Chapter 1
Esophageal Anatomy and Physiology for the Surgeon

Marco E. Allaix and Marco G. Patti

Abstract The esophagus can be divided into three anatomic parts, i.e., the cervical, thoracic, and abdominal esophagus. The esophageal wall consists of three layers: the mucosa, the submucosa, and the muscle layer, which is composed of an inner circular and an outer longitudinal layer. The lymphatic drainage is not segmental: lymph can flow for a long distance in the plexus before crossing the muscular layer and reaching the paraesophageal lymph nodes.

Keywords Cervical esophagus • Thoracic esophagus • Abdominal esophagus • Vagus nerves • Upper esophageal sphincter • Lower esophageal sphincter • Esophageal peristalsis

Anatomy of the Esophagus

The esophagus is a tube that originates at the level of the sixth cervical vertebra, posterior to the cricoid cartilage, and extends to the eleventh thoracic vertebra. It can be divided into three anatomic parts. The *cervical esophagus* lies just left of the midline, posterior to the larynx and trachea, and anterior to the prevertebral layer of the cervical fascia. The upper portion of the *thoracic esophagus* curves slightly to the right and passes behind the tracheal bifurcation and the left main stem bronchus. The lower portion of the thoracic esophagus runs behind the pericardium and the left atrium, where it bends to the left and enters the abdomen through the esophageal

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hiatus. The *abdominal esophagus* is 2–4 cm long and ends at its junction with the stomach. The esophageal lumen has three points of anatomical narrowing: (1) at the level of the cricoid cartilage, (2) at the left main bronchus and the aortic arch, and (3) at the diaphragmatic hiatus.

Architecture of the Esophageal Wall

The *mucosal* lining of the esophagus consists of stratified squamous epithelium that overlies a lamina propria and muscularis mucosa, which contains mainly longitudinal muscular fibers (Fig. 1.1). The squamous epithelium of the esophagus joins the junctional columnar epithelium of the gastric cardia at the level of the Z line. The *submucosa*, which contains elastic and fibrous tissue, is the strongest layer of the esophageal wall. The *esophageal muscle* is composed of an inner circular and an outer longitudinal layer. The upper esophageal sphincter is formed by the cricopharyngeal muscle and fibers from the esophageal wall and the inferior constrictors of the pharynx. The *lower esophageal sphincter* is not a well-defined anatomic structure, even though a thickening of the circular esophageal musculature at the level of the manometric high-pressure zone has been reported [1].

Contrary to the rest of the gastrointestinal tract, the esophagus has no serosal layer.

