# Esophageal Anatomy

Mariano A. Menezes, Francisco Schlottmann and Fernando A. M. Herbella

**Abstract**

The esophagus has a peculiar anatomy: (a) it is surrounded by important organs and structures, (b) it crosses three cavities: neck, thorax and abdomen, (c) its lymphatic distribution is abundant and erratic, (d) the organs and structures of the mediastinum frequently present anatomic variations, and (e) the classic anatomic description is different from clinical presentation. In addition, minimally invasive surgery also brought a restricted but magnified view of the esophagus, and available imaging technology forces the understanding of sectional and regional anatomy. For all these reasons, the knowledge of the surgical anatomy of the esophagus is essential for surgeons before performing an esophagectomy. This chapter reviews the surgical anatomy of the esophagus and neighbor structures of interest to perform an esophagectomy.

**Keywords**

Esophagus · Anatomy · Esophagectomy · Lymph nodes · Radiology

## Introduction

The esophagus has a peculiar anatomy. It is the only digestive organ that does not digest or absorb nutrients and lacks a serosa layer. From a surgical anatomy point of view, the esophagus has an exuberant lymphatic drainage able to spread metastasis quickly and far but is short of vascularization without a single artery bearing its name. The esophagus crosses three cavities (neck, thorax and abdomen) and it is surrounded by vital organs in a small container called mediastinum [1]. All these characteristics make the resection of the esophagus and the subsequent alimentary tract reconstruction a challenging procedure.

Anatomists frequently portrait the esophagus in didactic books in a stylized fashion commonly not useful for surgeons. In addition, minimally invasive surgery also brought a restricted but magnified view of the esophagus, and available imaging technology forces

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the understanding of sectional and regional anatomy. Thus, a strong knowledge of the anatomy of the esophagus is essential to all esophageal surgeons interested in performing an esophagectomy.

## Esophageal Anatomy

The esophagus is a hollow organ with a four-layer structure: mucosa, submucosa, muscularis propria, and adventitia [2]. The mucosa is made of squamous epithelium overlying a lamina propria and a muscularis mucosa. The submucosa is made of elastic and fibrous tissue and is the strongest layer of the esophageal wall. The esophageal muscle is composed of an inner circular and outer longitudinal layer. The upper third of the esophageal musculature consists of skeletal muscle and the lower two thirds consist of smooth muscle. The adventitia consists in connective tissue that merges with connective tissue of surrounding structures. Unlike the remainder of the gastrointestinal tract, the esophagus does not have a serosal layer.

The upper esophageal sphincter is formed by the cricopharyngeus muscle along with the inferior constrictors of the pharynx and fibers of the esophageal wall. The lower esophageal sphincter is not a distinct anatomic structure.

Microscopic anatomy of the esophageal wall is further divided for diagnostic and therapeutic purposes to allow a more refined staging and guide endoscopic resection in early esophageal cancer [3, 4]. Thus, mucosa layer is subdivided in: (a) M1—epithelium (defining a carcinoma in situ); (b) M2—lamina propria mucosae; and (c) M3—muscularis mucosae. Submucosal layer is also subdivided in three layers: (a) SM1—upper third of the submucosa; (b) SM2—middle third of the submucosa; and (c) SM3—lower third of the submucosa. Endoscopic resection is suitable for early cancers invading up to the SM1 [5].

Macroscopically, the esophagus is divided in three portions: cervical, thoracic/mediastinal, and abdominal, according to the boundaries of the cavities that it crosses (i.e. the thoracic outlet at the level of the manubrium and the diaphragm). The cervical esophagus lies left of the midline and posterior to the larynx and trachea. The thoracic portion may also be subdivided in: (a) Upper thoracic esophagus—from the sternal notch to the tracheal bifurcation; (b) Middle thoracic esophagus—the proximal half of the two equal portions between the tracheal bifurcation and the esophagogastric junction; and (c) Lower thoracic esophagus—the thoracic part of the distal half of the two equal portions between the tracheal bifurcation and the esophagogastric junction (Fig. 1). The upper thoracic esophagus passes behind the trachea and tracheal bifurcation, while the middle and lower thoracic esophagus passes behind the left atrium and then enters the abdomen through the esophageal hiatus of the diaphragm. The abdominal portion may be absent in the case of a hiatal hernia.

## Vascularization and Lymphatic Drainage

Esophageal vascularization is shared by small branches from adjacent organs. Arterial blood supply comes from branches of the inferior thyroid arteries, unnamed vessels originating directly from the thoracic aorta, bronchial arteries, inferior phrenic arteries, and left gastric artery. Blood is drained into the inferior thyroid, hemiazygos, azygos and left gastric vein [6].

Anatomy textbooks rarely describe a specific lymphatic drainage of the esophagus. Abundant lymphatics form a dense submucosal plexus. Thoracic lymph nodes are shown in a regular disposition seldom seen in an operation. Gray's anatomy textbook simply describes esophageal lymphatic drainage as "a plexus around that tube, and the collecting vessels from the plexus drain into the posterior mediastinal glands" [7]. Lymph from the cervical and upper-mid thoracic esophagus drains mostly into the cervical, paratracheal and subcarinal lymph nodes, whereas the lower thoracic and abdominal esophagus drains preferentially into the diaphragmatic, paracardial, left gastric, and celiac nodes [8].

