.15b). The submucosal dissection is continued using the endoknife and waterjet dissection to distend the space and enhance visualization. We do not recommend balloon dissection of this plane, as we have encountered increased bleeding with balloon dissection. During this phase, we monitor peak airway pressures and perform regular abdominal and neck examination to detect any pneumothorax, pneumoperitoneum, or crepitus. The submucosal dissection is continued until gastric sling fibers are identified (Fig. 6.15c) and dissection continued 2 cm beyond this point. The endoscope is withdrawn and the myotomy is begun, using the endoknife to divide first the inner circular muscle fibers and then the outer longitudinal muscle fibers (Fig. 6.15d, e). Continuous periodic inspection of the mucosa ensures no mucosal injury. The myotomy is continued until the gastric sling fibers are encountered; then the myotomy is continued 1–2 cm onto the gastric wall. The endoscope is withdrawn with retroflexion to check the myotomy and mucosa. The mucosa is closed with Resolution® Clips at the end of the myotomy, working from distal to proximal along the mucosal defect (Fig. 6.15f). The myotomy can be checked by endoscopy and by fluoroscopy after the procedure. In our practice, a laparoscopic antireflux procedure (a Toupet or Dor fundoplication) is performed after POEM (during the same anesthesia), based on patient preference.

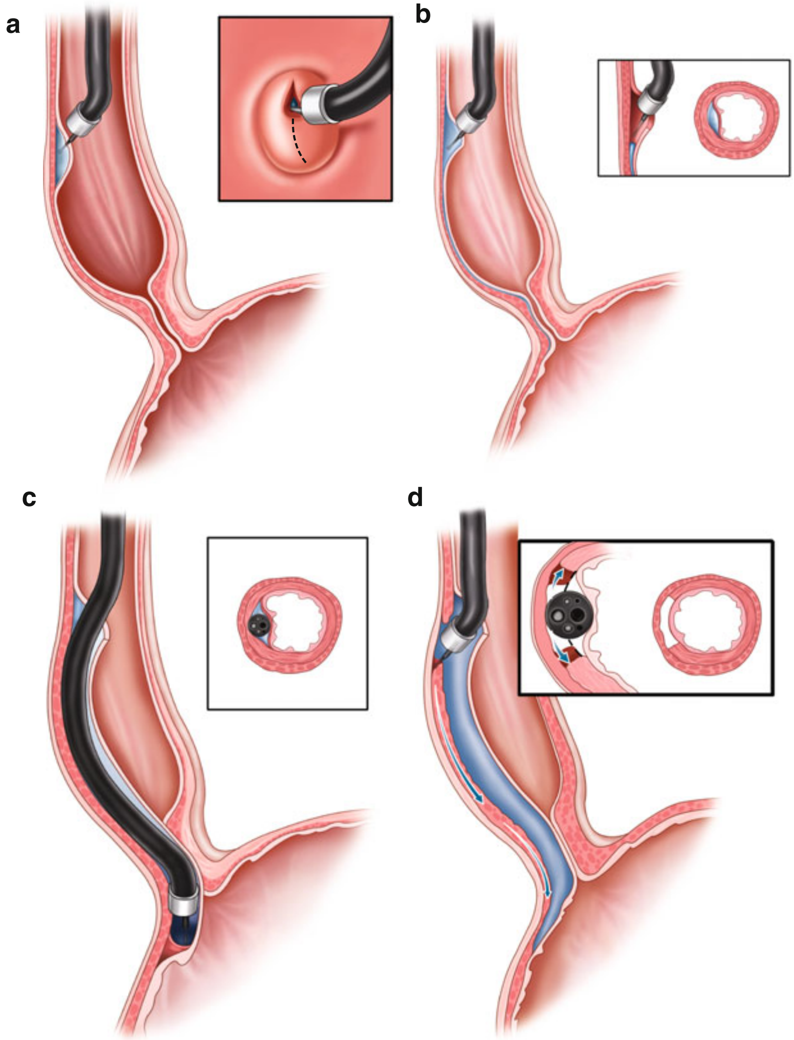

Fig. 6.15 Peroral endoscopic myotomy (POEM). (**a**) A diagnostic esophagogastroduodenoscopy (EGD) is performed. Approximately 10 cm cephalad of the gastroesophageal junction (GEJ), the mucosa is incised with electrocautery using the T-knife. A submucosal injection of a mixture of methylene blue, hypromellose, and epinephrine to a final concentration of 1:10,000 can facilitate this step. (**b**) Once the mucosa is incised, a submucosal tunnel is created. This step can be achieved using gentle electrocautery dissection and an ERBEJET® two waterjet dissector (ERBE, Tübingen, Germany). Any vessels traversing the tunnel can be cauterized using rats-tooth forceps with electrocautery. (**c**) The submucosal tunnel is continued until a point 2 cm distal to the GEJ is reached. This point can be recognized by the visualization of gastric "sling" fibers of muscle. Periodically, the scope is withdrawn from the tunnel and the mucosa is inspected to ensure that there are no breaches. (**d**) The circular muscle fibers are divided throughout the length of the submucosal tunnel. (**e**) The longitudinal muscle fibers are divided next. The length over which these muscle fibers are divided varies between practitioners. (**f**) Once the myotomy is completed and hemostasis achieved, the mucosal defect is closed with endoclips (e.g., Resolution® Clips)

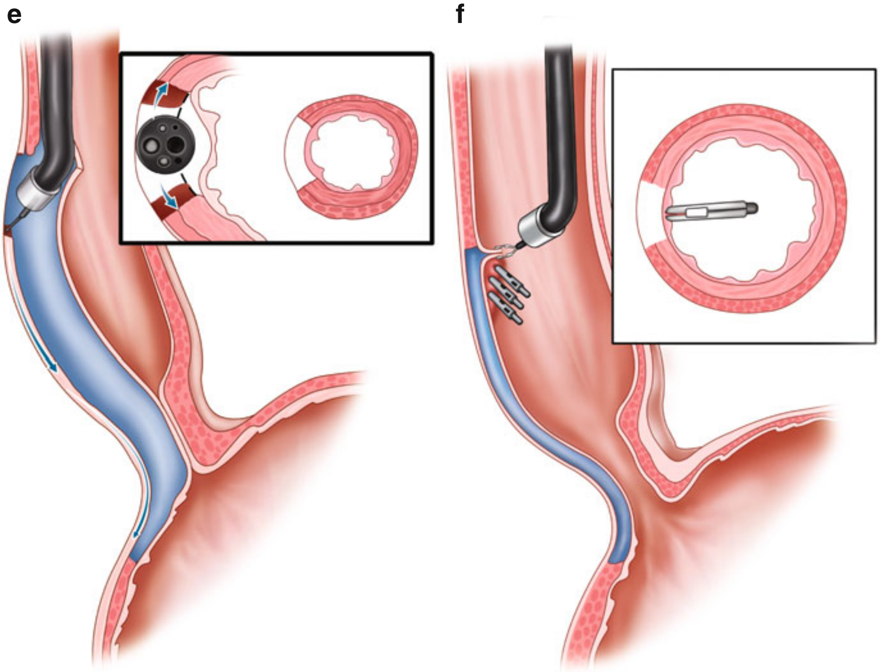

Fig. 6.15 (continued)

Endoscopic Drainage for Esophageal Perforation or Anastomotic Leak

The management of esophageal perforations and anastomotic leaks is often challenging. The focus is on control of sepsis, adequate nutrition, and closure of the leak or defect. In some patients, esophageal stenting, surgery, or a combination of the two is required to close the esophageal defect. In other instances, an endoscopic vacuum sponge may be used to control the cavity and promote healing. This kind of vacuum-assisted closure device (V.A.C.®, Kinetic Concepts, Inc., San Antonio, TX, USA) is passed into the esophagus and the vacuum is attached via a tube passed nasally to connect to wall suction. This device is not currently approved by the FDA for use in treating esophageal perforations, but preliminary results have shown it to be effective in selected patients.

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Chapter 7
Surgical Techniques

Min P. Kim, Karen J. Dickinson, Puja Gaur, and Shanda H. Blackmon

Laparoscopic Fundoplication

Indication

Patients with gastroesophageal reflux disease (GERD) refractory to medical therapy are evaluated for surgical treatment of reflux. Patients typically undergo esophagram, esophagogastroduodenoscopy (EGD), pH probe study, and manometry. Patients with a diagnosis of GERD on the basis of these studies are recommended to undergo fundoplication. The degree of fundoplication is based on esophageal manometric studies. We recommend a partial, 270° posterior fundoplication (Dor or Toupet) for patients with poor esophageal motility and a full, 360° fundoplication (Nissen) for patients with normal esophageal motility.

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Key Steps

1. Closure of crus
2. Nissen or Toupet fundoplication

Position

Supine position with a foot board to prevent migration on the operating table.

Port Placement

1. Use 5-mm optical trocar (e.g., Ethicon XCEL® trocar or Covidien Versaport™ bladeless optical trocar) to place first port under the left costal margin lateral to the mid clavicular line (Fig. 7.1a). Insufflate the abdomen to a maximum pressure of 15 mmHg.
2. Place 12-mm trocar in the midline approximately 12 cm from the xiphoid process.
3. Place a further two or three 5-mm trocars to facilitate dissection per the illustration (Fig. 7.1a). If a Nathanson liver retractor is used this is placed sub-xiphoid and the liver is retracted. Alternatively a 5-mm trocar placed laterally to the umbilicus on the right allows the use of a laparoscopic liver retractor to lift the left lobe of the liver
   - Left mid quadrant trocar: 8 cm left of the 12-mm port
   - Left upper quadrant trocar: 8 cm lateral to the left mid quadrant port
   - Right mid quadrant port: 8 cm away from the 12-mm port, at approximately a 30-degree angle towards the right costal margin
4. The surgeon stands on the right side of the patient and uses the right mid quadrant 5-mm port and the 12-mm port. The assistant stands on the left side of the patient and uses the left upper and left mid quadrant ports. The camera is placed in the left mid quadrant port. (Alternatively, if the patient is in the dorsal lithotomy position, the surgeon stands between the patient's legs.)

Operation

1. Divide the gastrohepatic ligament (Fig. 7.1b). Evaluate the hepatic branch of the vagus nerve and any aberrant hepatic arterial anatomy (Fig. 7.1c). If an accessory left hepatic artery is identified, then perform a clamp test. If the clamp test causes

ischemia of the left lobe of the liver (with or without laparoscopic ultrasound to quantify the flow), do not divide this vessel. If a replaced left hepatic artery is identified, do not divide this.

2. Mobilize the gastroesophageal junction (GEJ) (Fig. 7.1d). Divide the phreno-esophageal membrane, ensuring the preservation of the left anterior vagus nerve. Bluntly separate the esophagus from the right and left crus. Place a Penrose drain around the esophagus and secure the Penrose with a tie (e.g., Ethicon ENDOLOOP® or Covidien Surgitie™).
3. Close the crura. Approximate the left and right crura using suture (e.g., Covidien Endo Stitch™), leaving only the esophagus coming through the hiatus.
4. Divide the short gastric arteries. Use an energy device (e.g., Covidien LigaSure™ or Ethicon HARMONIC® scalpel) to divide the short gastric arteries and mobilize the fundus of the stomach (Fig. 7.1e).
5. Wrap the fundus. Place a suture 6 cm down from the GEJ and 2 cm posterior to the greater curvature (Fig. 7.1f) Bring this suture posterior to the esophagus but anterior to the posterior vagus, to create a wrap (Fig. 7.1g). Perform the "shoe-shine" technique to ensure proper placement of the fundus. The fundoplication can then be completed in two ways: Nissen or Toupet.

   – Nissen fundoplication (Fig. 7.1h)

     (i) Place a bougie (50 Fr) in the esophagus
     (ii) Wrap the fundus around the esophagus, using the technique described above.
     (iii) Stitch three interrupted stitches from the left side of the fundus to the right side of the fundus.
     (iv) Suture the right side of the fundus to the right crus; then suture the left side of the fundus to left crus.

   – Toupet fundoplication (Fig. 7.1i)

     (i) Suture three interrupted stitches from the right side of the fundus to the right side of the esophagus.
     (ii) Suture three interrupted stitches from the left side of the fundus to the left side of the esophagus, leaving a 90-degree gap.
     (iii) Suture the right side of the fundus to the right crus; then suture the left side of the fundus to the left crus (cruropexy).

6. Perform EGD. Withdraw the bougie and perform endoscopy to ensure proper placement of the wrap. Endoscopy can also aid in identifying the location of the EGJ, to ensure that the wrap is around the esophagus, not the stomach.

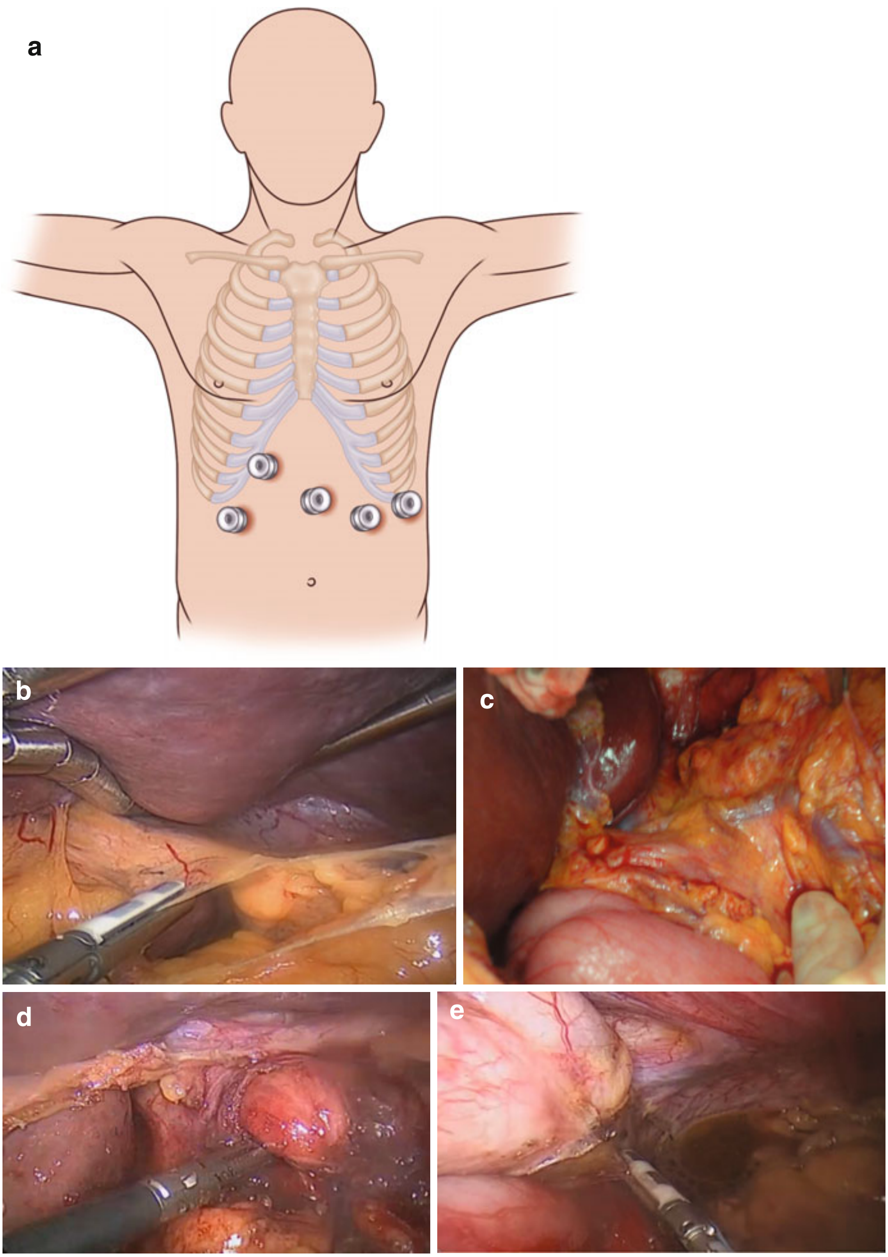


Fig. 7.1 (**a**) Port placement for laparoscopic fundoplication and for many foregut laparoscopic procedures. (**b**) Division of the gastrohepatic ligament. (**c**) The position of an aberrant left hepatic artery (replaced or accessory). (**d**) Dissection of the crura to allow mobilization of the gastroesophageal junction (GEJ). (**e**) Division of the short gastric arteries to allow mobilization of the fundus and dissection of the left crus. (**f**) A suture is placed 6 cm down the greater curve. This is used as a "passer" to allow passage of the wrap behind the GEJ (*dotted line*), using two graspers. (**g**) The shoeshine maneuver allows the wrap to be placed without tension. A tension-free wrap can be seen here, with the posterior vagus excluded from the wrap. (**h**) Nissen fundoplication. (**i**) Toupet fundoplication

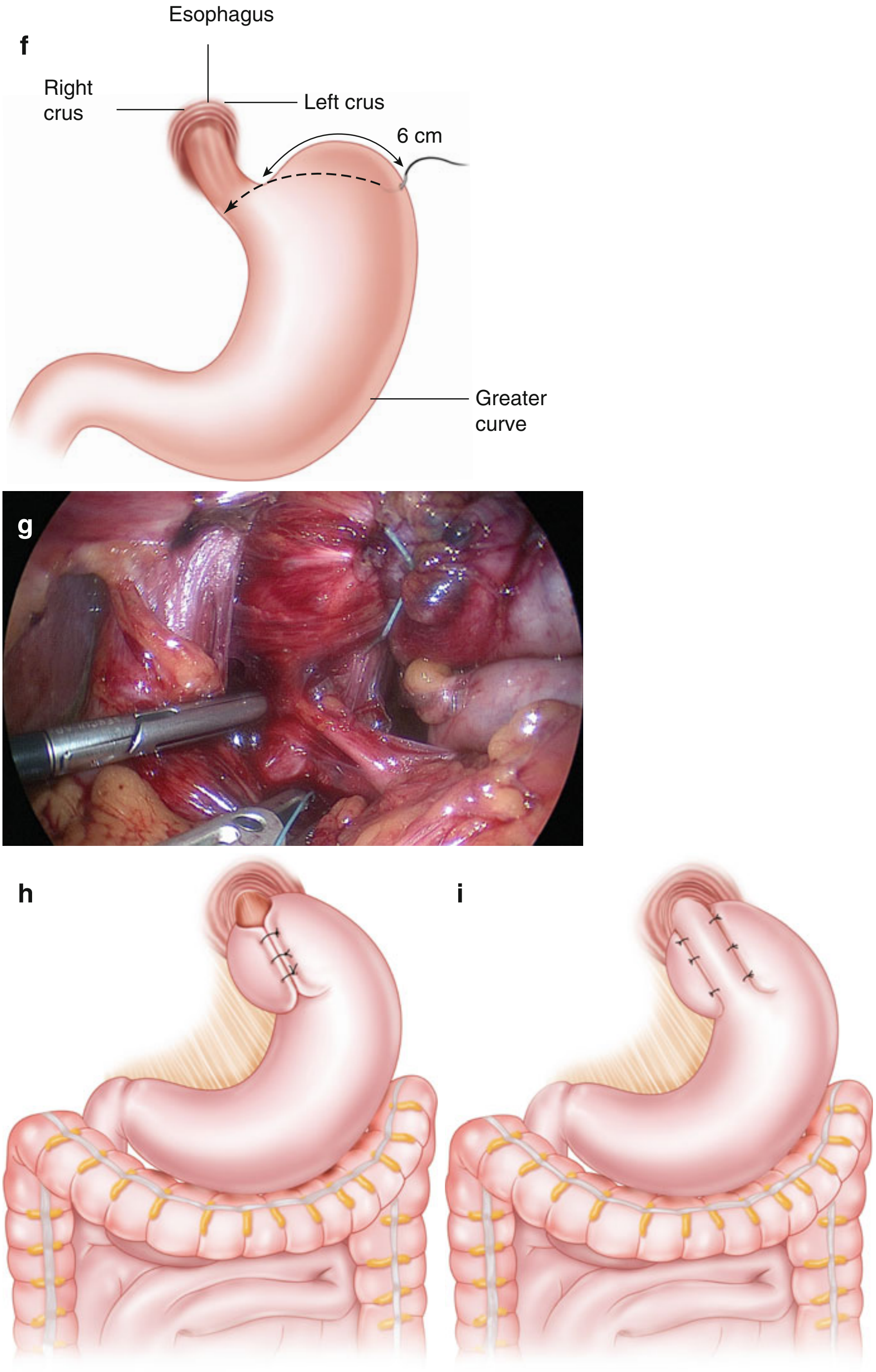


Fig. 7.1 (continued)

Laparoscopic Hiatal Hernia Repair

Indication

Patients with large, symptomatic hiatal hernia may benefit from surgical repair. Patients typically undergo an esophagram to classify the type of hiatal hernia and to identify a shortened esophagus.

Key Steps

1. Mobilization and resection of hiatal hernia sac
2. Reduction of stomach
3. Toupet fundoplication

Position

Supine position.

Port Placement

The port placement is the same as for laparoscopic fundoplication (*see* Fig. 7.1a).

Operation

1. Mobilize the hiatal hernia sac. The hernia sac is separated away from the mediastinum between the left and right crus (Fig. 7.2a). This dissection is carried out to separate the sac away from the mediastinum while keeping the peritoneum on the left and right crus and dividing the sac cephalad to the crus. The peritoneal covering provides the strength for the crural repair. This dissection allows for reduction of the stomach. Once the hernia sac is completely mobilized, resect the sac.
2. Reduce the stomach. Reduce the stomach into the abdomen and place a Penrose drain around the esophagus at the GEJ.
3. Close the crus (Fig. 7.2b). Place interrupted sutures to approximate the crus inferior to the esophagus. If there is tension, place a relaxing incision in the left diaphragm, place a Gore-Tex® mesh on the diaphragm, and close the crus primarily.
4. Divide the short gastric arteries and perform Toupet fundoplication as previously described.

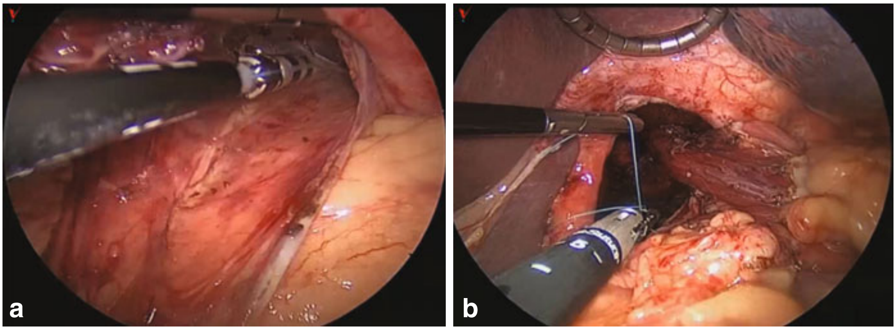


Fig. 7.2 (**a**) The hernia sac from the hiatal hernia is dissected free from the mediastinal structures, reduced from the thorax, and excised. (**b**) The crural repair is performed. The GEJ can be seen dissected free, and with a 3–4-cm length of intra-abdominal esophagus. The crural repair is performed with an endosuturing device (in this case, 0 Ethibond)

Robotic or Laparoscopic-Assisted Modified Heller Myotomy

Indication

Patients with achalasia diagnosed on manometry and esophagram can benefit from Heller myotomy. Techniques for the endoscopic management of achalasia (Botox injection, balloon dilation, and POEM) are outlined in Chap. 6.

Key Steps

1. Mobilization of left anterior vagus nerve
2. Esophageal myotomy
3. Dor fundoplication (Alternative: Toupet fundoplication)

Position

Supine position with foot board.

Port Placement (see Fig. 7.1a)

1. Use a 5-mm optical trocar (e.g., Ethicon XCEL® trocar or Covidien Versaport™ bladeless optical trocar) to place the first port under the left costal margin, lateral to the mid-clavicular line. Insufflate the abdomen.
2. Place a 12-mm trocar in the midline approximately 15 cm from the xiphoid process (camera port for robot).
3. Place three 8-mm robot metal trocars in the following locations:
   - Left mid quadrant trocar: 8 cm left of the 12-mm port on the left side
   - Left upper quadrant trocar: 8 cm lateral to the left mid quadrant port
   - Right mid quadrant port: 8 cm away from the 12-mm port, at approximately a 30-degree angle towards the right costal margin
4. Place a 12-mm trocar in the right lower quadrant as the assistant port.
5. Place a liver retractor through the 5-mm optical trocar and lift the left lobe of the liver.
6. Place a grasper in the right mid quadrant port and a grasper in left upper quadrant port. Place an energy device in the left mid quadrant port.

