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Anesthesia for Esophageal Surgery

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Abbreviations

ALI	Acute lung injury
ARDS	Acute respiratory distress syndrome
COPD	Chronic obstructive pulmonary disease
CT	Computerized tomography
CXR	Chest X-ray (radiograph)
DLT	Double lumen endotracheal tube(s)
ECG	Electrocardiogram
EGD	Esophagogastroduodenoscopy
EUS	Endoscopic ultrasound
GDFT	Goal-directed fluid therapy
GERD	Gastroesophageal reflux disease
LEA	Lumbar epidural analgesia
LES	Lower esophageal sphincter
LVEDVI	Left ventricular end diastolic volume index
MIE	Minimally invasive esophagectomy
MRI	Magnetic resonance imaging
NGT	Nasogastric tube
OLV	One lung ventilation
PCA	Patient controlled analgesia
PEEP	Positive end expiratory pressure
PET	Positron emission tomography
PH	Paraesophageal hernia(s)
PONV	Postoperative nausea and vomiting
SLT	Single lumen endotracheal tube(s)
TEA	Thoracic epidural analgesia
TEF	Tracheoesophageal fistula
THE	Transhiatal esophagectomy
TTE	Transthoracic esophagectomy
UES	Upper esophageal sphincter

Key Points

- Patients presenting for esophageal surgery frequently have comorbidities including cardiopulmonary disease which should be evaluated per published ACC/AHA guidelines. Particular attention should be paid to symptoms and signs of esophageal obstruction, gastroesophageal reflux disease (GERD), and malnutrition which may affect the risk of perioperative complications.
- Postoperative pain control strategies are dictated by the surgical approach to the esophagus. Use of thoracic epidural analgesia in patients undergoing transthoracic esophageal surgery provides optimal pain control, permits early patient extubation and mobilization, and may improve outcomes.
- Patients presenting for esophageal surgery commonly have pathology which increases their risk of regurgitation and aspiration. This is particularly true for patients with achalasia and other motor disorders of the esophagus, patients with high-grade esophageal obstruction, and those with severe GERD. Consideration should be given to pharmacologic prophylaxis, awake or rapid sequence induction in a head-up position, and appropriate postoperative care, including gastric drainage.
- Excessive perioperative intravenous fluid administration, especially crystalloid, may lead to exaggerated fluid shifts toward the interstitial space causing increased complications such as poor wound healing, slower return of GI function, abdominal compartment syndrome, impaired anastomotic healing, increased cardiac demand, pneumonia, and respiratory failure. The ideal fluid regimen

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for major esophageal surgery should be individualized, optimizing cardiac output and oxygen delivery while avoiding excessive fluid administration.
- Patients presenting for emergent repair of esophageal disruption, rupture or perforation may present with hypovolemia, sepsis, and shock. Anesthetic management strategies should be based on the severity of these presenting conditions and the nature of the planned procedure.
- Esophageal anastomotic leak is a frequent complication associated with high morbidity and mortality and is likely to be a function of numerous surgical, systemic, and possibly anesthetic factors. Since anastomotic integrity is dependent upon adequate blood flow and oxygen delivery, the development of anastomotic leak may be related to intraoperative management variables, particularly systemic blood pressure, cardiac output, and oxygen delivery and may thus be modifiable by anesthetic management.

Anatomy and Physiology of the Esophagus

The adult esophagus is a muscular tube, 18–26 cm in length, which acts as a conduit for the passage of food from the oral cavity into the stomach (Fig. 30.1). The esophagus begins at the level of the oropharynx; it then enters the superior mediastinum behind the trachea and left recurrent laryngeal nerve and passes into the posterior mediastinum behind the left mainstem bronchus. It continues caudad, passing posterior to the left atrium but anterior to the descending thoracic aorta. At the level of T10, the esophagus joins the stomach at the cardia after passing through the hiatus in the right diaphragm.

The upper esophagus is supplied by arterial branches of the superior and inferior thyroid arteries whereas the mid-esophagus receives its blood supply from the bronchial and right intercostal arteries as well as branches of the descending aorta. Distally, the esophagus is supplied by branches of the left gastric, left inferior phrenic and splenic arteries. Venous drainage from the upper segment is to the inferior thyroid veins, from the mid-segment to the azygous veins and from the lower esophageal segment to the gastric veins. The azygous and gastric veins form an anastomotic network between the portal and systemic venous systems and are thus the site of esophageal varices in patients with high portal pressure.

The esophagus receives innervation from both parasympathetic and sympathetic nerves. The parasympathetic input affects peristalsis via the vagus nerve, originating in the medulla, whereas both parasympathetic and sympathetic afferent nerves transmit information to the central nervous system via the spinal cord. Esophageal neuroanatomic pathways are shared by both the cardiac and respiratory systems, thus it may be difficult to ascertain which organ is responsible for chest pain syndromes.

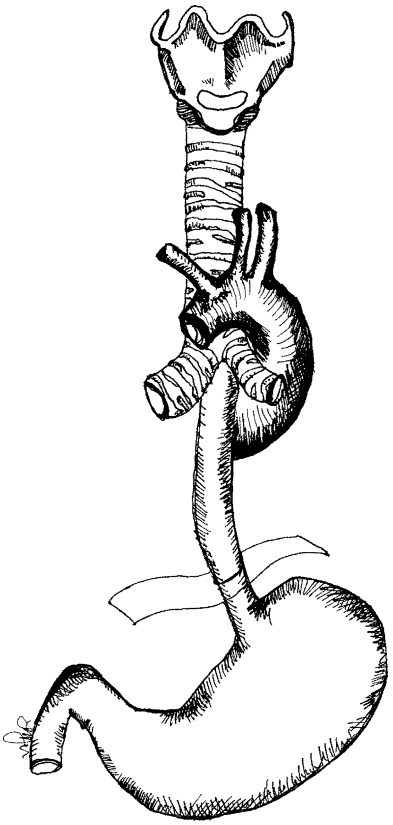

Fig. 30.1. Anatomic relationships between the esophagus, airway, aorta, diaphragm, and stomach.

Structurally, the esophagus is made up of four layers: the mucosa, submucosa, muscularis propria, and adventitia. The muscularis propria carries out most of the motor function of the esophagus. In the upper third of the esophagus, this muscularis propria is skeletal muscle but in the distal third it is smooth muscle, and the mid-section is mixed skeletal and smooth muscle. The upper esophageal sphincter (UES) is at the proximal origin of the esophagus where the inferior pharyngeal constrictor joins the cricopharyngeus muscle. UES tone is contracted at rest thus preventing aspiration of air during normal breathing. The lower esophageal sphincter (LES) is a 2–4 cm length of asymmetric circular smooth muscle within the diaphragmatic hiatus. At rest, the LES is contracted, preventing regurgitation of gastric contents. Swallowing elicits a wave of peristalsis which is under vagal control and carries a bolus of food from the pharynx to the stomach in 5–10 s. The coordinated relaxation of the LES allows the food bolus to enter the stomach.

A number of medications affect LES tone. Drugs known to decrease LES pressure include anticholinergics, sodium nitroprusside, dopamine, beta-adrenergic agonists, tricyclic antidepressant medications, and opioids. Drugs that have been found to increase LES tone include anticholinesterases, metaclopramide, prochlorperazine, and metoprolol.

Nonmalignant Disorders of the Esophagus and Surgical Therapies

Hiatal Hernia, Gastroesophageal Reflux Disease (GERD), and Esophageal Stricture

Gastroesophageal reflux and hiatal hernia may be present independently or may coexist. Esophageal strictures may be caused by a number of insults but are frequently related to gastroesophageal reflux. Gastroesophageal reflux is a common disorder and depending on diet and lifestyle, may affect up to 80% of the population. The term gastroesophageal reflux disease (GERD) applies when symptoms are more frequent or severe than the population norm. Pharmacotherapies including histamine blockers and proton pump inhibitors are widely used and may dramatically ameliorate symptoms and reduce the need for surgical therapy. Indications for surgery in patients with GERD include symptoms that are refractory to optimized medical therapy, esophageal stricture, pulmonary symptoms such as asthma and chronic cough, and severe erosive esophagitis.

GERD frequently coexists with hiatal hernia but many patients with a hiatal hernia remain asymptomatic. Hiatal hernias include the sliding hiatal hernia (type I) and paraesophageal hernias (PH) (types II, III, IV) (see Fig. 30.2a, b). Sliding hiatal hernias are most common and occur when the gastroesophageal junction and part of the fundus of the stomach herniate axially through the diaphragm into the thoracic cavity. Hiatal hernia is associated with a decrease in LES pressure [1] reducing barrier pressure between the esophagus and stomach, which in turn promotes reflux. PH occur when a portion of the stomach, typically the fundus, herniates into the thorax anterolateral to the distal esophagus (see Figs. 30.2b and 30.3). PH are much less common than type I hiatal hernias and comprise approximately 5–15% of hiatal hernias [2]. PH are at risk of incarceration and the presence of a PH is thus considered an indication for surgical repair [3].

Surgical therapies for GERD and hiatal hernia can be achieved via a number of surgical incisions, but most commonly utilize a laparoscopic approach. Relative to laparotomy or transthoracic approaches, laparoscopic surgeries may produce considerably less pain, eliminate the need for a tube thoracostomy, utilize smaller incisions which decrease the risk of postoperative incisional hernias, and provide visualization for the diagnosis of other intra-abdominal pathology. A transthoracic approach may be preferred for patients with severe peptic strictures, patients requiring reoperation, and for those with other intrathoracic pathologies.

The transthoracic total fundoplication (Nissen) is performed through a left lateral thoracotomy (see Table 30.1 for a summary of thoracic esophageal procedures and anesthetic considerations). The distal esophagus and the esophagogastric junction are mobilized with preservation of the vagus nerve and exposure of the crura and left hepatic lobe. At the surgeon's request, the anesthesiologist places a 56–60 Fr esophageal dilator orally and advances it through the gastroesophageal junction. The proximal stomach is brought into the chest and a 2 cm fundoplication wrap is created with the fundus of the stomach. The dilator is removed and the fundoplication wrap placed below the diaphragm without tension. A nasogastric tube (NGT) and a chest drain are left in place postoperatively. Nissen fundoplication yields a high patient satisfaction rate (90–95%) when the procedure is performed by experienced surgeons [4, 5]. The transthoracic partial fundoplication (Belsey) is similar to the Nissen fundoplication but the esophageal wrap extends only 240–270° and is thus a partial fundoplication. The Belsey fundoplication yields a reduction

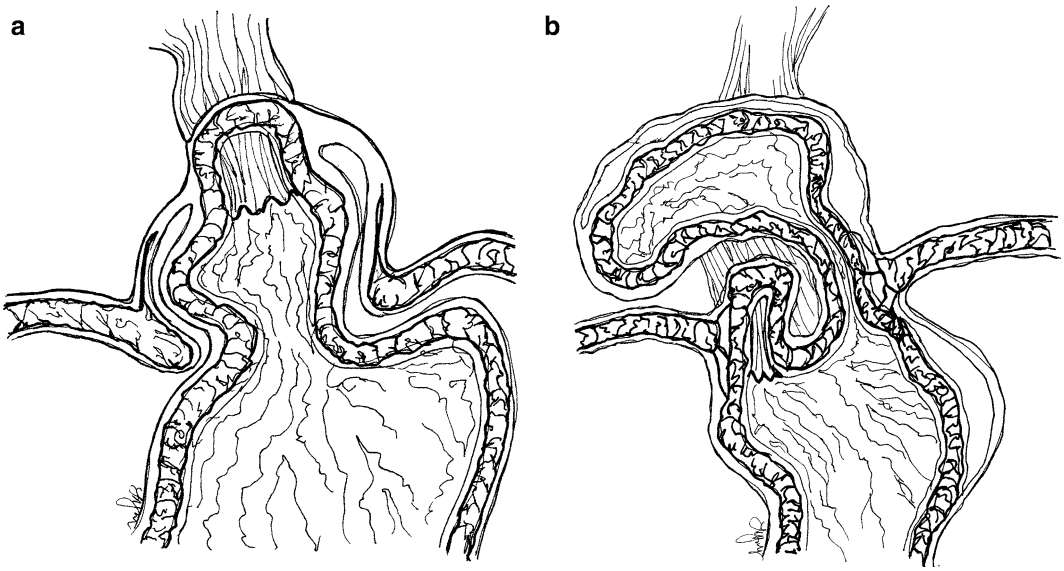

FIG. 30.2. (**a**) Type I hiatal hernia (sliding hernia). Note widening of the muscular hiatal orifice that allows cephalad herniation of the gastric cardia. (**b**) Type II hiatal hernia (paraesophageal hernia). The leading part of the herniating stomach is the fundus.

in GERD symptoms comparable to that of the Nissen and may cause fewer postoperative obstructive symptoms.