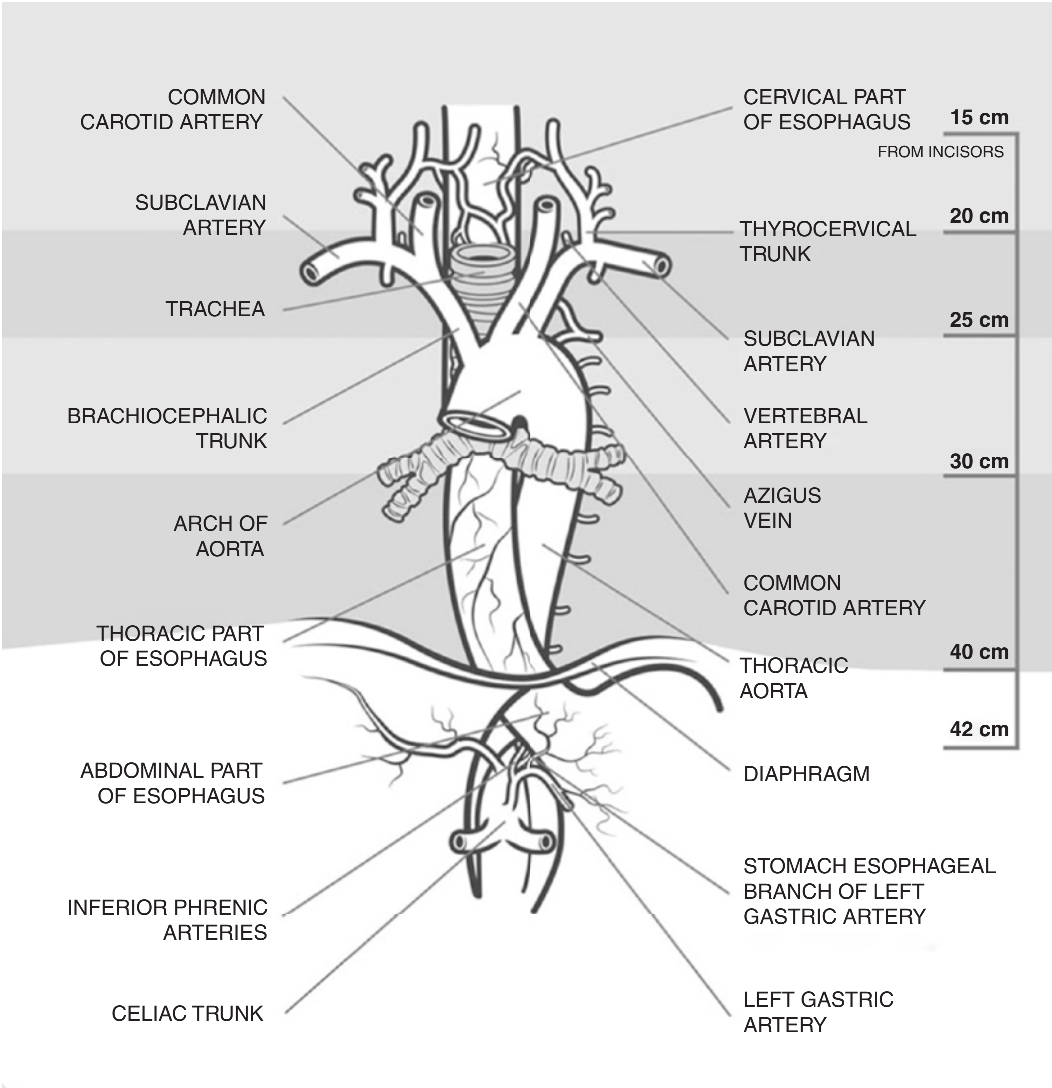


**Fig. 1** Esophageal anatomy: the three portions of the esophagus and surrounding structures in the posterior mediastinum

## Esophageal Surgical Anatomy

### Cervical Esophagus

The access to the cervical esophagus may be obtained through an oblique incision parallel to the medial border of the left sternocleidomastoid muscle or a necklace incision. The former is simpler and the latter allows bilateral access if a complete lymphadenectomy is anticipated. The oblique incision allows access to the esophagus after dividing the platysma muscle (in the subcutaneous) and the deep cervical fascia which will expose the infrahyoide muscles (sternothyroid muscle mainly) that are retracted or divided. These muscles are responsible for larynx depression and its division may impair swallowing and fonation thus preservation is preferred [9]. The esophagus will then be found between the trachea and the carotid sheath [10]. The anterior jugular vein and inferior thyroid vein may occasionally be ligated without consequences. The left recurrent laryngeal nerve lies in the groove between the trachea and esophagus where it is prone to be damaged [11].

A complete cervical lymphadenectomy is best accomplished through a collar incision. This bilateral access allows the resection of the internal jugular nodes below the level of the cricoid cartilage, supraclavicular nodes, and cervical paraesophageal nodes [12] (Fig. 2). Muscles are usually spared.