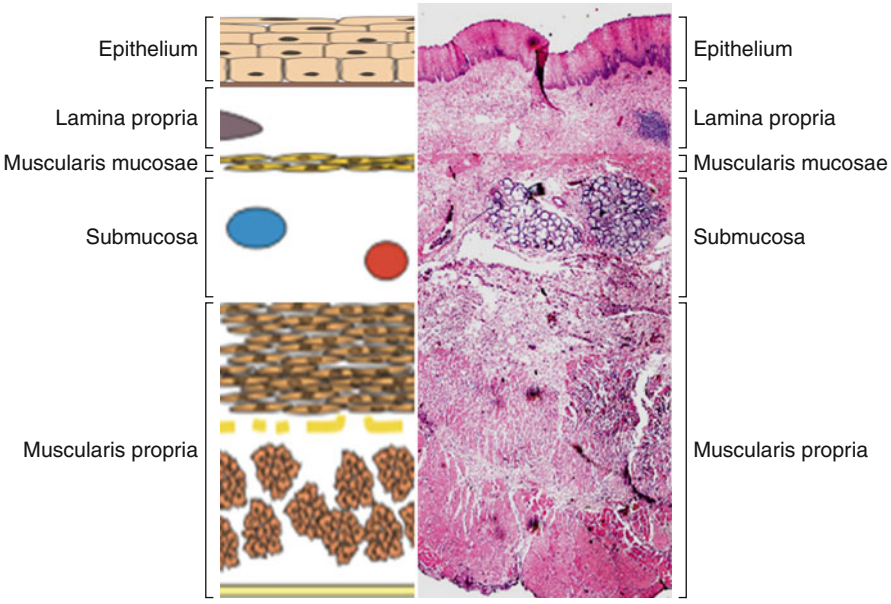

Fig. 1.1 Layers in the esophageal wall

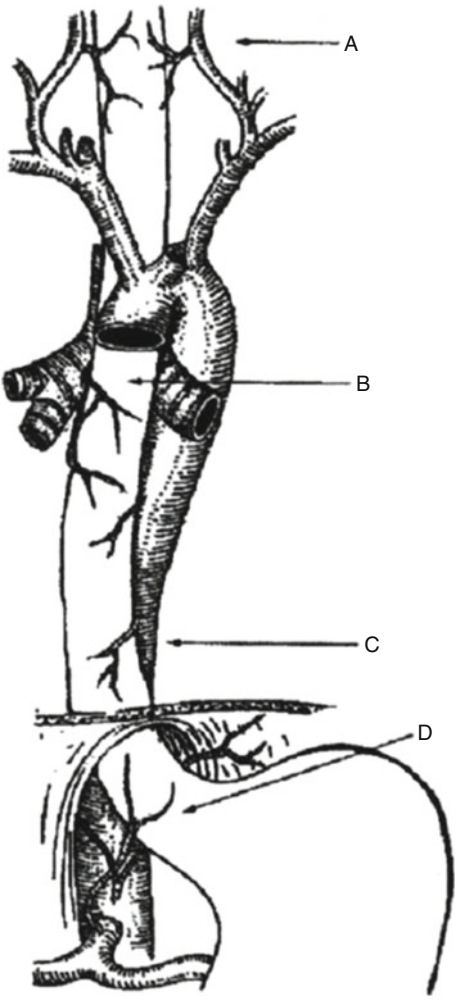

Fig. 1.2 Arterial blood supply to the esophagus. *A* inferior thyroid artery, *B* bronchial artery, *C* aorta, *D* left gastric artery

Blood Supply

The cervical portion of the esophagus is supplied by branches of the inferior thyroid arteries. The upper thoracic portion receives blood from the bronchial arteries, while the midthoracic portion is nourished by esophageal branches that arise directly from the aorta. The intercostal arteries may also contribute. The lower thoracic portion and diaphragmatic and abdominal segments are supplied by the left inferior phrenic artery and by the esophageal branches of the left gastric artery (Fig. 1.2).

The submucosal venous drainage is more complex and variable. The veins that drain the cervical esophagus are tributary of the inferior thyroid veins; the veins from the thoracic esophagus drain into the hemiazygos and azygos veins. The most

important veins are those that drain the lower esophagus. Blood from this region passes into the esophageal branches of the coronary vein, which is a tributary of the portal vein.

Lymphatic Drainage

Abundant lymphatic vessels form a dense submucosal plexus. Lymph usually flows longitudinally, running proximal in the upper two thirds and distal in the lower third of the esophagus. Lymph from the cervical esophagus drains mostly into the cervical and paratracheal lymph nodes, while lymph from the lower thoracic and abdominal esophagus reaches preferentially the retrocardiac and celiac nodes. However, the drainage is not segmental; therefore, lymph can flow for a long distance in the plexus before crossing the muscular layer and reaching the paraesophageal lymph nodes [2].

The thoracic duct originates from the cisterna chyli that is located in the abdomen, at the level of the second lumbar vertebra. The duct enters the chest through the aortic hiatus and runs in the posterior mediastinum to the right of the midline between the esophagus and the azygos vein. At the level of the fifth thoracic vertebra, it crosses the midline behind the esophagus and reaches the base of the neck. Then, it curves to the right to drain into the internal jugular vein. A single thoracic duct is described in about 70 % of people, while two or more are present in the remainder individuals [3] (Fig. 1.3).

Innervation

The striated muscle of the pharynx and upper esophagus is innervated by fibers that originate in the brain stem at the level of the nucleus ambiguus. The distal esophagus and LES receive nerves that originate in the dorsal motor nucleus of the vagus and end in ganglia in the myenteric plexus. The myenteric plexus is located between the longitudinal and the circular muscle layers and receives efferent impulses from the brain stem and afferent impulses from the esophagus. Two main types of effector neurons are found in this plexus: (1) excitatory neurons and (2) inhibitory neurons that mediate contraction of the musculature via cholinergic receptors and via vasoactive intestinal polypeptide and nitric oxide.