Chronic GERD can cause esophageal ulceration which leads to inflammation and may cause axial esophageal shortening and stricture formation. Medical therapy is inadequate for symptomatic stricture, though most can be internally dilated using any one of a number of dilating techniques. After dilation, surgical therapy aims to reduce reflux and prevent recurrence. The Collis gastroplasty, classically performed via a transthoracic approach, aims to lengthen the esophagus to facilitate a subsequent tension-free fundoplication. This procedure creates a tube of esophageal diameter from the lesser gastric curvature tissues via surgical stapling so that subsequent intra-abdominal fundoplication can be performed around the "neoesophagus." In the context of advanced GERD with esophageal shortening, Collis gastroplasty combined with a fundoplication (Belsey) provided relief of GERD symptoms to 70% of treated patients overall, and to 89% who presented without dysphagia [6]. The Collis gastroplasty has also been used for the treatment of advanced GERD without esophageal shortening. Esophageal strictures that are not amenable to dilation may require esophagoplasty or esophagectomy.

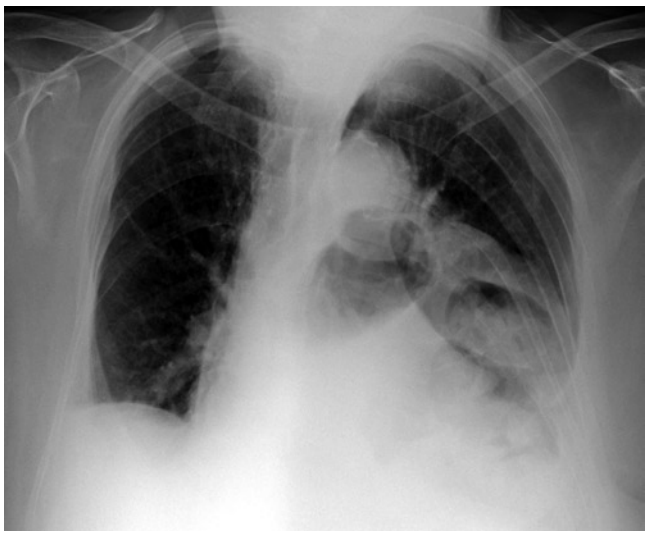

FIG. 30.3. Chest radiograph demonstrating a large left-sided type 4 paraesophageal hernia.

PH can be repaired through a midline laparotomy, a laparoscopic approach, or via thoracotomy. At our institution, most large PH are repaired through a left thoracotomy. Through a thoracotomy incision the esophagus can be easily isolated and encircled, the hernia sac opened, its contents reduced to the abdomen, and the hiatus narrowed. Esophageal lengthening and fundoplication procedures are also frequently performed as part of the same procedure. Both transthoracic and laparoscopic approaches to the repair of PH are associated with good results, though recurrence rates remain a concern for both procedures [7, 8].

Esophageal Perforation and Rupture

Esophageal perforation typically occurs in the hospital and is often iatrogenic. Multiple etiologies of perforation exist including upper gastrointestinal endoscopy and the traumatic placement of esophageal dilators, NGTs, and misplaced endotracheal tubes. Perforation or disruption of the esophagus may also occur from external trauma, typically gunshot wounds or less commonly, from blunt trauma, from a foreign body, or chemical ingestion.

TABLE 30.1. Common transthoracic esophageal procedures and anesthetic considerations.

Surgical procedure	Surgical incision(s)/approach	Anesthetic considerations
Transthoracic total fundoplication (Nissen) Transthoracic partial fundoplication (Belsey) Collis gastroplasty	Left thoracotomy	Pain control One lung ventilation Aspiration risk
Thoracoscopic esophagomyotomy Heller myotomy and modified Heller myotomy	Left thoracoscopy (4–5 ports) Left thoracotomy	Pain control One lung ventilation High aspiration risk Intraoperative esophagoscopy
Transhiatal esophagectomy	Midline laparotomy Left cervical Incision	Aspiration risk Risk of tracheobronchial injury, bleeding, cardiac compression, and dysrhythmias
Transthoracic esophagectomy (Ivor Lewis)	Midline laparotomy Right thoracotomy	Aspiration risk One lung ventilation
Three hole esophagectomy (McKewin)	Right thoracotomy Midline laparotomy Left cervical incision	Protective ventilation Fluid and hemodynamic management to optimize oxygen delivery Pain control Early extubation
Minimally invasive esophagectomy	Right thoracoscopy (4 ports) Laparoscopy (5 ports) Left cervical incision (variable)	Aspiration risk Protective ventilation Procedure duration

In contrast, esophageal rupture results from a sudden increase in intra-abdominal pressure with a relaxed LES and an obstructed esophageal orifice with vomiting, straining, weight lifting, childbirth, defecation, or blunt crush traumatic injuries to the abdomen and chest. Spontaneous rupture of the esophagus during vomiting is known as Boerhaave's syndrome. This rupture of the distal esophagus occurs under high pressure which forces gastric contents into the mediastinum and pleura [9].

Clinical presentation may be related to the mode of injury but is often nonspecific. Pain is the most common symptom [10], though fever, dyspnea, and crepitus also present not uncommonly. Mackler's triad, often associated with spontaneous esophageal rupture includes chest pain, vomiting, and subcutaneous emphysema. Soilage of the mediastinum elicits an inflammatory response that results in mediastinitis. Abdominal perforation may result in peritonitis. These patients may present with septic shock and are likely to deteriorate rapidly, particularly without aggressive resuscitation and definitive therapy.

Evaluation for esophageal perforation or rupture includes a plain film chest X-ray radiography (CXR) which may reveal mediastinal or free peritoneal air, pleural effusion, pneumothorax, widened mediastinum, and subcutaneous emphysema [11]. Computerized tomography (CT) scan will also confirm the rupture as evidenced by esophageal edema and thickening, possible abscess formation, as well as air and/or fluid in the pleural space. A water-soluble esophagogram will help to confirm the location and extent of the tear by allowing visualization of the extravasation of contrast.

Treatment of esophageal rupture or perforation depends mainly on the extent and location of the tear and the disease state of the esophagus. The time interval between injury and repair may also play a role in determining the appropriate strategy for treatment. Perforation of the cervical esophagus may be treated solely by drainage; surgical repair is preferred for thoracic or abdominal esophageal perforations. In a stable patient without severe esophageal pathology, primary closure of a thoracic or abdominal esophageal perforation can be attempted. If the area of injury is diseased, an esophagectomy may be required. Early aggressive surgical treatment of Boerhaave's syndrome is favored; left untreated this condition is virtually always fatal [9]. Conservative nonoperative therapies emphasizing aggressive drainage of fluid collections and appropriate antibiotic therapy are preferred by some clinicians for stable patients with contained esophageal leaks [12] and may be associated with acceptably low morbidity and mortality [12, 13]. Case reports and small case series have also demonstrated the efficacy of treating esophageal perforation and esophageal anastomotic leaks with self-expandable plastic and metallic stents [14–16].

Achalasia and Motility Disorders

Achalasia is a disease of impaired esophageal motility, most often affecting the distal esophagus. It affects approximately 1 in 100,000 persons per year, with an equal gender distribution [17]. The etiology of achalasia is unknown but characteristic features include increased LES pressure, incomplete relaxation of the LES with swallowing and loss of peristalsis which causes impaired esophageal emptying. Primary achalasia is due to a complete loss or relative absence of ganglion cells in the myenteric plexus. This causes an imbalance between excitatory and inhibitory neurons which results in impaired relaxation of the LES [18]. Other primary motor disorders of the esophagus include nutcracker esophagus and diffuse esophageal spasm. Secondary achalasia is most often caused by Chagas' disease, a systemic disease due to infection with *Trypanosoma cruzi* [19]. Other secondary motor disorders are associated with systemic disease processes such as scleroderma, diabetes, amyloidosis, Parkinson's disease, and neuromuscular diseases of skeletal muscle.

Achalasia progresses slowly and thus when patients finally present for treatment they are often at advanced stages of the disease. Symptoms of achalasia include dysphagia, first for solids and then liquids. As the esophagus dilates, regurgitation becomes a more frequent problem. Patients may describe chest pain due to esophageal spasm. Weight loss, symptoms of GERD, history suggestive for aspiration such as pneumonia and chronic cough are also consistent with achalasia [20].

Radiographic findings in advanced achalasia include absence of gastric bubble, esophageal dilation, and fluid filling [21]. Barium swallow reveals the esophageal air-fluid level and a characteristic bird's beak narrowing caused by the impaired relaxation of the LES [21] (see Fig. 30.4).

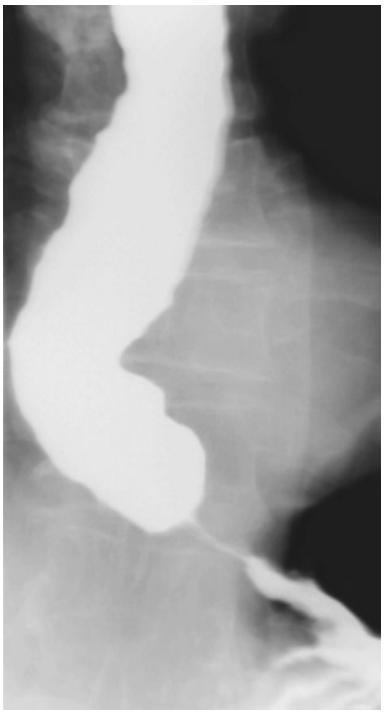

Fig. 30.4. This thoracic level barium swallow esophagogram illustrates a classic radiologic feature of achalasia – bird-beak appearance of the esophagus.

Esophageal manometry is a sensitive diagnostic test for achalasia and manifestations include elevated LES resting pressure and incomplete relaxation of the LES, aperistalsis of the esophageal body, and elevated lower esophageal baseline pressure [20]. Treatment goals for achalasia include elimination of the esophageal outflow obstruction due to the tight LES, alleviating dysphagia and minimizing gastroesophageal reflux [20]. Nonsurgical treatments include calcium channel blockers and nitrates, botulinum toxin injection, and balloon dilatation of the LES. The superiority of surgical myotomy with fundoplication is supported by a recent systematic review and meta-analysis [22].

Laparoscopic esophagomyotomy is performed with the patient in modified lithotomy, reverse Trendelenberg position and includes an anterior longitudinal myotomy of the distal esophagus, esophagogastric junction, and proximal stomach. Thoracoscopic esophagomyotomy is performed through a thoracoscope via the left chest which allows for optimal visualization of the lower esophagus and cardioesophageal junction [23, 24]. The Heller and modified Heller myotomy procedures are performed via a left thoracotomy incision and differ in the extent of the myotomy incision and the inclusion of a fundoplication to minimize reflux. The Heller procedure utilizes a shorter myotomy incision extended only 1 cm or less onto the stomach. The modified Heller myotomy includes a 10 cm myotomy incision and a partial anterior gastric fundoplication to decrease the risk of reflux postoperatively [24].

Minimally invasive laparoscopic and thoracoscopic Heller and modified Heller myotomy procedures have been shown to be safe, effective, and durable treatments for achalasia [25–37]. Patient outcomes after minimally invasive myotomy surgery for achalasia generally favor the laparoscopic approaches, however. Multiple investigators have found that patients experience superior dysphagia relief and less postoperative reflux with the laparoscopic approach as compared to the thoracoscopic approach [25, 28, 32, 33]. This difference may result from the limitations in extending the myotomy incision into the stomach and creating a fundoplication wrap from the thoracoscopic approach.

Tracheoesophageal Fistula (TEF)

Tracheoesophageal fistula (TEF) in adult patients is most commonly a result of malignancy, though TEF after traumatic injury [38] and intubation or tracheostomy [38–42] is also described. Though less common, TEF of congenital origins has also been reported [43–45]. Rarely, the diagnosis of TEF may be made intraoperatively [46], in the perioperative period [43, 47], or in chronically intubated patients [40–42].

TEF can be managed by either surgical or nonsurgical means, depending largely on the etiology. Nonoperative management of TEF with malignant etiology is generally favored as the presence of a TEF in association with malignancy generally indicates nonrespectability. Placement of an esophageal stent may provide suitable palliation [48] and survival is related to tumor biology rather than the fistula itself [48]. In critically ill patients dependent on mechanical ventilation, the use of esophageal stents to provide temporary closure of benign TEF was a safe and effective procedure for palliation [49]. The treatment of postintubation TEF is more aggressive and tracheal or laryngotracheal resection with primary closure of the esophagus has been recommended [50].

Esophageal Diverticula

Esophageal diverticula are classified according to their anatomic location (cervical or thoracic) and pathophysiology (pseudo- or traction diverticula). Most diverticula are acquired and occur in an elderly patient population. Pulsion or pseudodiverticula are the most common form and consist of a localized outpouching which lacks a muscular covering; that is, the wall consists of only mucosa and submucosa herniating through the muscle layer. Most pseudodiverticuli are of the Zenker's variety, located in the hypopharynx. Epiphrenic diverticula are located within the thoracic esophagus, typically in the distal esophagus [51]. True or traction diverticula occur within the middle one third of the thoracic esophagus as a result of paraesophageal granulomatous mediastinal lymphadenitis usually due to tuberculosis or histoplasmosis and are characterized by full-thickness involvement of the esophageal wall. These diverticula are typically small and most are asymptomatic. Complications are uncommon but may include TEF formation.