## Thoracic Esophagus

The access to the thoracic esophagus may be accomplished through a thoracotomy or thoracoscopy. A right approach allows access to the whole esophagus while a left approach is reserved when the interest is in the distal esophagus only. A thoracotomy is usually performed in the lateral position with the surgeon standing in the right side of the patient that allows a panoramic view of the posterior mediastinum after the lung is retracted (Fig. 3). A minimally invasive approach brings a restricted view but

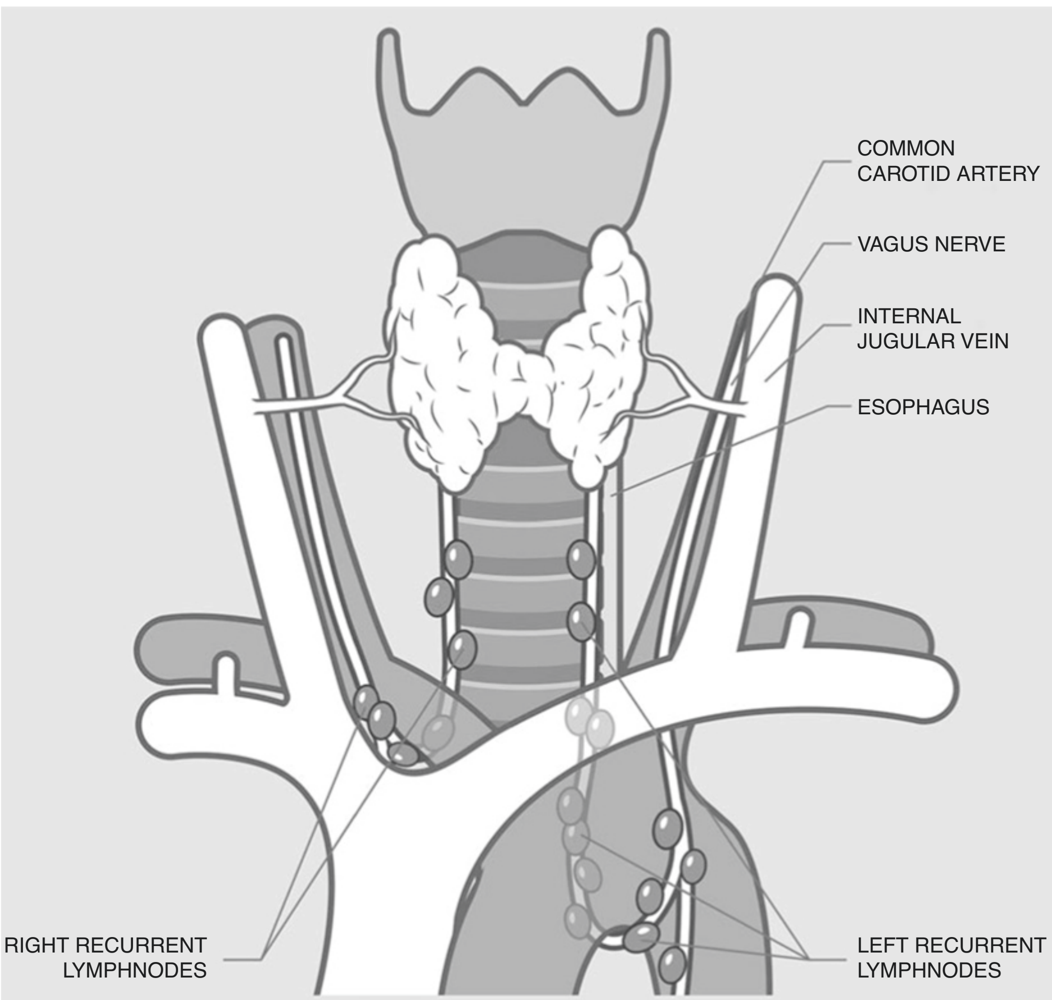


**Fig. 2** Cervical lymph nodes of interest for esophagectomy and lymphadenectomy

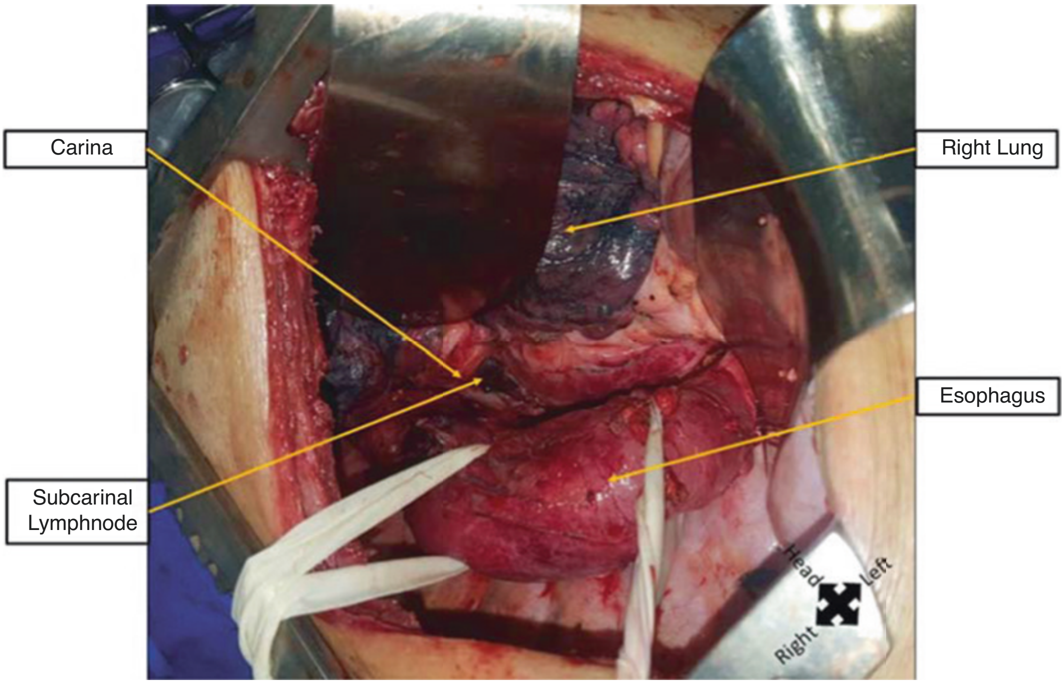


**Fig. 3** Right thoracotomy. The access through the intercostal space limits the view and access to the esophagus in the posterior mediastinum. An adequate retraction of the lungs medially is mandatory

with a magnified image (Fig. 4). Some surgeons advocate the operation to be performed in prone position with putative advantages of lower pulmonary complications and increased number of resected lymph nodes [13] (Fig. 5).