The vagus nerves run along each side of the neck until they reach the thoracic esophagus, where they form an extensive plexus. Above the diaphragm, they form two trunks [4]. The left trunk runs anterior while the right trunk is more posterior once they cross the esophageal hiatus. The anterior vagus then divides and gives rise to the hepatic branch and the anterior nerve of Latarjet, while the posterior vagus gives rise to the celiac branch and the posterior nerve of Latarjet. The posterior nerve of Latarjet runs parallel but deeper to the anterior counterpart in the gastrohepatic ligament about 1 cm from the lesser curvature of the stomach.

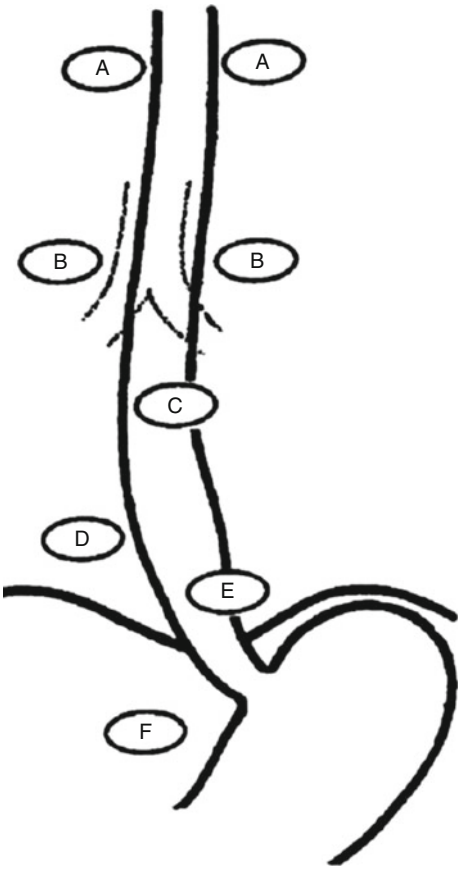

Fig. 1.3 Lymphatic drainage of the esophagus. *A* internal jugular nodes, *B* tracheobronchial nodes, *C* periesophageal nodes, *D* posterior mediastinal nodes, *E* retrocardiac nodes, *F* celiac nodes

Branches of the superior and inferior cervical ganglia in the neck, the splanchnic nerves, and the celiac plexus in the chest and in the abdomen provide the sympathetic innervations. These nerves do not have a motor function and mainly modulate the activity of other neurons.

Right Thoracoscopic View

The thoracoscopic approach to the right chest provides an excellent view of the esophagus from the thoracic inlet to the gastroesophageal junction (Fig. 1.4). The camera is usually inserted in the sixth intercostal space. In order to obtain adequate exposure, the right lung is deflated and retracted anteriorly, while the inferior pulmonary ligament is divided. After incision of the mediastinal pleura, most thoracic esophagus is exposed. The upper thoracic part of the esophagus is crossed anteriorly by the right brachiocephalic vessels. At the level of the right main stem bronchus,

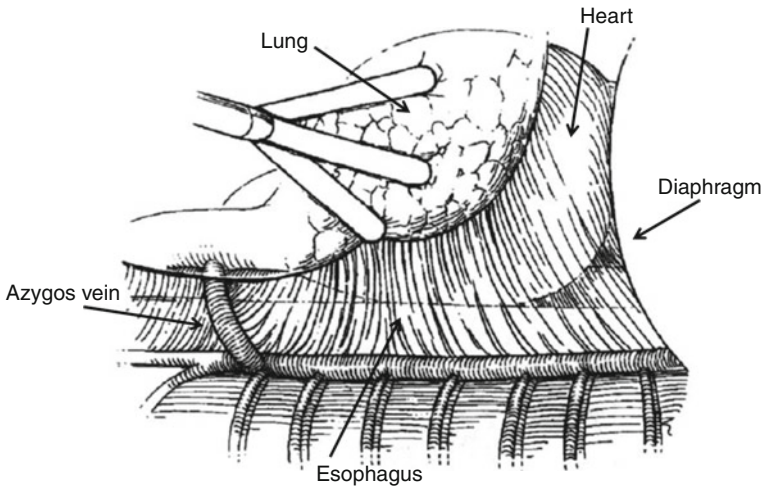

Fig. 1.4 Right thoracoscopic view

the azygos vein passes from a paravertebral position anteriorly to enter the superior vena cava, crossing over the esophagus [5]. Distal to the inferior pulmonary vein, the esophagus lies between the heart and the descending aorta. The sympathetic chain and ganglia run vertically, parallel and lateral to the azygos vein, crossing over the intercostal vessels.