Clinical presentation of Zenker's diverticulum usually includes dysphagia for solid food and regurgitation of undigested food substances. Patients may also complain of halitosis, gurgling associated with swallowing, and symptoms associated with aspiration such as nighttime cough, hoarseness of voice, bronchospasm, and chronic respiratory infection. Diagnostic confirmation is accomplished with barium contrast study which clearly demonstrates the diverticulum.

Surgical correction of Zenker's diverticulum is usually accomplished via a left cervical incision and includes a cricopharyngeal myotomy. While the myotomy may be sufficient therapy for small diverticula, larger sacs require diverticulectomy or diverticulopexy [51, 52]. Minimally invasive techniques used to treat Zenker's diverticulum have included endoscopic stapling diverticulostomy, fiberoptic endoscopic electrocautery, and laser coagulation techniques [51–54]. In general, minimally invasive treatments for Zenker's diverticulum have yielded satisfactory results in the majority of patients [54, 55] and most can be performed in an endoscopy unit with a brief general anesthetic or in an awake patient.

Thoracic esophageal diverticula are usually epiphrenic and most are found to be associated with an esophageal motor disorder such as achalasia. While many patients do not have symptoms specifically referable to the diverticulum, if present these may be difficult to distinguish from those of the associated motor disorder. Patients who are asymptomatic or present with mild symptoms are not surgical candidates. Presenting symptoms may include dysphagia, chest pain, regurgitation of ingested foods, and symptoms of aspiration. Patients with epiphrenic diverticula are advised to undergo both barium

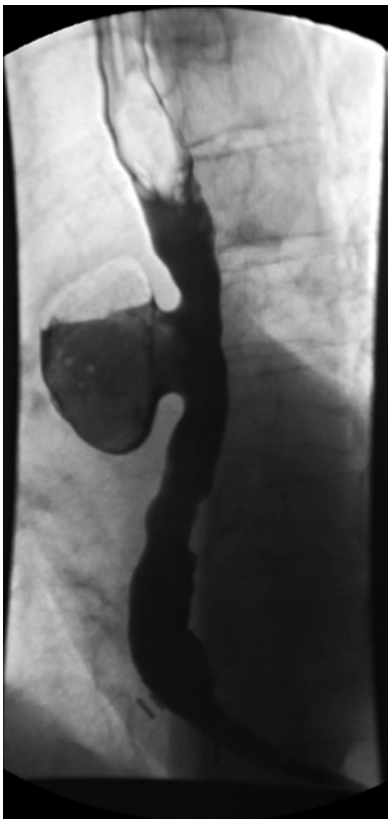

FIG. 30.5. A thoracic level barium swallow esophagogram which demonstrates a large mid-esophageal diverticulum filled with contrast.

swallow examination (see Fig. 30.5 for barium esophagogram of a mid-espophageal diverticulum) and esophageal manometry to delineate any associated pathology such as motility disorder, malignancy, or stricture. Patients with incapacitating symptom profiles are referred for surgery.

Surgical goals include resection of the diverticulum and usually, a myotomy to treat the accompanying motor disorder, with or without an antireflux procedure. The classical surgical approach has been through a left thoracotomy incision, through which the diverticulum is dissected and excised; a myotomy and a fundoplication may also be performed. Results of surgical therapy are favorable, completely eliminating symptoms in 74% of patients [56]. Thoracoscopic and laparoscopic approaches have also been described but the number performed is relatively low, commensurate with the rarity of these lesions.

Malignant Disease of the Esophagus and Esophagectomy

Esophageal Cancer

Malignant esophageal tumors can be classified on the basis of histologic types – squamous cell carcinoma and adenocarcinoma, which differ with respect to affected populations, incidence, etiology, and risk factors. While squamous cell carcinoma still accounts for the vast majority of esophageal cancers worldwide, the incidence of adenocarcinoma has risen sharply throughout the Western world, now accounting for nearly half of esophageal cancers in many countries [57, 58]. Potential etiologic and predisposing factors identified through epidemiologic study include tobacco use and excessive alcohol ingestion, gastroesophageal reflux, obesity, achalasia, and low socioeconomic status [57].

Clinical presentation of patients with esophageal cancer is variable; patients may present with symptoms of dysphagia, odynophagia, and progressive weight loss. Patient evaluation should include a thorough history and physical examination with attention to local tumor effects, possible sites of metastasis, and general health. Clinical investigations include the barium contrast swallow study to define esophageal anatomy and esophagogastroscopy to permit biopsy and definitive identification of tumor type. Both CT scans and magnetic resonance imaging (MRI) are used clinically for noninvasive staging of esophageal cancer. Endoscopic ultrasound (EUS) has been used for imaging of local/regional esophageal disease and may be considered complementary to CT scanning. Positron emission tomography (PET) is being used with greater frequency for the purpose of staging esophageal cancer and for assessing the response to induction chemotherapy.

In an effort to avoid the morbidity, mortality, and expense associated with esophagectomy, many centers are employing relatively new approaches to esophageal preservation in patients with malignant and premalignant esophageal lesions. The close surveillance of many patients with premalignant disease of the esophagus has led to the early identification of many cases of high-grade dysplasia and superficial adenocarcinoma. Advances in the use of minimally invasive endoscopic techniques permit the staging of superficial esophageal cancers by endoscopic biopsy [59, 60] and where appropriate, endoscopic resection of adenocarcinoma limited to the esophageal mucosa [61, 62].

Unfortunately, patients often present with advanced local/regional and metastatic disease. The failure of surgery to cure most advanced local and regional disease and the early systemic dissemination of esophageal cancers has led to significant interest in improving chemotherapeutic regimens. Chemotherapies are now routinely used in the context of esophageal cancer both for palliation of locally advanced and metastatic disease and increasingly as an adjunct to surgical resection. 5-Fluorouracil and cisplatin are widely used in combination preoperative therapy for both adenocarcinoma and squamous cell carcinoma of the esophagus [63]. Combination therapy may improve survival but appears to also increase the risk of serious therapy-associated complications [64]. Neoadjuvant chemotherapy with or without radiotherapy is widely used and is believed to improve curative resection rate, though survival differences have been difficult to demonstrate in small studies. A recent review of meta-analyses investigating neoadjuvant chemotherapy with radiation suggests an improved pathologic response which may improve survival but also underscores the need for additional high quality clinical trials to confirm these findings [65].

Esophagectomy

Esophagectomy is indicated for the resection of esophageal cancer without local invasion or metastasis [66], curative resection of high-grade dysplasia [67], and may also be used for severe nonmalignant disorders including esophageal injury, nondilatable stricture, severe recurrent GERD, and achalasia [68, 69]. Esophagectomy surgery can be performed via a transhiatal approach by laparotomy, a two incision surgery utilizing both laparotomy and right thoracotomy (Ivor Lewis), a three incision approach (McKewin) which also requires a cervical incision for anastomosis, and minimally invasive approaches utilizing laparoscopy and/or thoracoscopy (see Table 30.1). Consideration for the transhiatal, transthoracic, and minimally invasive esophagectomy (MIE) will be discussed later.

Transhiatal esophagectomy (THE) is performed for tumors throughout the esophagus but is often preferred for lower tumors. The primary advantage of this resection is that it avoids a thoracotomy and the possibility of an intrathoracic anastomotic leak. This procedure is accomplished via a large upper abdominal incision which is used to mobilize the stomach and through which transhiatal esophageal dissection is carried out and a cervical incision through which the conduit is introduced and the anastomosis is made. The transhiatal approach to esophagectomy requires the manual dissection of the esophagus from the mediastinum blindly via the abdominal hiatus.

There continues to be considerable debate regarding the relative risk of THE relative to the transthoracic esophagectomy (TTE) procedure, both from a surgical and oncologic standpoint. While the morbidity and mortality associated with THE have declined over the past several decades [70], the advantage of THE over TTE remains controversial with both early morbidity and mortality advantages demonstrated [71, 72] and refuted [73]. It is also not clear whether surgical approach affects long-term survival; a meta-analysis of multiple comparative studies demonstrated equivalent (20%) 5-year survival in both groups [71], though a trend towards an improved survival in the TTE group has also been reported [72].

The transthoracic approach to esophagectomy is performed for malignant, premalignant, or nonmalignant disease of the esophagus and employs an abdominal incision for mobilization of the stomach and formation of a gastric tube or other esophageal conduit and a right thoracotomy through which the diseased esophageal portion is resected and the anastomosis is made. The TTE is often preferred when the resection extends to other mediastinal structures, mediastinal fibrosis is known or suspected, tumor may involve the airway or vascular structures, or an intrathoracic anastomosis is required.

The term "minimally invasive esophagectomy" (MIE) encompasses a variety of surgical approaches to esophagectomy that attempt to minimize the degree of surgical trespass in one or more body cavities. True MIE using laparoscopy and thoracoscopy is performed in very few centers. Analogous to the open procedures, several variants are possible; the most popular are the minimally invasive equivalents of the Ivor Lewis and three hole esophagectomies. Thus far, outcome data are limited, but encouraging. In a clinical series of 222 MIE cases, morbidity and mortality outcomes compared favorably to those of open esophagectomy [74]. Randomized trials directly comparing MIE with open esophagectomy will be required before definitive benefits can be declared, but it is conceivable that advantages with regard to pain control, respiratory complications, length of stay, total cost, and quality of life may yet be demonstrated.

Esophageal Conduits

Although a variety of conduits have been used after esophageal resection, stomach is usually preferred because of its excellent blood supply, because it can be readily mobilized to reach the thorax or neck, and because only one anastomosis is required. However, the stomach may not be a suitable conduit in the case of prior gastric surgery or tumor involvement. In such cases, an alternative conduit must be used. The pedicled colonic interposition utilizes a segment of colon with an attached vascular pedicle as an esophageal replacement conduit. While the pedicled colon graft has adequate mobility its use is associated with numerous complications including conduit redundancy and symptoms related to inadequate food transit [75–79] which may impact quality of life [76] and long-term outcomes [80]. Additionally, atherosclerotic disease may affect vascular supply to the colon which may in turn increase the risk of colonic ischemia and necrosis, a major cause of morbidity and mortality [81–83].

Jejunum has a number of theoretical advantages over that of colon for use as an esophageal replacement. First, its diameter more closely approximates that of the esophagus. Secondly, it is generally disease free. Additionally, its intrinsic peristaltic activity may improve food transit and reduce symptoms postoperatively [84–88]. Use of the jejunum for interposition has previously been limited by the vascular anatomy of the jejunum. The jejunal mesentery lacks the collateral arcades of the colon which permit them to reach interposition sites in the thorax and neck. Ischemia of the interposition graft is the likely cause of jejunal loop gangrene which plagued early attempts and led to an interest in vascular augmentation of the interposition graft, now known as "supercharging."

Recent advances in microvascular surgery have enabled specialized centers to expand the indications for jejunal interposition beyond short-segment esophageal replacement. Esophagectomy with "supercharged" jejunal interposition graft is undertaken as a one-stage procedure which includes esophageal resection, construction of the interposition graft with esophageal and jejunal reconstruction. The superior jejunal vascular arcade is "supercharged" by reimplantation into cervical or internal mammary arteries. The inferior arcade retains its native supply from the superior mesenteric artery. A recent series utilizing this supercharging technique

for construction of jejunal interposition grafts for esophageal reconstruction demonstrated a 92% success rate for discharge with an intact flap. Ninety-five percent of patients were discharged on a regular diet and without reflux symptoms [89, 90]. Despite some successes, this technique remains the purview of highly specialized centers with multidisciplinary teams and is considered only in the absence of a suitable gastric conduit.

Anesthetic Management of Esophageal Surgery Patients

Preoperative Evaluation and Preparation

A thorough history and physical examination should be performed prior to anesthetizing a patient for esophageal surgery. Comorbid conditions should be evaluated and optimized prior to surgery. Particular attention should be given to signs and symptoms of esophageal obstruction, GERD, and silent aspiration. Symptoms of obstruction, particularly dysphagia and odynophagia, may lead to reduced oral intake and malnutrition which can lead to increased morbidity and mortality [91, 92]. Symptoms of severe GERD with aspiration may include water brash (hypersalivation in response to reflux), coughing when supine, globus sensation (feeling of lump in throat), laryngitis, and asthma-type symptoms.

The presence of significant cardiovascular disease has important implications for patients undergoing major surgical procedures involving the esophagus. Patients may be evaluated for cardiovascular risk with attention to the ACC/AHA guidelines for perioperative cardiovascular evaluation [93]. The risk of cardiovascular complications during major surgical procedures of the esophagus may be increased by a number of factors inherent to surgery and anesthesia care, including the degree of planned physiologic trespass, hypoxemia, hemorrhage, dysrhythmias, and pain. One lung ventilation (OLV) is often required for surgery of the esophagus. Oxygenation, ventilation, and weaning from mechanical ventilation may be more difficult in the patient with pulmonary disease. The minimum preoperative evaluation of the cardiopulmonary system should include a twelve-lead electrocardiogram (ECG) and CXR. A preoperative ECG serves as a screening test for myocardial ischemia and arrhythmias and provides a baseline for comparison in the event of perioperative cardiac complications. Preoperative CXR may reveal evidence of aspiration as well as coexisting pulmonary and cardiac disease. Patients with a history of morbid obesity or chronic lung disease should also undergo preoperative pulmonary function testing if the procedure involves a thoracotomy approach.