The important structures that are intimately related to the thoracic esophagus are the trachea and pericardium ventrally; the azygos vein and right pleura on the right laterally, the spine and thoracic duct dorsally, and the aorta and left pleura left laterally [14].

The anatomy of the vagus had some relevance at the time when vagal-sparing esophagectomy was attempted in order to prevent morbidity related to vagotomy [15]. Currently, this procedure is seldom performed but a selective preservation of pulmonary vagal branches is proposed [16].

Pleural preservation is desired during a transhiatal esophagectomy to minimize the consequences of thoracic drainage. Pleural lesion may occur during dissection of the mid-thoracic esophagus if a recess of the pleura intervenes between the esophagus and the azygos vein on the right side below the pulmonary veins. However, the pleura is more commonly injured during the dissection of the distal left esophagus where they are in close contact [11].

The azygos system anatomy is of interest during an esophagectomy since the arch of the azygos vein is divided to allow a better exposure of the upper thoracic esophagus, and these veins are resected during an en-bloc esophagectomy [17]. Some authors, on the other side, believe the resection of the azygos system is not considered essential since it does not affect the number of retrieved lymph nodes [18]. Variations of the azygos system are uncountable and related to the origin of the veins or the communication between the left and right-side systems. However, the clinical importance of these variations is negligible since they can be promptly recognized during an esophagectomy and comprise small caliber vessels that can be easily ligated without any consequences [11].

The recurrent laryngeal nerve has a thoracic course and can be injured during the dissection

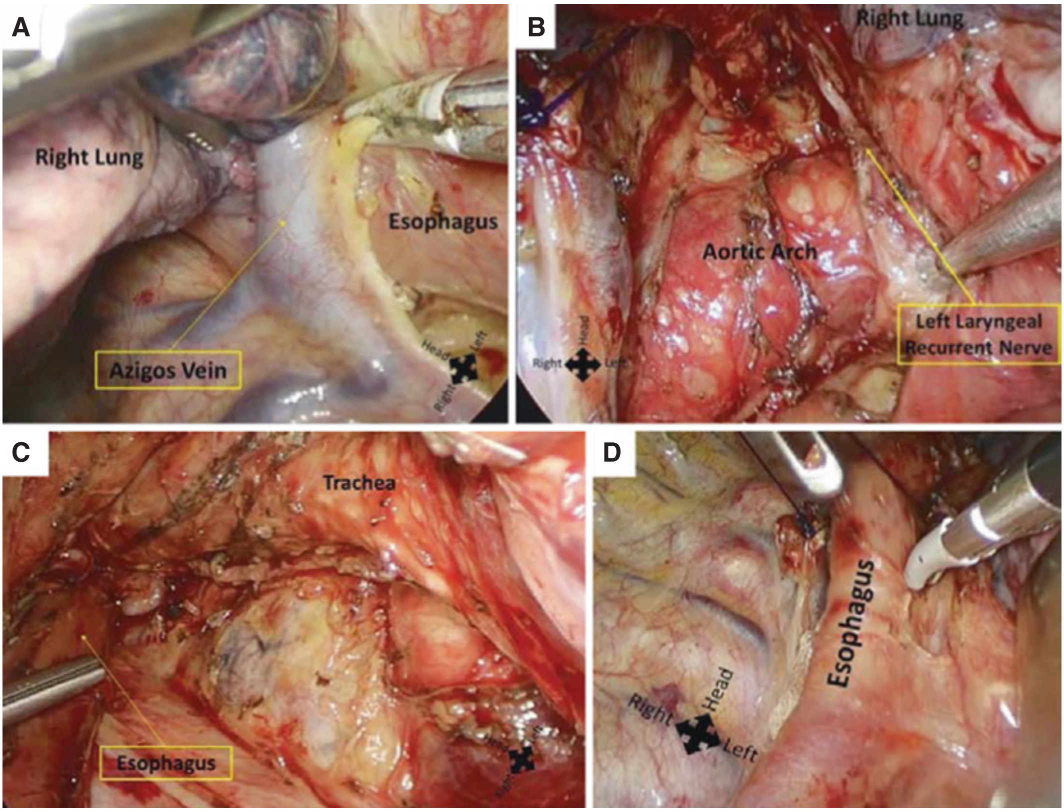


**Fig. 4** Right thoracoscopy in lateral position. Minimally invasive surgery allows a magnified but restricted operative view but camera freedom of movement allows visualization of the complete thoracic cavity: upper part where the azigos vein crosses the esophagus (A) area of the aortic arch where left laryngeal nerve lymph nodes are located (B), trachea (C), the whole extension of the esophagus (D)