Left Thoracoscopic View

Left thoracoscopy provides a good view of the esophagus from the aortic arch to the gastroesophageal junction (Fig. 1.5) [6]. The camera is usually inserted in the sixth intercostal space. After deflation and anterior retraction of the lung, the inferior pulmonary ligament is divided and the mediastinal pleura opened. The esophagus can be identified in the space between the pericardium and the descending aorta. Behind and lateral to the aorta, the hemiazygos vein runs along the anterolateral aspect of the vertebral bodies, draining the left intercostal veins. It crosses behind the esophagus to join the azygos vein on the right at the level of the eighth thoracic vertebra.

Sympathetic chain's anatomy on the left is similar to that on the right.

Laparoscopic View

The scope is placed in the midline or slightly to the left, about 14 cm below the xiphoid process [7]. The left lobe of the liver must be retracted anteriorly and to the right in order to have the esophageal hiatus and abdominal esophagus

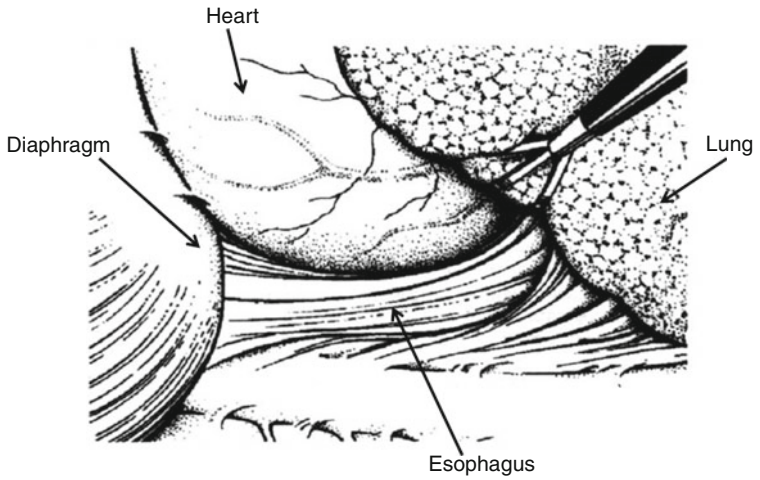

Fig. 1.5 Left thoracoscopic view

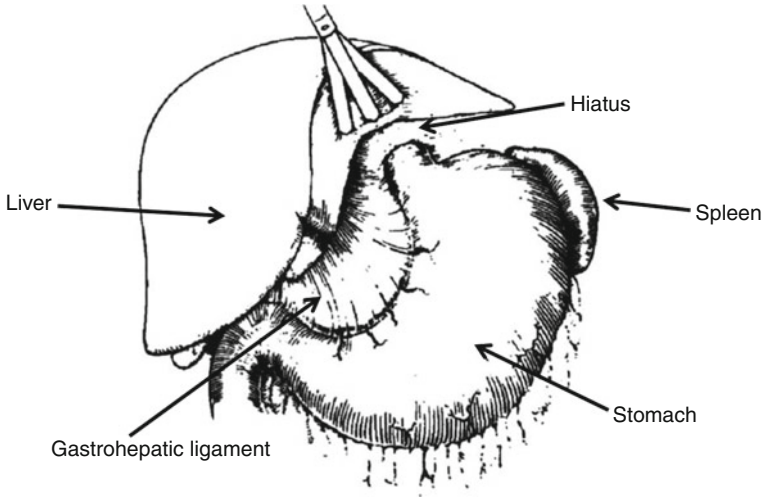

Fig. 1.6 Laparoscopic view

exposed (Fig. 1.6). The phrenoesophageal membrane covers the hiatus and the intra-abdominal esophagus. If the gastrohepatic ligament is stretched flat by pulling the stomach caudad and to the left, the caudate lobe of the liver and a portion of the inferior vena cava can be seen through the transparent upper part. The hepatic branch of the anterior vagus is visible in the gastrohepatic ligament, sometimes close to an accessory left hepatic artery arising from the left gastric artery.

