Chapter 1

Anatomy of Esophagus

Murat Ferhat Ferhatoglu and Taner Kıvılcım

Additional information is available at the end of the chapter

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Abstract

Anatomy knowledge is the basic stone of healing diseases. Arteries, veins, wall structure, nerves, narrowing, curves, relations with other organs are very important to understand esophagial diseases. In this chapter we aimed to explain anatomical fundementals of oesophagus.

Keywords: anatomy, esophagus, parts of esophagus, blood supply of esophagus, innervation of esophagus

1. Introduction

Esophagus is a muscular tube-like organ that originates from endodermal primitive gut, 25–28 cm long, approximately 2 cm in diameter, located between lower border of laryngeal part of pharynx (**Figure 1**) and cardia of stomach. Start and end points of esophagus correspond to 6th cervical vertebra and 11th thoracic vertebra topographically, and the gastroesophageal junction corresponds to xiphoid process of sternum. Five cm of esophagus is in the neck, and it descends over superior mediastinum and posterior mediastinum approximately 17–18 cm, continues for 1–1.5 cm in diaphragm, ending with 2–3 cm of esophagus in abdomen (**Figure 2**) [1, 2]. Sex, age, physical condition, and gender affect the length of esophagus. A newborn's esophagus is 18 cm long, and it begins and ends one or two vertebra higher than in adult. Esophagus lengthens to 22 cm long by age 3 years and to 27 cm by age 10 years [3, 4].

2. Structure of esophagus

Esophagus consists of four histologic layers: mucosa, submucosa, muscularis propia, and adventitia.

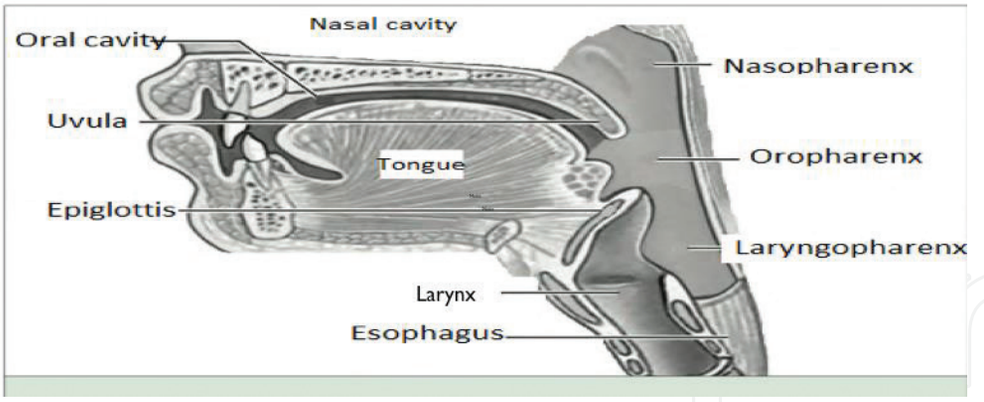

Figure 1. Anatomy of larynx (with permission of Turkish Surgery Association).