Patients with severe GERD or those otherwise at risk for aspiration pneumonitis may benefit from prophylactic medication to increase gastric pH and decrease gastric volume. Though definitive evidence of risk reduction is lacking, appropriate pharmacologic prophylaxis with H_2 receptor antagonists or proton pump inhibitors is known to reduce gastric volume and acidity [94–99] and is thus likely to reduce the incidence and severity of pneumonitis should aspiration occur.

Patients may present for esophagectomy surgery after having received neoadjuvant chemotherapy which may improve survival [63, 65]. The chemotherapeutic agents used to treat esophageal cancer cause bone marrow suppression and patients often present with some degree of anemia and thrombocytopenia. The need for optimizing patient status prior to major surgery should be balanced with the risk of delaying the resection of malignant tumors. Occasionally, severe thrombocytopenia may preclude the preoperative placement of an epidural catheter in which case alternative plans for analgesia should be made.

Intraoperative Monitoring

In general, intraoperative monitoring for esophageal surgery cases should be commensurate with the degree of physiological trespass inherent in the planned procedure and the nature and severity of patient comorbidity. Routine monitoring should include pulse oximetry, noninvasive blood pressure monitoring, and electrocardiography. Since many patients presenting for esophageal surgery have comorbid disease of the cardiovascular and respiratory systems, consideration should be given to invasive monitors where appropriate. With the exception of patients with advanced cardiovascular or pulmonary disease, routine intraoperative monitors will generally suffice for those patients presenting for endoscopic and minimally invasive procedures limited to the abdominal cavity. Transthoracic approaches to the esophagus generally mandate a more aggressive approach to monitoring. An indwelling arterial catheter for continuous measurement of systemic arterial blood pressure is the standard of care for these procedures. Surgical manipulation of thoracic and mediastinal structures can profoundly affect determinants of cardiac performance including venous return and cardiac filling and may contribute to the development of dysrhythmias, all of which can compromise cardiac output and hemodynamic status. In addition, many of these procedures require lung isolation and OLV, a ventilation strategy which substantially limits arterial oxygenation. Surgical dissection can lead to unexpected bleeding, occasionally massive in nature. Point of care testing of arterial blood samples can aid in the assessment and maintenance of adequate arterial oxygenation, acid base status, as well as hemoglobin and electrolyte concentrations.

In the patient with normal cardiovascular reserve, central venous access is not generally necessary and does not provide useful information for volume management. Nonetheless, central access may be required in patients with very limited peripheral venous access, especially obese patients in whom it may be difficult to re-establish lost venous access intraoperatively, patients requiring emergency surgery for esophageal trauma or perforation as septic complications can rapidly ensue, and those patients who are likely to require vasopressor

or inotropic support. Patients undergoing esophageal surgery should also undergo bladder catheterization for decompression and for the monitoring of urine output. Temperature monitoring is easily accomplished via a probe in the oropharynx, axilla, or bladder catheter. Euthermia can be achieved by use of commercially available forced warm air heating blankets and fluid warmers.

Pain Control

Pain control after esophageal surgery is dictated largely by the surgical approach to the esophagus. Most patients undergoing endoscopic surgery of the esophagus have little pain postoperatively and thus do not require an aggressive plan for analgesia. Similarly, a laparoscopic approach is generally not associated with high analgesic requirement postoperatively. However, the thoracotomy incision utilized in most transthoracic esophageal surgeries is one of the most painful surgical incisions in common use. As such, anesthetic techniques for postoperative pain control play an extremely important role in optimizing outcomes after transthoracic esophageal procedures. Although a variety of pain control approaches have been utilized, most centers favor the use of thoracic epidural analgesia (TEA) for its excellent analgesia [100, 101], favorable safety profile, cost savings [102, 103], its potential role in improving outcomes after transthoracic esophageal surgery [103–107], and as a component in multimodal strategies to expedite patient mobilization and recovery after esophagectomy [108–111].

In comparison to parenteral opioid pain therapy alone, TEA provides superior analgesia after esophagectomy [100, 101] and is considered by many surgeons and anesthesiologists to represent the "gold standard" with regard to postoperative pain control after thoracotomy in general. However, for technical and safety reasons, not all patients are suitable candidates for the placement of thoracic epidural catheters. For patients in whom TEA is not possible but epidural analgesia per se is not contraindicated, lumbar epidural analgesia (LEA) may represent a compromise approach for analgesia after thoracoabdominal esophagectomy though pain control postoperatively is inferior to that obtained by TEA [112].

A variety of nonneuraxial techniques have been studied and recommended for postthoracotomy pain control; the most promising of these include intrapleural, intercostal, and paravertebral approaches. Intercostal nerve catheters in combination with patient controlled analgesia (PCA) have been compared with TEA producing mixed results [113, 114]. Intrapleural and thoracotomy wound catheters have also been utilized, though rigorous comparison to standard therapies are lacking [115, 116]. Paravertebral blockade has shown promise as an alternative therapy [117] with analgesic efficacy comparable to that of TEA by randomized trial [118] and meta-analysis [119] and with a favorable side-effect profile [119] and has been advocated as a superior modality by several authors [120, 121]. Whether paravertebral analgesia will replace TEA for postthoracotomy pain may depend on the identification of outcome advantages that have thus far been ascribed only to TEA.

Specific epidural management strategies should ideally consider the dermatomal range of incision(s), the impact of incisional pain on respiratory function, the likelihood and impact of respiratory depression, and the intraoperative impact of an epidural induced sympathectomy on hemodynamic status. Since the thoracoabdominal esophagectomy requires both thoracotomy and laparotomy incisions, any plan for postoperative pain control should address this fact. A variety of management strategies have been reported, but most centers which perform transthoracic and thoracoabdominal esophageal surgeries utilize a multimodal approach to pain management including preoperative placement of a thoracic epidural catheter unless contraindicated, intra- or postoperative bolus and infusion of a dilute local anesthetic such as ropivacaine or bupivacaine along with fentanyl or hydromorphone. An additional epidural bolus of preservative free morphine may provide a wider neuraxial spread and may provide synergism with the infused local anesthetics, but requires postoperative respiratory monitoring because of the possibility of delayed respiratory depression. Whether to bolus or infuse epidural local anesthetics pre- or intraoperatively has been a subject of debate among anesthesiologists. Arguments that a preemptive initiation of analgesia might provide better acute and chronic pain control have been based largely on theoretical considerations. Results thus far are mixed, suggesting that preoperative dosing of epidural catheters may produce better acute pain control [122, 123]. Although acute pain after thoracotomy has been shown to predict chronic pain [124], the efficacy of preemptive epidural analgesia on preventing chronic postthoracotomy pain is not supported by a recent meta-analysis [123].

Induction and Airway Management

Induction of general anesthesia and airway management in patients undergoing esophageal surgery is dictated largely by patient factors including cardiopulmonary status, hemodynamic and nutritional status at the time of induction, mediastinal mass effect if any, perceived risk of aspiration pneumonitis, and procedural factors including anticipated length of and nature of the procedure (i.e., if OLV is required for an intrathoracic procedure). Patients presenting for emergency procedures of the esophagus and stomach may lack the desired preoperative evaluation of cardiopulmonary status and can present with unstable hemodynamic or pulmonary status from a variety of factors including underlying cardiopulmonary disease, aspiration, sepsis, acute respiratory distress syndrome (ARDS), or hemorrhage. Most practitioners favor intravenous induction agents such as propofol, thiopental, etomidate, or ketamine in conjunction with a rapidly acting neuromuscular blocking agent such as succinylcholine or rocuronium to facilitate smooth induction of anesthesia and rapid tracheal intubation.

Patients presenting for elective esophageal procedures will be stable at induction but complications arising from the presence of a mediastinal mass may accompany the induction of anesthesia, positive pressure ventilation, and muscle relaxation. Tracheobronchial compression or obstruction and cardiovascular collapse associated with anesthetic induction in patients with anterior mediastinal masses have been well described and is discussed in Chap. 14. Airway compromise has also been reported spontaneously or during the conduct of anesthesia in patients with posterior [125–129] and superior [130–132] mediastinal masses. Posterior mediastinal masses, including those of esophageal origin [125–127] and the dilated esophagus itself [133] may impinge on the airway and cause obstruction. The trachea is most easily compressed posteriorly because of the lack of cartilaginous support, and thus posterior compression can result in near complete expiratory obstruction [129]. The identification of patients with mediastinal masses who are at risk for cardiopulmonary complications is imprecise but specific factors associated with increased risk have been reported [134] and may aid in management.

Anesthetic management of patients for esophageal surgery presents an additional challenge with regard to the perceived risk of aspiration. Patients in need of esophageal surgery are widely considered to be at elevated risk of aspiration and its sequelae [135–138] (see Fig. 30.6) and the use of rapid sequence induction techniques are widely used and advocated [136, 137]. Those patients with severe gastroesophageal pathology, particularly those with obstructive disease and dysmotility syndromes may represent high-risk subgroups but clear risk stratification is lacking. Achalasia, in particular, has been associated with spontaneous aspiration pneumonitis [139, 140] and these patients may benefit from longer periods of NPO status. Practice guidelines for preoperative fasting have been published [141] and effect of fasting regiments has been reviewed [142] but apply to healthy patients undergoing elective surgical procedures. Optimal periods of NPO status in patients with severe gastroesophageal pathology are not known.

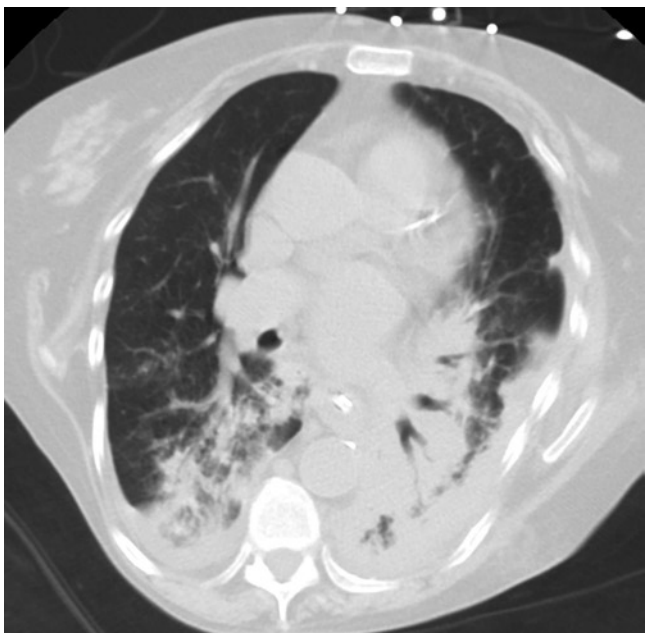

FIG. 30.6. CT scan of the thorax which demonstrates multifocal bibasilar consolidations consistent with the patient's history of aspiration pneumonitis.

Rapid sequence induction and intubation has been widely advocated in patients thought to be at elevated risk of regurgitation and aspiration. This technique has classically referred to the rapid intravenous administration of induction agent and muscle relaxant, accompanied by the application of cricoid pressure (Sellick maneuver) and immediate laryngoscopy and tracheal intubation without intervening positive pressure ventilation. The rationale underlying this approach is that (1) the cricoid cartilage is positioned anterior to the esophagus, (2) that downward pressure on the cricoid cartilage on a patient in the supine position would be transmitted to the esophagus, occluding the esophageal lumen by compressing it against the adjacent vertebral body, and (3) that this compression would result in a clinically significant effect on passive regurgitation, and thus aspiration in the anesthetized patient. Arguably, rapid sequence induction with cricoid pressure has represented the standard of care for patients at risk for pulmonary aspiration in many centers. There is currently, however, considerable controversy regarding the efficacy and safety of this maneuver [143, 144]. There is also a growing awareness that the assumptions underlying the use of cricoid pressure and the efficacy of cricoid pressure in preventing regurgitation and aspiration remain unproven. Pressure applied to the cricoid cartilage increases the lateral displacement of the esophagus without reliably compressing it [145]. Though a recent study has shown that cricoid pressure compresses the hypopharynx, decreasing its diameter by 35%, it is not known whether this is sufficient to obliterate the lumen [146]. Cricoid pressure also displaces and compresses the airway [145], potentially increasing the difficulty associated with airway management [147, 148], and is contraindicated in the context of known or suspected cricoid or tracheal injury, unstable cervical spine, and during active vomiting. Additionally, cricoid pressure is not without risk, having been associated with fracture of the cartilage [149] and a variety of other risks [147, 148, 150]. It is also worth noting that cricoid pressure is associated with a decrease in LES pressure and esophageal barrier pressure [151] which could increase the risk of passive regurgitation in the anesthetized patient. This is consistent with the well-described phenomenon of regurgitation and aspiration during the application of cricoid pressure [135, 152, 153]. Finally, reviews of the available evidence regarding the efficacy of cricoid pressure in preventing aspiration in the context of rapid sequence induction fail to support the notion that it decreases the risk of aspiration [148, 154]. Since our current understanding of aspiration and the protective effects of cricoid pressure, if any, are incomplete, the decision to apply cricoid pressure in the context of a rapid sequence induction

should be individualized and based on an understanding of the relevant anatomic and physiologic principles and the specific clinical context.