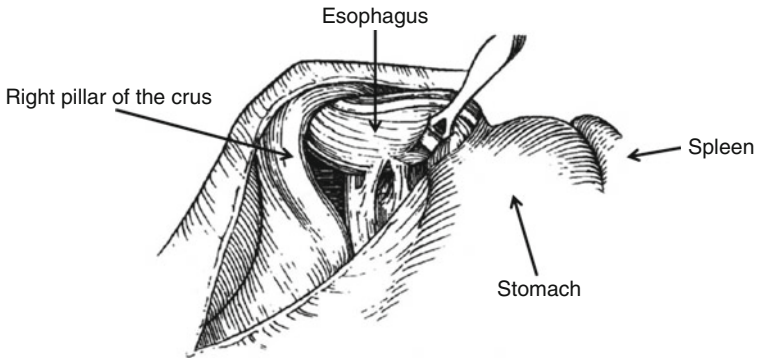

Fig. 1.7 Dissection of the right and left pillars of the crus

After dividing the gastrohepatic ligament and the phrenoesophageal membrane, the right border of the crus and the intra-abdominal esophagus are clearly visible (Fig. 1.7). The anterior vagus nerve can be identified on the anterior aspect of the esophagus. Its bifurcation is usually covered by the gastroesophageal fat pad. The posterior vagus nerve becomes evident after blunt dissection of the space between the esophagus and right pillar of the crus, and anterior lift of the esophagus, since it passes through the hiatus posterior to the esophagus. Variations of the typical anatomy are present in about 10 % of patients, consisting of extension of the esophageal plexus into the abdomen or early bifurcation of the two trunks above the diaphragm [8].

Physiology

The coordinated activity of the upper esophageal sphincter (UES), the esophageal body, and the lower esophageal sphincter (LES) is responsible for the motor function of the esophagus and the progression of the bolus from the pharynx to the stomach.

Upper Esophageal Sphincter

The UES receives motor innervation directly from the nucleus ambiguus. The sphincter is in a state of continuous tonic contraction. The UES prevents passage of air from the pharynx into the esophagus and reflux of esophageal contents into the pharynx. During a swallow, the tongue moves a bolus into the pharynx, which contracts while the UES relaxes. After the bolus has reached the esophagus, the UES regains its resting tone.

Esophageal Body

When a bolus passes through the UES, a contraction originates at the level of the upper esophagus and progresses distally toward the stomach. This wave that is initiated by swallowing and is called *primary peristalsis* travels at a speed of 3–4 cm/s with amplitudes of 60–140 mmHg in the distal esophagus. Local stimulation of sensory receptors in the esophageal body by distention elicits a peristaltic wave at the point of stimulation that moves distally. It is called *secondary peristalsis* and aims to improve esophageal emptying when the lumen is not completely cleared of ingested food by the primary waves or when gastric contents reflux into the esophagus. *Tertiary waves* are non-propulsive contractions. They are considered abnormal and are frequently diagnosed in asymptomatic elderly people or in patients with esophageal motility disorders.

Lower Esophageal Sphincter

The main function of the lower esophageal sphincter (LES) is to prevent reflux of gastric contents into the esophagus. The LES is 3–4 cm long, its pressure profile is slightly asymmetric, and the resting pressure ranges between 15 and 35 mmHg [9–11]. When a swallow occurs, the LES relaxes for 5–10 s to allow the bolus to enter the stomach; then it returns to its resting tone.

LES relaxation is mediated by non-adrenergic, non-cholinergic neurotransmitters, such as vasoactive intestinal peptide and nitric oxide [12]. The resting tone mainly depends on the intrinsic myogenic activity. During fasting, the LES presents cyclic phasic contractile activity synchronous with phases II and III of the interdigestive motor complex [13].

The LES relaxes periodically independently from swallowing. These periodic relaxations are called *transient lower esophageal sphincter relaxations* to distinguish them from relaxations secondary to swallows. The cause of these transient relaxations is not known, but gastric distention is thought to play a role [14]. Transient LES relaxations are responsible for the physiologic gastroesophageal reflux present in any individual. When they are more frequent and prolonged, they are the most common cause of abnormal reflux in patients with gastroesophageal reflux disease (GERD) and normotensive LES. Decreased LES length and/or pressure is responsible for pathologic reflux in the remaining patients with GERD.

The crus of the diaphragm at the level of the esophageal hiatus contributes to the LES resting pressure. This pinchcock action of the diaphragm protects against reflux caused by sudden increased intra-abdominal pressure. This synergistic action of the diaphragm is lost in presence of a sliding hiatal hernia, as the gastroesophageal junction is located above the diaphragm [15].

Conflict of Interest The authors have no conflicts of interest to declare.

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