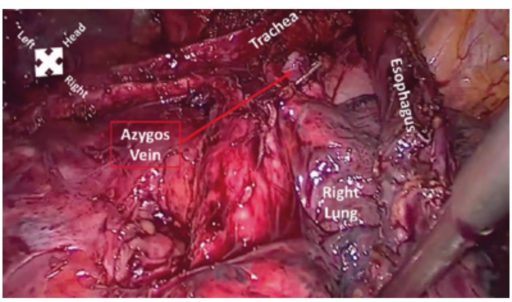


**Fig. 5** Right thoracoscopy in prone position. Minimally invasive surgery allows a magnified but restricted operative view. The prone position has the advantage of removing the lungs from the operative view and allows good access to the respiratory tract to perform lymphadenectomy of peritracheal lymph nodes. The laryngeal recurrent nerves are; however, in an obstructed view

of the lymph nodes present along its course (node stations 2 and 4) [19]. The right recurrent nerve originates at the origin of the right subclavian artery behind the sternoclavicular joint, loops around the artery and ascends to the neck. The left recurrent nerve originates at the inferior border of the aortic arch, them it loops around the aorta and ascends to the neck [20]. Anatomic variations are uncommon. Non-recurrence may occur in 10% of the cases but since the nerve does not have a thoracic course in these cases, it is automatically protected from injury [11].

The thoracic duct origins in the cisterna chyli in the abdomen, ascends to the posterior mediastinum, to the right of the midline, between the descending thoracic aorta on the left and the azygos vein on the right. The duct inclines to the left, enters the superior mediastinum, and ascends toward the thoracic inlet along the left edge of the esophagus. The thoracic duct usually ends at the junction of the left subclavian and internal jugular veins [21]. There are commonly major anatomical variations that may lead to intraoperative injury during an esophagectomy [11]. The intraoperative identification of the injury and the duct itself may be difficult. Therefore, mass ligation of the duct including all tissue between the aorta, spine, esophagus, and pericardium is recommended in cases of suspect lesion of the duct [22]. Mass ligation is preferred over identification and individual ligation since duplication or plexiform ducts are common [11].

A proper lymphadenectomy is an essential part of an oncologic esophagectomy [23]. Thus, the knowledge of the anatomy of the lymph nodes that drain the esophagus is mandatory. Unfortunately, anatomy textbooks frequently show a regular disposition of nodes not useful for surgeons (Fig. 6). In addition, there is no standard classification and nomenclature of

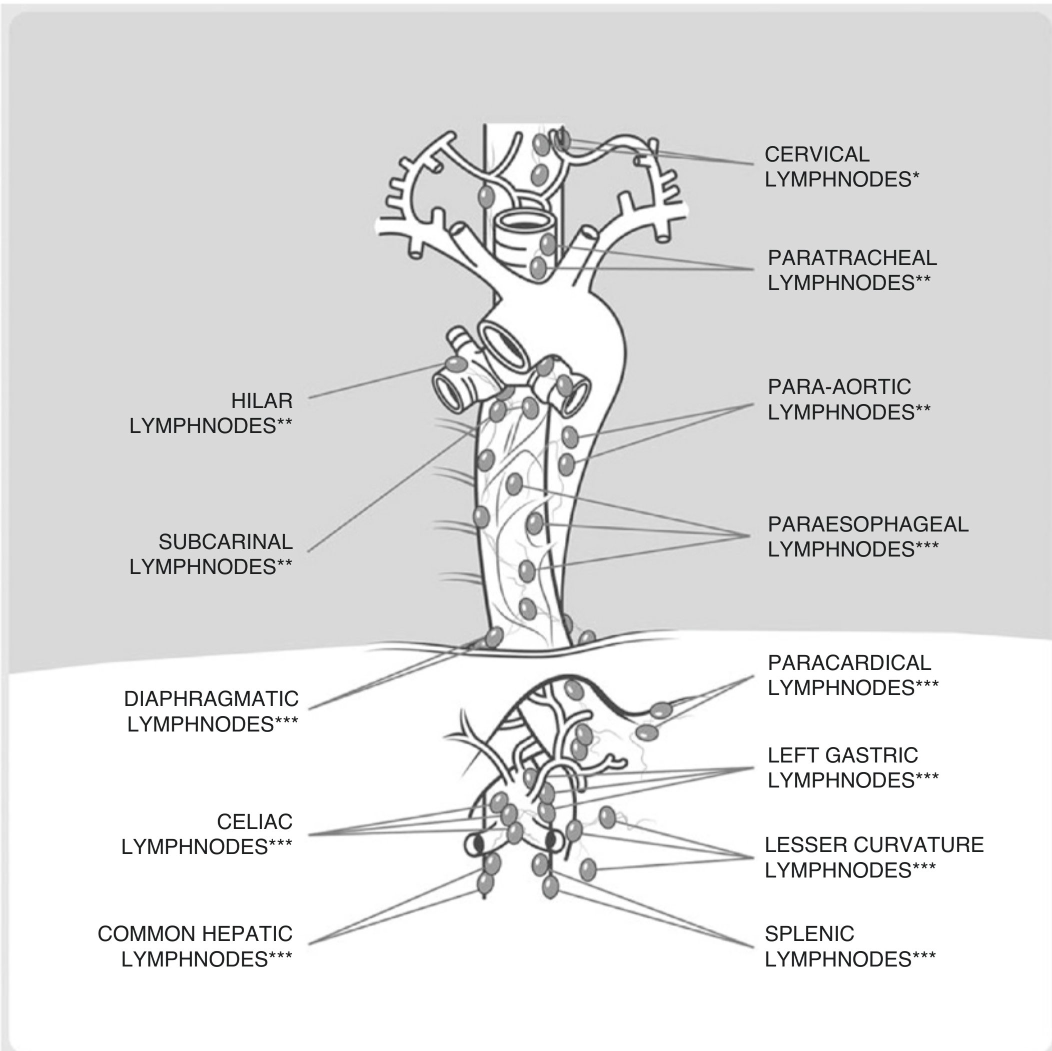


**Fig. 6** Lymph nodes of interest to esophagectomy and lymphadenectomy. The exuberant lymphatic drainage of the esophagus may lead to metastasis in cervical (*), thoracic (**) and abdominal (***) periesophageal lymph nodes

mediastinal lymph nodes, and the number and location of lymph nodes is commonly erratic (Table 1) [24].