Operation: Technique #1, Dor fundoplication

1. Mobilize the vagus nerve. Divide the gastrohepatic ligament and spare the hepatic branch of the vagus nerve. Divide the phrenoesophageal attachment, sparing the left vagus nerve. Dissect the esophagus away from the superior portion of the left and right crus only. Dissect the left vagus nerve away from the esophagus and place a vessel loop around it (Fig. 7.3a).
2. Mobilize the gastric fat. Separate the gastric fat pad away from the stomach in the line of the esophagus. Excise the fat pad.
3. Divide the esophageal muscle. Grasp the esophageal muscle and divide the muscle using either scissors, a bipolar energy device, or a cautery hook (but no cautery attached), utilizing gentle blunt dissection until mucosa is visualized (Fig. 7.3b). Separate 6 cm of the esophageal muscle while preserving the mucosa. Use hook cautery to divide 2 cm of the stomach below the gastric fat pad (Fig. 7.3c).
4. Test the myotomy by performing an EGD to ensure that the myotomy is intact and complete (Figs. 7.3d–g). Submerge the esophagus under water and insufflate it to ensure that there is no leakage of air.
5. Perform the Dor fundoplication (Fig. 7.4a–c). Divide the short gastric arteries. Place three interrupted stitches from the left side of the myotomy to the anterior portion of the stomach. Place three interrupted stitches from the right side of the myotomy to the greater curvature of the stomach. Place three interrupted sutures from the posterior portion of the stomach to the right crus and diaphragm.

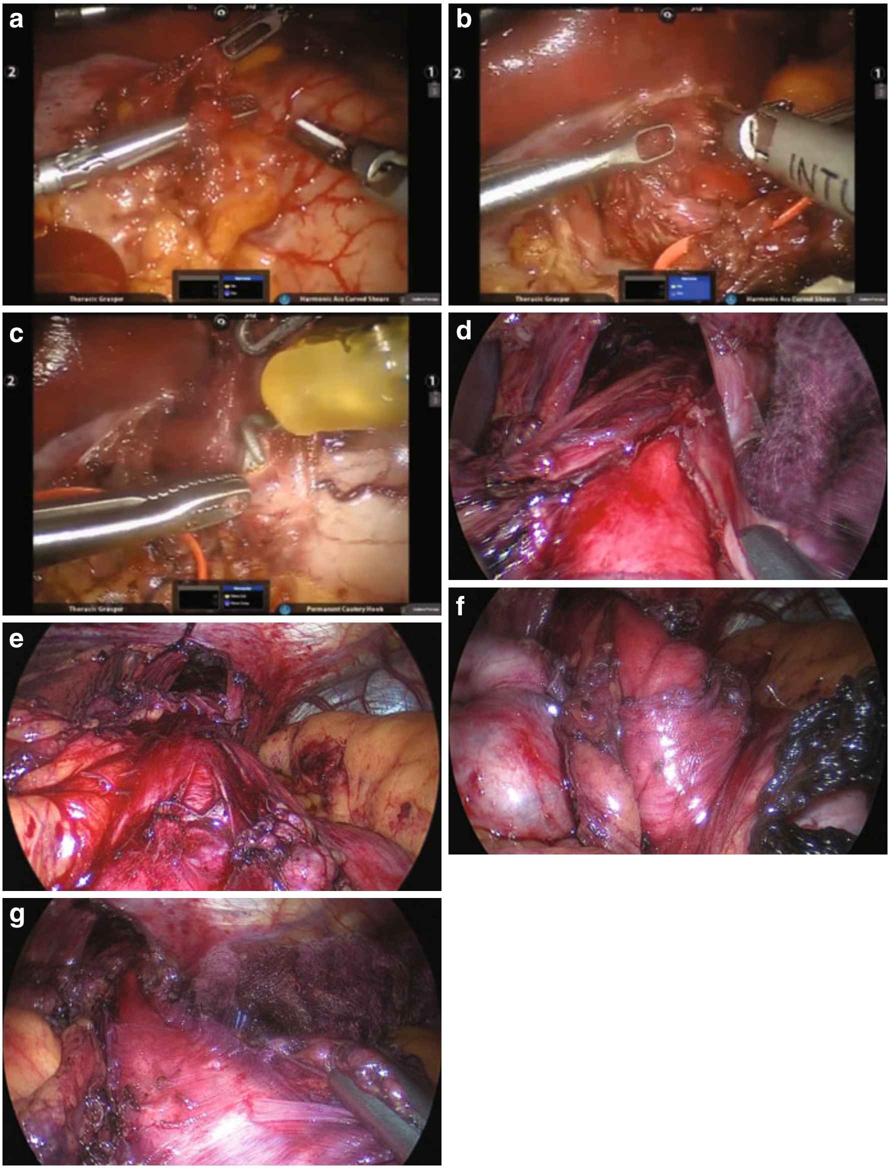


Fig. 7.3 (**a**) Mobilization of the left vagus nerve. The left vagus nerve is identified during the robotic dissection and can be seen here. It is subsequently slung to protect it during completion of the myotomy. (**b**) Performing a robotic myotomy. The esophageal muscle is divided using the harmonic scalpel, hot blade upwards for a robotic myotomy. We also use a hook without electrocautery as an alternative method for the myotomy. (**c**) The myotomy is extended down the stomach over a distance of 2–3 cm using hook dissection and electrocautery, used sparingly. (**d**) The complete myotomy can be seen here, with mucosa pouting out from the muscular layers of the esophagus. (**e**) The myotomy has begun and circular muscle is demonstrated proximally prior to division. (**f**) The myotomy continues; circular muscle is shown distally prior to division. (**g**) The "sling fibers" of the proximal stomach are shown prior to division

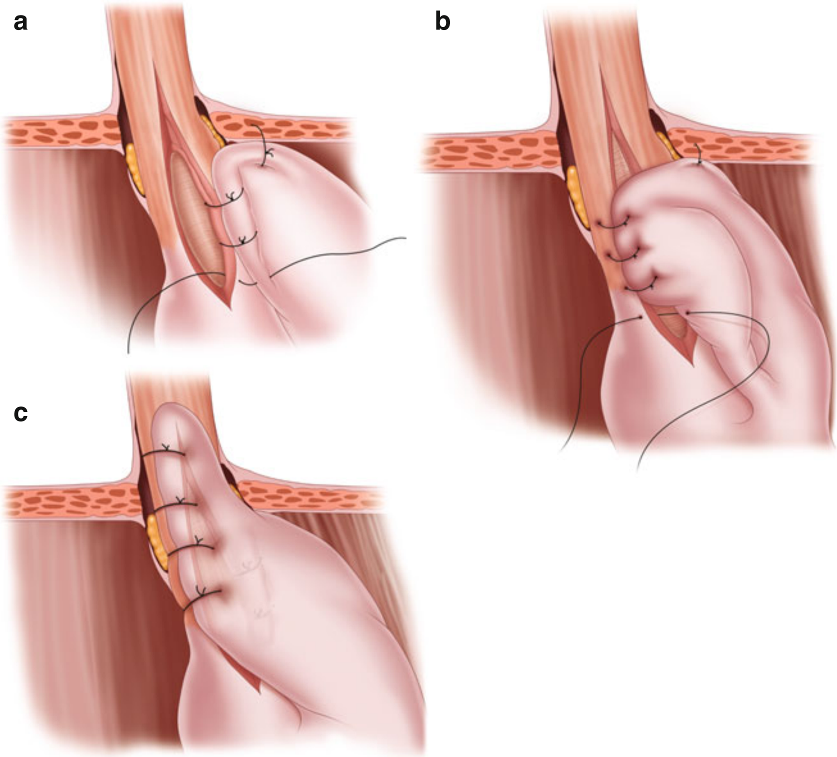


Fig 7.4 Dor fundoplication. (**a**) The myotomy is complete and the left side of the fundus used to create the Dor wrap is sutured to the left side of the myotomy and to the left crus. (**b**) The right side of the fundus is sutured to the right side of the myotomy. (**c**) The right side of the wrap is also sutured to the crus

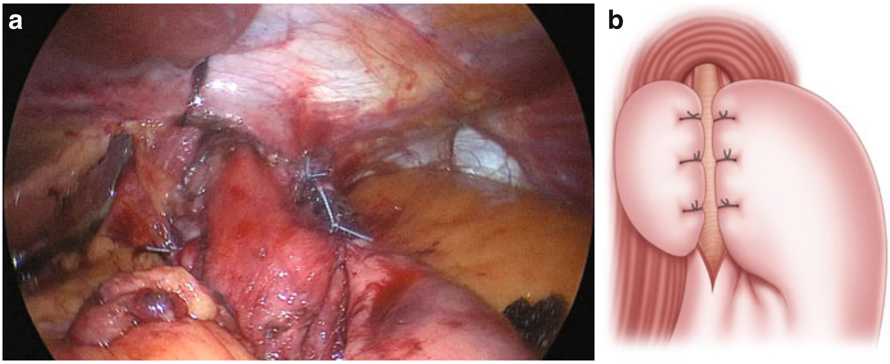


Fig 7.5 Toupet fundoplication. (**a**) Intraoperative appearances of a Toupet fundoplication. (**b**) Toupet fundoplication: the left side of the fundus is sutured to the muscle to the left of the mucosa. The right side of the fundus is sutured to the muscle to the right of the mucosa

Operation: Technique #2, Toupet Fundoplication

1. Divide the right pars flaccida (gastrohepatic ligament) and spare the hepatic branch of the vagus nerve. Identify and spare any replaced or accessory left hepatic artery coming off of the left gastric artery. Dissect the right crus and find the decussation of the right and left. Leave the lining on the right crus and do not expose the muscle. Clear the retroesophageal space by placing two graspers together and separating the fibers. Encircle the esophagus with umbilical tape or a Penrose drain.
2. Divide the short gastric artery and separate the posterior attachments of the stomach. Dissect the left crus and avoid injury to the left (anterior) vagus nerve. Clear the anterior esophagus to the level of the inferior pulmonary veins.
3. Divide the esophageal muscle. Grasp the esophageal muscle and divide the muscle using scissors, a bipolar energy device, or a cautery hook (but no cautery attached), utilizing gentle blunt dissection until mucosa is visualized. Separate 6 cm of the esophageal muscle while preserving the mucosa. Use hook cautery to divide 2 cm of the stomach below the gastric fat pad. Use light from the endoscope to aid in visualization of the distal 2 cm onto the stomach.
4. Test the myotomy by endoscopy after the myotomy to ensure that the myotomy is complete; submerge the esophagus under water and insufflate it to ensure that there is no leakage of air.
5. Perform Toupet fundoplication (Fig. 7.5a, b).

Management of Mucosal Injury Following Surgery

In the event of a mucosal perforation, repair the mucosa with interrupted absorbable sutures. Reinforce the repair by closing the muscle over the mucosal closure. Perform a contralateral myotomy away from the repair. Repeat the leak test. Reinforce closure with a fundoplication serosal patch.

Esophagectomy

Indication

Patients with esophageal cancer undergo clinical staging with EGD, endoscopic ultrasound (EUS), and PET-CT scanning. Patients with early-stage cancer may undergo endoscopic or surgical resection. Patients with local and regional disease may receive multimodality treatment with induction chemoradiation therapy followed by surgical resection, if there is no disease progression. The type of surgery is based on the location of the tumor, the medical condition of the patient, and surgeon preference. Our preferences are:

- Ivor Lewis esophagectomy for patients with lower esophagus and GEJ tumors
- Three-field esophagectomy for patients with mid esophageal tumors
- Transhiatal esophagectomy for patients with mid esophageal tumor who cannot tolerate one-lung ventilation.

Minimally Invasive Ivor Lewis Esophagectomy

Position

1. Supine
2. Left lateral decubitus

Abdominal Port Placement

1. Use a 5-mm optical trocar (e.g., Ethicon XCEL® trocar or Covidien Versaport™ bladeless optical trocar) to place the first port under the left costal margin, lateral to the mid-clavicular line. Insufflate the abdomen once the trocar enters the peritoneal cavity (Fig. 7.6a).
2. Place a 12-mm trocar in the midline approximately 12 cm from the xiphoid process.
3. Place four 5-mm trocars in the following locations:
   - Left mid quadrant trocar: 8 cm left of the 12-mm port
   - Left upper quadrant trocar: 8 cm lateral to the left mid quadrant port
   - Right mid quadrant port: 8 cm away from the 12-mm port, at approximately a 30-degree angle towards the right costal margin
   - Supraumbilical trocar: 1 cm above the umbilicus

4. Place a liver retractor through the 5-mm optical trocar and lift the left lobe of the liver.
5. The surgeon stands on the right side of the patient and uses the right mid quadrant 5-mm port and the 12-mm port. The surgeon and assistant will need to change positions and ports throughout the procedure for optimal access. Initially, the assistant stands on the left side of the patient and uses the left upper and left mid quadrant ports. The camera is placed in the left mid quadrant port. The surgeon begins the procedure operating around the esophageal hiatus from the right side of the patient.

Operation

1. Perform exploratory laparoscopy, looking for liver, peritoneal, and omental disease.
2. Mobilize the esophagus at the GEJ. The camera is placed in the left mid quadrant port. Divide the gastrohepatic ligament and phrenoesophageal attachment. Mobilize the esophagus from the left and right crura. Place a Penrose drain around the esophagus. Place the Penrose in the mediastinum.
3. Mobilize the stomach. Divide the short gastric artery using an energy device. Place the camera in the supraumbilical port and divide the greater omentum, preserving the right gastroepiploic artery (Fig. 7.6b). Take down the avascular adhesions between the posterior stomach and the retroperitoneum. Place the camera back in the left mid quadrant port. Divide the left gastric artery. Creation of an omental pedicle is optional for patients who have had induction chemoradiation therapy (Fig. 7.6c).
4. Create a gastric conduit (Fig. 7.7a). Divide the lesser omentum between the 3rd and 4th venous plexus. Create a gastric conduit using an Endo GIA™ stapler (Covidien, Minneapolis, MN), initially 40 mm, then switching to 60 mm × 2 (Fig. 7.7b). The gastric conduit should be narrow (3–4 cm).
5. Perform pyloroplasty. Place the camera in the supraumbilical port. Use the Endo Stitch™ to place stay sutures in the superior and inferior portions of the pylorus. Divide the pylorus using cautery in longitudinal fashion (Fig. 7.7c). Close the pylorus in transverse fashion, using interrupted stitches (Fig. 7.7d).
6. Place a laparoscopic J-tube. Find the ligament of Treitz and travel 15 cm distally on the jejunum (Fig. 7.8, *top*). Place the bowel against the left lower quadrant. Place four T fasteners (Fig. 7.8, *second from top*). Place the needle through the incision from the abdominal wall into the small bowel. Thread a wire through the needle. Remove the needle and place an introducer with a dilator over the wire into the bowel (Fig. 7.8, *second from bottom*). Remove the wire and the dilator. Place the feeding tube over the wire (Fig. 7.8, *bottom*). See Chap. 8 for further details of J-tube placement.

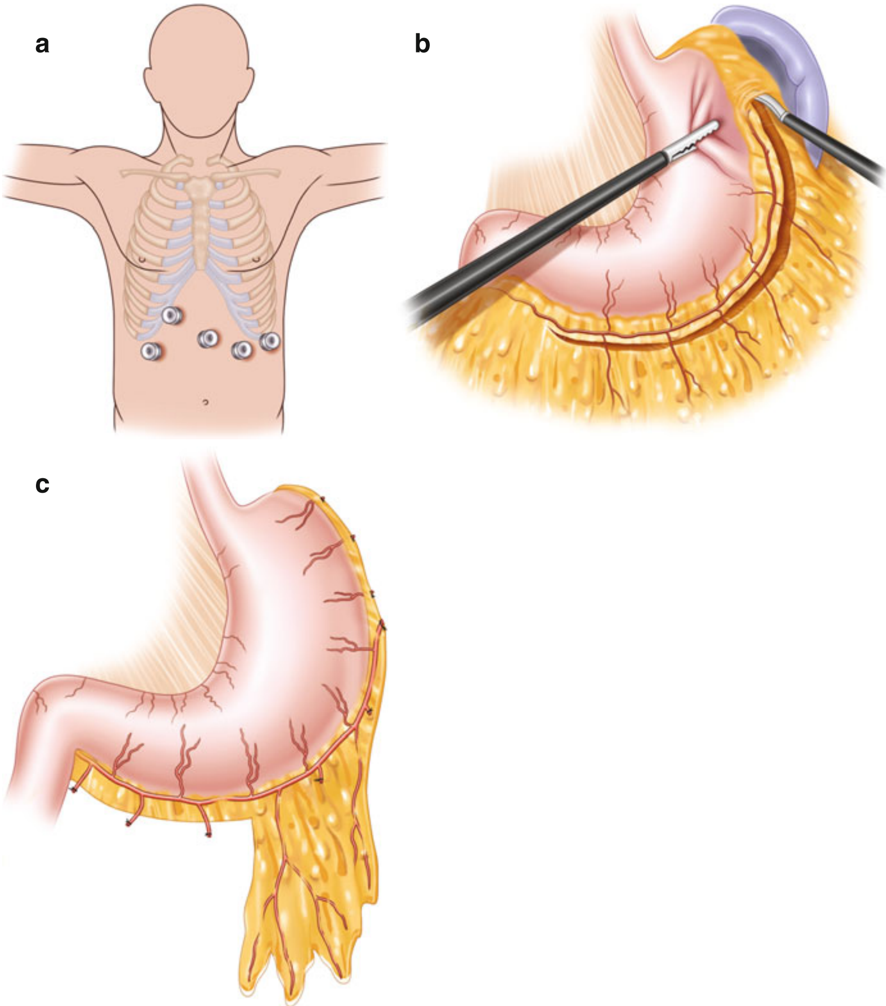


Fig. 7.6 (**a**) Port placement for minimally invasive Ivor Lewis esophagectomy. (**b**) Division of the greater omentum, preserving the right gastroepiploic artery. (**c**) Omental pedicle preserved during dissection of the greater omentum. This pedicle will be used to wrap around the esophagogastric anastomosis

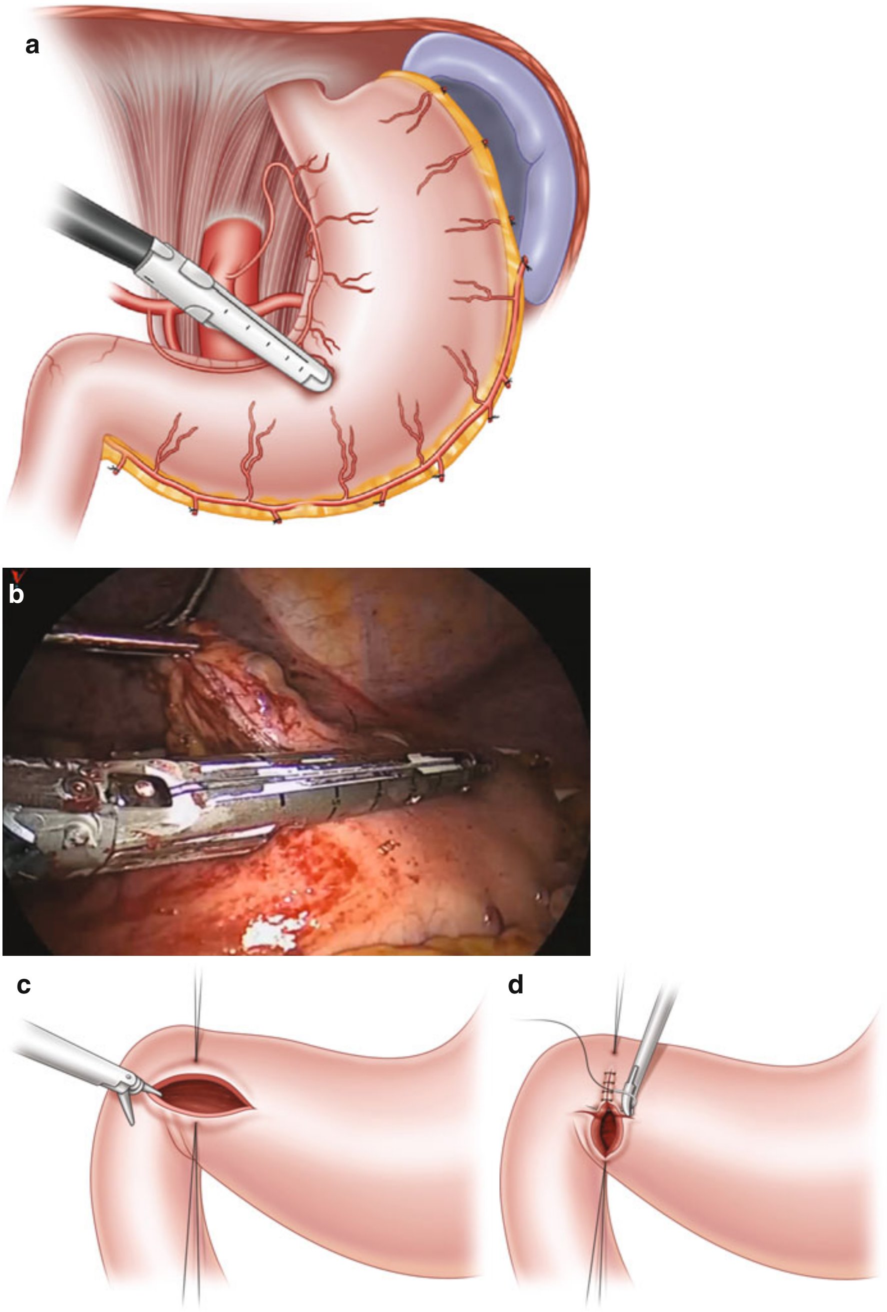
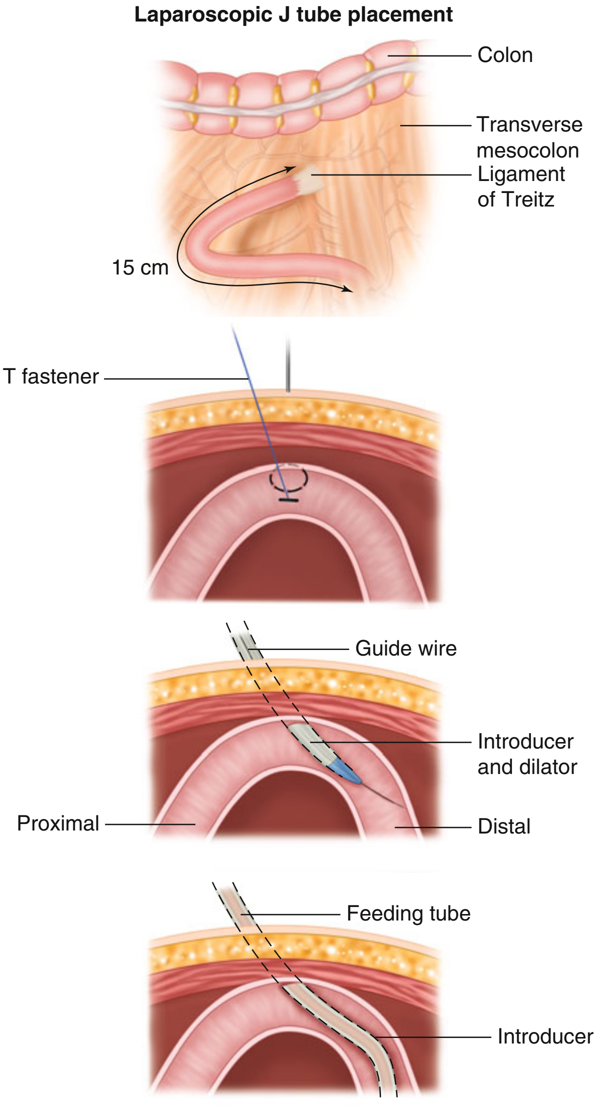


Fig. 7.7 (**a**) Creation of the gastric conduit. (**b**) Creation of the gastric conduit intraoperatively. (**c**) Pyloroplasty is performed by placing stay sutures at superior and inferior portions of the pylorus and performing a longitudinal, full-thickness division. (**d**) Pyloroplasty is completed by closing the opened pylorus in transverse fashion

Fig 7.8 Laparoscopic J-tube placement. *Top*, The ligament of Treitz is identified by lifting the transverse mesocolon cephalad. A location on the jejunum that will come to the abdominal wall without tension is identified, usually about 15 cm distal to the ligament. *Second from top*, T fasteners are placed through the abdominal wall and fix the jejunum at this point. *Second from bottom*, A needle and guidewire are passed into the jejunum in the center of the T fasteners. A dilator and then an introducer are subsequently passed. *Bottom*, The introducer is left in place and the jejunostomy feeding tube is passed through it. The T fasteners are then secured to fix the jejunum to the abdominal wall. The jejunostomy tube is secured to the skin with 0 silk



Right Chest Port Placement

1. Place three 1-cm incisions (Fig. 7.9a):
   - 10 mm port: 1-cm incision in the mid-to-anterior-axillary line in the fourth to fifth intercostal space
   - 10 mm port: 1-cm incision in the posterior axillary line in the fifth intercostal space
   - 10 mm port: 1-cm incision in the anterior axillary line in the seventh to eighth intercostal space
2. Utility incision: Make a 3–4 cm incision over the eighth to ninth intercostal space, centering the incision along the scapula tip line.