Though there is little definitive evidence with regard to practical aspects of aspiration pneumonitis risk reduction to guide the practitioner, we suggest the following approach. If there is any anatomic or historical evidence to suggest a difficult intubation, serious consideration should be given to intubation in the awake patient, particularly for patients at highest risk of aspiration – those presenting with achalasia, high-grade esophageal obstruction and those requiring emergency procedures with full stomachs. For those patients with airways judged to be easily manageable, the use of a rapid sequence induction is prudent. Minimizing the time between loss of consciousness, muscle relaxation, and tracheal intubation with a lubricated cuffed tube is likely to reduce risk. It is also worth considering the possible effect of patient position on aspiration risk. A head-up or reverse Trendelenberg position may reduce the passive reflux of gastric contents and aspiration risk [155–157] in addition to the known benefits of this position on pulmonary mechanics, particularly in the obese patient and has been previously advocated [135, 155].

The suggestion that aspiration of gastric contents may be a contributing factor in the development of pulmonary complications in thoracic surgery patients is derived, in part, from evidence of intraoperative tracheal aspiration in intubated patients undergoing thoracotomy [158]. In this study, premedication with ranitidine decreased the incidence of measured gastric acid regurgitation but effects on reduction of tracheal acid aspiration were not statistically significant. Clearly, acid aspiration in patients intubated with double lumen endotracheal tubes (DLT) is possible [158] though dye studies suggest that gel lubrication of the tube cuff may reduced leakage and aspiration [159, 160]. Other strategies to minimize the risk of tracheal aspiration in patients undergoing esophageal surgery include appropriate preoperative suctioning of the NGT if present, and of the NGT and oropharynx prior to tracheal extubation. A low level of continuous suctioning of the NGT after major esophageal surgery may also help reduce the incidence of subacute and chronic aspiration postoperatively [161].

Intraoperative Management

After the induction of general anesthesia and tracheal intubation, the maintenance of anesthesia can be accomplished by a variety of approaches, though many authors prefer a balanced anesthetic technique with the use of a volatile inhalational agent such as isoflurane, sevoflurane or desflurane, a nondepolarizing paralytic agent, intravenous opioids, and opioids and/or local anesthetic agents via an epidural catheter if present [109, 111]. As volatile anesthetic agents are known to precondition the myocardium against subsequent ischemic insult, there is a theoretical advantage in the use of these agents. Given the overlap of risk factors for coronary disease and esophageal disease, patients presenting with surgical esophageal disease may also be at risk for myocardial ischemia and thus may benefit from such protection, though clinical evidence of benefit in this population is lacking. A total intravenous anesthetic with propofol infusion is also a viable option, though this technique lacks the theoretical advantage of myocardial preconditioning and is likely to be significantly more expensive, particularly for longer surgeries.

Lung Isolation and One Lung Ventilation

Surgical approaches to the thoracic esophagus have been greatly facilitated by the development of techniques for lung isolation and OLV. In most major centers, lung isolation and OLV are considered the standard of care for transthoracic approaches to the esophagus and are essential for thoracoscopic esophageal surgery. The most commonly utilized modalities are DLT and endobronchial blockers. Left-sided DLT are most commonly employed for transthoracic esophageal surgery and they have the advantage of being easily placed by experienced practitioners, providing excellent lung isolation and operating conditions while providing access to both lungs for suctioning, ventilation, and oxygen administration. Additionally, because the left mainstem bronchus is longer than that of the right, positioning is more easily accomplished without compromising left upper lobe ventilation.

However, the use of a DLT may be relatively or absolutely contraindicated in some patients or may be difficult to achieve, necessitating another approach. First, endotracheal intubation with a DLT may require more time than with a single lumen tube [162]. This may increase the risk of aspiration in the high-risk patient particularly in the context of a difficult airway. The use of adjunctive airway devices such as the endotracheal tube introducer may be more difficult with a DLT [163], though difficult endotracheal intubation with a DLT can be aided by the use of adjunctive devices such as the Glidescope video laryngoscope [164] or the Airway Scope [165]. Additionally, some patients may present with anatomic abnormalities of the airway such as subglottic stenosis or extrinsic compression of the trachea or either mainstem bronchus. Passage of a DLT may be difficult or even dangerous in this context. If it is likely that the patient will require postoperative mechanical ventilation or if extubation is delayed for another reason, exchanging the DLT for a single lumen tube at the end of surgery places the patient at additional risk for loss of airway and aspiration.

The above limitations of DLT have prompted interest in the use of endobronchial blockers for esophageal surgeries. A detailed discussion of endobronchial blockers and their applications can be found in Chaps. 16 and 17. Endobronchial blockers are placed through (coaxially) or occasionally alongside single lumen endotracheal tubes (SLT) and can be used in patients with tracheostomies. The use of endobronchial blockers is well described for thoracic procedures, including esophageal surgery [166] and is preferred by some authors [163]

because of the perceived reduction in aspiration risk with the use of the SLT and rapid sequence induction, the improved ease of managing difficult airways, and lung collapse scores equivalent to that of the DLT [167].

Fluid Management

Fluid requirements vary widely between patients and procedures and ultimately represent the sum of preoperative deficits, maintenance requirements, and ongoing losses. Preoperative fluid deficits in patients with severe esophageal disease may be substantial, though they have not been well defined. Fluid requirements in patients undergoing esophageal procedures may be complicated by the fact that patients may be relatively hypovolemic after long preoperative fasts, particularly if esophageal obstruction or dysphagia limit fluid intake. Perioperative losses occur via a number of mechanisms including urinary, gastrointestinal, and evaporative losses, bleeding, and interstitial fluid shifting. This shift of fluid from the vascular compartment into the interstitial space accompanies surgical trauma and is likely to reflect vascular injury and loss of endothelial integrity. So called "third space" losses describe fluid loss into noninterstitial extracellular spaces which are not in equilibrium with the vascular compartment and thus considered to be a "nonfunctional" extracellular fluid compartment. This space has not been well characterized and its existence has been questioned [168].

In general, minor procedures and those involving minimally invasive surgical procedures tend to be associated with low fluid requirements. Patients undergoing longer and more complex procedures involving open abdominal and/or thoracic incisions may require significantly more intraoperative fluid to maintain homeostasis. Despite many studies in the area of perioperative fluid balance and fluid therapy, a consensus of best practice does not yet exist. However, recent advances in understanding the pathophysiology of fluid shifting in the perioperative setting, advances in the clinical management of fluid balance, and the application of advanced monitoring modalities to drive rational goal directed fluid therapies (GDFTs) justify several conclusions.

First, excessive perioperative intravenous fluid administration, particularly crystalloid, is likely to contribute to an exaggerated fluid shifting towards the interstitial space, potentially increasing complications associated with poor wound healing, slower return of GI function, abdominal compartment syndrome, impaired anastomotic healing, increased cardiac demand, pneumonia, and respiratory failure [169]. Prospective trials examining "liberal" vs. "restrictive" fluid regimens in patients undergoing major surgical procedures generally favor greater fluid restriction [170–172] as do retrospective studies of patients undergoing pulmonary resection surgery [173–175] and esophagectomy [176, 177]. Interpretation of these prospective trials is limited, however, by a lack of standard definition of the terms "restrictive" and "liberal." What is liberal in one study may be restrictive in another. Retrospective analyses are limited in this regard by the potential for uncontrolled bias. Most studies of both types, however, are consistent with the idea that crystalloid overload rather than fluid overload, per se, is most closely related to adverse outcomes, but these studies do not permit identification of a suitable fluid regimen most compatible with favorable outcomes. However, inadequate fluid resuscitation in patients with significant fluid losses may cause hypovolemia and subsequently, a decrement in stroke volume, cardiac output, and tissue oxygen delivery which could compromise renal function, wound healing, anastomotic integrity, and even cardiovascular stability. Optimizing fluid regimens is likely to be dependent upon adequately measuring fluid requirements or surrogates thereof in individual patients rather than relying upon formulas for "restrictive" or "liberal" regimens. While fluid requirements have not been well characterized in patients undergoing esophageal surgery specifically, recent evaluation of crystalloid requirements to maintain the left ventricular end diastolic volume index (LVEDVI) in patients undergoing colorectal surgery has been made. The rate of crystalloid infusion required to maintain LVEDVI in patients undergoing open and laparoscopic colorectal surgery was 5.9 and 3.4 mL/kg/h, respectively [178]. However, interindividual variability was high, consistent with the need for an individualized approach. Fluid requirements for thoracic surgical procedures or for esophageal surgeries in particular are not known.

Clearly, an ideal fluid regimen for major surgeries including esophageal surgeries is individualized and optimizes cardiac output and oxygen delivery while avoiding excessive fluid administration. There is an emerging body of evidence that fluid therapies which are designed to achieve individualized and specific flow-related hemodynamic endpoints such as stroke volume, cardiac output, or measures of fluid responsiveness such as stroke volume variation (collectively referred to as GDFT) may provide a superior alternative to fixed regimens or those based on static measures of cardiac filling such as central venous pressure which does not predict fluid responsiveness or correlate with circulating blood volume in hospitalized patients [179] or after TTE [180]. GDFT in the setting of major surgery has been shown to reduce the length of stay [181–188], promote earlier return of bowel function [181], reduce postoperative nausea and vomiting (PONV) [181], morbidity [183–185, 189], and vasopressor use [190]. A review of nine studies utilizing GDFT revealed that of these, seven reported reduced hospital length of stay, three reported reduced PONV and ileus, and four reported a reduction in complications [191].

The use of GDFT for fluid management in thoracic surgery is currently in its infancy and most available studies are small and have investigated primarily patients undergoing cardiac surgery. In addition to the pulmonary artery catheter-derived cardiac output measurements which are not generally used for most general thoracic surgeries and the transesophageal echocardiographic and esophageal Doppler modalities which are inappropriate for esophageal procedures, a number of

minimally invasive modalities compatible with transthoracic esophageal surgery are available. These include primarily devices that use proprietary algorithms to estimate stroke volume index, cardiac index, and/or stroke volume variation [192–195]. The utility of these modalities in directing GDFT in the context of an open hemithorax and OLV has yet to be demonstrated, but other studies demonstrating clinical advantages of GDFT in intra-abdominal surgeries invite a closer examination of the potential benefits.

In addition to the potential importance of the amount and timing of fluid administration, there is also emerging clinical evidence that the choice of fluid type may be important in affecting clinical outcomes. As above, most studies reporting the adverse effects of excessive perioperative fluid administration to patients undergoing thoracic surgery are consistent with the idea that crystalloid overload, rather than fluid overload per se is related to adverse outcomes. These include retrospective studies of factors affecting adverse outcomes after pulmonary resection [173, 174] and esophagectomy [176, 177] as well as number of prospective studies of perioperative fluid therapy [171, 172, 185]. Colloid therapy has been shown to be superior to crystalloid therapy in prospective trials of goal directed fluid management, improving outcomes and postoperative recovery [196]. Goal directed colloid but not crystalloid fluid therapy improved microcirculatory blood flow in a porcine model of anastomotic colon [197] and increased tissue oxygen tension in patients undergoing abdominal surgery [198]. This finding may be of particular relevance to esophageal surgery where anastomotic integrity may be related to blood flow and oxygen delivery to a potentially flow-compromised gastric tube-esophageal anastomosis. The improved efficacy of colloids in improving patient and surrogate outcomes in GDFT trials may be related to a number of possible factors including a greater effect on plasma volume expansion [199] and putative beneficial effects of colloids, on vascular injury, permeability, and the development of edema [200–205]. Taken together, these studies suggest that it may be preferable to use colloids to minimize fluid shifting across a potentially injured vascular barrier. This topic has been recently and extensively re-examined in a review by Chappell et al. [168] in which the authors make a compelling argument for the use of colloids in the replacement of plasma volume losses due to fluid shifting or bleeding.

The ideal choice of colloid solution for plasma volume expansion in major thoracic surgery (including esophageal surgery) also requires further elucidation. However, a number of theoretical advantages of the synthetic colloids have begun to emerge in preclinical studies. These include inhibition of endothelial–leukocyte interactions [206, 207], transendothelial migration of neutrophils [208], and vascular fluid flux [209]. The primary colloid solutions available in the United States for this purpose are human albumin, hetastarch, and the (newly available in the United States) third generation tetrastarch, (Voluven) – a lower molecular weight starch with a number of theoretical advantages, including improved clearance in patients with impaired renal function [210], and reduced adverse effects on renal integrity [211, 212] and coagulation function [213, 214]. Voluven appears to share favorable characteristics of other synthetic colloids on endothelial cell–leukocyte interaction [207] and has been associated with an inhibition of systemic inflammatory mediators and markers of endothelial cell injury and activation in a clinical study of patients undergoing major abdominal surgery [215].