**Table 1** Mediastinal Lymph Nodes Classification according to a Japanese society of esophageal disease and American joint committee for cancer and their correlations

| Japanese society for esophageal disease | American joint committee for cancer |
|---|---|
| 102—Deep cervical | 1—Highest mediastinal |
| 105—Upper thoracic esophaggeal | 2—Upper paratracheal |
| 106—Thoracic paratracheal | 2—Upper paratracheal<br>4—Lower paratracheal |
| 107—Bifurcation | 7—Subcarinal |
| 108—Middle thoracic paraesophageal | 8M/8Lo—Paraesophageal |
| 109—Pulmonary hilar | 8M—Paraesophageal |
| 110—Lower thoracic paraesophageal | 8Lo—Paraesophageal |
| 111—Diaphragmatic | 15—Diaphragmatic |
| 112—Posterior mediastinal | 9—Pulmonary ligament |

## Abdominal Esophagus

The esophagus has a constant and short course in the abdomen that is familiar to surgeons used to laparoscopic surgery of benign esophageal disorders at the esophagogastric junction [25].

A 2 or 3-field lymphadenectomy will include the lymph nodes of the upper abdomen in a similar fashion to the D2 lymphadenectomy of the gastric cancer [26, 27] (Fig. 6).

## Anatomy for Esophageal Replacement

Alimentary tract reconstruction after an esophagectomy is regularly accomplished with a gastric tube as a graft. However, the colon may be used in particular situations [28, 29]. The vascular anatomy of these organs is therefore important to establish an adequate blood supply to the replacing organ.

For a gastric tube, the left gastric artery and coronary vein are divided, as well as the short gastric vessels. The blood supply will be provided by the right gastric artery and the right gastroepiploic artery [30] (Fig. 7).

For a colonic interposition, diverse segments of the colon can be used (Table 2). The most common reconstruction options are the left

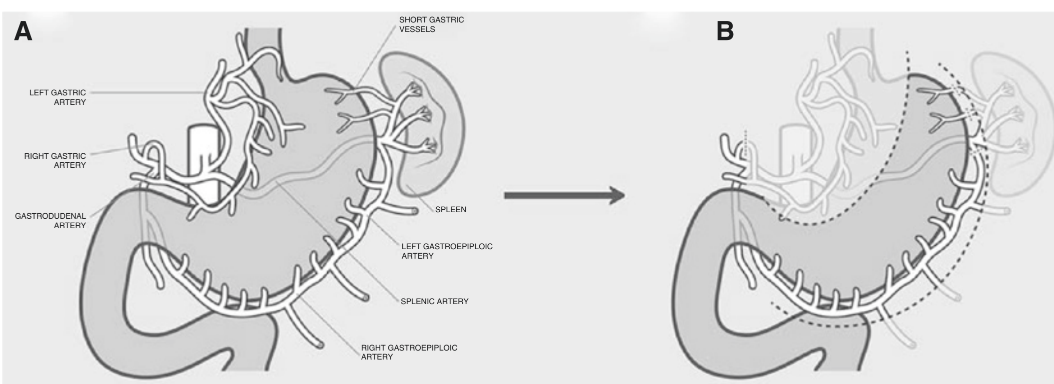


**Fig. 7** Vascular anatomy of the stomach of interest to esophageal replacement (A). The greater curvature gastric tube is supplied by the right vessels (B)

**Table 2** Relationship between blood supply, the segment of the colon used for esophageal replacement and type of peristalsis

| Arterial supply | Colon conduit | Peristalsis |
|---|---|---|
| Ileocolic artery | Ascending + transverse | Antiperistalsis |
| Right colic artery | Cecum + ascending | Isoperistalsis |
| | Ascending + transverse | Antiperistalsis |
| Middle colic artery | Cecum + ascending + transverse | Isoperistalsis |
| | Ascending + transverse | Antiperistalsis |
| Left colic artery | Transverse + descending | Isoperistalsis |

colon, with the ascending branch of the left colic vessels, and the right colon with the middle colic vessels or even with the left colic vessels [29–33] (Fig. 8). Since a segment of transverse colon is need irrespective if right or left colon is used, vascularization of the graft is dependent on anastomosis between the different colic pedicles. In a series of mesenteric arteriograms, the marginal artery in the right colon was present in only 30% of the cases, while in the left colon it was present in all cases [34]. Thus, the blood supply of the right colon is less reliable than that of the stomach and left colon [35]. Some surgeons prefer to have a preoperative angiography in order to identify the anatomy of the arteries and the continuity of the marginal artery [36] while others do not consider it necessary [37].

The replacing organ may reach the neck through different routes: posterior mediastinum, anterior mediastinum, transpleural (rare) and subcutaneous (rare). There are controversial results on the length of the anterior (retrosternal) as compared to the posterior route [39, 40]. The anterior path, however, is more constricted at the level of thoracic inlet [41].