Operation

1. Perform diagnostic thoracoscopy.
2. If suitable to proceed with esophagectomy, a silk suture can be passed through the central tendon of the right hemi-diaphragm and pulled, using a transfascial suture passer through the skin and clipped outside the chest to hold it in the retracted position using a mosquito. The retraction that this suture provides allows excellent exposure to the hiatus from the chest.
3. Mobilize the esophagus. Divide the pleura overlying the esophagus at the GEJ. Find the Penrose drain and bring it out through the utility incision. Divide the pleura overlying the esophagus. Divide the azygous vein if the lesion is mid-esophagus (Fig. 7.9b). Use blunt dissection and an energy source to separate the esophagus from the pericardium, aorta, and bronchus.
4. Dissect mediastinal lymph nodes. Dissect out paraesophageal lymph node and station 7 and 9 lymph nodes.
5. Create anastomosis. *Option 1* (using EEA™ 28-mm stapler [Covidien] with 3.5-mm staples)
   - Anvil placement. Partially transect the esophagus using LigaSure™ and place the anvil in the esophagus, using an anvil grasper. Complete the division of the esophagus. LigaSure™ allows mucosa to fuse to the esophageal muscle layers, which is essential to complete an intact anastomosis. Send the proximal esophageal margin to pathology.
   - If negative, then proceed with the anastomosis. Place two purse-string sutures using Endo Stitch™ and tie it down (Fig. 7.9c). Use ENDOLOOP® (Ethicon) to secure the esophagus around the anvil.
   - Place the EEA™ stapler in the specimen (Fig. 7.9d). Make the anastomosis (Fig. 7.9e, f) and send the gastric and esophageal "donut" to pathology.
6. Create anastomosis. *Option 2* (stapled side to side) (Fig. 7.10a). Make an incision in the gastric conduit about 5 cm from the tip. Place the gastric conduit under the esophagus. Place stay sutures between the opening in the gastric conduit and the end of the esophagus. Place the metal end of an Endo GIA™ stapler with purple load in the gastric conduit, with the stapler end in the esophagus; make the stapled anastomosis (Fig. 7.10a, b).

– Close the opening with two-layer interrupted suture closure with 3-0 absorbable suture in the deep layer and 3-0 silk suture in the superficial layer (Fig. 7.10c).

7. Divide the specimen using the Endo GIA™ stapler, and send the specimen to pathology
8. Place a nasogastric tube (NGT) and a right chest tube after the esophageal reconstruction with gastric conduit is complete (Fig. 7.10d). It is often necessary also to place a left chest tube for pleural fluid drainage.

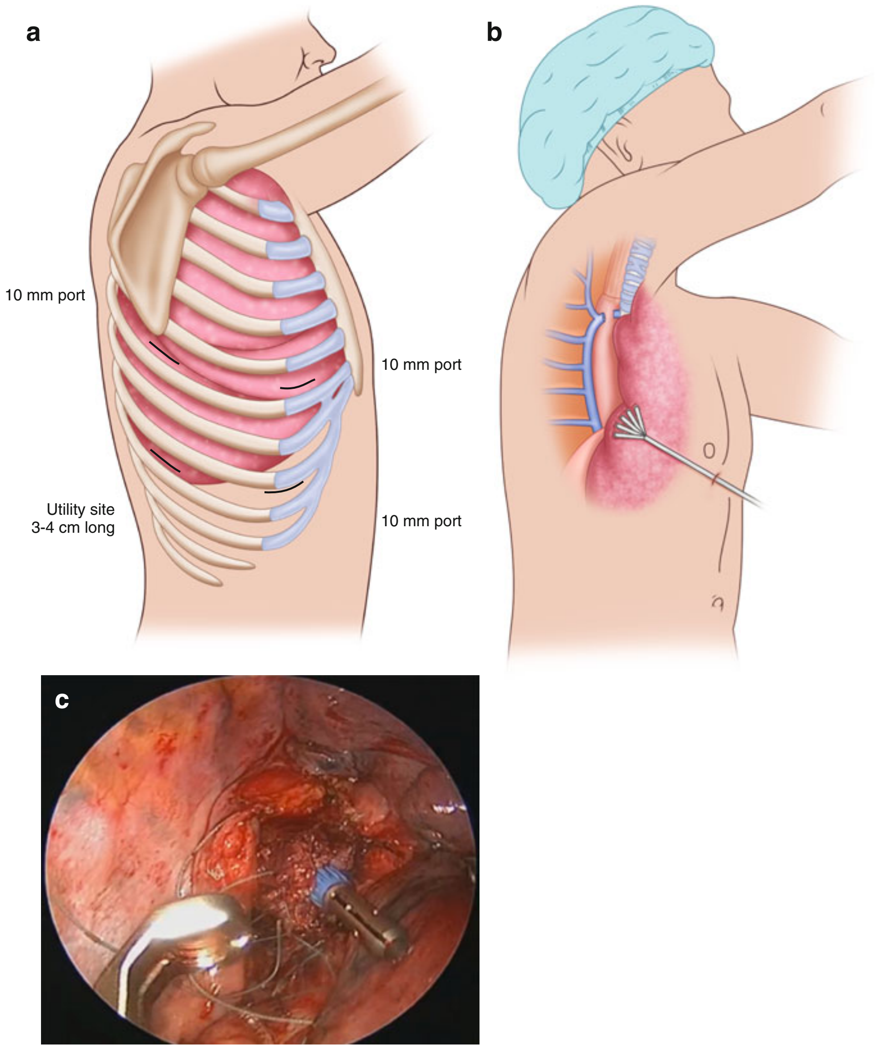
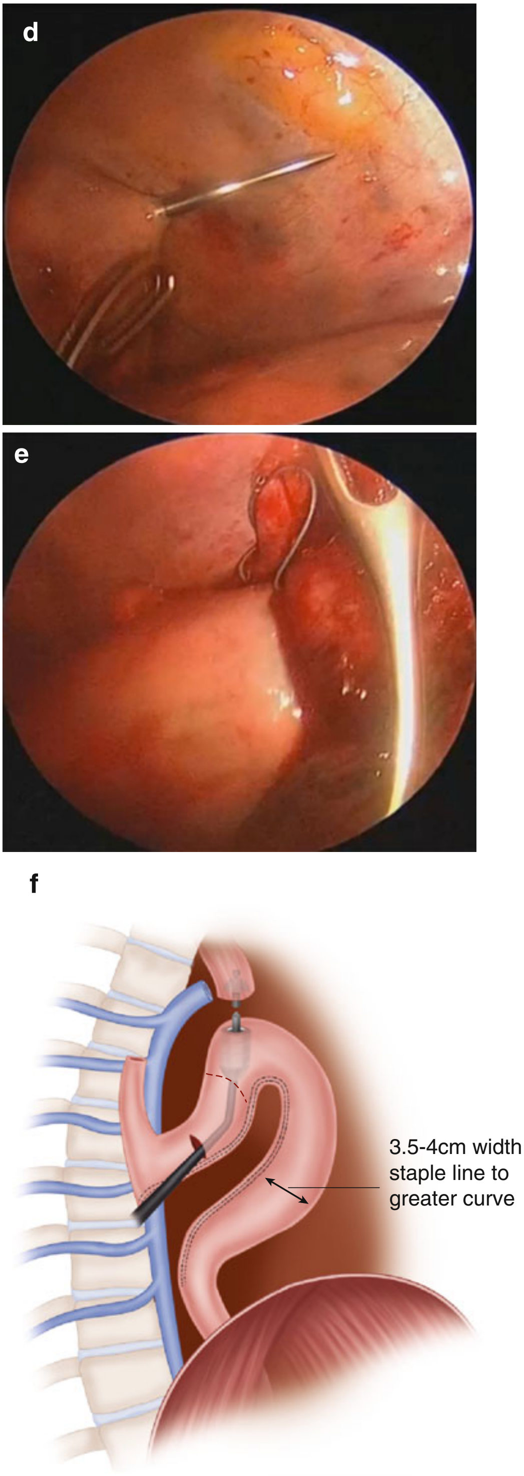


Fig. 7.9 (**a**) Thoracic port placement. (**b**) Dissection of thoracic esophagus; the azygous vein is seen divided. (**c**) The fundamentals of performing an EEA™-stapled esophagogastric anastomosis during minimally invasive Ivor Lewis esophagectomy. Anvil placement and purse-string suture placement in the esophagus. (**d**) Passage of the EEA™ stapler through the proximal end of the gastric conduit. (**e**) Performing the esophagogastric anastomosis using the EEA™ stapler. (**f**) Performing the EEA-stapled anastomosis intrathoracically

Fig. 7.9 (continued)



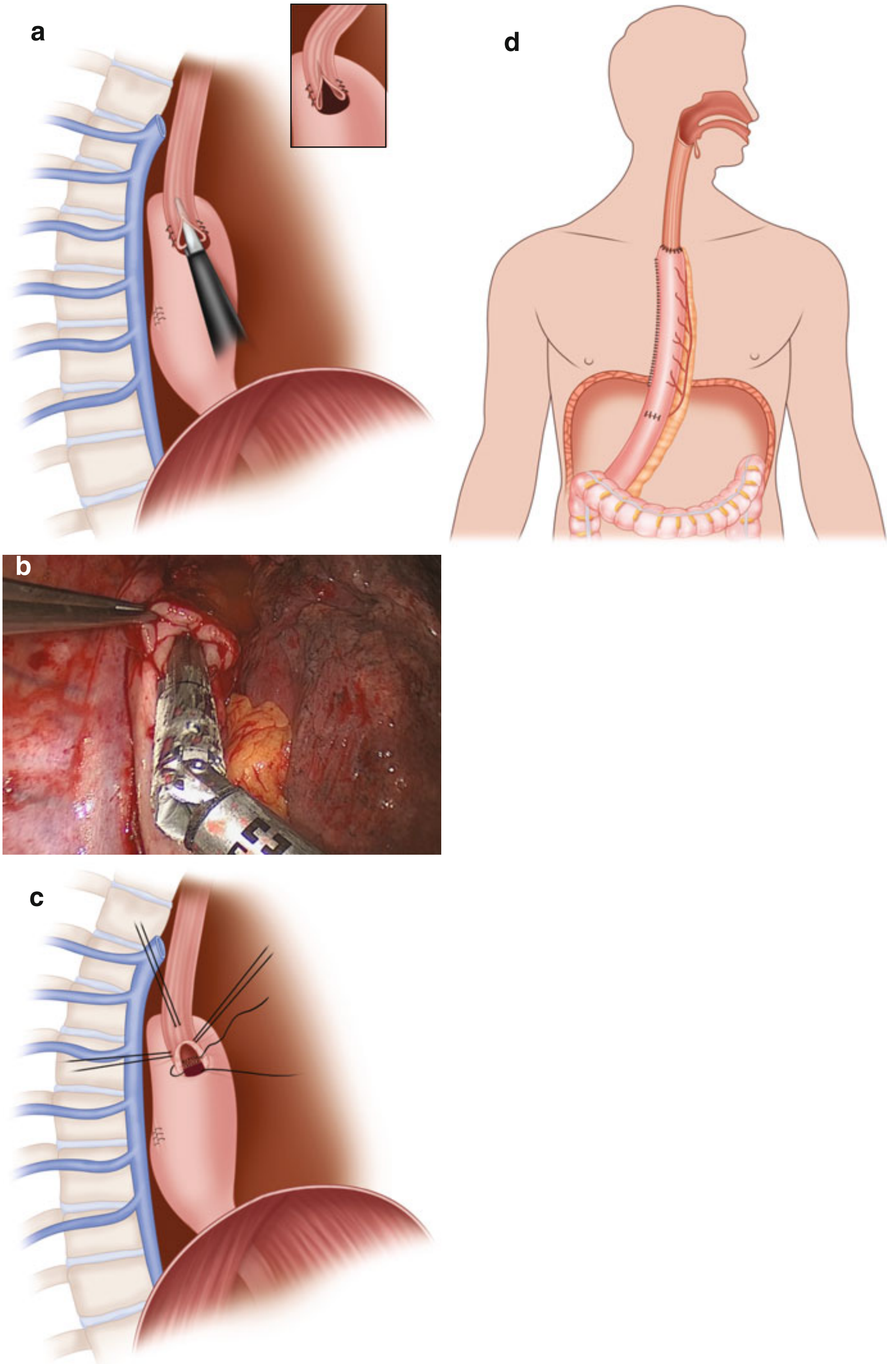


Fig. 7.10 (**a**) Schematic demonstrating a stapled side-to-side esophagogastric anastomosis. (**b**) Performing the stapled anastomosis between the gastric conduit and the esophagus. (**c**) The closure of the enterotomy after stapled side-to-side anastomosis. (**d**) Completed anatomy after minimally invasive Ivor Lewis esophagectomy

Minimally Invasive McKeown (Three-Incision) Esophagectomy

Position

1. Left lateral decubitus position
2. Supine, with neck extended and rotated to the right

Right Chest Port Placement

1. Place four 1-cm incisions:
   - 10 mm port: 1-cm incision in the mid-to-anterior axillary line in the fourth to fifth intercostal space
   - 10 mm port: 1-cm incision in the posterior axillary line in the fifth intercostal space
   - 10 mm port: 1-cm incision in the anterior axillary line in the seventh to eighth intercostal space
   - 10 mm port: 1-cm incision over the eighth to ninth intercostal space, centering the incision along the scapula tip line

Operation

1. Perform diagnostic thoracoscopy.
2. Using an endosuturing device, place a traction suture through the diaphragm. Using a transfascial suture passer, draw the suture through the skin and use a mosquito to clip it at the level of the skin, to allow good visualization of the hiatus.
3. Mobilize the intrathoracic esophagus: Divide the azygous vein with an endoscopic stapler. Divide the anterior and posterior pleura overlying the esophagus on either side. Take fat and lymphatic tissue along with the esophagus if the surgery is for cancer; if the surgery is for a benign etiology, take only esophagus. Dissect around the esophagus and place a Penrose drain around it. Repeat this procedure so that two Penroses encircle the esophagus. Dissect the esophagus from the pericardium, the aorta, and the airway. Place one of the Penroses in the thoracic inlet and place the other Penrose around the esophagus at the GEJ. These drains will remain in place when the thoracic portion is completed and thoracic incisions closed.
4. Dissect mediastinal lymph nodes: Remove the paraesophageal and mediastinal lymph nodes.
5. Place a right (and left) chest tube.

Abdominal Port Placement

1. Use a 5-mm optical trocar (e.g., Ethicon XCEL® trocar or Covidien Versaport™ bladeless optical trocar) to place the first port in the right costal margin, lateral to the mid-clavicular line. Insufflate the abdomen.

2. Place a 12-mm trocar in the midline approximately 12 cm from the xiphoid process.
3. Place four 5-mm trocars in the following locations:
   - Left mid quadrant trocar: 8 cm left of the 12-mm port
   - Left upper quadrant trocar: 8 cm lateral to the left mid quadrant port
   - Right mid quadrant port: 8 cm away from the 12-mm port, at approximately a 30° angle towards the right costal margin
   - Supraumbilical trocar: 1 cm above the umbilicus
4. Place a liver retractor through the 5-mm optical trocar and lift the left lobe of the liver.
5. The surgeon stands on the right side of the patient and uses the right mid quadrant 5-mm port and the 12-mm port. The surgeon and assistant will need to change positions and ports throughout the procedure for optimal access. Initially, the assistant stands on the left side of the patient and uses the left upper and left mid quadrant ports. The camera is placed in the left mid quadrant port. The surgeon begins the procedure operating around the esophageal hiatus from the right side of the patient.

Operation

1. Mobilize the esophagus at the GEJ. The camera is placed in the left mid quadrant port. Divide the gastrohepatic ligament and phrenoesophageal attachment. Mobilize the esophagus from the left and right crura. Identify the Penrose that was placed around the esophagus in the chest and use it to complete the esophageal dissection.
2. Mobilize the stomach. Divide the short gastric arteries using an energy device. Place the camera in the supraumbilical port and divide the greater omentum, preserving the right gastroepiploic artery. Take down the adhesions between the posterior stomach and the retroperitoneum. Place the camera back in left mid quadrant port. Divide the left gastric artery. Perform posterior antral release.
3. Create a gastric conduit. Divide the lesser omentum between the 3rd and 4th venous plexus. Create a gastric conduit using Endo GIA™ stapler, initially 40 mm, then switching to 60 mm × 2. The gastric conduit should be narrow. Divide the stomach completely when making the conduit. Stitch the tip of the gastric conduit to the lesser curve side of the specimen.
4. Perform pyloroplasty. Place the camera in the supraumbilical port. Use the Endo Stitch™ to place stay sutures in the superior and inferior portions of the pylorus. Divide the pylorus using cautery in longitudinal fashion. Close the pylorus in transverse fashion using interrupted stitches.
5. Place a laparoscopic J-tube. Find the ligament of Treitz and travel 15 cm distally on the jejunum. Place the bowel against the left lower quadrant. Place four T fasteners. Place the needle through the incision from the abdominal wall into the small bowel. Thread a wire through the needle. Remove the needle and place an introducer with a dilator over the wire into the bowel. Remove the wire and the dilator. Place the feeding tube through the introducer and remove the introducer.

Left Neck Incision

Make an incision anterior to the left sternocleidomastoid muscle, starting about 1 cm from the sternal notch.

Operation

1. Dissect cervical esophagus (Fig. 7.11a). Divide the platysma and omohyoid muscle. Retract the carotid sheath laterally and retract the trachea medially, with no traction on the recurrent laryngeal nerve. Dissect on the esophagus down to the mediastinum. Identify the Penrose drain and use it to complete the mobilization of the cervical esophagus. Take steps to avoid injury to the recurrent laryngeal nerve:
   - Monitor using neural integrity monitoring (NIM) tube.
   - Divide thoracic vagus from right chest.
   - Prevent traction on the vagus nerve.
2. Deliver the specimen. Pull the esophagus out through the left neck slowly, while visualizing the specimen and the gastric conduit going into the mediastinum.
3. Create an anastomosis. Divide the cervical esophagus using LigaSure™. Send the proximal portion for frozen section. Once the margin is negative, create a stapled side-to-side anastomosis:
   - Place the gastric conduit behind the esophagus.
   - Make an incision on the gastric conduit 5 cm inferior to the proximal end.
   - Place a linear stapler and perform side-to-side functional end-to-end anastomosis. (See Chap. 10.)
   - Close the opening. For the first layer, use interrupted sutures with 3-0 Vicryl. For the second layer, use interrupted sutures with 3-0 silk in Lembert fashion.
4. Place an NGT. The NGT can be placed and bridled into position or placed retrograde from the abdomen or through a pharyngostomy tube port.

Open Transhiatal Esophagectomy

Position

The patient is placed in a supine position.

Operation

1. Perform midline incision. Use a Thompson retractor to provide exposure to the left upper quadrant of the abdomen.
2. Mobilize the GEJ. Divide the gastrohepatic ligament and phrenoesophageal attachment. Dissect the esophagus away from the crus. Place a Penrose drain around the esophagus.
3. Mobilize the stomach. Divide the short gastric arteries. Divide the greater omentum about 3–4 cm away from the right gastroepiploic artery. Divide the left gastric artery.
4. Perform a left neck incision and cervical esophageal dissection. Divide the platysma and omohyoid muscle. Retract the carotid sheath laterally and retract the trachea medially, with no traction on the recurrent laryngeal nerve. Dissect on the esophagus down to the mediastinum. Place a Penrose drain around the esophagus and use it to complete the mobilization of the cervical esophagus.
5. Perform mediastinal dissection. Dissect bluntly around the esophagus toward the thoracic inlet from the neck and abdomen.
6. Create a gastric conduit (Fig. 7.11b–h). Create the gastric conduit using an Endo GIA™ stapler with a purple load. Suture the proximal portion of the conduit to the lesser curve of the specimen. (For details about gastric conduit preparation, please refer to Chap. 10.)
7. Perform pyloroplasty.
8. Deliver the specimen into the neck, along with the gastric conduit, ensuring prior to delivery that there is adequate length (Fig. 7.11i).
9. Create the anastomosis. Divide the cervical esophagus using the LigaSure™. Send the proximal portion for frozen section. Once the margin is negative, create a stapled side-to-side anastomosis:
   - Place the gastric conduit behind the esophagus.
   - Make an incision on the gastric conduit 5 cm inferior to the proximal end.
   - Place a linear stapler and perform side-to-side functional end-to-end anastomosis.
   - Close the opening. For the first layer, use interrupted sutures with 3-0 Vicryl. For the second layer, use interrupted sutures with 3-0 silk in Lembert fashion.
10. Place an NGT.

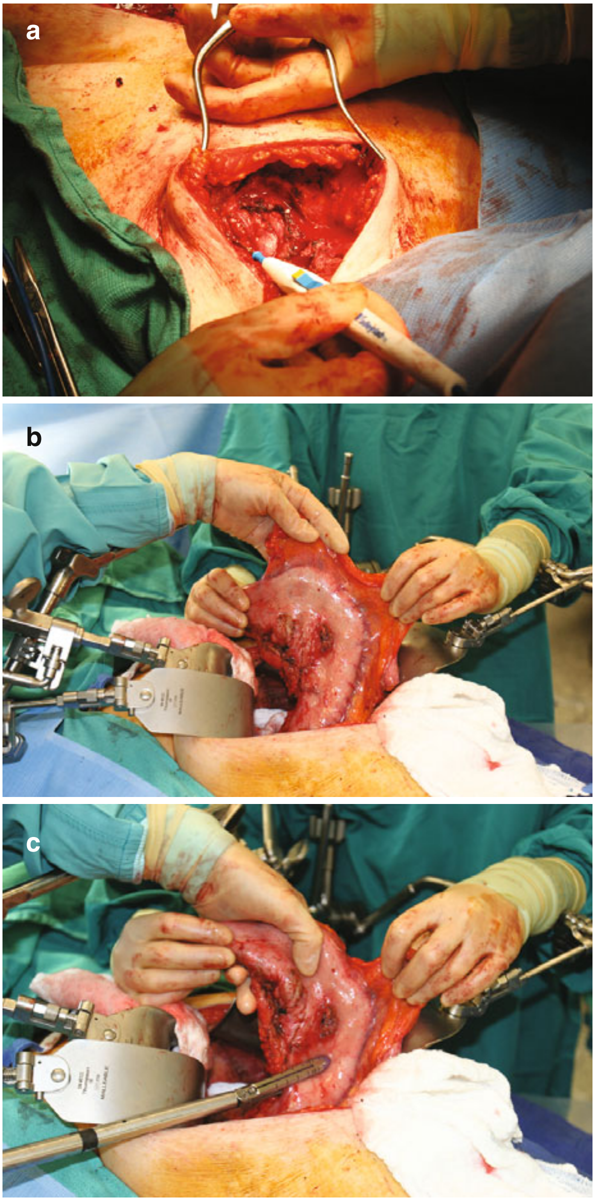
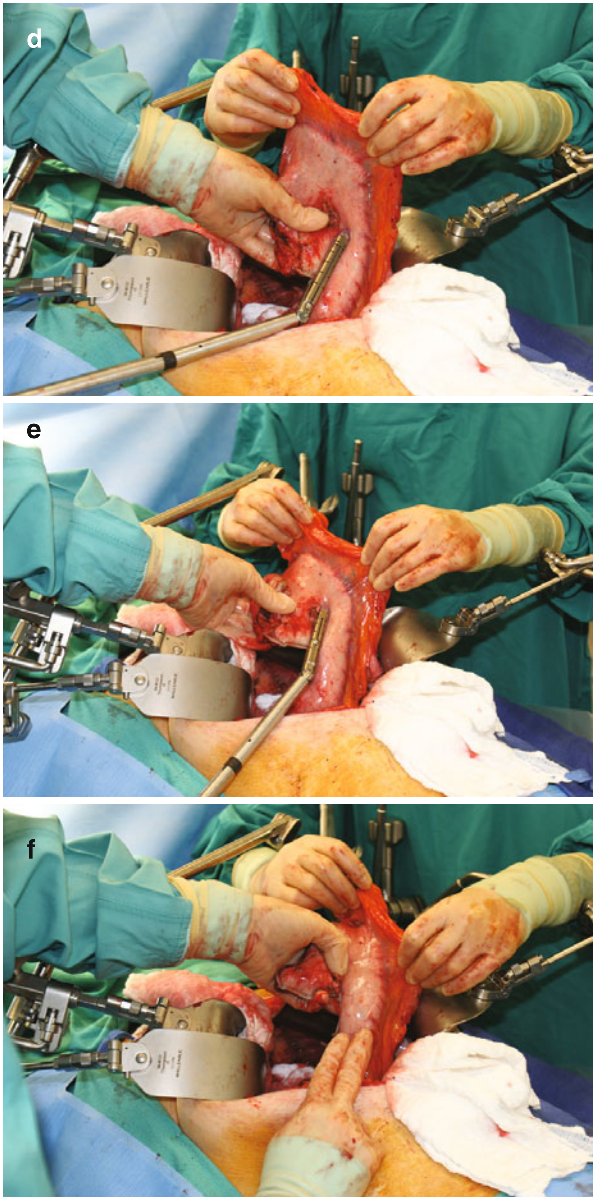