Intraoperative Complications

Intraoperative management of patients undergoing esophageal surgery may be complicated by a variety of surgical and anesthetic problems. Hypotension is not uncommon during major esophageal surgeries and may result from compression of the heart or major vessels, myocardial ischemia, hypovolemia, or use of an indwelling epidural catheter leading to a thoracic sympathectomy.

Hypoxemia during esophageal surgery occurs not infrequently in patients undergoing OLV and typically is due to right to left shunt flow via the nonventilated lung as well as by volume loss and atelectasis in the dependent lung. Less commonly, hypoxemia during transthoracic esophageal surgery results from trauma to the ventilated lung and resultant tension pneumothorax which can be treated surgically by needle or finger puncture of the contralateral pleura. Pulmonary edema can result from fluid overload, cardiac failure, and immunologic reactions to medications and other immunogens including latex. The diagnosis of fluid overload and/or cardiac failure may be difficult in the context of esophageal surgery as transesophageal echocardiography is usually contraindicated or impractical and data from central venous or pulmonary artery catheters, if present, are of limited value in this regard. Electrocardiographic evidence of myocardial ischemia along with pulmonary edema, particularly if it is not responsive to pharmacologic therapy to improve myocardial oxygen supply/demand inequality, may require aborting the surgical procedure, particularly if detected prior to esophagotomy. Rarely, pulmonary embolization can occur with preferential distribution to the ventilated, perfused lung.

Postoperative Management and Complications

Postoperative management of patients after esophageal surgery is largely dependent on the specific procedure performed and the patient's response to anesthesia and surgery. In general, most patients should be suitable for extubation after elective esophageal surgery, particularly those undergoing esophagoscopy and minimally invasive laparoscopic or thoracoscopic surgical procedures. The extubation of patients undergoing esophagectomy procedures will be discussed later. Provided that patients are stable from a hemodynamic and metabolic standpoint and that neuromuscular and respiratory functions are adequate and a plan for suitable analgesia has been initiated, extubation in the OR is generally appropriate. In most cases, dosing of an indwelling thoracic epidural catheter is well tolerated during

wound closure as the intravenous or inhalational anesthetic is reduced. Following suctioning of the oropharynx and NGT, if present, the patient should be allowed to emerge from general anesthesia and extubated following the return of protective airway reflexes. Placing the patient in a 30° head-up position may improve pulmonary ventilation and decrease aspiration risk. If a gastric drain is indicated for the procedure, it should be secured prior to emergence and extubation.

Hypotension occurs not infrequently after esophageal surgery. Causes include inadequate intraoperative plasma volume expansion, hemorrhage, cardiac dysrhythmias, most commonly atrial tachyarrhythmias, pneumothorax, and sympathectomy from use of TEA. Careful hemodynamic assessment of the postoperative patient should permit the distinction between hypovolemia and other causes. Urine output and chest drain output should be carefully followed and hemoglobin concentration monitored in patients suspected of ongoing bleeding. Routine postoperative chest radiography is indicated in patients undergoing transthoracic or transhiatal procedures and when postoperative cardiovascular or respiratory complications are suspected. Most commonly, epidural related sympathectomy is the cause and can be treated by additional fluid repletion, temporary discontinuation of the infusion, supine re-positioning or leg elevation to augment venous return, or reducing the concentration of local anesthetic in the epidural infusion. Occasionally, hemodynamically fragile patients may require substitution of epidural local anesthetic solution with an opioid such as hydromorphone or morphine, though pain control with this regimen is usually suboptimal.

Atrial tachyarrhythmias occur frequently after thoracic surgical procedures, including esophageal surgeries and may result in significant hemodynamic instability due to a rapid ventricular response and/or myocardial ischemia. This complication has been best studied in patients undergoing esophagectomy surgery and will be discussed later. Myocardial ischemia, congestive heart failure, and pulmonary thromboembolic complications are also possible though appropriate patient selection, preoperative cardiovascular evaluation, and thromboprophylaxis should significantly reduce these risks.

Respiratory insufficiency, seen most commonly in patients with baseline impairment of respiratory function, may be related to weakness from inadequate reversal of neuromuscular blockade. Typically, these patients retain carbon dioxide and may become hypercapnic and obtunded. Often, retractions due to upper airway obstruction can be observed. Other causes of hypoventilation such as bronchospasm, aspiration pneumonitis, pulmonary edema, and pneumothorax, and ARDS should be ruled out with the appropriate diagnostic modalities. Inadequate pain control after thoracotomy or laparotomy can also result in splinting with reduced tidal volumes and hypoventilation. Typically, adequate treatment of incisional pain leads to a dramatic improvement in respiratory function. Chest radiography and arterial blood gas analysis should be performed immediately in any patient with acute respiratory decompensation after thoracic surgery.

Anesthetic Considerations for Specific Esophageal Procedures and Disorders

Esophagoscopy

Esophagoscopy may be performed with either a rigid or flexible endoscope and is used for a number of specific diagnostic and therapeutic purposes. In general, most diagnostic esophagoscopies are performed using flexible endoscopes, often in awake sedated patients and frequently in a gastroenterology suite without the care of an anesthesiologist. Conscious sedation performed by a nurse or other assistant under the direction of an endoscopist, usually a gastroenterologist, is most often accomplished with the use of a benzodiazepine such as diazepam or midazolam with or without the addition of an opioid such as meperidine. Patient acceptance of the procedure without sedation, even with ultrathin esophagoscopes, is quite limited [216]. Often, a local anesthetic such as lidocaine or benzocaine is applied topically to facilitate patient acceptance and reduce gagging during the procedure. If local anesthetic is used, the total acceptable dose should be carefully considered as methemoglobinemia has been associated with topical use of benzocaine for surgical procedures [217], including esophagogastroduodenoscopy (EGD) [218]. Flexible esophagoscopy is also routinely performed by thoracic surgeons immediately prior to esophageal surgery to assess the location and extent of esophageal lesions and the degree of esophageal obstruction. Most of these patients have known esophageal disease and are presenting for curative or palliative esophageal surgery. These patients are usually at elevated risk for regurgitation and aspiration and should be treated appropriately. The airway should be secured prior to instrumentation of the esophagus under general anesthesia.

Rigid esophagoscopy is most frequently employed for the extraction of esophageal foreign bodies, often in children, as well as for the removal of retained food items. As with laryngoscopy, this is a very stimulating procedure and not likely to be well tolerated without general anesthesia. These patients should also be considered high risk for aspiration and managed accordingly, with the rapid placement of a cuffed endotracheal tube before or immediately after induction of anesthesia. In selected patients who are felt to be at lower risk for aspiration with this procedure and who meet NPO guidelines, it may be appropriate to consider deeper levels of sedation. Monitored anesthesia care with sedation using dexmedetomidine infusion for rigid esophagoscopy and dilation of the UES with botulinum toxin injection for dysphagia has been described [219]. Anesthetic management considerations for rigid esophagoscopy include the extreme neck extension desired by surgeons for alignment of the oral–esophageal axis, the risk of aspirating objects once extracted from the esophagus [220], and the need for a relaxed patient to minimize movement during the procedure. The latter need can be achieved with deep levels of inhalational anesthetic or with short-acting muscle relaxants.

Additional therapeutic uses of esophagoscopy include esophageal stent placement for TEF, benign and malignant strictures [221, 222], and perforation [14, 223]. Nonsurgical treatment of achalasia, including esophageal dilatation and intraesophageal delivery of botulinum toxin can also be accomplished endoscopically [224]. Endoscopic techniques are also used in the staging of superficial esophageal tumors and complete resection of mucosal adenocarcinoma [59–62].

Tracheoesophageal Fistula (TEF)

Anesthetic management of the patient with TEF is uniquely challenging for the following reasons. First, positive pressure ventilation inevitably results in ventilatory gas entering the esophagus and stomach. Ventilation of the gastrointestinal tract may result in worsening pulmonary compliance because of abdominal distention and a concomitant increase in the risk of further aspiration and other complications [43, 225, 226]. For these reasons, maintenance of spontaneous ventilation is usually preferred and can be accomplished with either an inhalational induction or an awake intubation, though baseline decrements in pulmonary function and compliance on the affected side are likely to increase difficulties associated with oxygenation and adequate ventilation after induction of anesthesia. The preoperative placement of a gastrostomy tube will aid in venting the stomach in the event that positive pressure ventilation becomes necessary but is contraindicated if the stomach is to be used as a conduit within the thorax. Additionally, chronic aspiration and its sequelae of pneumonia, sepsis, and hypoxemia may complicate the anesthetic management of these patients, particularly during OLV. Positive pressure ventilation can be safely performed once lung isolation has been accomplished. Lung isolation is essential to prevent ventilation of the fistula, to provide adequate pulmonary ventilation, and to prevent further soilage of the lung.

The anesthetic plan for airway management and ventilation in adult patients with TEF should reflect the anatomic position of the fistula in the respiratory tract. Typically, the identification and localization of the fistula is made before presentation to the operating theater. Occasionally, the exact level of the fistula is not known. Though not always successful, bronchoscopic examination of the airway may identify the level of airway involvement and can be performed preoperatively. Bronchoscopy can also be performed after tracheal intubation with either a DLT [227] or SLT [228] and used to guide placement after localization of the TEF.

The DLT is preferred in most cases of TEF since it can be placed into the mainstem bronchus contralateral to the fistula, providing lung isolation, OLV, and protection from soilage of the ventilated lung. Thus, right-sided DLT should be used for left-sided lesions and vice versa. Occasionally, for a tracheal TEF well above the carina, a SLT may be used if the cuff can be inflated below the fistula. If this is not possible, a right DLT is preferable for distal tracheal fistulae or if the fistula site is not identified preoperatively. In patients with severe pulmonary disease, OLV may be incompatible with adequate oxygenation and ventilation. Rarely, alternative approaches for oxygenation and ventilation that minimize gas flow into the esophagus may be required. The use of a left DLT for lung isolation with high frequency oscillation ventilation on the right side has been described for optimizing gas exchange in a patient with a low tracheal TEF and ARDS [229]. An alternative approach in critically ill ventilated patients with benign TEF utilizes temporary stenting to functionally separate the airway and esophagus, minimizing air leak, and improving CO_2 removal [49]. This procedure was easily performed and well tolerated and could presumably serve as a bridge to definitive surgical correction following improvement in the patient's status.

Postoperative goals include optimizing pulmonary function to facilitate a return to spontaneous ventilation with adequate gas exchange. The continuation of positive pressure ventilation may lead to disruption of the esophageal closure and could thus cause a ventilatory leak. Achieving this goal requires adequate pain control and may also require aggressive pulmonary toilet with bronchoscopy prior to emergence.

Transthoracic Nissen and Belsey Fundoplication, Collis Gastroplasty, and Paraesophageal Hernia Repair

Transthoracic antireflux procedures require monitoring, arterial and venous access commensurate with an open thoracotomy but are otherwise without many specific implications for the anesthesiologist. Lung isolation and OLV is required as is an aggressive plan for postoperative pain control, ideally TEA. Following induction, intubation, and placement of vascular cannulae, the patient is placed in the right lateral decubitus position. It may be desirable to decompress the stomach at this point, particularly if significant amounts of air were introduced during mask ventilation. After withdrawing an indwelling gastric tube, a large bougie/dilator is advanced into the esophagus at the surgeon's request to facilitate the fundoplication. The dilator should be well lubricated with a water soluble lubricant and passed atraumatically into the upper esophagus with manual guidance or with the use of a largynoscope to aid engagement with the esophageal orifice. Caution should be exercised during advancement and communication with the surgeon is important, particularly if resistance is encountered as esophageal disruption can occur. It is then passed slowly through the esophagogastric junction and left in this position until the fundoplication sutures are secured at which time it can be withdrawn.

Unless complications are encountered intraoperatively, most patients can be allowed to emerge from anesthesia at the conclusion of surgery and extubated at emergence. The stomach should be drained with a NGT postoperatively. Oral feeding is begun after return of normal bowel activity which may require several days after open repair. Dysphagia to solid foods can be experienced by some patients for several weeks after surgery and is more common with transthoracic procedures and total fundoplications but typically resolves spontaneously.

Esophagectomy

Transhiatal Esophagectomy (THE)

Patients presenting for this procedure require standard monitoring plus a Foley catheter and arterial catheter for continuous arterial blood pressure monitoring. Patients will also benefit from the preoperative placement of an epidural catheter. After preoxygenation and induction of general anesthesia, the trachea is intubated with a SLT and both arterial and adequate intravenous access is obtained – generally two peripheral venous cannulae and an arterial catheter. A NGT is placed and secured in its position after the esophageal anastomosis is made.