## Esophageal Radiologic Anatomy

The development of clinical imaging has allowed surgeons to better stage patients with esophageal cancer and plan the surgical approach. The old barium esophagram has been replaced by newer studies.

## Endoscopic Ultrasound

Endoscopic ultrasound allows visualization of the esophageal wall and adjacent structures. The sonographic image distinguishes 5 distinct layers (Fig. 9): the innermost layer with increased echogenicity and a thin hypoechoic layer immediately deep to it correspond mainly to the mucosa and partly to the muscularis mucosae, and the next echogenic layer corresponds to the submucosa. The fourth hypoechoic layer is the muscularis propria layer and the outermost echogenic layer is the adventitia with fat appendage [42]. Lymph nodes can also be identified by endoscopic ultrasound [43].

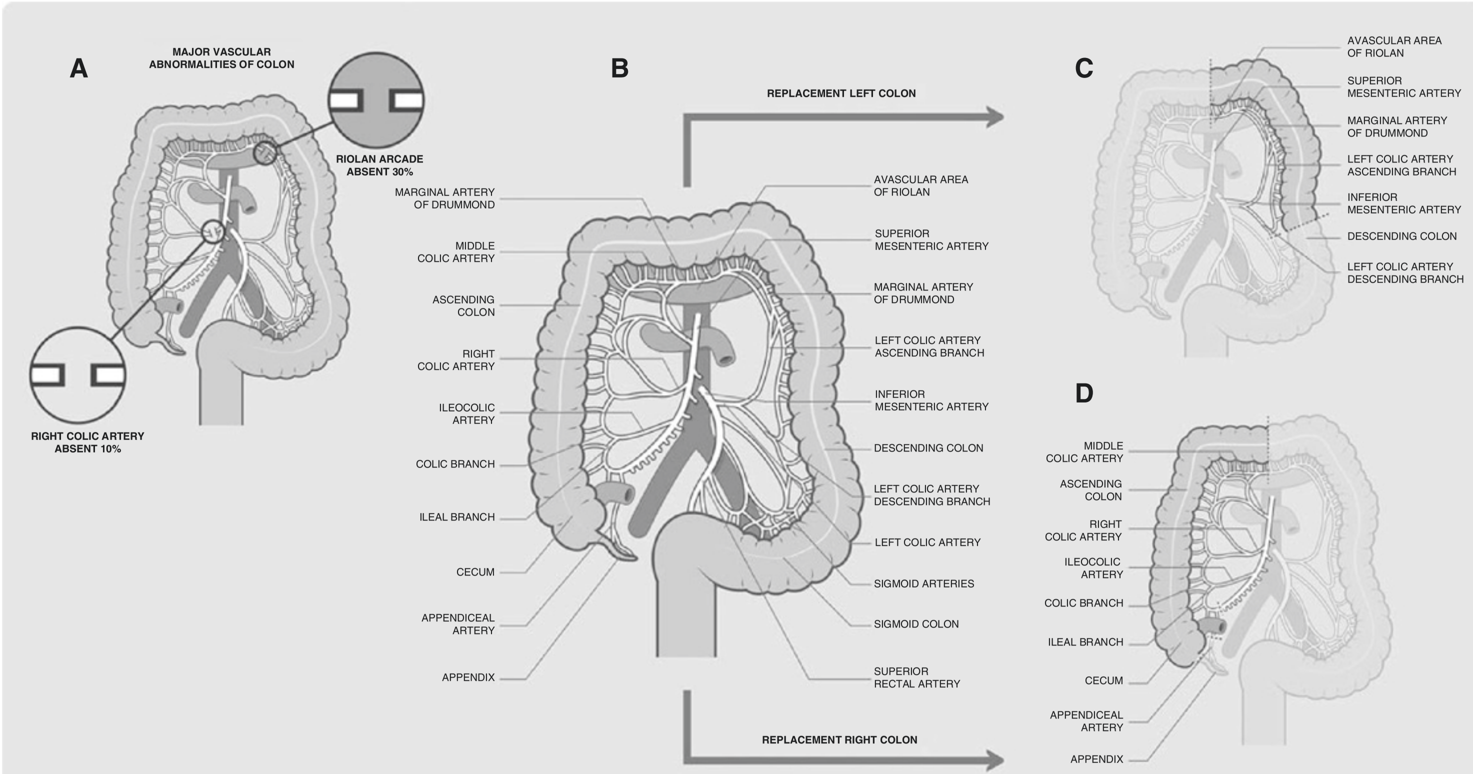


**Fig. 8** Vascular anatomy of the colons of interest to esophageal replacement. A patent arcade communicating the superior and inferior mesenteric vessels is mandatory to supply the graft. This communication is absent in some cases but it can be tested during the operation (A). The vessels that supply the left or right colon used as a graft are represented in B, C, and D

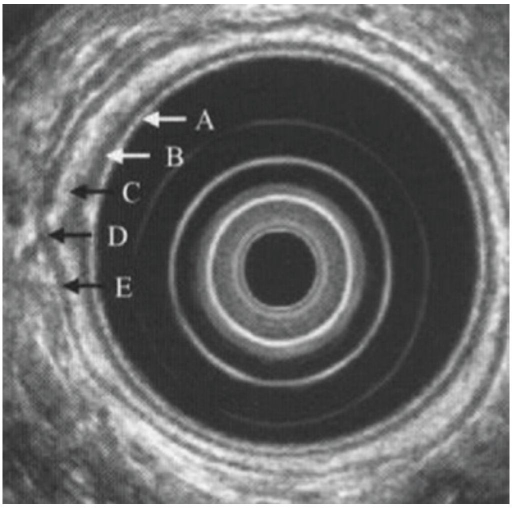


**Fig. 9** Endoscopic ultrasound of the esophagus with five distinct layers: A) mucosa, B) muscularis mucosae, C) submucosa, D) muscularis propria, and E) adventitia

## Computed Tomography

Computed tomography of the neck, chest and abdomen allows high quality imaging of the esophagus and 3D reconstruction [44] (Fig. 10). The detection of lymph nodes by computed tomography correlates well to anatomic findings [24–45].