Fig. 7.11 (**a**) Cervical dissection of the esophagus. (**b**) Stomach before the gastric conduit is created. (**c**) First stapler to the lesser curve of the stomach, to create the gastric conduit. (**d**) Second stapler to the stomach, to create the gastric conduit. (**e**) Third stapler to the stomach, to create the gastric conduit. (**f**) Gastric conduit width is about two fingerbreadths. (**g**) The gastric conduit is created with a width of about 3–4 cm. (**h**) Fourth stapler to the stomach, to create the gastric conduit. (**i**) The length of the gastric conduit is tested extracorporeally to ensure that it reaches the neck without tension for anastomosis. In this case, the patient had a previous gastrostomy tube and the site is oversewn and excluded or could be incorporated if this was on the greater curve side

Fig. 7.11 (continued)



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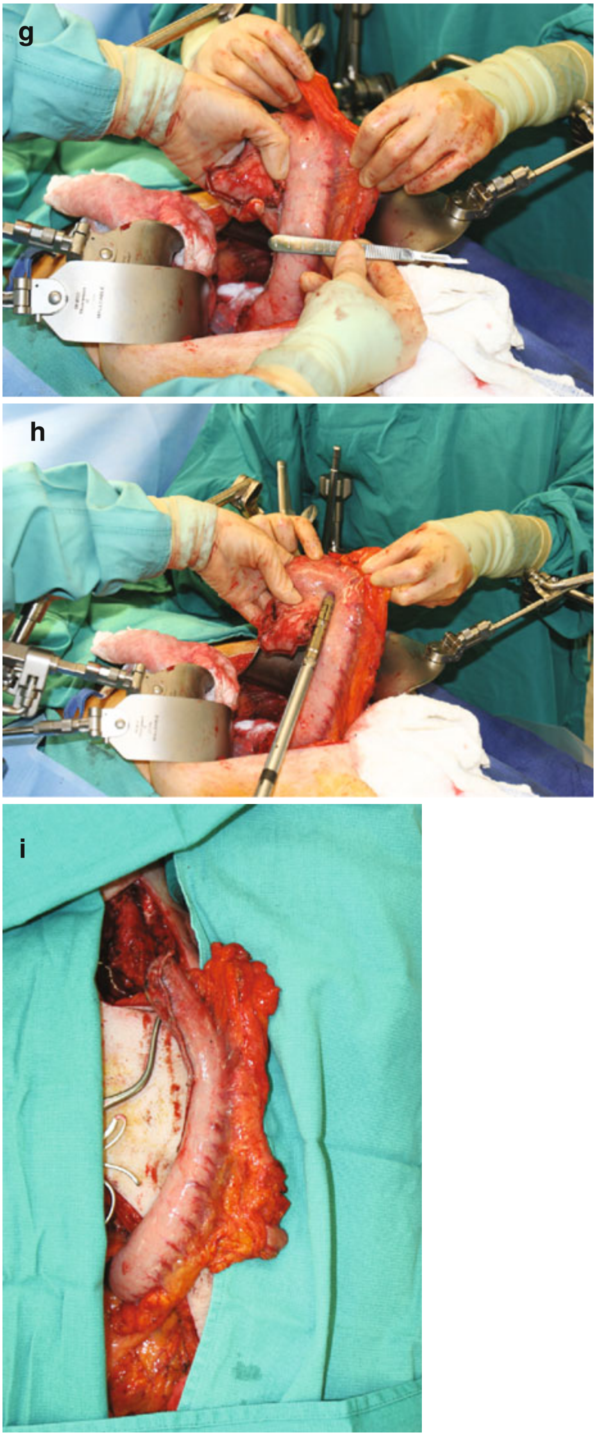

Suggested Reading

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Chapter 8
Management of Esophageal Leaks and Fistulas

Min P. Kim, Karen J. Dickinson, and Shanda H. Blackmon

Esophageal Perforations

Diagnosis of esophageal perforation can be made with a water-soluble esophagram followed by thin barium if no leak is seen with the water-soluble contrast. If there is still a concern for perforation after an esophagram, a CT scan is performed to evaluate for extraluminal air and extraluminal collection. The esophagus is divided into three parts: cervical, thoracic, and abdominal (Fig. 8.1). We recommend different management options based on the location of the perforation.

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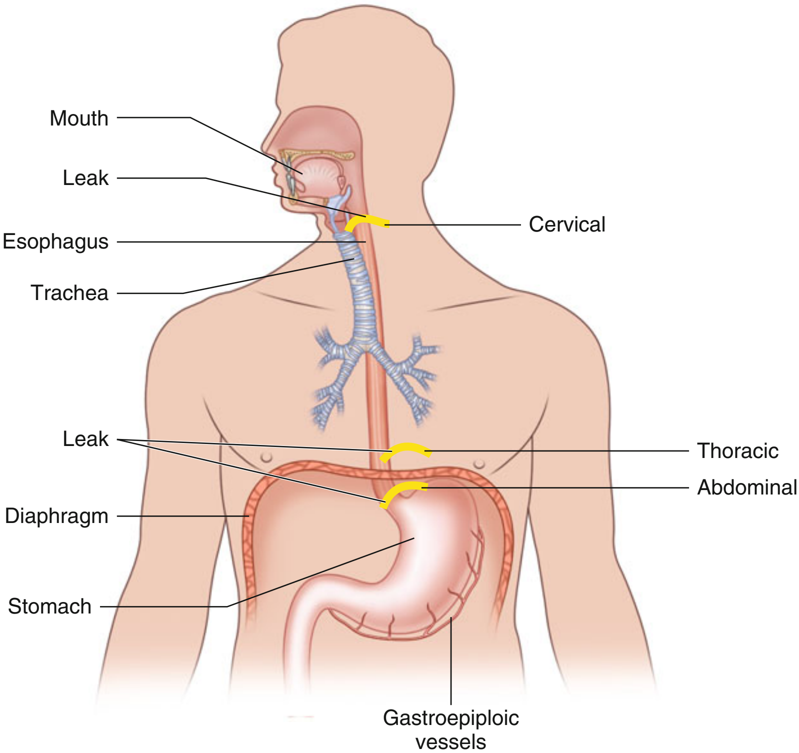

Fig. 8.1 The most common sites of cervical, thoracic, and abdominal esophageal perforations

Cervical Esophageal Perforation

Often, cervical esophageal perforation is treated by neck incision and washout of the wound. Nutrition and sepsis must be addressed. The patient is kept NPO with a Dobhoff feeding tube, a feeding tube placed surgically or by percutaneous endoscopy, or total parental nutrition (TPN). This combination provides the best opportunity to heal the leak. Esophageal stenting in this location is very difficult for the patient to tolerate. It leads to opening of the upper esophageal sphincter and higher risk of aspiration, so we typically rely on surgical drainage and antibiotics as treatment for cervical esophageal perforation.

Position

The patient is supine with a shoulder roll and the head turned towards the right side.

Operation

1. Make an incision anterior to the left sternoclavicular muscle.
2. Divide the omohyoid to expose the esophagus.
3. Irrigate the left neck and leave a Jackson-Pratt (JP) or Penrose drain.
4. Perform dressing changes.

Patient with Pneumomediastinum but Without Obvious Esophageal Leak

A patient with pneumomediastinum without any extravasation of contrast on esophagram or CT of the chest (Fig. 8.2) may be treated with NPO and IV antibiotics. Imaging should be repeated in at intervals to confirm the resolution of the pneumomediastinum and the lack of extraluminal fluid or contrast. Once the pneumomediastinum is resolved, the patient's diet should be advanced. As a follow-up, the cause of the pneumomediastinum should be investigated, most commonly with esophagogastroduodenoscopy (EGD) initially.

Fig. 8.2 CT scan demonstrating pneumomediastinum

Thoracic Esophageal Perforation

Patients without systemic sepsis and with evidence of thoracic esophageal perforation (Fig. 8.3) initially can be managed with esophageal stent placement, NPO, and IV antibiotics. Some smaller perforations or leaks without sepsis can be treated with endoluminal clips e.g. through the scope clips or over the scope clips (Fig. 8.4). Based on the degree of contamination of the mediastinum and the pleural space, the patient may require concomitant washout of the chest cavity. If the stent fails or if the leak from the perforation is large and the patient is systemically unwell, we perform surgical repair with intercostal muscle flap and wide drainage.

Fig. 8.3 Contrast swallow demonstrating a thoracic esophageal perforation

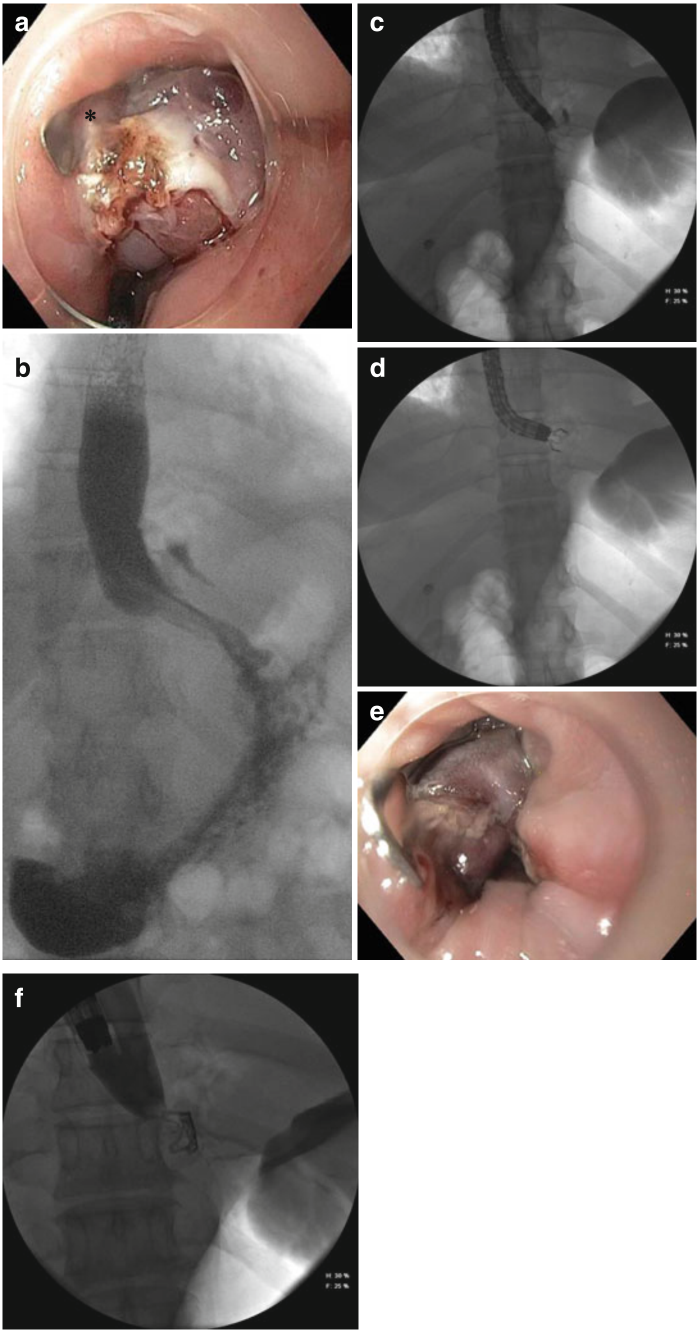

Fig. 8.4 Endoscopic treatment of an esophageal perforation using an over the scope clip. (**a**) Endoscopic appearances of esophageal perforation. * denotes the perforation. (**b**) Contrast esophagram demonstrating the esophageal perforation. (**c**) Combined endoscopic and radiological examination demonstrating the esophageal perforation and determining the correct positioning of the endoscope for clip deployment. (**d**) Deployment of the over the scope Ovesco clip to seal the esophageal perforation. (**e**) Endoscopic appearances of the esophageal perforation sealed by the Ovesco clip. (**f**) Contrast esophagram to demonstrate complete closure of the esophageal perforation by the Ovesco clip

Esophageal Stent

Position

The patient is supine.

Operation

1. Perform endoscopy to determine the location of the perforation (Fig. 8.5).
2. Irrigate the area with saline flushing from the endoscope.
3. Mark the proximal and distal point of perforation using a paper clip taped on the skin of patient, using fluoroscopy
4. Place a stiff guidewire into the stomach and remove the endoscope. Use fluoroscopy to ensure that the guidewire remains in the stomach.
5. Place the delivery system over the wire into the area of the perforation. Place two thirds of the stent above the area of the perforation.
6. Remove the delivery system.
7. Perform an on-the-table esophagram to assess for a seal; then perform an awake swallow test.
8. Place a bridle around the proximal point of the stent (Fig. 8.6), or alternatively use an Apollo OverStitch™ device (Apollo Endosurgery, Austin, TX) to suture the stent in place.

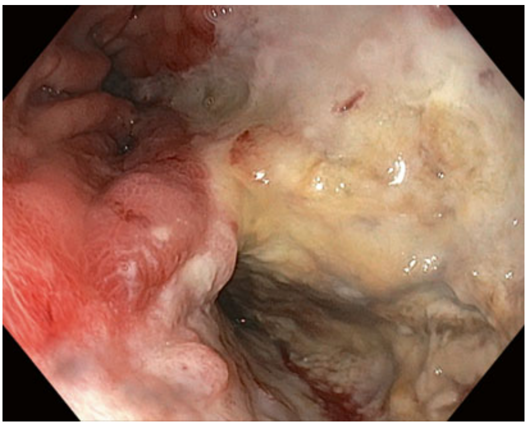

Fig. 8.5 Endoscopic appearance of a large intra-thoracic anastomotic leak post-esophagectomy. The gastric conduit can be seen to the left and cavity formed from the anastomotic leak to the right of the image

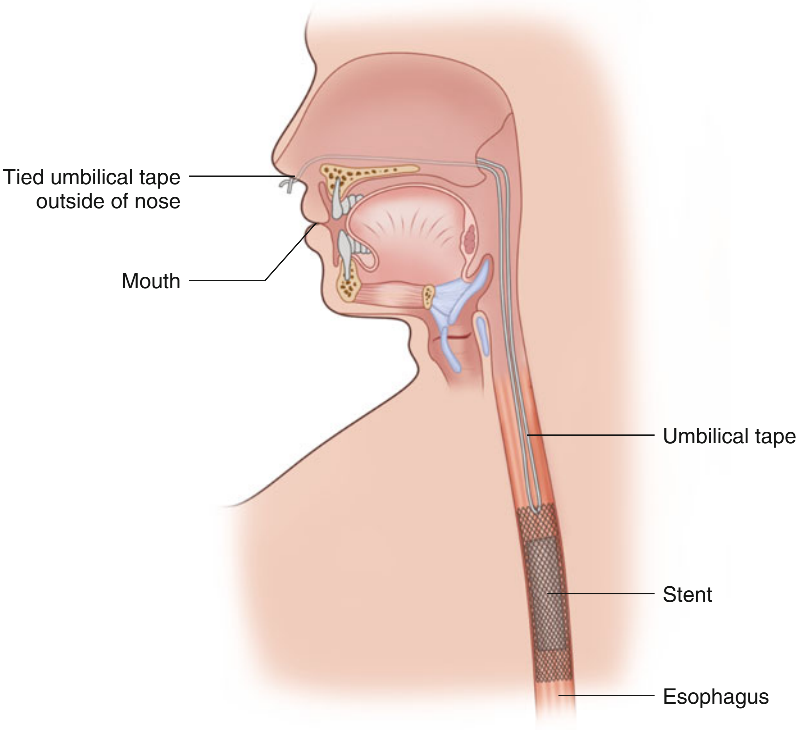

Fig. 8.6 Bridling the stent. One method for reducing the rate of stent migration is to "bridle" the stent. This involves hooking an umbilical tape through the proximal portion of the stent before placement. Once the stent is in place, the umbilical tape is carefully withdrawn through the esophagus and tied outside the nose to secure it. The stent depicted is a WallFlex™ stent (Boston Scientific, Marlborough, MA)

Thoracoscopic Washout of the Chest

Position

The patient is in a lateral decubitus position.

Operation

1. Place the ports:
   - Initial working port: 1-cm incision 1–2 cm below the scapular tip, which allows the visualization of the two anterior ports
   - Camera port: 1-cm incision above the diaphragm in the posterior axillary line
   - Working port: 1-cm incision in the sixth intercostal space, in the anterior axillary line
2. Perform washout:
   - Remove the contents of the perforation.
   - Irrigate the chest cavity with saline.
   - Decorticate the lung.
   - Place a chest tube in the area of the perforation.

Surgical Repair

If the leak is not sealed by the esophageal stent (Fig. 8.7), or if the perforation is large, primary closure with an intercostal muscle flap may be required. The lack of seal after stent placement is likely to be due to leakage from a proximal or distal point. Rarely, a hole in the middle of the stent may lead to a persistent leak. For a classification system of stent leakage and management, see Figs. 8.8 and 8.9. Exchange of the esophageal stent may seal the leak. If stent exchange or manipulation does not seal the leak, surgery is advised. For the best opportunity to seal the leak, we advise leaving the esophageal stent in place while performing the closure and muscle flap (Fig. 8.10).

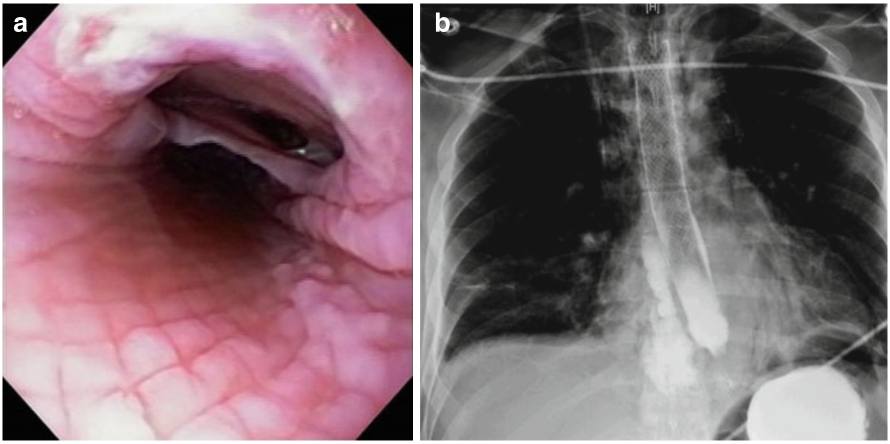

Fig. 8.7 (**a**) Endoscopic appearance of a persistent esophageal perforation despite stent placement. (The stent has been removed in this picture for the endoscopist to assess the esophageal wall.) (**b**) Fluoroscopic examination of the esophagus demonstrating a persistent thoracic esophageal leak despite stenting of the esophagus

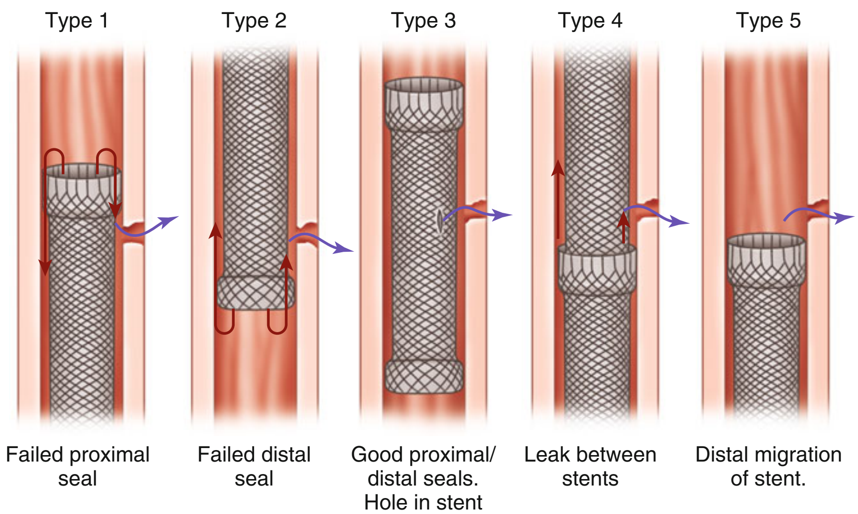

Fig. 8.8 Classification of stent leaks. *Arrow* indicates path of leak (From Stephens et al. (2014); with permission from Elsevier.)

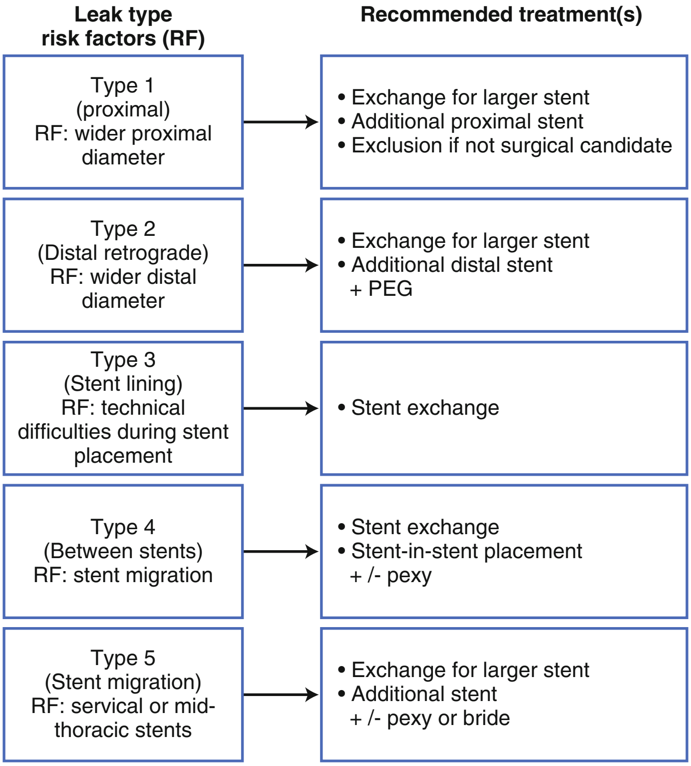

Fig. 8.9 A type-dependent treatment algorithm for stent leaks (From Stephens et al. (2014); with permission from Elsevier.)

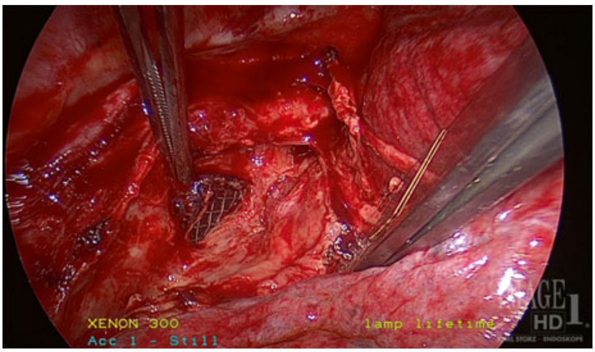

Fig. 8.10 Surgical repair of an esophageal perforation for failure of endotherapy. The stent is left in place as the surgical repair is performed and a muscle flap is buttressed in place. It is important to move the stent landing zones every two weeks to prevent erosion into the aorta or airway

Right-Sided Perforation Repair

Typically a perforation in the upper or mid esophagus is repaired through the right chest.

Position

The patient is in the left lateral decubitus position.

Operation

1. Make a right posterior-lateral muscle-sparing thoracotomy incision.
2. Harvest either the 5th or 6th intercostal muscle (Figs. 8.11 and 8.12), based on the location of the leak on the esophagram.
3. Irrigate the chest cavity.
4. Identify the area of the perforation (Fig. 8.13). If there is no perforation into the pleural space, then divide the pleura overlying the esophagus (Fig. 8.14) and irrigate the mediastinum.
5. Place 3–0 Vicryl suture to approximate the area of the perforation. If the tissue does not hold, then place interrupted suture from the intercostal muscle flap to the area of the perforation (Figs. 8.15 and 8.16).
6. Place a chest tube above the muscle flap.

Left-Sided Perforation Repair

Typically, a lower esophageal perforation is repaired through the left chest.

Position

The patient is in a right lateral decubitus position.

Operation

1. Make a left posterior-lateral thoracotomy incision over the 7th or 8th intercostal space.
2. Harvest either the 7th or 8th intercostal muscle, based on the location of the leak shown by the esophagram.
3. Irrigate the chest cavity.
4. Identify the area of the perforation and open the pleural surface.
5. Place 3–0 Vicryl or PDS suture to approximate the area of perforation. If the tissue does not hold, then place interrupted suture from the intercostal muscle flap to the area of perforation.
6. Place a chest tube above the muscle flap.