The transhiatal approach to esophagectomy requires the manual dissection of the esophagus from the mediastinum blindly via the abdominal hiatus. The manual compression of the heart and great veins commonly causes hypotension, usually transiently. Optimizing volume status prior to this step may partially mitigate the decrement in blood pressure and cardiac output. Close communication between surgeon and anesthesiologist is critical during this stage, as it may become necessary for the surgeon to temporarily discontinue the dissection to permit hemodynamic recovery, particularly in the elderly or fragile patient. The duration of hypotension during dissection may be related to a patient history of cardiac disease and the presence of a midesophageal tumor [230]. The transhiatal dissection may also precipitate atrial and/or ventricular ectopy which could theoretically contribute to hypotension and reduced cardiac output during this phase. Atrial arrhythmias are commonly associated with transhiatal dissection and are more likely in patients with cardiac disease [230]. In a small study of transhiatal esophagectomies, arrhythmias occurred during transhiatal manipulation in 65% of cases, but were transient, did not require treatment, and were not correlated with hypotension [231]. Other potential intraoperative complications include pneumothorax, mediastinal bleeding from injuries to the aorta or azygous vein, and injury of the membranous trachea. Pneumothorax is easily managed surgically with the placement of a tube thoracostomy from the operative field. Massive hemorrhage is rare but is likely to require emergent thoracotomy and repair with aggressive transfusion and resuscitation. Tracheal injury also requires definitive repair and the anesthesiologist may be required to advance the endotracheal tube beyond the site of injury to facilitate ventilation during the repair. For this reason, only full-length uncut endotracheal tubes should be used for THE.

Following completion of the cervical anastomosis and wound closure, the NGT is secured in position. If in situ, the epidural catheter should be appropriately dosed prior to emergence. Tracheal extubation is performed at emergence with return of protective airway reflexes and the patient is transferred to a unit where appropriate monitoring and pain control can be accomplished. The head of the bed should be elevated between 30 and 45° to optimize respiratory mechanics and to minimize the potential for reflux and aspiration. Postoperative therapy includes antibiotics and thromboprophylaxis. Postoperative complications attributable to the THE include recurrent laryngeal nerve injury which results in hoarseness and an increased risk of aspiration pneumonitis, chylothorax, and anastomotic leak.

Transthoracic Esophagectomy (Ivor Lewis; TTE)

Unless contraindicated, a thoracic epidural catheter should be placed preoperatively. Induction and maintenance of general anesthesia can be accomplished with standard agents. For the reasons enumerated earlier, a rapid sequence induction is recommended and endotracheal intubation should ideally be accomplished with attention to the risks of aspiration. Lung isolation is not required for laparotomy and thus, some practitioners intubate initially with a SLT, replacing it with a DLT prior to the thoracotomy incision and after suctioning of the stomach. It is also reasonable to place a DLT at induction unless difficult placement is predicted in a patient with elevated risk of aspiration, such as high-grade obstruction, gastroparesis, or emergency surgery. In such a case, the practitioner should first rapidly secure the airway with a SLT, evacuate stomach contents intraoperatively, and then either place a DLT prior to thoracotomy or simply use an endobronchial blocker.

After induction, an NGT is placed with consideration to possible partial or complete esophageal obstruction that may necessitate surgical assistance for positioning distally. Decompression of the stomach and esophageal conduit is of paramount importance; thus the NGT should be secured intraoperatively to prevent its removal by the patient or inadvertent removal during patient movement and transport. Muscle relaxation with nondepolarizing muscle relaxants provides optimal operating conditions. An arterial catheter and large bore peripheral or central venous access should be obtained after induction.

Intraoperative hypotension occurs not infrequently during TTE surgery and usually results from hypovolemia and/or TEA-related sympathectomy. Hypotension may precipitate myocardial or cerebral ischemia and may also contribute to gastric tube ischemia. Thus, potential causes should be immediately sought and treated. The mobilized gastric tube has a limited blood supply, usually from the right gastroepiploic artery and blood flow at the distal segment is decreased. Factors such as hypotension may further compromise perfusion of the gastric tube and may thus increase the risk of anastomotic leak. Since anastomotic integrity is dependent upon adequate blood flow and oxygen delivery [232–234], the development of anastomotic leak may be related to intraoperative management variables, particularly systemic blood pressure and cardiac output and may thus be modifiable by anesthetic management.

Some esophageal surgeons eschew the use of vasoconstricting agents for fear of the theoretical adverse effects on gastric tube blood flow, though the limited available data do not support this reasoning. The effect of vasoconstrictors on gastric tube blood flow has not been well studied, but a small clinical study by Al-Rawi et al. demonstrated that a TEA-induced

sympathectomy decreased gastric tube blood flow during esophagectomy and that IV infusion of epinephrine restored blood flow [235]. The use of norepinephrine to maintain arterial blood pressure during esophagectomy as part of a multimodal anesthetic regimen has been associated with reduced respiratory morbidity without increasing the incidence of anastomotic complications [111]. Given the established relationship between gastric tube blood flow and anastomotic leak [232, 234, 236], maintenance of normal hemodynamics should be a priority in the intraoperative management of these patients. Towards this end it may be prudent to postpone dosing the indwelling epidural catheter in a hypotensive patient and to consider the use of inotropic agents with or without vasopressor activity.

Following uneventful TTE, most patients can be extubated in the operating room provided that they are normothermic, metabolically and hemodynamically stable, well oxygenated, and pain control modalities have been employed. Although an older randomized trial comparing early vs. late extubation after esophagectomy reported a higher mortality in the early extubation group, this difference was not statistically significant [237] and has not been observed subsequently. Early extubation after esophagectomy has been well studied and is supported by a number of retrospective and observational analyses [108, 238, 239] as well as reports of standardized management approaches [109] and fast track clinical pathways [108, 110, 240]. Factors which may predict failure or complications associated with early extubation include a history of smoking and chronic obstructive pulmonary disease (COPD) [241]. Epidural analgesia may facilitate successful early extubation [108, 239, 241].

At emergence, patients should be seated 30° above supine and extubated upon return of protective airway reflexes. Supplemental oxygen may be delivered via face tent or nasal cannulae. If postoperative ventilatory support is required or extubation must be delayed for other reasons, tube exchange can be performed with laryngoscopy, adjunctive airway devices, or via a tube exchange catheter.

Minimally Invasive Esophagectomy (MIE)

At this time, there is little specific data available to guide anesthetic management of the patient undergoing MIE but principles of management in the patient undergoing open esophagectomy are likely to apply. OLV is considered essential for any thoracoscopic procedure, including MIE and thus, lung isolation is required. The use of DLT and bronchial blockers for esophageal surgery has been discussed earlier and applies here as well. Because of the longer duration of MIE surgery, a DLT is preferred as bronchial blockers are less stable positionally [167] and are likely to require more frequent repositioning.

Avoiding a large thoracotomy incision in the context of MIE might conceivably reduce major pulmonary complications after esophagectomy. Though high quality comparative studies are few and randomized controlled trials are completely lacking, a systematic review of the available studies indicates an overall incidence of pulmonary complications of 22.9% in TTE and 15.1% in MIE [242]. Rigorous comparison to the TTE awaits adequately powered prospective trials. It is not clear that patients undergoing MIE require aggressive pain control modalities such as TEA for optimal postoperative pain control. However, the TEA remains the standard of care in centers which perform these surgeries largely because of the theoretical and demonstrated advantages of TEA in the context of open esophagectomy and thoracic surgery in general.

Postoperative Care of the Esophagectomy Patient

With appropriate pain control regimens, most patients are extubated in the operating room. Early ambulation and chest physiotherapy are used to reduce respiratory complications. Pleural drains are removed as soon as drainage is minimal and absence of air leak is confirmed, though mediastinal drains may be left until confirmation of intrathoracic anastomotic integrity is confirmed. The indwelling epidural catheter is generally used and left in situ until pleural drains are removed, at which time pain control can be adequately accomplished with parenteral or enteral medications. Feeding via jejunostomy tubes is initiated after 24 h postoperatively and advanced over a period of several days. A contrast study of the esophagus is usually performed on or about the fifth postoperative day and if normal, a clear diet by mouth is begun at that time. At discharge, the patient will be eating solid food and the jejunostomy tube is clamped. At surgical follow-up in several weeks, the feeding tube is removed.

Adverse Outcomes After Esophagectomy

Adverse outcomes after esophagectomy surgery have historically been divided into surgical and anesthetic complications. At first glance, this division is logical and appealing, but recent insight into the pathophysiology of complications after major thoracic and thoracoabdominal surgeries is beginning to blur this distinction.

Esophageal Anastomotic Leaks

As mentioned earlier, the development of an esophageal anastomotic leak is a frequent and serious complication of esophagectomy. This complication is particularly worrisome when the leak is mediastinal in location. Mortality rates from intrathoracic leaks range from 3.3 to 71% [243]. Preoperative, operative, and postoperative factors that may predispose to the development of anastomotic leak have been well described in the literature [243] and include comorbidities such as diabetes, pulmonary disease, and cardiovascular disease; a variety of surgical and technical factors; and postoperative factors including gastric distension, prolonged ventilatory support, and hypoxia. Though still considered a surgical complication, accumulating evidence suggests that intraoperative management may have an impact on the incidence of this complication. Because of

the tenuous blood supply to the mobilized gastric tube, fluid status, hemodynamics, and oxygenation may affect anastomotic integrity through effects on oxygen delivery [232, 233] and blood flow [232]. Though the optimization of tissue oxygen delivery through appropriate management of hemodynamics, fluid status, and oxygenation is a priority for all perioperative patients, this truism may be particularly critical for patients undergoing esophageal anastomoses.

Cardiovascular Complications

Cardiovascular complications account for significant morbidity and mortality after esophagectomy. The most common cardiac complication is arrhythmia, typically atrial tachyarrhythmias such as atrial fibrillation, atrial flutter, and paroxysmal supraventricular tachycardia. While generally considered benign after cardiac surgery, these diagnoses may be more ominous after general thoracic surgery including esophagectomy. There is considerable evidence that atrial tachyarrhythmias after esophagectomy are associated with a higher rate of ICU admission, greater length of hospital stay, and a higher mortality [244, 245]. These findings are consistent with those for general noncardiac thoracic surgery patients in whom atrial fibrillation was a marker for increased morbidity and mortality [246]. Atrial fibrillation after esophagectomy is also associated with a higher rate of pulmonary complications, anastomotic leakage, and sepsis [245]. Risk factors for the development of atrial dysrhythmias after esophagectomy include older age, perioperative theophylline use, a low diffusion capacity [244, 247], COPD, male sex, and history of cardiac disease [247]. Larger studies of general thoracic surgery patients including esophagectomies point to similar risks for the development of atrial fibrillation – male sex, older age, history of congestive heart failure, arrhythmia, peripheral vascular disease and resection of mediastinal tumor, pulmonary resection, esophagectomy, and intraoperative blood transfusion [246].

The prophylaxis of atrial tachyarrhythmias in general thoracic surgery has been the subject of numerous clinical trials and observational studies but no clinical standard for prophylaxis exists. A review of trials of pharmacologic prophylaxis for postoperative atrial arrhythmias reported that calcium channel blockers and beta blockers reduced the risk of tachyarrhythmias, though the latter increased the risk of pulmonary edema [248]. The routine prophylactic use of digoxin, flecainide, and amiodarone is not supported by the available evidence [248]. The available evidence supports individualized prophylaxis in patients at higher risk of atrial tachyarrhythmias after esophagectomy with either calcium channel blockers or beta blockers, with attention to the potential for adverse effects of the latter.

Pulmonary Complications

Respiratory morbidity occurs frequently after thoracic surgery in general and after esophagectomy in particular [107, 249]. Pulmonary complications of thoracic surgery are variably defined in the literature, but include pneumonia, aspiration pneumonitis, acute lung injury (ALI), ARDS, bronchopleural fistula, atelectasis, and pulmonary embolism. Any individual or cluster of these complications can result in respiratory insufficiency or respiratory failure, which may require specific therapies including the continuation or reinstitution of mechanical ventilation. The overall incidence of serious respiratory morbidity is highly variable but is between 10 and 30% in most large series [250–253]. Factors predictive of pulmonary complications after esophagectomy include age [250, 251], proximal location of esophageal tumor, and duration of surgery [250], as well as forced expiratory volume in 1 s (FEV_1) [251] which predicts pulmonary complications in patients with COPD [254].

ALI and ARDS are among the most severe pulmonary complications associated with esophagectomy and their incidence in a large series was 23.8 and 14.5%, respectively [255]. ARDS was associated with a 50% mortality rate in this series. Risk factors included low body mass index, tobacco history, surgeon experience, duration of surgery and OLV, anastomotic leak, and cardiorespiratory instability. The pathophysiology of ALI and ARDS are complex and thought to result from direct or indirect pulmonary injury. Though injury can occur from a variety of mechanisms, the final pathway appears to involve inflammatory mediators including cytokines and cellular mediators. Still a very active area of investigation, it has become clear that surgical stress itself elicits an already well characterized and profound inflammatory response that includes cytokines such as IL-1, IL-8, TNF-alpha, IL-6, selectins, neutrophil elastase, and thrombomodulin [256–260]. In particular, IL-8 has been implicated in the development of ARDS [261] and is likely to provide a strong signal for the chemotactic migration of neutrophils [262, 263], the alveolar infiltration of which is characteristic of the disease process. The degranulation of neutrophils and an increase in pulmonary capillary permeability has been demonstrated after esophagectomy and has been proposed as a human model of lung injury [260]. Causative involvement of IL-8 is suggested by studies of IL-8 antagonists in animal models [262], the presence of high concentrations in both ventilated and nonventilated lungs [264], and the relationship between IL-8 concentrations in lavage fluid and the subsequent development of pulmonary complications after esophagectomy [265].