## Magnetic Resonance

Dedicated techniques of magnetic resonance protocols increased esophageal anatomy visualization as compared to computed tomography. Magnetic resonance is able to detect individual layers of the esophageal wall, the thoracic duct, a connective tissue layer attaching the esophagus to the anterior wall of the aorta, and a fascial plane passing between layers of the right and left parietal pleura posterior to the esophagus [46]. Some surgeons believe the study of these planes and layers allow a more detailed dissection of the esophagus in order to preserve nerves and retrieve lymph nodes more efficiently [14].

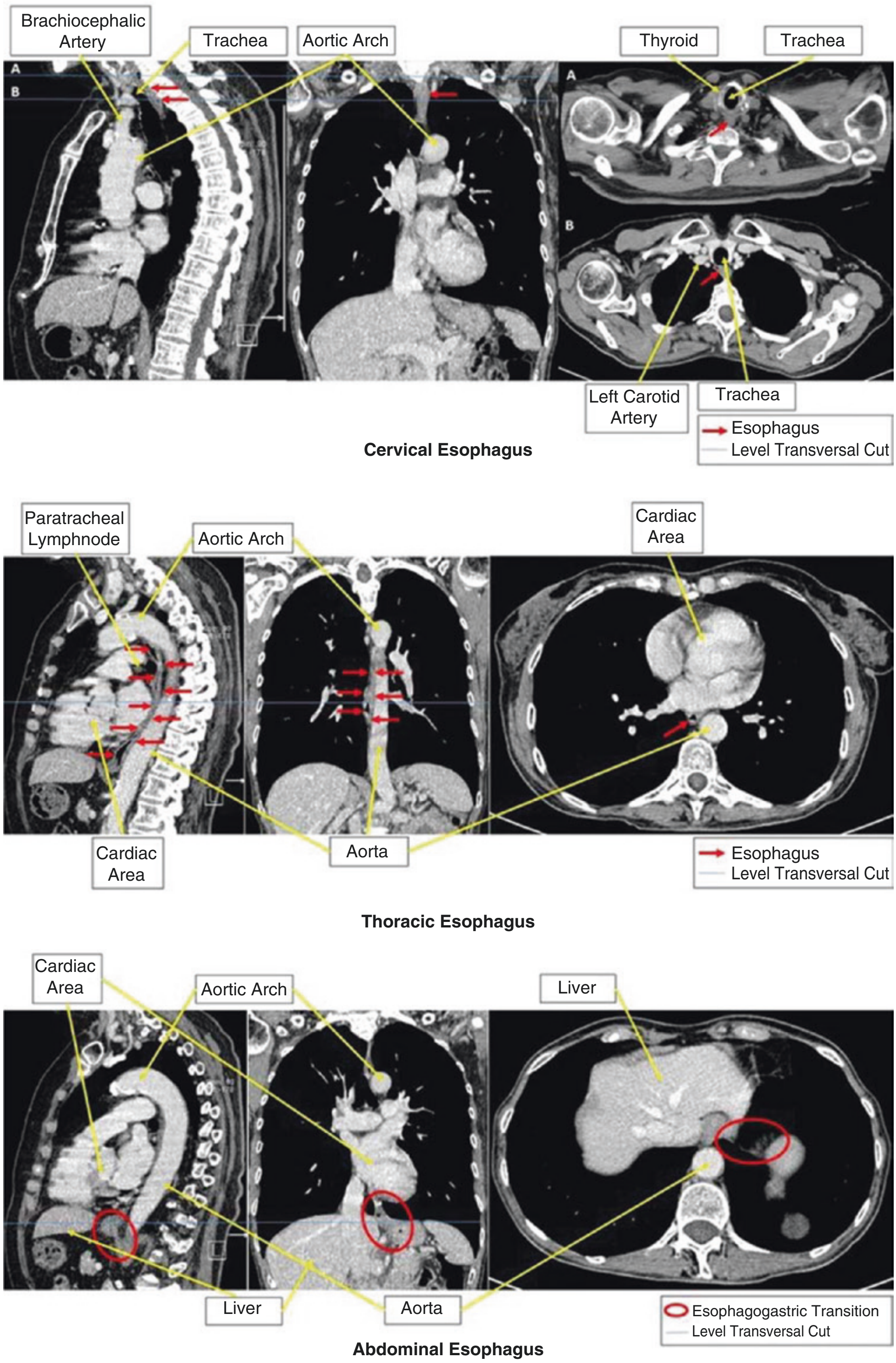


**Fig. 10** Computerized tomography scans of the esophagus and surrounding structures. Tomography has a limited differentiation of tissues in the mediastinum as compared to magnetic resonance but the visualization of the esophagus and lymph nodes are adequate for clinical decisions

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