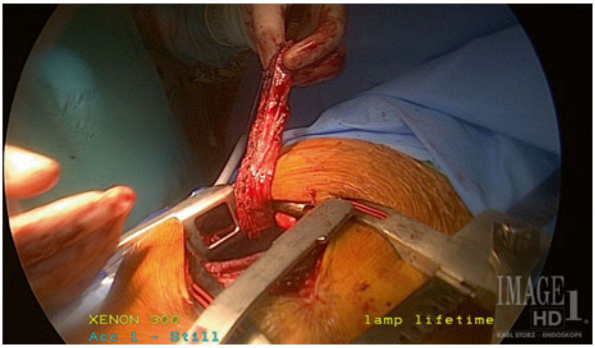

Fig. 8.11 Muscle-sparing thoracotomy is performed to repair an esophageal perforation. During the incision, care must be taken to harvest an intercostal muscle flap to provide a buttress for reinforcement of the primary esophageal repair

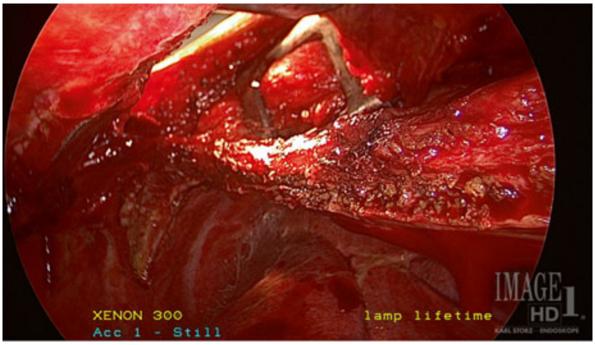

Fig. 8.12 Using thoracoscopy in conjunction with a limited muscle-sparing thoracotomy allows harvest of an intercostal muscle flap and repair of the esophageal perforation

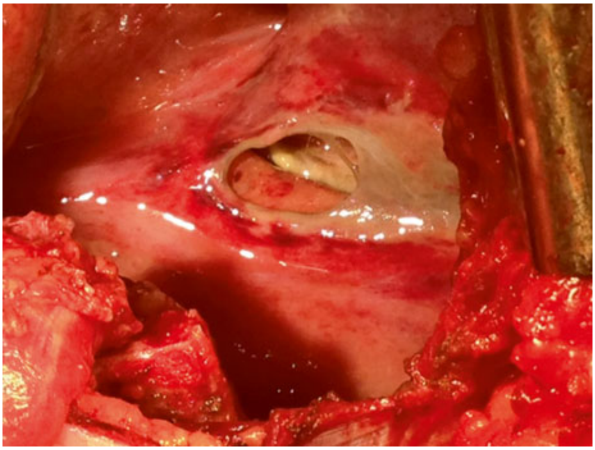

Fig. 8.13 Boerhaave esophageal perforation seen at thoracotomy

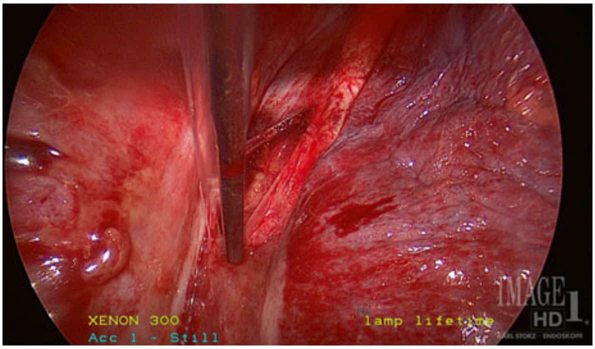

Fig. 8.14 Division of the pleura overlying the esophageal perforation. Division allows assessment of the size of the perforation and washout of the mediastinum and any associated cavity

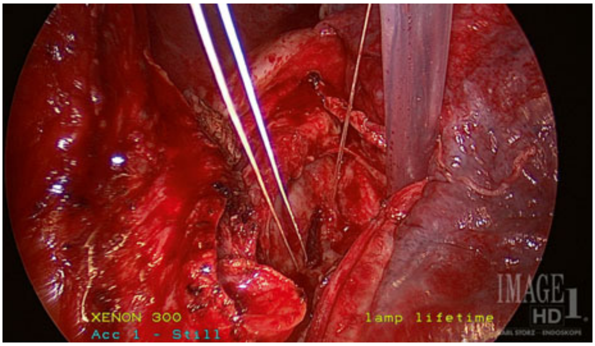

Fig. 8.15 The esophageal perforation can be repaired primarily, but if the tissue is too friable, then interrupted sutures can be placed to secure an intercostal muscle to buttress the esophageal defect

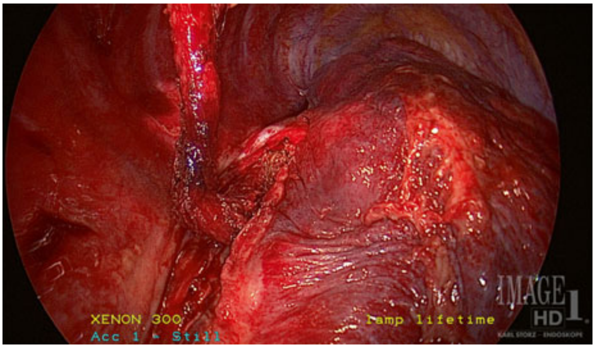

Fig. 8.16 Intercostal muscle used to buttress the esophageal perforation

Abdominal Esophageal Perforation

Patients with abdominal esophageal perforation, typically located at the GEJ (Fig. 8.17), usually have perforations from excessive vomiting or retching. We place an esophageal stent and perform washout of the abdomen; laparoscopic placement of a gastrostomy tube (G-tube) and jejunostomy tube (J-tube) is also performed. The G-tube is placed to gravity and the patient is fed through the J-tube. The G-tube decompresses the stomach to avoid a retrograde leak. This may occur as the stent crosses the GEJ and allows free reflux of gastric contents. To reduce aspiration, the patient is kept NPO and with a venting gastrostomy.

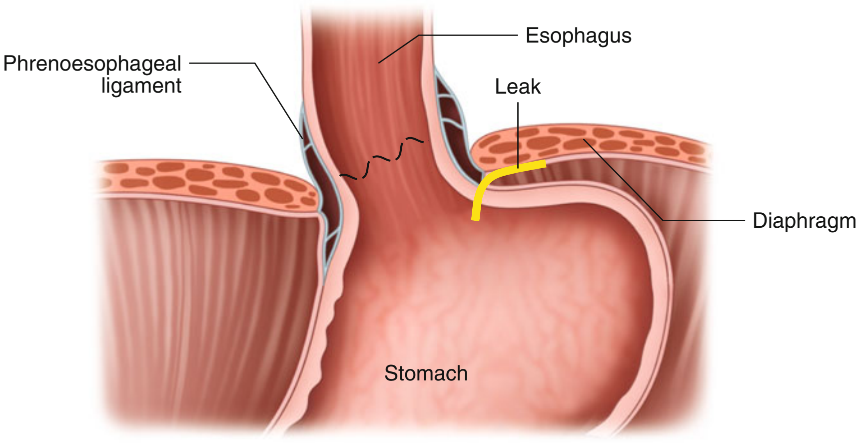

Fig. 8.17 The common site of an intra-abdominal esophageal perforation

Esophageal Stent

An esophageal stent is placed in the manner described above for management of thoracic esophageal perforation.

Laparoscopic G-Tube and J-Tube

Position

The patient is placed in a supine position.

Operation

1. Place a 5-mm instrument port in the right upper quadrant under direct vision (e.g., Ethicon XCEL® trocar) or using an optical trocar.
2. Place a 5-mm camera port below the umbilicus.
3. Place the distal anterior wall of the stomach to the medial left upper quadrant of the abdomen.
4. Place four T fasteners.
5. Place the needle in the middle of the T fastener into the stomach. Place a wire through the needle into the stomach and remove the needle. Inject saline to distend the stomach.
6. Over the wire, serially dilate the tract. Place the introducer with the dilator over the wire into the stomach. Remove the dilator and the wire. Place the G-tube over the introducer into the stomach. Remove the introducer.
7. Identify the jejunum at the ligament of Treitz (Fig. 8.18a) by lifting the omentum to expose the transverse colon. Follow the base of the mesentery to identify the proximal jejunum. Identify a portion of jejunum (approximately 15 cm from the ligament of Treitz) that will come up to the anterior abdominal wall without tension (Fig. 8.18b).
8. Place four T fasteners. Each fastener is passed through a needle (Fig. 8.18c) into the bowel wall (Fig. 8.18d). All four fasteners should form a square (Fig. 8.18e).
9. Place the needle in the middle of the T fasteners into the jejunum (Fig. 8.18f). Place a wire through the needle into the antimesenteric side of the jejunum and remove the needle.
10. Over the wire, serially dilate the tract. Place the introducer with the dilator over the wire into the jejunum. Remove the dilator and the wire. Place the J-tube over the introducer into the jejunum (Fig. 8.18g). Remove the introducer. Tie the T fasteners to the skin with the securing mechanism to secure the tube to the anterior abdominal wall (Fig. 8.18h).
11. After the J-tube is fastened with the four T fasteners, secure the tube approximately 2 cm proximal and distal with two other T fasteners (six used in total). Doing so will reduce the risk of volvulus of the small bowl around the J-tube.

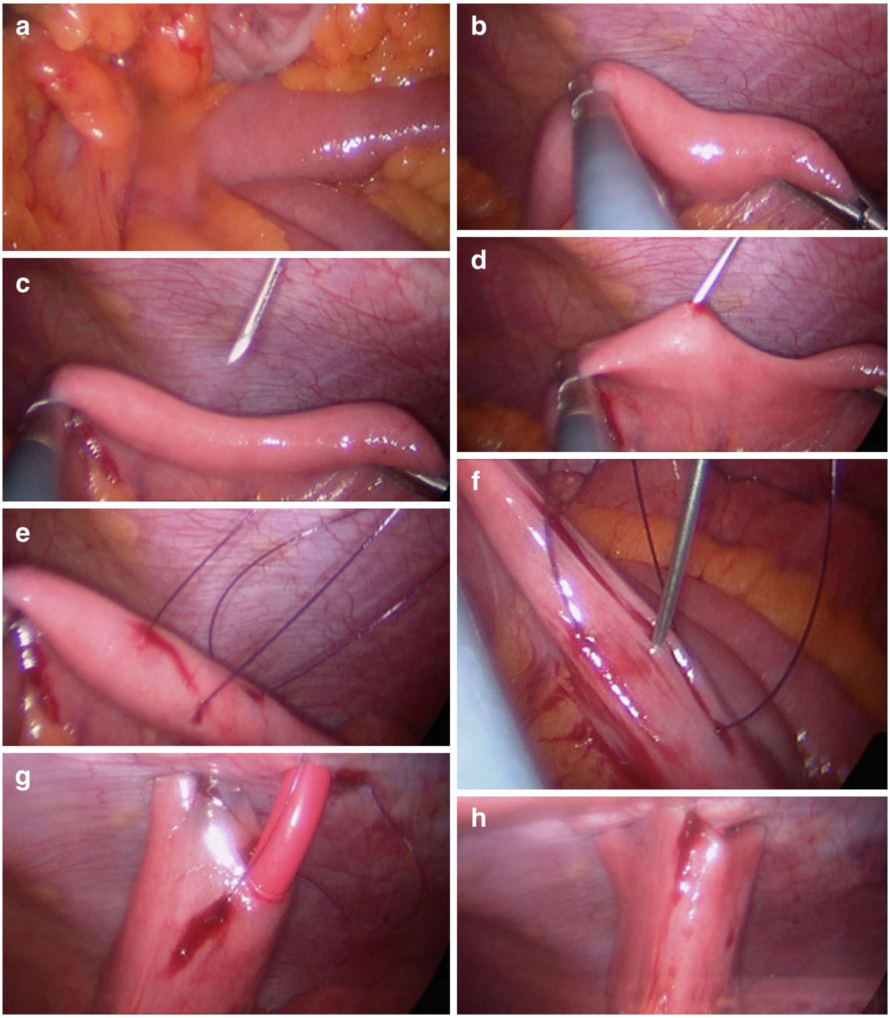

Fig. 8.18 (**a**) Laparoscopic identification of the ligament of Treitz. (**b**) Identification of a segment of jejunum that will reach the abdominal wall without tension. (**c**) A T fastener is placed through the abdominal wall. (**d**) The T fastener is placed into the jejunum and the “T” is deployed. (**e**) Four T fasteners in total are placed in this manner, forming a square. The jejunostomy tube (J-tube) will ultimately be positioned in the center of this square. (**f**) A needle is passed through the abdominal wall and into the center of the T fasteners; a guidewire is passed through this needle. Subsequently a dilator and then an introducer are passed over the guidewire to establish a tract for the J-tube. (**g**) The J-tube is placed into the jejunum through the introducer, and the introducer is withdrawn. (**h**) The T fasteners are snugged to the skin and deployed to fasten them, holding the J-tube securely to the abdominal wall. An endoscopic whitzel or pursestring over the tube entry site into the small bowel is recommended to limit leakage around the tube. It is very important to pass a further two T fasteners, one approximately 3–4 cm proximal and the other distal to the feeding jejunostomy and through the jejunum. These fasteners secure the jejunum longitudinally and reduce the risk of torsion around the J-tube and subsequent bowel obstruction

Esophageal Diversion and Exclusion

If a persistent leak remains uncontrolled despite an esophageal stent and muscle flap and the patient is septic, then esophageal exclusion or diversion may provide a way to salvage the patient.

Esophageal Exclusion with Salivary Tube

Position

The patient is in a supine position.

Procedure

1. Perform a left neck incision in front of the sternocleidomastoid muscle, extending to sternal notch.
2. Divide the omohyoid.
3. Identify the esophagus and dissect and preserve the recurrent laryngeal nerve.
4. Dissect around the esophagus and mobilize the esophagus proximally and distally to bring a section of the esophagus to the left neck.
5. Place a 2–0 Vicryl around the esophagus. Make a small incision in the esophagus with purse-string suture around it. Place an NGT through the opening. A Montgomery salivary tube is sutured to the NGT and is pulled out through the esophagus to the left neck (Fig. 8.19). Alternatively, the esophagus can be sewn on the side circumferentially to the skin, opening as a side ostomy without the salivary bypass tube (Fig. 8.20). To completely divert the saliva, a 0 Vicryl suture can be used to tie off the distal end of the esophagus just caudal to the area of diversion. The Vicryl should dissolve in 2–3 months, allowing time for the leak to heal without saliva passing through the area of the leak. Once the esophageal lumen reconstitutes, the side diversion can be repaired.

Fig. 8.19 A Montgomery salivary tube is useful for allowing esophageal drainage if the esophagus is too tethered or short to be delivered to the skin of the neck

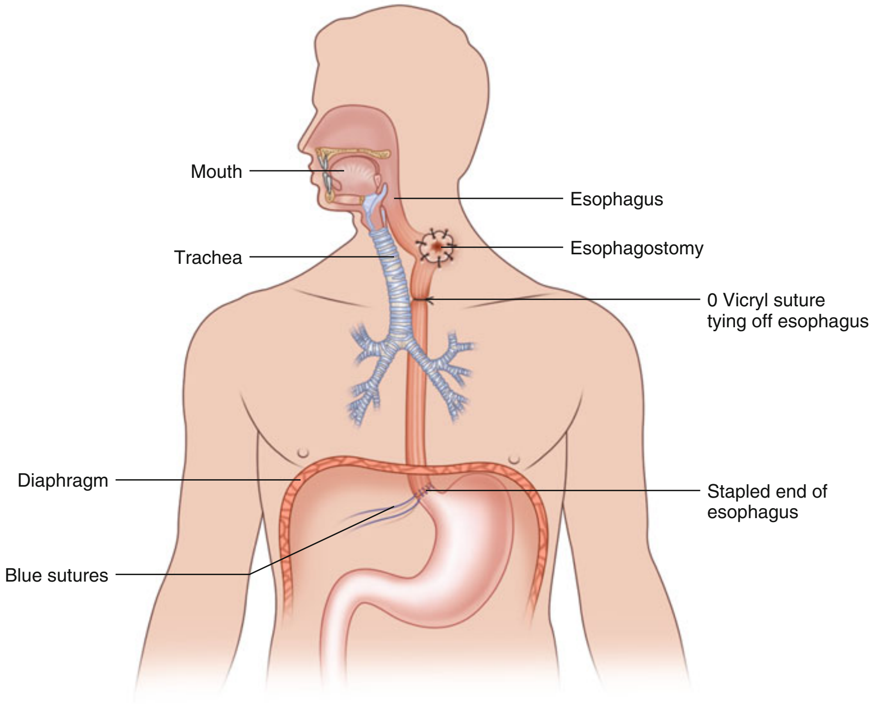

Fig. 8.20 Side esophagostomy. A side esophagostomy allows diversion of esophageal contents to the skin. To completely divert saliva, the esophagus can be ligated distally with an absorbable suture if temporary diversion is required

Esophageal Diversion

If the patient has persistent, uncontrolled leak despite esophageal exclusion, or if the patient is not a candidate for exclusion (such as a patient with esophageal tumor perforation), then we recommend esophageal diversion. If a gastric conduit anastomotic leak is caused by a nonviable conduit or necrosis, then diversion is advised.

The diversion procedure occurs in two parts: First, a right thoracotomy is performed, with resection of the esophagus. Second, a left neck incision is performed and the esophagus is brought out to the left chest. A chest diversion (Fig. 8.21) is always better than a neck diversion (Fig. 8.22), as it will result in a better-fitting ostomy.

Position: Resection of the Esophagus

The patient is placed in a left lateral decubitus position.

Operation

1. Perform a right posterolateral muscle-sparing thoracotomy.
2. Divide the esophageal pleura.
3. Divide the azygous vein with a stapler.
4. Mobilize the entire esophagus. Place a Penrose drain around the esophagus. Dissect the esophagus away from the pericardium, airway, and aorta. Divide the vagus nerve at the level of the azygous vein and separate it away from the esophagus. Place the Penrose drain in the thoracic inlet. Staple the end of the esophagus at the level of the diaphragm and use the entire length of the esophagus to be mobilized out of the neck. Do not transect the esophagus above the azygous vein if you want to have plenty of length to mobilize for chest diversion.

Position: Creation of Ostomy

The patient is in a supine position.

Operation

1. Perform left neck incision anterior to the sternocleidomastoid muscle (4–5 cm).
2. Divide the omohyoid muscle.
3. Dissect and preserve the recurrent laryngeal nerve.

4. Dissect down to the Penrose that was left at the top of the thoracic esophagus and bring the Penrose and the esophagus out of the left neck. If the Penrose cannot be reached with a finger, a video mediastinoscope may be used to safely identify the Penrose and grasp it for retraction.
5. Tunnel the end of the esophagus to the left chest. Stretching the esophagus towards the chest will allow a test to ensure that adequate length is available to reach the ostomy site.
6. Identify the area for the ostomy. The ideal site (with unlimited esophageal length) is inferior to the border of the clavicle and medial, traveling over the sternocleidomastoid and making a gentle curve. A Kocher clamp is used to elevate the skin, and the Bovie or a knife is used to cut away a circle of skin 2 cm in diameter. Dissection of the esophagus away from the trachea to ensure the creation of a gentle curve will prevent dysphagia. Some surgeons advocate going through the sternocleidomastoid muscle, but our service typically passes the esophagus over this muscle. Finally, the esophagus is passed out of the ostomy hole and is sutured circumferentially around the edge of the wall to the dermis with absorbable suture. Leaving the terminal end of the esophagus hanging out of the skin edge is important, as the esophagus will retract (as when a pie crust is baked). Leaving additional length allows the patient to have extra length, better emptying into the bag, and demarcation without wasting precious esophagus (Fig. 8.23). By using this technique, the patient will have fewer events requiring manual dilation.
7. Place a vented ostomy bag over the ostomy.

Other novel ways to treat a perforation are discussed in Chap. 6.

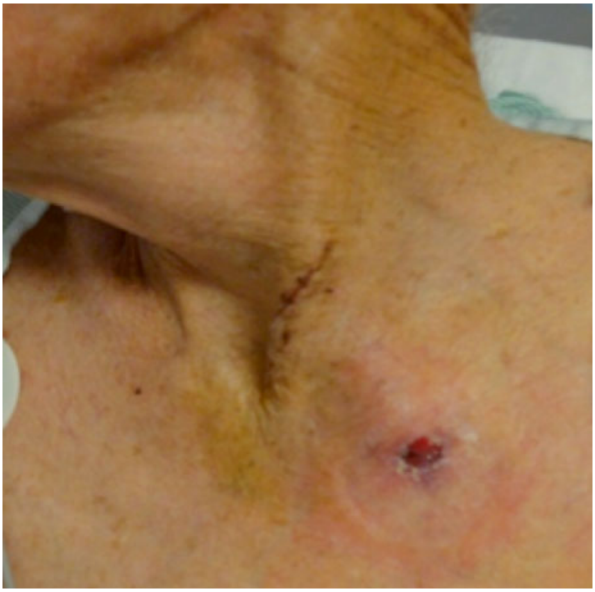

Fig. 8.21 Chest wall esophagostomy. This is the preferred site for placement of an esophagostomy, as esophageal length is maximally preserved. Additionally, the patient's quality of life is improved, as this site is easier to care for and it is easier to manage the stoma bag under clothes

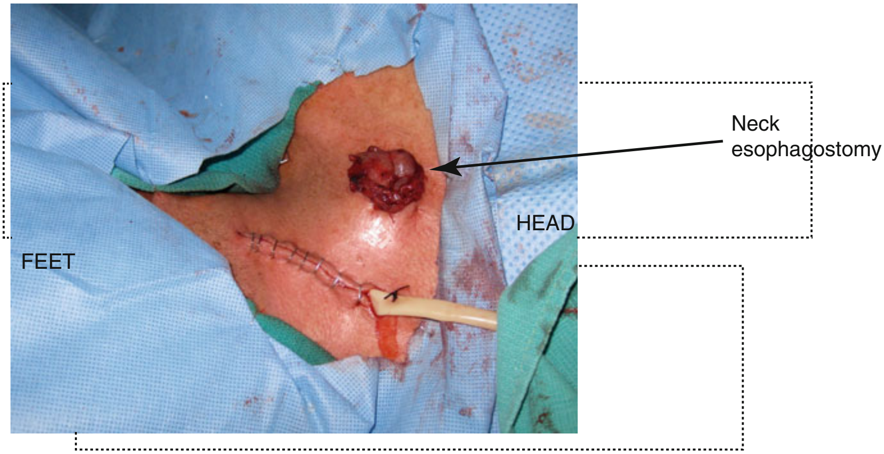

Fig. 8.22 Neck esophagostomy. We prefer the chest wall esophagostomy, but in some situations (e.g., inadequate esophageal length), a cervical esophagostomy is the only option

Fig. 8.23 Diverting the esophagus onto the left chest. Significant esophageal length can be preserved for future esophageal reconstruction

Suggested Reading

Schaheen L, Blackmon SH, Nason KS. Optimal approach to the management of intrathoracic esophageal leak following esophagectomy: a systematic review. Am J Surg. 2014;208(4): 536–43.

Stephens EH, Correa AM, Kim MP, Gaur P, Blackmon SH. Classification of esophageal stent leaks: leak presentation, complications, and management. Ann Thorac Surg. 2014;98(1): 297–303; discussion 303–4.

Chapter 9
Esophagostomy Management

Shanda H. Blackmon

The decision to remove an esophagus that is unsalvageable in an emergent setting typically results in diversion. Immediate reconstruction is ill-advised, typically because infection will complicate healing of a new anastomosis, patients are often too ill to undergo reconstruction, and such cases are long and require preparation and the assembly of a specialized team. Once a patient's esophagus is diverted and drained, control of a septic source can lead to stabilization and survival. Diversion onto the anterior chest wall (*see* Chap. 8) is always better than diversion onto the neck.

The patient will require feeding tube access in addition to the diversion, as enteral nutrition is optimal. If a portion of the stomach is available, it is advisable to place a gastrostomy tube as well as a feeding jejunostomy tube. This allows decompression and the patient will have an alternate source of feeding if the jejunostomy tube is dislodged. A gastrostomy tube also allows rapid identification of the stomach on re-entry to the abdomen for reconstruction.

Counseling the patient about changing ostomy bags, available emotional support, and criteria for reconstruction is paramount (Figs. 9.1, 9.2, 9.3 and 9.4).