Improving Outcomes After Esophagectomy

The use of TEA for postoperative analgesia has been reviewed earlier, but its potential value in improving outcomes after esophagectomy merits additional mention. Improved outcomes associated with the use of TEA after transthoracic esophageal surgery [103–107] may be related to improved postoperative pulmonary function and resultant decrease in pulmonary complications [104] and an improvement in gastric tube blood flow [266, 267]. The use of TEA has been associated with a decreased risk of anastomotic leak in a retrospective study of esophagectomy patients [106]. A causative role is implied by

animal experiments in which the use of TEA improved microcirculation and motility in the gastric tube [267] and a clinical study with similar findings [266]. For these reasons and the overwhelming evidence of superior pain control, TEA represents the standard of care for TTE in most institutions.

Though lung injury in this context is multifactorial, there is a growing awareness that anesthetic and perioperative factors are involved. These include, atelectasis which is obligate in the operative hemithorax during OLV, direct injurious effect of volutrauma or barotrauma in the contralateral lung during OLV, oxygen stress and toxicity resulting from high FIO_2 in the ventilated lung, and ischemia reperfusion injury in the ipsilateral lung after re-ventilation. Strategies to protect the lung and optimize outcomes after major thoracic surgery are most likely to be successful if they minimize these injurious stimuli. Guidance in the absence of definitive outcome data in the perioperative thoracic surgery setting is based largely on results from studies of animal models, surrogate markers of lung injury, and patients with established lung injury. Nonetheless, several reasonable conclusions can be drawn at this time.

First, ventilation strategies, particularly during OLV, should be tailored to patient physiology. That OLV itself may be a factor in the inflammatory response accompanying thoracic esophageal surgery is suggested by studies of cytokine and complement levels during and after OLV [256, 268]. Thus, ventilation should be as physiologic as possible in an effort to minimize the likelihood of volutrauma. So-called protective ventilation strategies represent a physiologic approach to tidal ventilation and are likely to improve outcomes in this patient population by minimizing the risk of alveolar overdistension as well as cyclic collapse of alveoli. Specifically, protective ventilation in the context of thoracic surgery and OLV has referred to lower tidal volumes (4–6 mL/kg ideal body weight) with added positive end expiratory pressure (PEEP). This ventilatory strategy in patients undergoing TTE has been shown to minimize surrogate markers of systemic inflammation (IL-1Beta, IL-6, IL-8) [256, 269] while improving oxygenation intra- and postoperatively, and decreasing the duration of mechanical ventilation [256]. Specific protective pharmacologic agents have not been well studied, though there is preliminary data suggesting that prostaglandin E1 may also lead to a reduction in the inflammatory response [270] and improvements in gastric tube [271] and tracheal [272] blood flow in esophagectomy. Since oxygen toxicity and oxidative stress may also contribute to the development of adverse outcomes, it may be prudent to minimize FIO_2, though the large obligate right to left shunt in the nonventilated lung during OLV limits the extent to which this maneuver is practicable.

It is clear that anesthetics themselves may modify the inflammatory response to surgical stimulation and trauma [273] and produce other specific and in some cases, desirable biologic effects such as myocardial protection. Recent evidence suggests that sevoflurane may also affect lung tissue by modulating the inflammatory response to OLV. De Conno et al. demonstrated an attenuated increase in the bronchoalveolar lavage levels of TNF-alpha, IL-6, IL-8, MCP-1 in patients anesthetized with sevoflurane vs. propofol [274]. This immunomodulation was accompanied by a reduction in adverse clinical events suggesting a protective role of sevoflurane.

Surgery for Esophageal Rupture and Perforation

Patients presenting for emergent repair of esophageal disruption, rupture, or perforation may present with pain, hypovolemia, sepsis, and shock. Anesthetic management should be based on the severity of these presenting conditions and the nature of the planned procedure. To the extent possible, fluid deficits should be corrected preoperatively and may be guided by standard and invasive monitoring as appropriate. Because of the likelihood of further fluid losses and hemodynamic decompensation, an arterial catheter for continuous blood pressure monitoring and arterial blood gas sampling is indicated.

The principles of anesthetic management are based on correcting preoperative fluid deficits, minimizing hemodynamic derangements, avoiding increases in abdominal pressure which may exacerbate leakage of gastroesophageal contents, and minimizing the risk of aspiration, particularly during induction. In general, a rapid sequence induction is indicated with the choice and dose of induction and neuromuscular blocking agents tailored to the patient's hemodynamic status. If a thoracotomy is planned or likely, surgical exposure will benefit from the use of a DLT, but this advantage should be considered in light of airway anatomy, anticipated ease of intubation, and the potentially elevated risk of aspiration should placement of the DLT require additional time.

Intraoperative management is likely to be dominated by the need for continuous fluid resuscitation. Arterial blood gas analysis and pulmonary artery catheter data may be used to guide fluid management and plasma volume expansion as well as the likely need for blood products. This factor combined with the probability of ongoing fluid shifts, pulmonary edema, and the need for inotropic and vasopressor support usually mandates postoperative ventilatory support.

Surgery for Achalasia

Esophagomyotomy is most commonly performed to relieve esophageal obstruction at the sphincter level as well as for the relief of pain from esophageal spasm. Esophagomyotomy can be performed laparoscopically, thoracoscopically, or via thoracotomy, with or without the addition of an antireflux procedure. Either transthoracic procedure requires a suitable plan for lung isolation and postoperative pain control, though a TEA may not be absolutely essential for the thoracoscopic esophagomyotomy. Arguably, the most important anesthetic consideration is the possibility of aspiration on induction of anesthesia with loss of protective airway reflexes. Because achalasia results in a dilated esophagus with impaired motility, the likelihood

of retained food material in the esophagus is dramatically increased. It may also be desirable to restrict oral intake to only clear liquids for 2 days prior to surgery in an effort to reduce food retention. Approaches to minimize the risk of regurgitation and aspiration have been discussed previously and are especially important in these patients.

Additional anesthetic considerations for esophagomyotomy procedures include pain control and lung isolation. The use of thoracoscopy to perform a transthoracic myotomy undoubtedly reduces pain intensity and may not require TEA, though many practitioners still prefer it. After induction and intubation with a DLT or SLT with blocker and placement of a NGT, the patient is turned in the lateral decubitus position, usually right lateral decubitus and the transthoracic myotomy is performed. Most patients can be extubated in the operating room after return of protective airway reflexes. The NGT is usually removed and feedings initiated and advanced after the return of normal peristaltic activity.

Surgery for Esophageal Diverticula

Zenker's Diverticulum

While Zenker's diverticulum is not a disorder of the thoracic esophagus, its repair is often undertaken by thoracic surgeons and so it will be briefly discussed. Anesthetic management of patients with Zenker's diverticulum should be focused on the prevention of aspiration. Patients should be restricted to clear liquids for at least 24 h preoperatively and encouraged to manually express and empty the diverticulum prior to anesthetic induction if this is possible. Other efforts to avoid aspiration of diverticular contents include a head-up position (30°) during induction and a rapid sequence induction without cricoid pressure. In the patient with difficult airway anatomy it may be preferable to intubate the trachea prior to induction of anesthesia. Caution should be exercised during placement of a gastric drain tube or esophageal bougie as these may enter the diverticulum and cause perforation.

Thoracic Diverticula

Patients presenting with thoracic esophageal diverticula may represent a subclass of patients at the highest risk for aspiration in the perioperative period. The reasons for this are twofold. First, these diverticula may be large and potentially contain significant quantities of food material. Secondly, these diverticula cannot be emptied by manual expression, though drainage may be possible with the careful placement of a large bore drain tube. Additionally, most thoracic diverticula are associated with an esophageal motility disorder such as achalasia which is itself, a high-risk condition with regard to aspiration. Thus, all reasonable precautions should be taken, including a head-up position, and either a rapid sequence induction or an awake intubation depending on the anticipated ease of airway management.

Transthoracic repair of esophageal diverticula is usually accomplished via a left thoracotomy incision. Surgical exposure is facilitated by lung isolation and OLV. During dissection, the anesthesiologist may assist by passing a large esophageal bougie with surgical guidance until it passes the diverticular aperture. If not already in situ, a NG tube should be placed prior to emergence and should remain in place until esopohageal integrity has been demonstrated by a contrast esophagram several days postoperatively. Most patients presenting for elective transthoracic resection of esophageal diverticula can be extubated following the procedure provided that a suitable plan for pain control has been initiated.

Clinical Case Discussion (Fig. 30.7)

Case: A 61-year-old male presents with a 14-month history of episodic dysphagia to solids that is progressively worsening. He notes no pain or weight loss. His evaluation included an EGD and biopsy showing high-grade dysplasia with features highly suspicious for invasive esophageal adenocarcinoma. Further evaluation in preparation for surgery included a whole-body PET-CT scan following injection of 14.014 mCi of F-18-FDG intravenously. Figure 30.7 shows the distal esophageal lesion illuminated by the marker. His past medical history is significant for CAD (MI 12 years prior treated with angioplasty). He has not had a recent cardiac catheterization. He also has intermittent supraventricular tachycardia (PSVT) controlled with diltiazem. He denies ever having an electrophysiologic study performed. He also suffers from HTN (enalapril), hypercholesterolemia (simvastatin), and asthma (albuterol as needed and Claritin). His only surgery has been a C4–7 discectomy and fusion and a L4–S1 laminectomy. He is scheduled for an Ivor-Lewis esophagectomy.

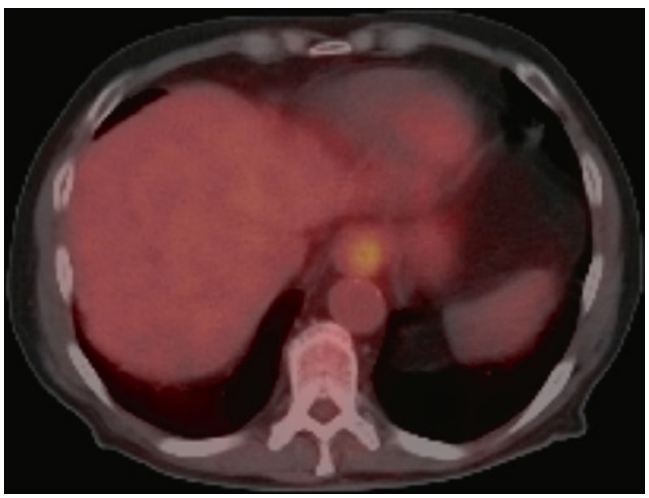

FIG. 30.7. PET scan reveals focal soft tissue thickening with increased uptake of FDG in the distal esophagus at the gastroesophageal junction consistent with esophageal carcinoma.

Questions

- What further preoperative evaluation might be considered reasonable?
- What are the anesthetic considerations for this esophageal surgery?
- What specific intraoperative management strategies might be prudent in this patient?

Focused Preoperative History, Physical, and Investigations

- Patient reports a daily requirement for his MDI and has recovered recently from a viral pharyngitis (physical exam, preoperative MDI use) (see Chap. 8).
- Cardiac evaluation: baseline ECG to evaluate impulse initiation site, AV node conduction, and QTc in the context of PSVT history and diltiazem use. Stress echocardiogram to evaluate audible murmur and ventricular function (see Chap. 2).
- Careful airway evaluation with particular attention to cervical extension after cervical fusion.
- Focused neurologic exam to identify any preoperative deficits given the risk of position-related neurologic injury in left lateral decubitus position (see Chaps. 17 and 18).

What Intraoperative Management Considerations Will Optimize the Patient's Surgery?

- Thoracic epidural to provide postoperative analgesia for a right thoracotomy and upper midline laparotomy (see Chaps. 30 and 46).
- Avoidance of beta-blockade because of a significant history of reactive airway disease and chronic calcium channel blockade use. Intraoperative application of external electrodes for emergency cardioversion, pacing, or defibrillation. Calcium channel blockers indicated for treating hemodynamically stable PSVT (see Chap. 8).
- Fluid management strategy which seeks to optimize overall oxygen delivery, with particular attention to the high-risk esophageal anastomosis. A variety of methods can be used to guide fluid therapy (base deficit, serum lactate, mixed venous O_2 saturation). Optimal fluid management will seek to optimize cardiac output and oxygen delivery while avoiding excessive fluid administration.
- High postoperative risk of atrial arrhythmias, in particular, atrial fibrillation. Treatment usually includes rate control with a beta blocker especially in the patient with CAD but preoperative use of a calcium channel blocker and history of asthma may preclude its use. Amiodarone can be used if atrial fibrillation is sustained and resistant to rate control with calcium channel blockers (see Chap. 41).

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