A barrier cream or other skin protection or should be applied before the ostomy bag is fitted. The perfect ostomy bag includes the following:

- A vent for air that is swallowed
- A good fit onto the skin
- Easy application and flexibility to conform to the skin folds
- An easy mechanism for the patient to empty it after meals

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Fig. 9.1 Preparation of the skin

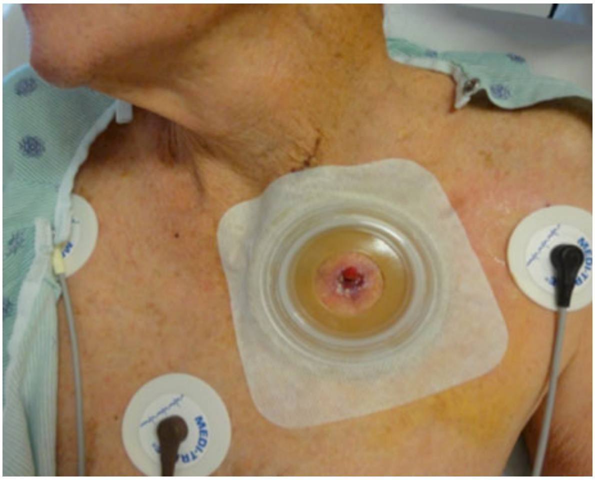

Fig. 9.2 Cutting the ostomy wafer to fit the end of the esophagus. The ostomy wafer fits best on an esophagostomy that has been delivered onto the chest. In this position, the patient can often perform placement alone in front of a mirror. Diversion onto the neck makes ostomy management more difficult and uncomfortable for the patient, but sometimes, because of length issues, is inevitable

Fig. 9.3 Placing the bag over the hole the bag should be vented so that when the patient swallows air, it can escape. In this photo, the vent is located at the top of the bag

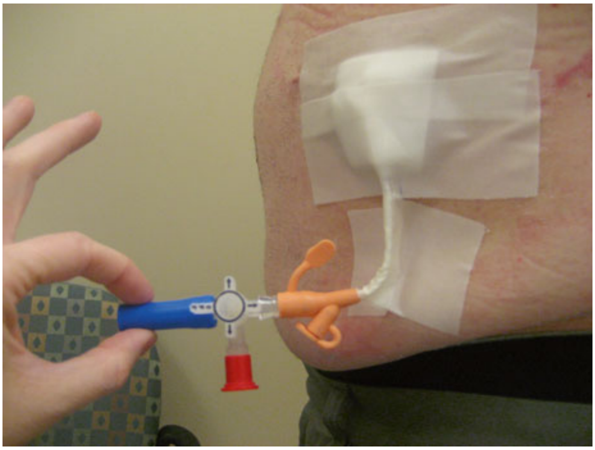

Fig. 9.4 Proper taping and securing of jejunostomy tube and lines, using a tape-to-tape "mesentery" hinge the lopez valve will allow the tubing to connect to feeding tube pump apparatus. The three-way stopcock allows the patient to irrigate and flush the tube without leakage and can be removed at night for comfort

Chapter 10
Esophageal Reconstruction

Karen J. Dickinson, Puja Gaur, and Shanda H. Blackmon

There are several ways to create a neo-esophagus when resection of the esophagus is required. Table 10.1 lists options for conduits.

Special thanks to K.R. Shen for intraoperative images donated to this chapter.

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Table 10.1 Esophageal Tube Conduits

Conduit	Blood supply	Selection/placement
Stomach	Gastroepiploic	First choice for total esophageal replacement
Colon	Marginal artery of Drummond	Second choice for total esophageal replacement
Free jejunum	Mesenteric anastomosis to LIMA/LIMV or cervical vessels	Isolated short-segment cervical esophageal reconstruction
Pedicled jejunum	SMA	Optimal for Merendino resection (vagus-sparing resection) or short segmental resection
Long-segment supercharged pedicled jejunum	*Superior:* Mesenteric anastomosis to LIMA/LIMV or cervical vessels *Inferior:* SMA	Second choice for total esophageal replacement
Skin/forearm	Radial artery anastomosis to LIMA/LIMV or cervical vessels	Optimal for segmental neck resection, small area patch
Myocutaneous flap	Flap artery anastomosis to LIMA, LIMV, cervical vessels, or AV loop	Last choice when no other options remain or when a small patch to augment a stricture or narrowing is needed

AV arteriovenous, *LIMA* left internal mammary artery, *LIMV* left internal mammary vein, *SMA* superior mesenteric artery

Gastric Conduit

The stomach is always the first choice of esophageal reconstruction, when available (Fig. 10.1). The procedure involves four key steps:

- Mobilization of the stomach
- Division of the left gastric artery and short gastric vessels
- Preservation of the gastroepiploic artery
- Preparation for passage to the chest or neck for anastomosis

Approaches for reconstruction of the esophagus using a gastric conduit include the Ivor Lewis esophagectomy, McKeown esophagectomy, transhiatal esophagectomy, or the minimally invasive approach. The details of these operations are described in Chap. 7.

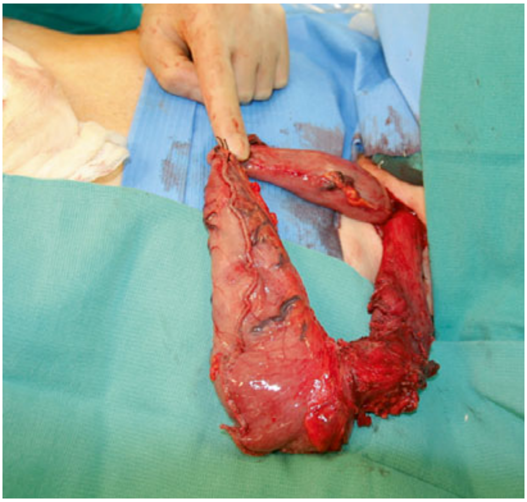


Fig. 10.1 Esophageal reconstruction using a gastric conduit. During a transhiatal esophagectomy the gastric conduit that will become the neo-esophagus is delivered into the neck. The esophagus is divided at least 5 cm proximal to the tumor to obtain a good margin. The cephalad portion of the conduit will also be excised and the specimen sent to pathology

Colon Conduit

We prefer to perform a supercharged colon conduit instead of a colon conduit alone, to avoid poor venous drainage, but, as an alternative, the colon can be used without supercharging. The procedure involves six key steps:

- Identification of the segment of colon to be used
- Mobilization of the colon
- Division of vessels
- Preservation of the marginal artery
- Preparation for passage to the chest or neck for anastomosis
- Creation of the anastomosis

Position

- Supine position
- For cervical anastomosis, the neck is extended and rotated to the right
- For intrathoracic anastomosis, a subsequent left lateral position is used for right thoracotomy
- The legs are prepared and draped in case vein from the leg is required for harvesting

Incisions

A midline laparotomy is typically used for colon preparation.

Operation

1. Dissection of the colon:
   (a) Midline abdominal incision
   (b) Lysis of adhesions if present
   (c) Identification of the segment of colon for use as the conduit
   (d) Transillumination and mobilization of the bowel mesentery
   (e) Identification of the blood supply to the colon
   (f) A Wood's lamp can be used to assess for adequate blood supply of the colon prior to transposition.
2. Selection and division of colon blood supply branches:
   (a) Choose the arcade based on transilluminated visualization and length.

(b) The ideal colonic arterial choice is depicted in Fig. 10.2 (a, left colon; b, transverse colon; c, right colon). There will be anatomic variations and shortened mesenteries from scar tissue.
(c) For a supercharged colonic conduit, the vessel will eventually be connected by a microvascular anastomosis to the left internal mammary artery (LIMA) and left internal mammary vein (LIMV) or jugular vein (Fig. 10.3).
(d) Open the mesentery to optimize length of available colonic graft (Fig. 10.4).
(e) Do not divide this segment until the tunnel has been created and the donor vessels have been prepared, because once the blood supply has been divided, the clock starts for ischemia time.

3. Preparing the neck; Dissection of the neck and blood supply:

(a) Perform an incision anterior to the sternocleidomastoid muscle low on the neck, extending onto the chest either midline or to the left of midline (Fig. 10.5a).
(b) Detach the sternocleidomastoid at the head of the clavicle.
(c) Dissect around the left first rib about 3 cm lateral to the sternal border.
(d) Divide the clavicle just lateral to the head and medial to the ligamentous attachments of the clavicle to the first rib. Divide the first rib 3 cm lateral to the sternal border; when supercharging the colon, allow enough space to dissect the LIMA for microvascular augmentation of the pedicled colonic flap.
(e) A hemimanubrectomy is performed, angled to the left on top of the second rib. The manubrium, the head of the clavicle, and the proximal first rib are removed en bloc. Beware of the internal mammary artery, which will be located beneath the cartilaginous portion of the ribs, about 1 cm from the sternal border (Fig. 10.5b).
(f) A rongeur is used to resect additional bone if needed; smooth the edges so that nothing sharp will injure the bowel or mesentery.
(g) Prepare the recipient vessels for microvascular anastomosis. The LIMA is typically an adequate artery, but the LIMV may or may not be robust enough for use. If not, consider using the jugular vein. A saphenous vein graft can be used to lengthen the artery or vein, depending on the position of the conduit and recipient vessels.

4. Creation of the tunnel for the conduit:

(a) Create a substernal tunnel, if possible.

- From the abdomen, make an incision on the anterior midline aspect of the diaphragm.
- Create a substernal tunnel while attempting to stay extrapleural. (An intrapleural route may be necessary in some cases.) Allow enough space for the conduit and mesentery to pass unobstructed. (About 5 cm should be adequate.)

(b) A posterior mediastinal route is an alternative.
(c) If neither a retrosternal route nor a posterior mediastinal route is available, a subcutaneous route may be taken as a last resort.

5. Delivery of the colon through the substernal tunnel:

(a) Prepare a large camera bag or ultrasound probe cover.
(b) Ensure that the tunnel is large enough to allow for the colon and mesentery, as well as postoperative edema.
(c) Deliver the bag through the tunnel from bottom to top (Fig. 10.6).
(d) Trace the bowel back to the mesentery and place the untwisted segment of colon into the bag (Fig. 10.7); moisten the inside and outside of the bag. Feed the bag and colon into the tunnel from below while placing gentle traction from above. Suction can be placed inside the bag to facilitate delivery of the conduit if necessary.

6. Microvascular anastomosis:

(a) The vascular augmentation is performed prior to the esophagocolostomy.
(b) A Wood's lamp can be used to assess the vascularity of the colon prior to anastomosis (Fig. 10.8).
(c) The operating microscope is used to prepare the recipient vessels.
(d) A 2-mm to 4-mm coupler device is typically used to create the venous anastomosis.
(e) Saphenous vein grafts can be used to compensate for length issues.
(f) Venous anastomosis is performed prior to arterial anastomosis, to lessen congestion.
(g) With the aid of the operating microscope, the arterial anastomosis is typically performed using 9-0 nylon sutures.

7. Esophagocolonic anastomosis:
Care is taken not to disturb the vascular anastomosis while the anastomosis is being performed. At least three anastomotic techniques are available to connect the esophagus to the colon:

(a) *Stapled, functional end-to-end*. This technique is also referred to as the modified Collard or Orringer technique. The proximal segment of the esophagus is positioned adjacent to the segment of colon in a side-by-side fashion. The tip of the colon is stapled closed and the colon is passed behind the esophagus. A tacking suture is used to hold the bowel in this position. An enterotomy is created 45–60 mm from the terminal end of the colon and Endo GIA™ 60-mm (purple tristaple for Covidien or blue staple for Ethicon) single stapler ends are passed into the opened end of the esophagus and the antimesenteric enterotomy of the colon. By firing the stapler, a functional end-to-end anastomosis is created. The "hood" is closed with interrupted absorbable sutures, or alternatively with a TA™ stapler if there is adequate residual lumen.
(b) *Hand-sewn end-to-end or end-to-side* (either single-layer or double-layer). An interrupted absorbable suture is typically used for this anastomosis (Fig. 10.9).

(c) *Stapled with circular EEA™ device*. The anvil is placed into the terminal end of the esophagus and a purse-string 3-0 Prolene suture is used to secure all layers of the esophageal wall tightly around the anvil. The circular stapler is passed into the proximal open end of the colon and through the antimesenteric side of the bowel to join to the anvil. Once the two devices are coupled and the stapler is fired, the rings are inspected and the terminal end of the colon is closed with a longitudinal staple line. This technique is not our choice for an anastomotic technique, as we have seen blow-outs of this staple line. It is important to be sure that the remaining defunctionalized limb is short because the limb may act as a pseudo–Zenker's diverticulum if it is left too large.

8. Re-creating continuity within the abdomen:

(a) The colon can be brought to the stomach remnant or to the small bowel. In cases of gastric conduit necrosis, a small remnant of stomach is typically available, but in patients with gastric cancer, there may be only duodenum (Fig. 10.10). In this case, the colon should be reconnected to the proximal jejunum. The rest of the colon is then reconnected and the mesenteric defects are closed.
(b) Most distal anastomoses can be performed in the same manner as the esophagocolonic anastomoses. Typically, a stapled side-to-side anastomosis is performed.

9. Feeding jejunostomy:

(a) Tunnel the feeding tube through a very small hole through the left anterior side of the bowel, and cap the feeding tube.
(b) An antimesenteric portion of proximal jejunum is selected for placement.
(c) Place a 3-0 silk purse-string suture on the antimesenteric side of the jejunum.
(d) Use the Bovie to make a hole through the center of the purse-string.
(e) Place the feeding tube into the bowel lumen and tighten the purse-string.
(f) The tube can be placed with a Witzel procedure or the jejunum can be fixed in four places around the tube to the anterior abdominal wall. (We do both to lessen drainage around the tube.)
(g) Fix the tube to the outside of the abdomen.

10. Intraoperative and postoperative management:

(a) Perform meticulous laparotomy and instrument count.
(b) Modifications may be needed if the patient has a tracheostomy.
(c) Securing lines and tubes to the abdomen is a key part of postoperative management of these patients.
d) We have found that a nasogastric tube (NGT) is not necessary and may even cause postoperative problems.
(e) Do not place drains directly on the anastomosis.
(f) Make sure the conduit is not redundant and is as straight as possible. When creating the anastomosis, avoid pockets where food may pool.
(g) Make sure that the patient is not given inotropic or vasoconstrictor drugs during or after the surgery.
(h) Keep the operating and recovery rooms warm.

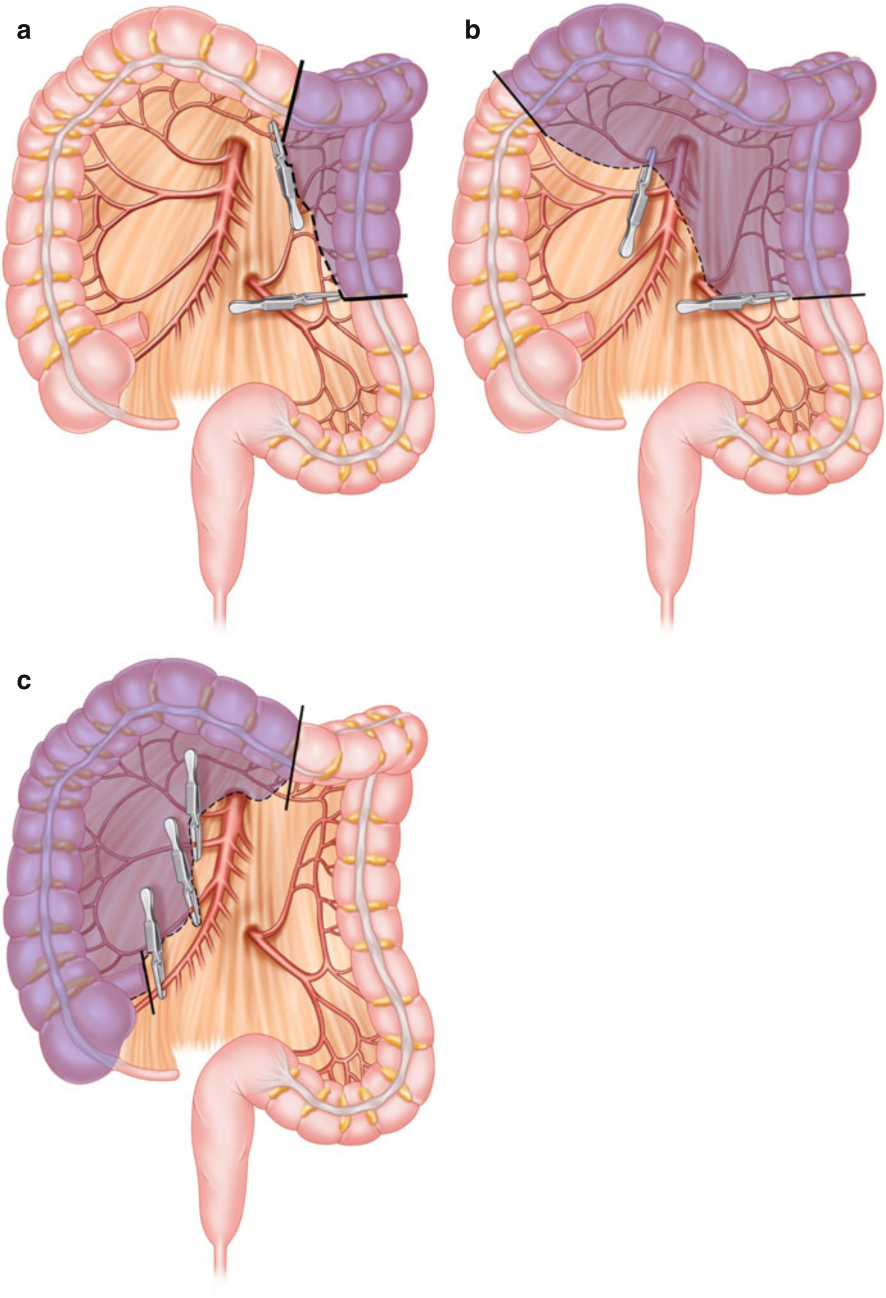


Fig. 10.2 (**a**) Left colon resection to provide a conduit for esophageal reconstruction. (**b**) Transverse colon resection to provide a conduit for esophageal reconstruction. (**c**) Right colon resection to provide a conduit for esophageal reconstruction

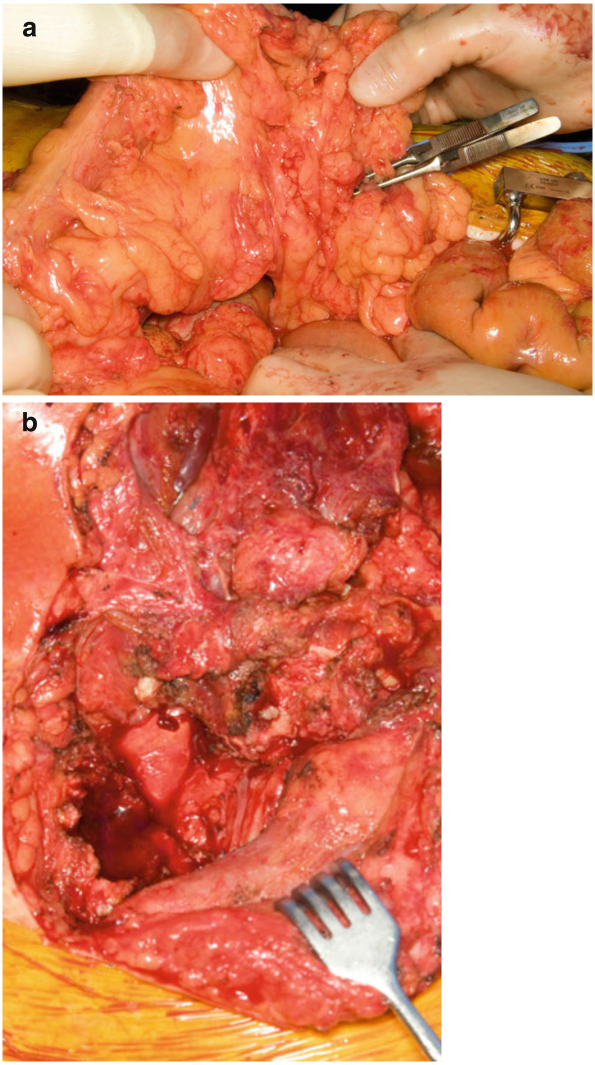
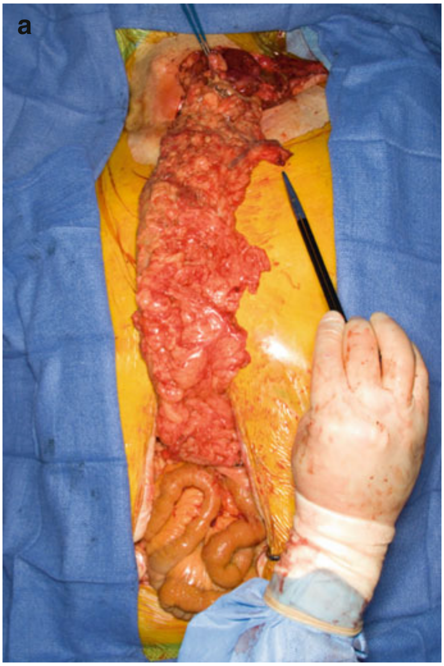


Fig. 10.3 (**a**) Preparing the colonic conduit. (**b**) The colon has been delivered to the neck in preparation for the microvascular anastomoses and subsequent esophagocolonic anastomosis



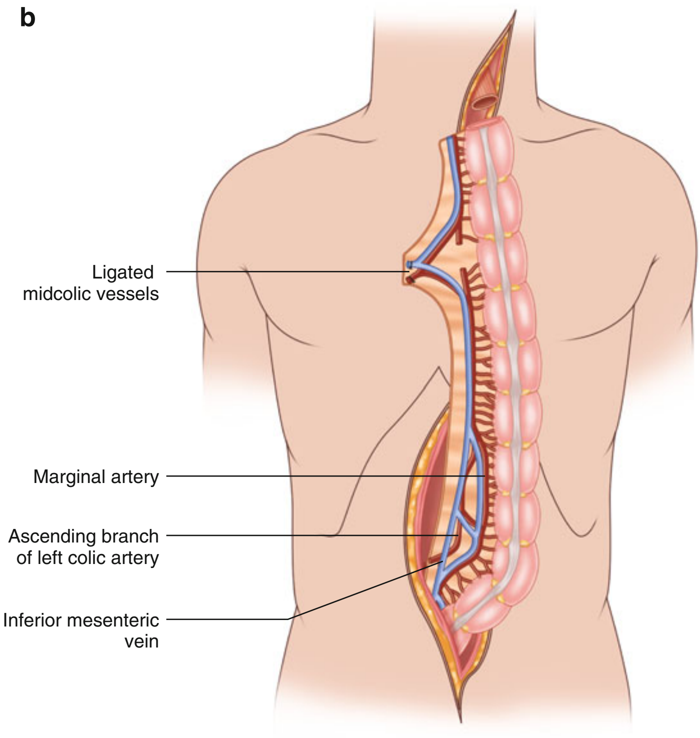


Fig. 10.4 (**a**) The colonic mesentery has been "unfurled" to allow the colon to reach the neck. (**b**) Schematic of the unfurled colonic mesentery

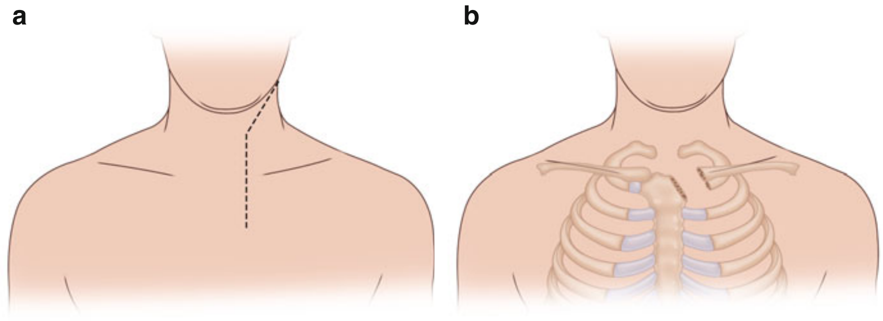


Fig. 10.5 Neck incision to prepare the neck for the conduit. (**a**) Left oblique neck incision carried onto the chest para-median and to the left side of the patient to expose the internal mammary artery and vein and (**b**) resect the head of the clavicle, the head of the first rib, and perform a hemi-manubriectomy

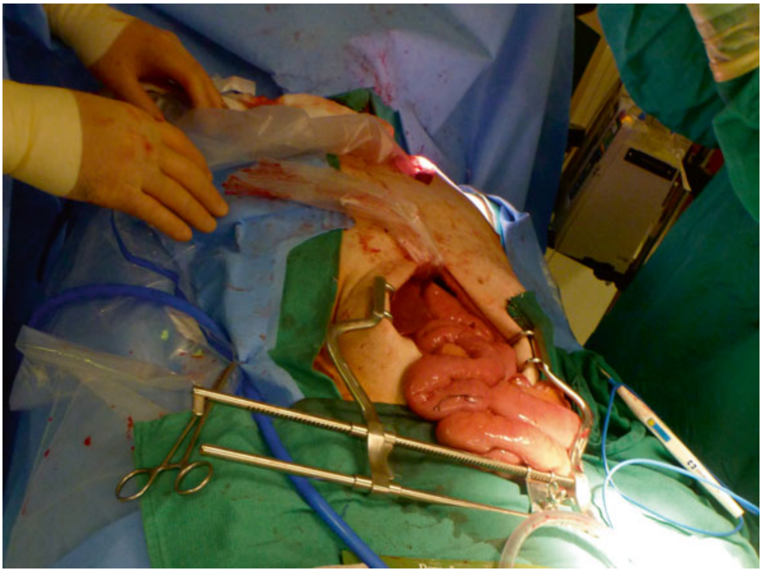


Fig. 10.6 A laparoscopic camera bag or ultrasound probe cover is passed through the tunnel created for the conduit

Fig. 10.7 The prepared colonic graft is passed into the bag for delivery to the neck

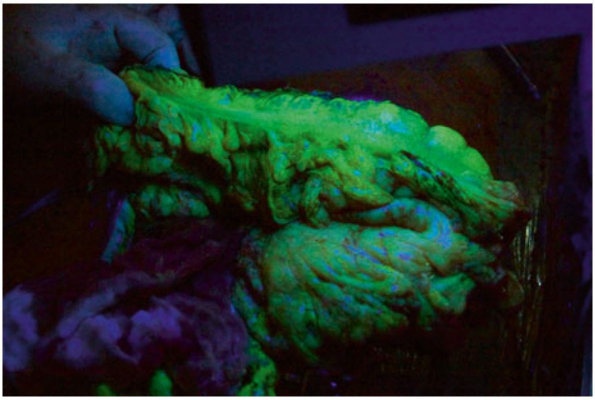


Fig. 10.8 A Wood's lamp can be used to assess the perfusion to the colonic conduit prior to anastomosis

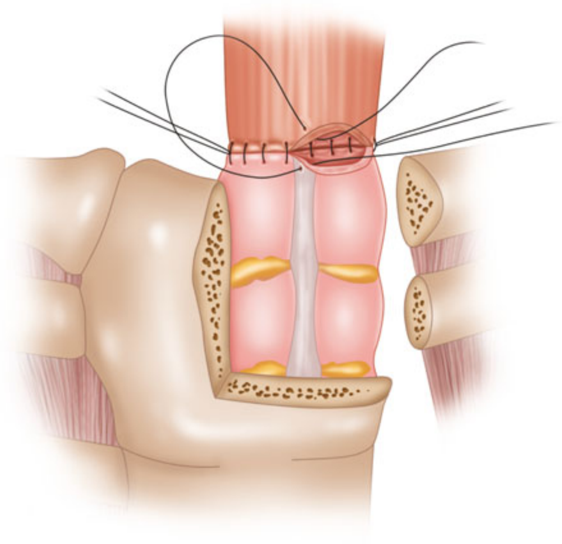


Fig. 10.9 After the neck has been prepared and the colon delivered, the esophagocolonic anastomosis is performed. If the conduit is supercharged, the enteric anastomosis is performed after the microvascular anastomosis. This image depicts the hemi-amnubriectomy, resection of the head of the clavicle, resection of the head of the first rib, and preservation of the ligamentous attachment between the first rib and clavicle. Anastomosis can be performed with a double-layer hand-sewn technique or stapled

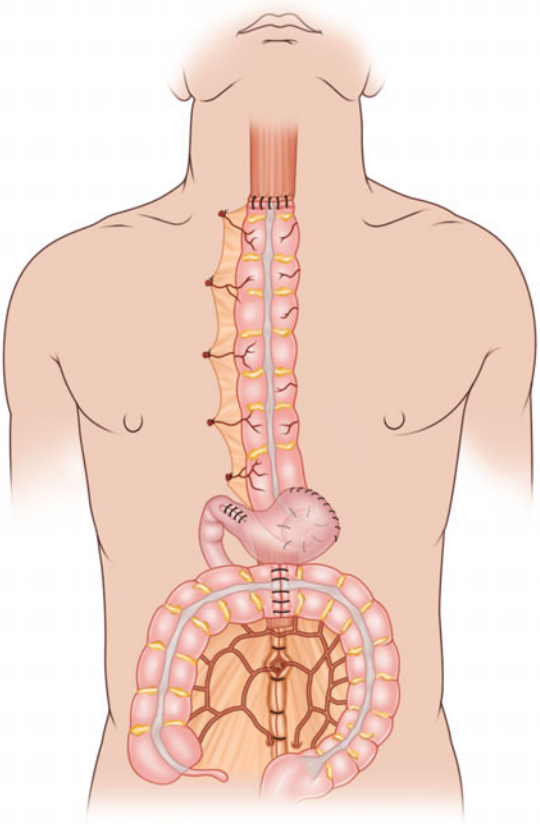


Fig. 10.10 Restoring intestinal continuity after creation of the esophagocolonic anastomosis

Jejunal Conduit

Jejunal grafts can be used to reconstruct the esophagus in three ways:

- Free jejunal conduit
- Roux-en-Y reconstruction
- Supercharged pedicled jejunum reconstruction

The jejunum is a long, hollow organ that extends from the ligament of Treitz under the transverse mesocolon (superior and inferior duodenal recesses) to the ileum, with an indistinct boundary of transition. The mesentery serves as the sole attachment of this organ to the body. The wall of the jejunum has three layers: serosa, muscularis propria, and mucosa. The muscularis propria, like the esophagus, has an outer longitudinal layer and an inner circular layer. The lumen is lined by folds (called *valvulae conniventes*) that run perpendicular to the longitudinal axis.

The blood supply to the jejunum arises from the superior mesenteric artery (SMA). Jejunal branches arise from the left side of this artery, and the right side of the SMA provides branches to the ileum and colon. There are one to five jejunal arteries.

Position

Patients are placed in the supine position for all jejunum transfers. The legs are prepared into the field in case a saphenous vein graft harvest is required. The head is turned slightly to the right, and a roll is placed beneath the shoulders. The neck is prepared into the field. Slight modifications may be needed for patients who have a tracheostomy or who require reversal of an esophageal diversion.

Free Jejunal Conduit Creation to Replace Cervical Esophagus

Reconstruction of the cervical esophagus using a free jejunal conduit (Fig. 10.11) involves five key steps:

- Identification of the segment of jejunum to be used
- Mobilization of the jejunum
- Division of vessels
- Creation of the vascular anastomosis
- Creation of the bowel anastomosis

Incisions

With the patient in a supine position, a midline laparotomy is typically used for jejunum preparation.

Operation

1. The approach to the exposure of the cervical esophagus is as described previously, with resection of the hemimanubrium, the head of the first rib, and the clavicle.
2. The esophagus is dissected inferiorly and superiorly to identify the area of pathology for resection.
3. The vessel to which the jejunal vessels will be anastomosed is dissected free and slung.
4. A concomitant laparotomy incision is made in order to identify a suitable segment of jejunum that can be used as a free flap. The mesentery of the identified segment is transilluminated to delineate the vascular anatomy. The vessels upon which this flap will be fed are identified. They are dissected as far proximal towards the SMA as possible and are slung.
5. Once a suitable jejunal flap has been identified, the esophageal resection is performed. The jejunal vessels are divided and the proximal ends are suture ligated. The free flap is covered in a warm gauze and delivered to the neck for the vascular and bowel anastomoses.
6. The microvascular anastomosis is performed as described previously (Fig. 10.12).
7. Following the vascular anastomosis, the free jejunum is sutured to the proximal and distal esophagus with two end-to-end hand-sewn anastomoses.

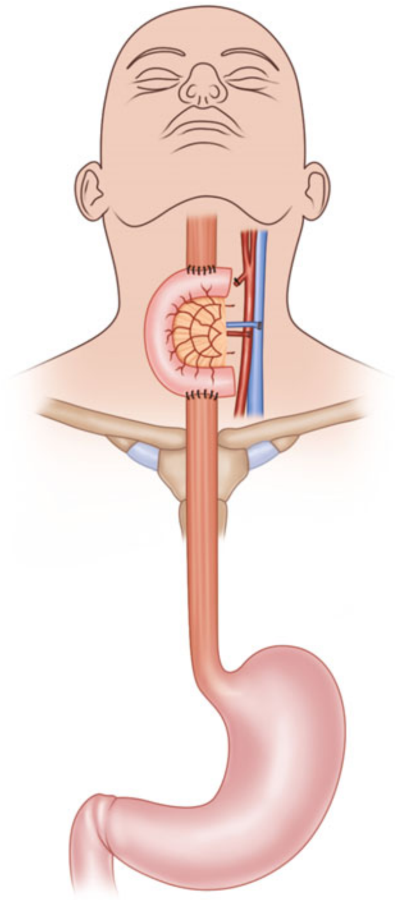


Fig. 10.11 Free jejunal conduit interposition to reconstruct the cervical esophagus. The mesenteric artery and vein are connected to the cervical vessels with a microvascular anastomosis, and the interposition of the free jejunum is attached to replace only a short segment of esophagus

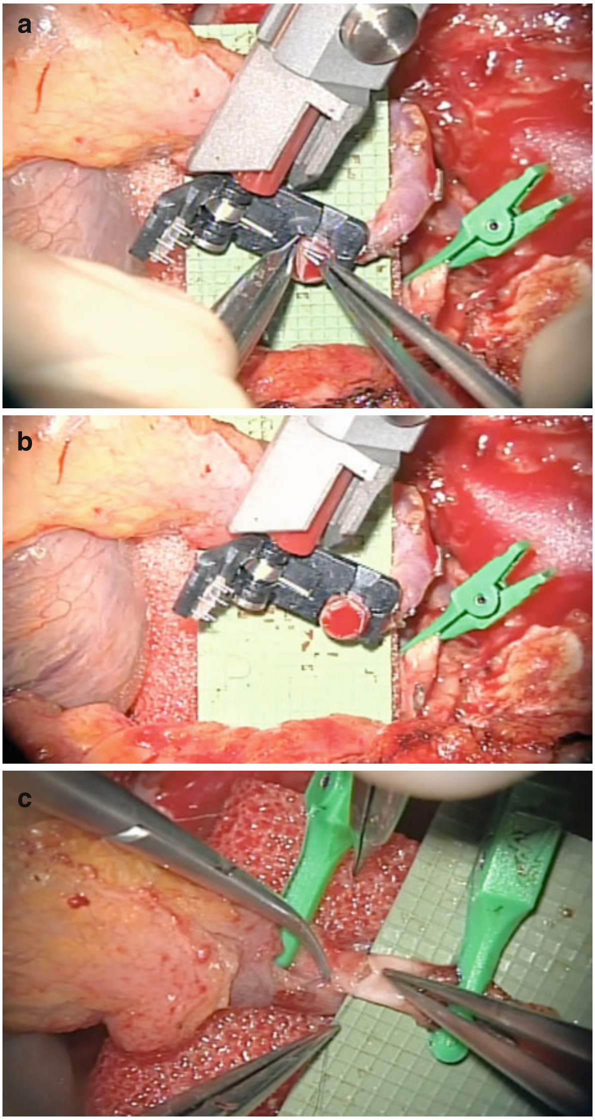


Fig. 10.12 (**a**) A 2-mm to 4-mm coupler device is used to create the venous anastomosis; the veins to be anastomosed are carefully loaded onto this device. (**b**) The device is fired and the venous anastomosis is complete. The venous anastomosis is preformed before the arterial anastomosis, to reduce congestion of the bowel. (**c**) The arterial anastomosis is then performed, typically with 9-0 nylon sutures and using the operating microscope

Pedicled Jejunal Conduit to Replace Distal Esophagus

A pedicled jejunal conduit can be used to replace the distal esophagus (Fig. 10.13); this technique is known as the Merendino procedure. Six key steps are involved:

- Identification of the segment of jejunum to be used
- Mobilization of the jejunum
- Division of the mesentery
- Preservation of the marginal artery
- Preparation for passage to the low chest or hiatus
- Creation of the bowel anastomosis

Incisions

With the patient in a supine position, a midline laparotomy is typically used for jejunum preparation, but the procedure also may be performed via a left thoracoabdominal incision.

Operation

1. The Merendino procedure is suitable for a localized resection of the distal esophagus, such as in a patient with a gastrointestinal stromal tumor (GIST) or high-grade dysplasia in this area. The resection is vagus-sparing.
2. The midline laparotomy is performed and the left lobe of the liver is released to allow visualization of the hiatus.
3. The crura are dissected, as are the distal esophagus and the gastroesophageal junction (GEJ). The vagi are dissected free from the esophagus. The gastric cardia, fundus, and lesser curve are dissected free of fat and vessels, and a proximal gastric resection is performed.
4. The lower esophagus is dissected free and divided at an appropriate level; a purse-string suture is placed.
5. The anvil of an EEA™ stapling device (usually 28 mm) is placed into the distal esophagus and secured with the purse-string suture.
6. An appropriate segment (10–15 cm) of jejunum is prepared, taking care to maintain the pedicled blood supply by transilluminating the mesentery. The mesentery is divided in order to allow this segment of the jejunum to reach the hiatus. The proximal end of the jejunum is left open (using a TA™ stapler to divide the bowel), and the distal end is stapled closed with a GIA™ stapling device (blue load).
7. The EEA™ gun is placed through the open proximal jejunal end and an end-to-side esophagojejunal anastomosis is fashioned. The open jejunal end is closed with a firing of the GIA™ blue load; it may be oversewn with 2-0 silk interrupted sutures.

8. The end-to-side jejunogastrostomy may be hand-sewn or, via a gastrostomy, may be stapled using the EEA™ stapler in a manner similar to the discussion above.
9. Attention should be paid throughout to the vascularity of the pedicled jejunal flap.
10. A stapled side-to-side jejunojejunostomy is performed distally to restore intestinal continuity.

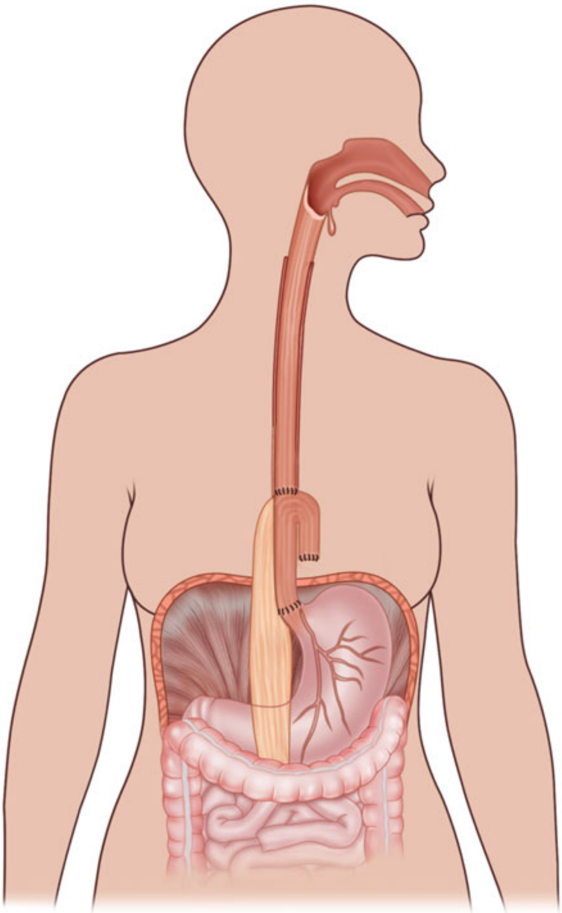


Fig. 10.13 Reconstruction after the Merendino procedure. A pedicled jejunal graft is used to reconstruct the lower esophagus

Roux-en-Y Jejunal Conduit to Replace the Distal Esophagus

A Roux-en-Y jejunal conduit (Fig. 10.14) may be used to reconstruct the esophagus when the stomach is not available, such as with extension of the GEJ down the lesser curve, synchronous gastric and esophageal tumors, or previous gastric surgery or omentectomy that precludes the use of stomach as a conduit. The procedure includes a number of key steps:

- Identification of the segment of jejunum to be used
- Mobilization of the jejunum
- Division of vessels
- Preservation of the marginal artery
- Preparation for passage to the chest or neck for anastomosis
- Creation of the vascular anastomosis
- Creation of the bowel anastomosis

Incisions

For jejunum preparation, a midline laparotomy with the patient supine is typically used. Dissection of the esophagus and stomach may be performed by a laparotomy and right thoracotomy or using a thoracoabdominal incision.

Operation

1. Perform laparotomy or a left-sided thoracoabdominal incision when the anastomosis will be at or above the level of the diaphragm.
2. Resect the pathology, in the form of esophagectomy with gastrectomy or total gastrectomy.
3. Once the pathology has been resected, the esophagus is transected either in the right chest or left chest as per thoracoabdominal total gastrectomy.
4. Identify the ligament of Treitz.
5. Approximately 45 cm distal to this ligament, the jejunum is assessed for transection to form the alimentary limb. Particular attention is given to the mesenteric arcade. (Transillumination of the mesentery will facilitate this assessment.) The jejunum must be transected at a level that will reach the esophagus. This goal can be achieved by dividing mesenteric vessels but allowing a continuous arcade to supply the tip of the jejunum.
6. Divide the mesenteric vessels.
7. Transect the jejunum with a stapler (GIA™ 60 cm, blue load), oversewing with interrupted 2-0 silk.
8. Deliver the jejunum to the esophagus through the diaphragmatic hiatus in an antecolic or retrocolic manner. The retrocolic path may be shorter and may allow less tension on the esophagojejunal anastomosis. The diaphragmatic

hiatus may need to be enlarged to allow free passage of the jejunum without tension on the mesentery.

9. The jejunum is left in its new position for a period of time, in order to detect any ischemia.
10. If the jejunum remains healthy, an esophagojejunal anastomosis is performed. As discussed in previous sections, several options are available, including a stapled, functional end-to-end anastomosis; a hand-sewn end-to-end or end-to-side anastomosis (either single-layer or double-layer); or an anastomosis stapled using the circular EEA™ device.
11. The jejunojejunostomy is created approximately 70 cm distal to the esophagojejunal anastomosis. It may be created in a side-to-side fashion using a GIA™ 60 stapler (blue load) and closing the enterotomy in one layer (3/0 PDS) or two layers (3-0 Vicryl and 3-0 silk). Alternatively, a two-layer side-to-side or one-layer end-to-side anastomosis may be constructed.
12. The jejunal mesenteric defects are closed with interrupted 2-0 silk.

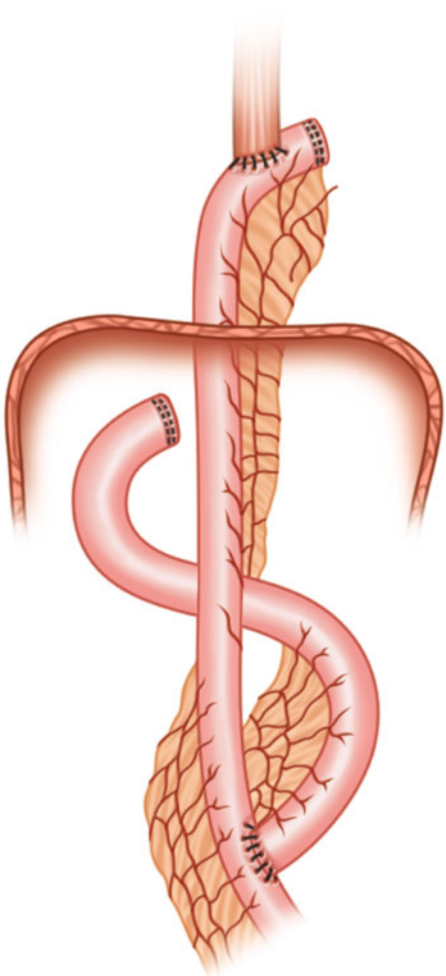


Fig. 10.14 Roux-en-Y reconstruction of the distal esophagus with jejunum. The surgeon should be careful to close all mesenteric defects to prevent postoperative hernia. The Roux can be tunneled either antecolic or retrocolic

Long-Segment Supercharged Jejunal Pedicled Reconstruction

Preoperative Planning

The most important part of this surgery is planning and preparation. When a patient is known to have extensive disease that will preclude reconstruction with a stomach conduit, the operating room, staff, patient, and family need to be prepared. The first step in planning the surgery is deciding which route will be taken for the small bowel. There are two main routes for reconstruction with jejunum: the substernal route and the posterior mediastinal route (Fig. 10.15).

The posterior mediastinal route is frequently used when the patient is having immediate reconstruction with any conduit. It is more anatomic and potentially shorter.

The substernal route, on the other hand, is the best option when reconstruction is delayed (such as when scar tissue precludes the use of the posterior mediastinum). It offers easier access to chest vessels, is outside the field for potential recurrence or radiation, and may empty better. It may be unavailable for patients with previous coronary artery bypass grafting (CABG), however.

The procedure includes a number of key steps:

- Midline abdominal incision
- Lysis of adhesions, if present
- Identification of the ligament of Treitz
- Transillumination and mobilization of the bowel mesentery
- Identification of the segmental blood supply to the jejunum. (To minimize ischemia time, the branches to the small bowel should not be divided until the neck and tunnel have been prepared.)
- Takedown of any feeding jejunostomy site

Operation

1. The neck dissection and laparotomy are performed in the same manner as for the supercharged colonic interposition. The substernal route is preferred for the delivery of the jejunal graft, and this route is prepared accordingly. To avoid tension, we like to have at least a 5-cm tunnel for the graft to lie within.
2. Selection and division of the jejunal branches:

   (a) One must choose the arcade based on transilluminated visualization and length. There will be anatomic variations and shortened mesenteries from scar tissue, but the ideal jejunal arterial choice is depicted in Figure 10.16.

   (b) The first branch of the jejunal blood supply provides blood to the proximal segment beginning after the ligament of Treitz; this first segment with its blood supply is typically left in situ for the Roux limb reconstruction.

   (c) Perform all of the dissection before dividing any of the blood supply to the small bowel, to minimize ischemic time (Fig. 10.17). Once the second arcade has been identified and the remaining segments appear to be appropriate, the mesentery is divided a little proximal to the second arcade to provide additional proximal bowel length for what will become the monitoring flap.

(d) This second arcade will eventually be connected by a microvascular anastomosis to the LIMA and LIMV or jugular vein.
(e) Open up the mesentery to allow length of the flap (Fig. 10.18).
(f) The mesentery between the third and fourth arcade can be divided only up to the level of the bridging arteries. If the division of the mesentery is continued up to the level of the bowel wall, the third arcade segment of bowel will die.
(g) The second and third jejunal branches to the SMA are tied off. It is key to divide the vessels as close to the SMA as possible so that collateral blood flow is maximized.
(h) The fourth arcade is left attached to the SMA (vascular pedicle).
(i) The mesentery between the second and third arcades can be divided up to the level of the bowel to allow the proximal jejunum to unfurl (Fig. 10.16). This step is critical in establishing a straight jejunal conduit. At this point, the most proximal end of the bowel is ischemic.
(j) Once the blood supply has been divided, the clock starts for ischemia time. (Do not divide this segment until the tunnel has been created and the donor vessels have been prepared) (Fig. 10.19).
(k) The blood supply to the small bowel is fairly brisk, so it may not appear ischemic even after ligation of the proximal branches, making it unclear that vascular augmentation is actually necessary. Although the bowel may appear pink, a significant amount of edema enters into the bowel wall and mesentery over the next several days after the procedure, so adequate venous drainage is most critical during this period.

3. Planning the intra-abdominal route for the jejunum:

   - *Antecolic tunneling of the jejunal segment* (Fig. 10.20)
     - Little preparation is needed for an antecolic route, but measure the length needed.
     - Plan for additional length with an antecolic route.
   - *Retrocolic tunneling of the jejunal segment* (Fig. 10.21)
     - Transverse mesentery of the colon is transilluminated.
     - Select a portion of the transverse colon mesentery away from the marginal artery of Drummond and the middle colic artery. Use Bovie electrocautery to create a window at least twice the size of the small bowel, so that it may pass through the window without resistance.
     - Once the jejunum has passed through the window and has been connected to the new blood supply and the bowel anastomosis is complete, make sure the edge of the mesentery is tacked to the edge of the jejunum to prevent herniation through the transverse colon mesentery.

4. Delivery of the jejunum through the substernal tunnel

    (a) Prepare a large camera bag or ultrasound probe cover.
    (b) Ensure that the tunnel is large enough to allow for the bowel, mesentery, and postoperative edema.
    (c) Deliver the bag through the tunnel, from bottom to top (Fig. 10.22).
    (d) Trace the bowel back to the mesentery and place the untwisted segment of jejunum into the bag; moisten the inside and outside of the bag. Feed the bag and jejunum into the tunnel from below with gentle traction from above. Suction can be placed inside the bag to facilitate delivery of the conduit if necessary.

5. Microvascular anastomosis (Fig. 10.12)

    (a) The vascular augmentation is performed prior to the esophagojejunostomy.
    (b) An operating microscope is used to prepare the recipient vessels.
    (c) A 2-mm to 4-mm coupler device is typically used to create the venous anastomosis.
    (d) Saphenous vein grafts can be used to compensate for length issues.
    (e) Venous anastomosis is performed prior to arterial anastomosis, to lessen congestion.
    (f) With the aid of the operating microscope, the arterial anastomosis is typically performed using 9-0 nylon sutures.

6. Creation of the indicator flap

    (a) The very distal segment of jejunum, with its own mesenteric blood supply, is externalized at the end of the case to serve as an indicator flap.
    (b) Transilluminate the indicator flap to ensure that it has adequate blood supply.
    (c) Divide the jejunum and mesentery to create enough length to externalize.
    (d) Use 3-0 silk ties or clips to tie off the connection in the distal mesentery, to provide length for the monitoring segment to pass outside the chest.
    (e) Once the anastomosis is complete and the skin is closed, the monitoring flap should exit from a small opening in the initial incision (Fig. 10.23a, b).
    (f) Be sure to open the segment of bowel so that it can drain secretions.
    (g) This is resected to skin level at the bedside just prior to discharge.

7. Esophagojejunal anastomosis

    (a) The same three anastomotic techniques that were discussed previously are available to connect the esophagus to the proximal segment of jejunum:

        – Stapled, functional end-to-end (Fig. 10.24)
        – Hand-sewn end-to-end (either single-layer or double-layer), typically using an interrupted, absorbable suture
        – Stapled with a circular EEA™ device

(b) Care is taken not to disturb the vascular anastomosis while the esophagojejunal anastomosis is being performed.

8. Continuity in the abdomen is re-created by one of two methods:

   - Creation of a Roux anastomosis (preferred)

     – The bowel and mesentery must be correctly oriented.
     – An isoperistaltic anastomosis is created between the proximal jejunum and the downstream segment of jejunum, in a side-to-side (functional end-to-side), stapled manner.
     – Optimally, this anastomosis is made about 20–40 cm past the diaphragmatic tunnel, to lessen bilious passage toward the neck. The longer the segment, the less the absorption time and the greater the potential for side effects.
     – The afferent limb of the jejunum is connected to the jejunal interposition.

   - Jejunogastric anastomosis

     – The bowel must be oriented so that the mesentery is passing behind the stomach.
     – A posterior stapled EEA™ anastomosis can be made by placing an anvil into the stomach and passing the EEA™ stapler through the terminal end of the small bowel exiting from the antimesenteric side of the jejunum about 4 cm from the distal end.
     – The ends of the EEA™ are connected (recommend at least a 25–29 mm diameter gun) and fired.
     – Donuts are inspected for completeness.
     – Do not forget to reconnect the ends of jejunum (stapled side-to-side, functional end-to-end anastomosis).

9. Feeding jejunostomy

   (a) Tunnel the feeding tube through a very small hole through the left anterior side of the bowel, and cap the feeding tube.
   (b) An antimesenteric portion of proximal jejunum is selected for placement.
   (c) Place a 3-0 silk purse-string suture on the antimesenteric side of the jejunum.
   (d) Use the Bovie to make a hole through the center of the purse-string.
   (e) Place the feeding tube into the bowel lumen and tighten the purse-string.
   (f) The tube can be placed with a Witzel procedure or the jejunum can be fixed in four places around the tube to the anterior abdominal wall. (We do both to lessen drainage around the tube.)
   (g) Fix the tube to the outside of the abdomen.

10. Intraoperative and postoperative management
    (a) Perform meticulous laparotomy and instrument count.
    (b) Modifications may be needed if the patient has a tracheostomy.
    (c) Securing lines and tubes to the abdomen is a key part of postoperative management of these patients.
    (d) We have found that an NGT is not necessary and may even cause postoperative problems.
    (e) Do not place drains directly on the anastomosis.
    (f) Make sure the conduit is not redundant and is as straight as possible. When creating the anastomosis, avoid pockets where food may pool.
    (g) Make sure that the patient is not given inotropic or vasoconstrictor drugs during or after the surgery.
    (h) Keep the operating and recovery rooms warm.

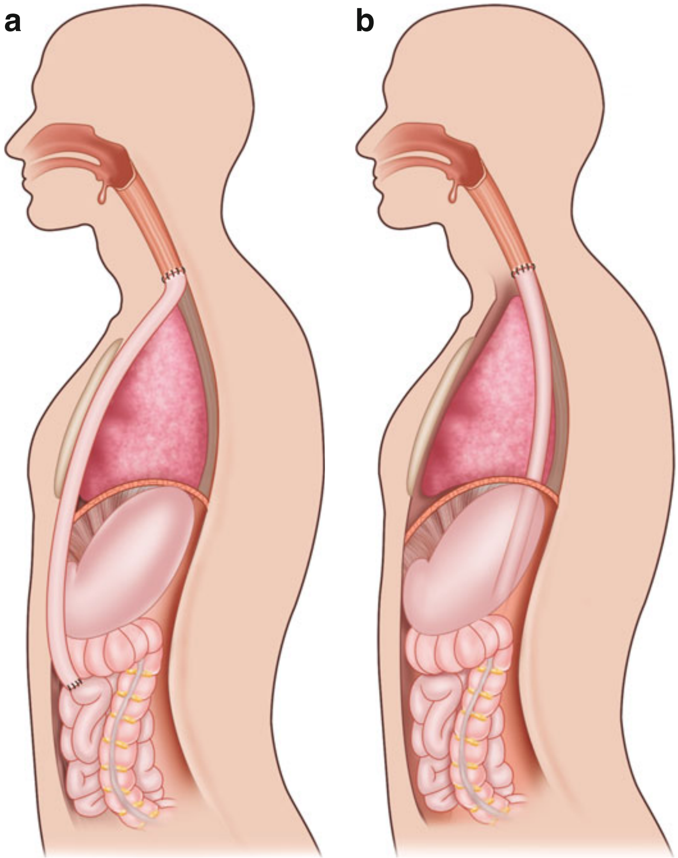


Fig. 10.15 (**a**) The substernal route for jejunal reconstruction of the esophagus. (**b**) The posterior mediastinal route for jejunal reconstruction of the esophagus

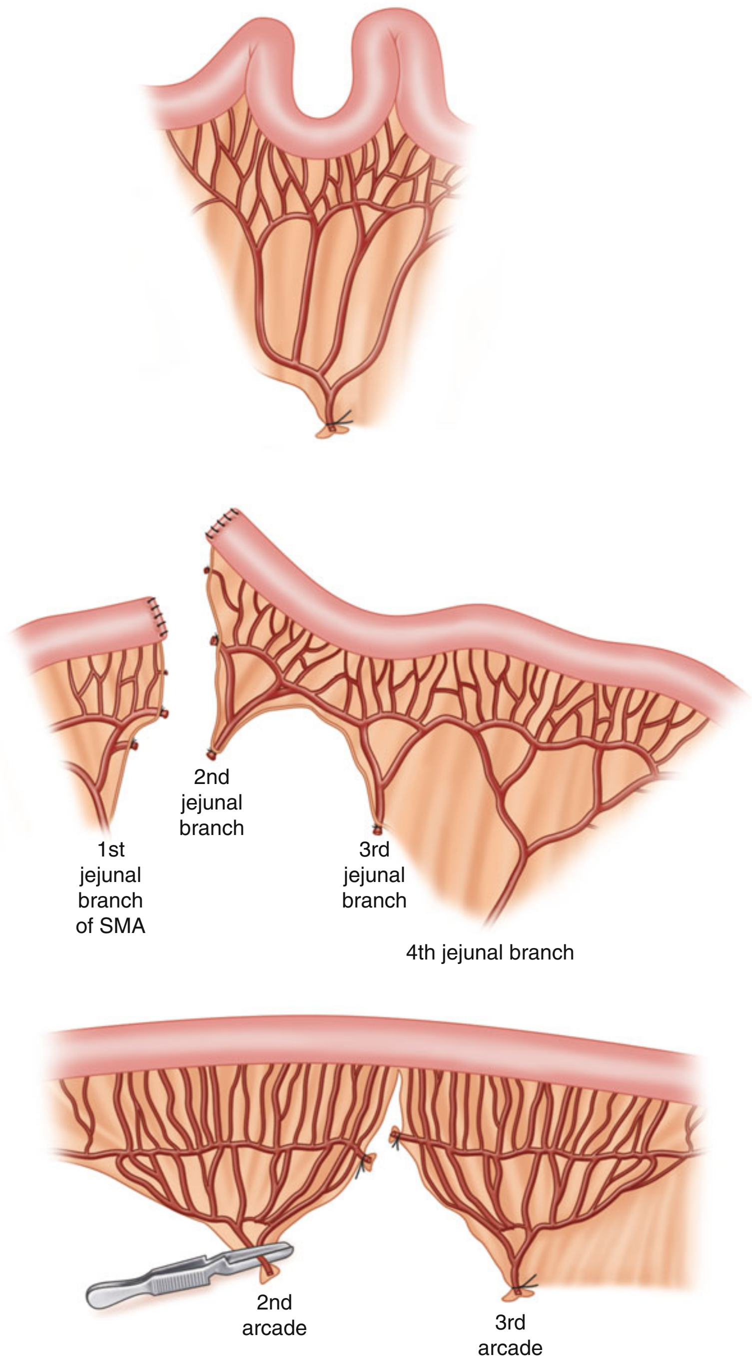


Fig. 10.16 Preparation of the jejunum for use as a supercharged pedicled jejunal graft. Unfurling the mesentery is a key step of this procedure: To ensure a good functional result, the jejunal graft must be of sufficient length, without tension, and straight. *SMA,* superior mesenteric artery

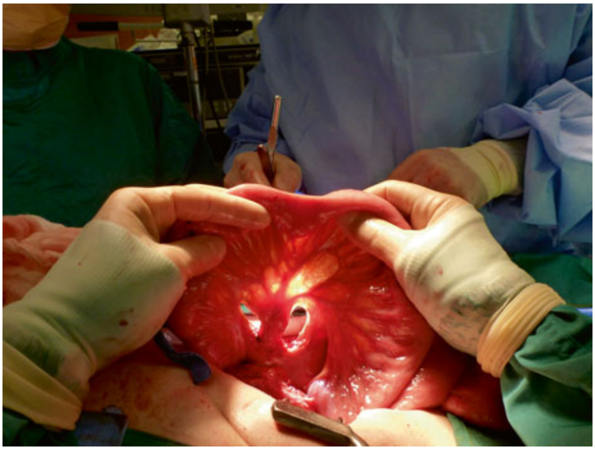


Fig. 10.17 The vessels of the jejunal mesentery are dissected with the aid of transillumination to determine a suitable vessel to anastomose and to identify and preserve the vascular arcade

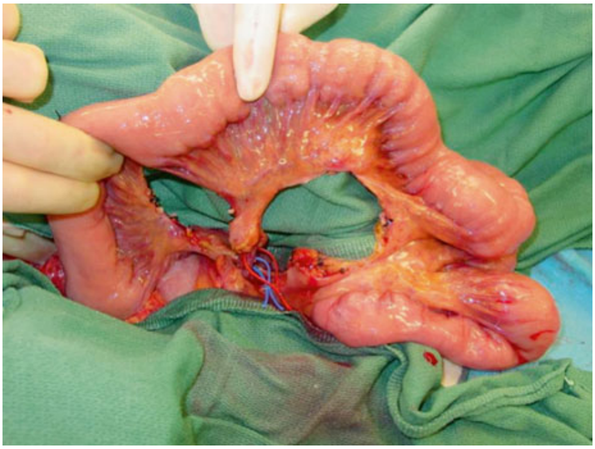


Fig. 10.18 The vessels to be anastomosed are marked and the mesentery is unfurled. Vessels not contributing to the arcade are divided

Fig. 10.19 After the mesentery is unfurled, the vessels to be anastomosed are clamped and divided. The length of the conduit is tested to establish whether it will reach the esophagus without tension

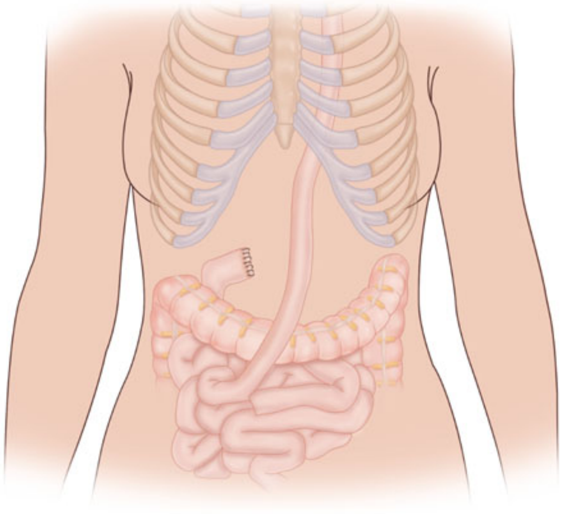


Fig. 10.20 The antecolic route for the jejunal conduit

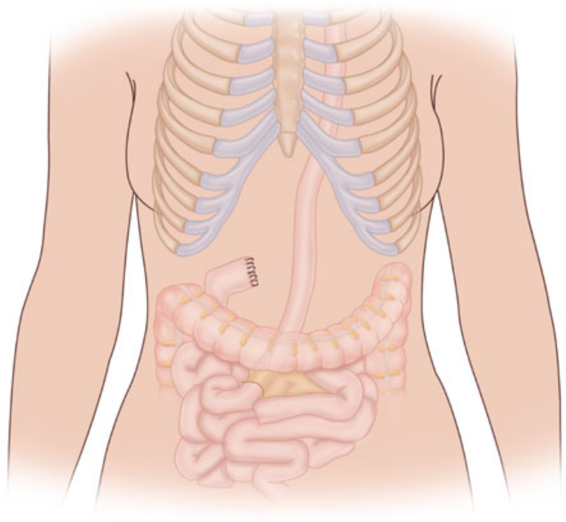


Fig. 10.21 The retrocolic route for the jejunal conduit. This is the more popular route, as it is shorter

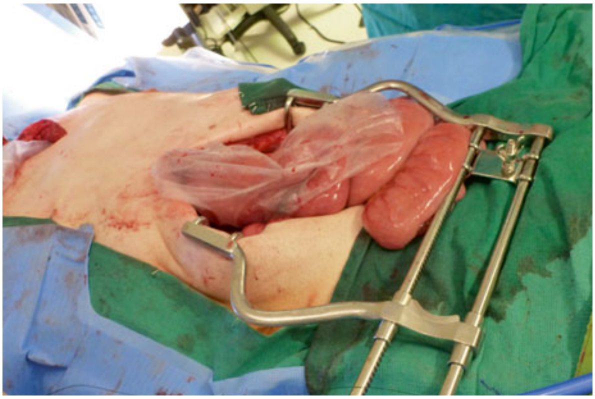


Fig. 10.22 The jejunum is delivered to the neck using a laparoscopic camera bag or ultrasound bag to reduce the tension on the bowel as it is passed through the tunnel

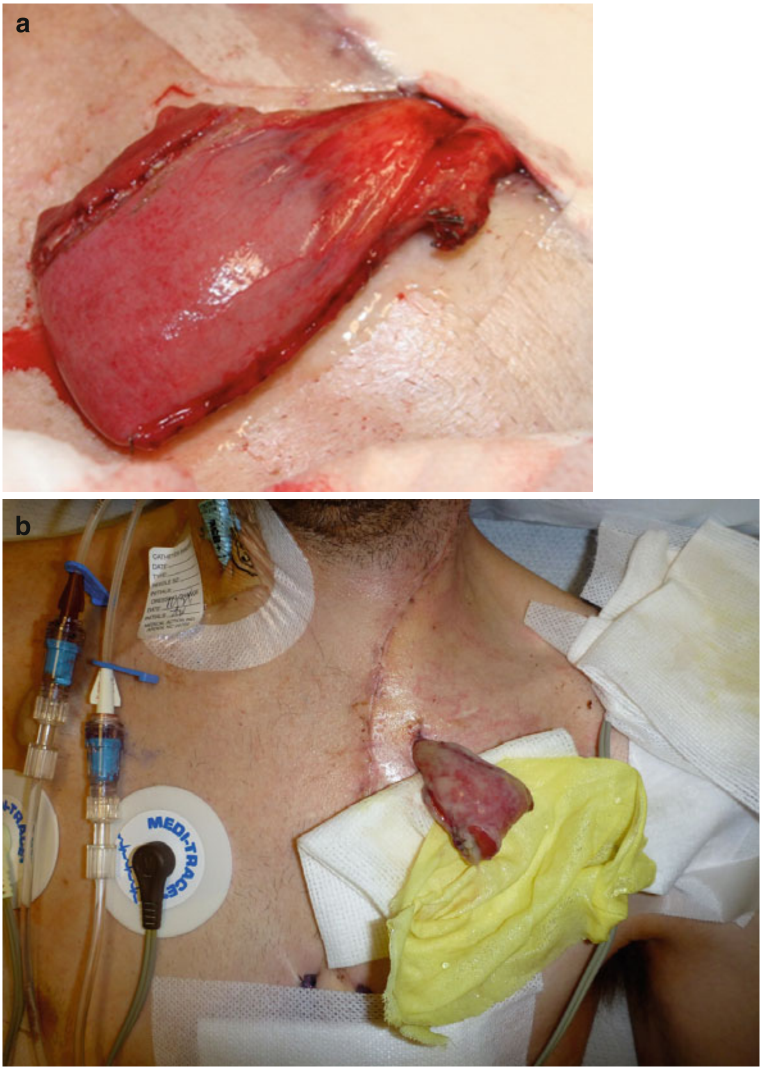


Fig. 10.23 (**a**) The jejunal indicator flap intraoperatively. (**b**) The postoperative appearance of the jejunal indicator flap. The whitish appearance is normal and can be gently peeled off to examine the jejunum below

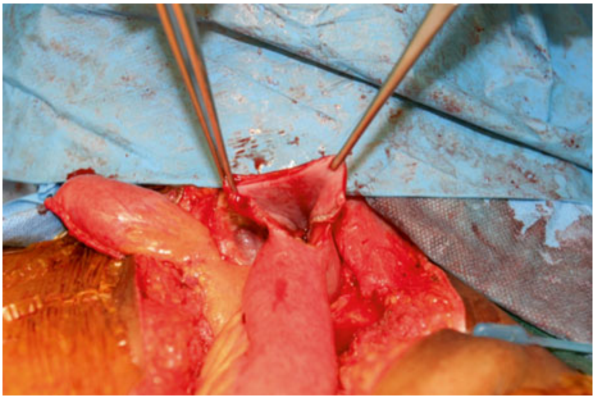


Fig. 10.24 A stapled, functional end-to-end esophagojejunal anastomosis; the indicator flap can be clearly seen medially

Myocutaneous Flaps for Esophageal Reconstruction

If the stomach, jejunum, and colon are unavailable for esophageal reconstruction, it is important to be aware of other options. These options are uncommonly used and often require collaboration with plastic surgical colleagues. They include myocutaneous flaps from the forearm, thigh, or latissimus dorsi muscle (Figs. 10.25 and 10.26). Tubular grafts can be constructed. These surgeries often take the form of staged procedures.

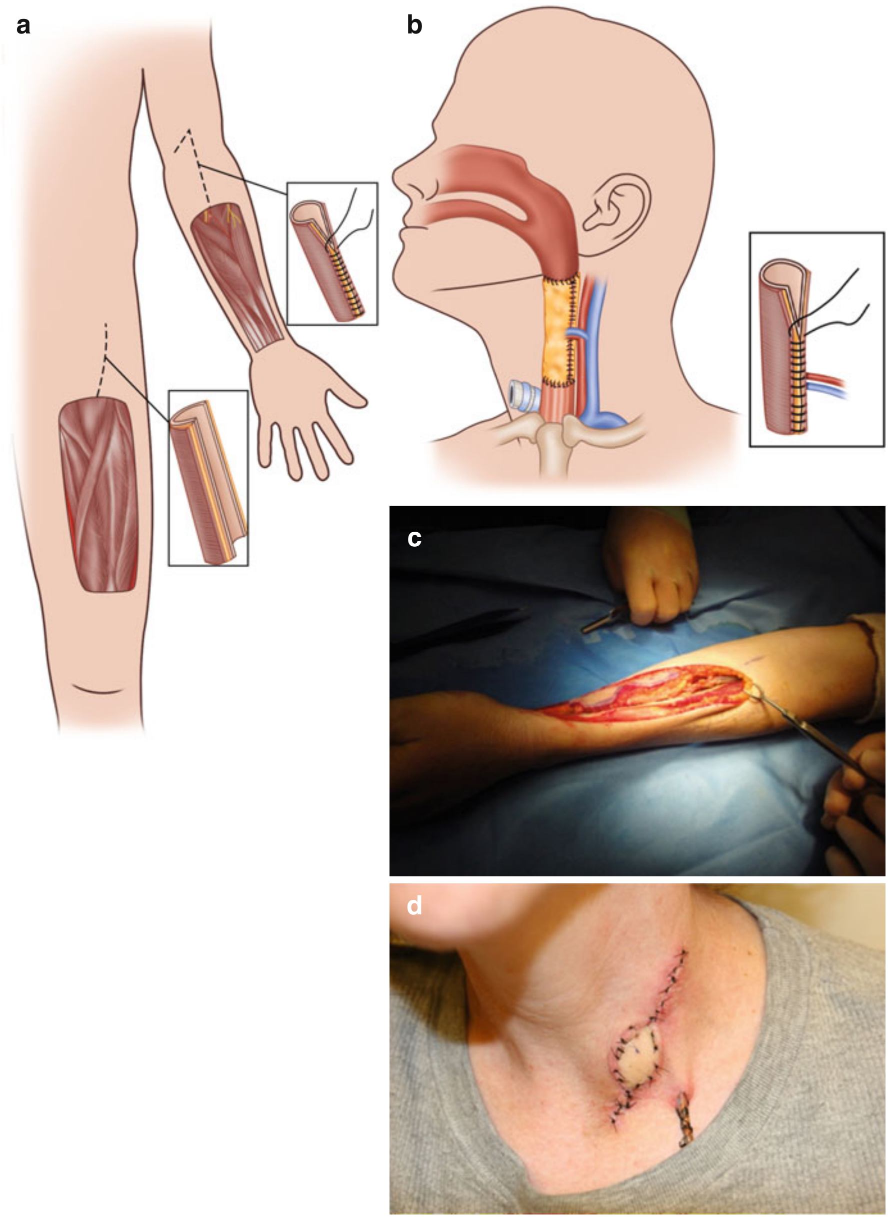


Fig. 10.25 Myocutaneous flaps for reconstruction of the esophagus. (**a**) The radial forearm and lateral thigh flaps are both options for esophageal reconstruction. (**b**) These myocutaneous flaps can be tubularized and anastomosed to the cervical esophagus. (**c**) Harvesting a radial forearm flap. (**d**) Postoperative appearance following reconstruction of the esophagus using a radial forearm flap

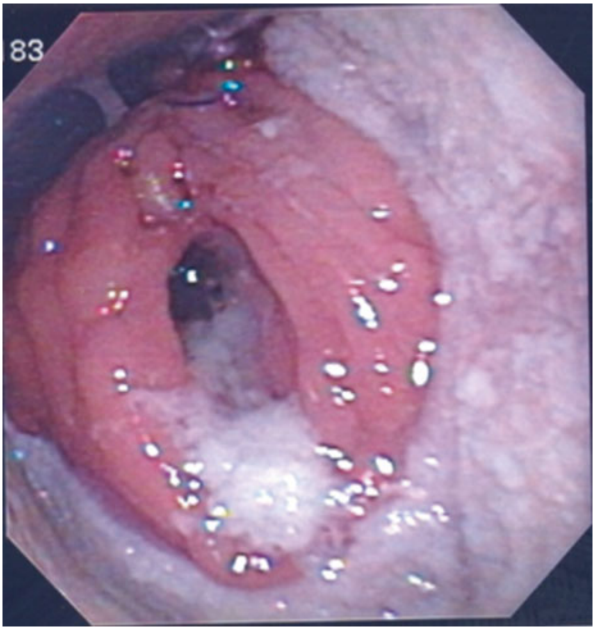


Fig. 10.26 Postoperative endoscopic appearance of a myocutaneous latissimus dorsi flap used to reconstruct the esophagus

Suggested Reading

Blackmon SH, Correa AM, Skoracki R, Chevray PM, Kim MP, Mehran RJ, et al. Supercharged pedicled jejunal interposition for esophageal replacement: a 10-year experience. Ann Thorac Surg. 2012;94(4):1104–11; discussion 1111–3.

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