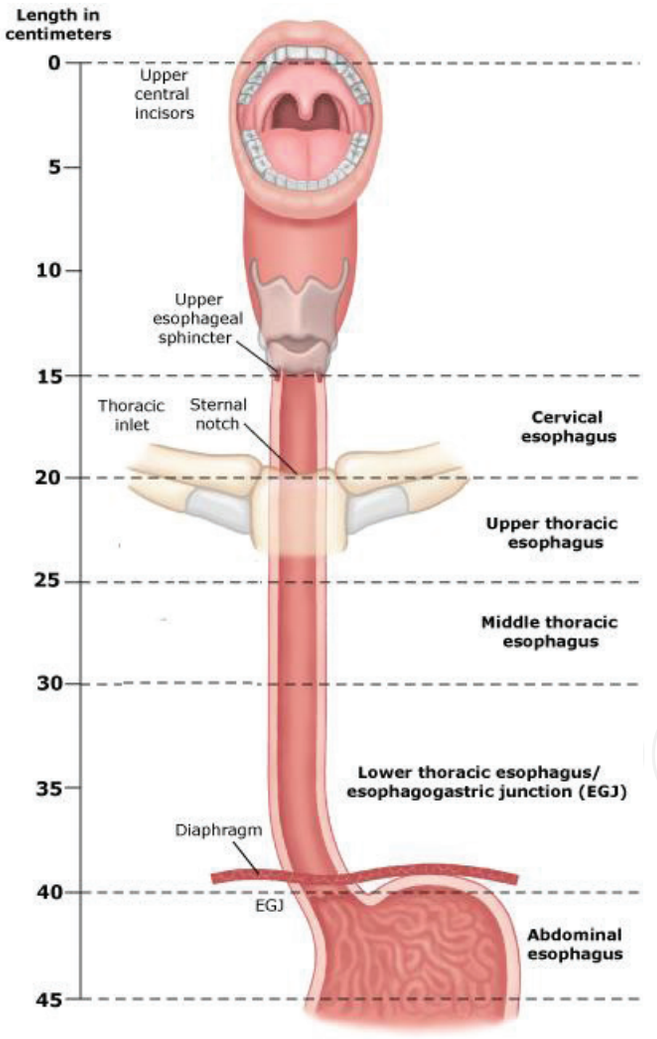

Figure 2. Length of esophageal parts.

2.1. Mucosa

Nonkeratinized stratified squamous epithelium covers all esophageal lumen. Lamina propia and lamina muscularis mucosa are located under this epithelium. Lamina propia consists mostly of loose connective tissue and lamina muscularis mucosa consists of some smooth muscle tissue and elastic fibers. Nonkeratinized stratified squamous epithelium of mucosa transforms simple columnar epithelium in cardia of stomach, occurring at a point called "Z line," an irregular zigzag line. On endoscopy, esophageal mucosa is paler than mucosa of stomach.

2.2. Submucosa

This layer consists of elastic and collagen fibers that form a dense, irregular connective tissue. This layer consists of veins, lymphatics, and meissner plexus.

2.3. Muscularis propia

Both longitudinal and circular muscles form tube-like esophagus: longitudinal muscle fibers are located superficially and the circular muscle fibers are located deeply. Longitudinal fibers begin from posterior face of cricoid cartilage and form a triangle named as "Lamier triangle," which is limited by longitudinal muscle fibers laterally and cricopharyngeus muscle superiorly. Another triangle, called "Killian triangle," is found in this area, and borders of this triangle are formed by inferior constrictor muscle of pharynx and cricopharyngeus muscle. These weaker areas are important for the formation of Zencker's diverticula. Longitudinal muscle fibers are gathered laterally in upper portion of esophagus, but these fibers expand and surround all surfaces at lower sides, becoming strongest in lower third part of esophagus. Circular muscle fibers are located under longitudinal muscle, and the circular muscle is thinner than longitudinal muscle. Circular muscles are not actually circular at all parts of esophagus; these fibers are more elliptic in upper third part and become more circular at lower third part of esophagus. Circular muscle fibers do not make a regular formation, but run in an irregular pattern making a shutter-like system. Spontaneous perforation of esophagus usually occurs in last 2 cm, and this perforation consists of entire esophageal wall, causing mediastinitis because of gastric acid leakage. Upper part of esophagus consists of striated muscle and the lower part consists of smooth muscle fibers. Transition zone differs in all humans, but mostly upper quarter consists only of striated muscle fibers; second quarter consists of both striated and smooth muscle fibers; and lower half consists of only smooth muscle fibers (Aurbach plexus is in this layer).

2.4. Adventitia

This layer surrounds most of the esophagus and consists of loose connective tissue. Because no serosa is found on esophagus, infections, and tumors can spread easily [5, 6].

3. Narrowings and curves of esophagus

Esophagus has seven narrowing points that can be seen using esophagoscopy or barium passage graphy. Four classic narrowings are found in almost all people; three other narrowings are found in certain medical conditions.

First classical narrowing is at the beginning point, and oropharyngeal muscle forms it; this part is the second narrowest point after orifice of appendix vermiformis in alimentary tract. This first narrowing point's luminal diameter is approximately 1.4–1.5 cm, and it is located 15 cm after maxillary central incisor teeth. Topographically, this first point corresponds to corpus of 6th cervical vertebra. This narrowing is named "upper esophageal sphincter." Second narrowing corresponds to plane that is located at superior border of sternum. Anterior and posterior esophageal walls become closer in hyperflexion, and this partial narrowing point occurs. Third narrowing is one of classical narrowings made by aortic arch. This point corresponds to 4th thoracic vertebra topographically and measures 1.5–1.6 cm in width. Point is located 22.5 cm after maxillary central incisor teeth, 7 cm below cricopharyngeus muscle [2]. Fourth narrowing (third classical narrowing) is located at crossing point of esophagus and left main bronchium. This point is located at level of 5th dorsal vertebra, and 27.5 cm after maxillary central incisor teeth and 9 cm below oropharyngeal muscle. Fifth narrowing point is formed if patient has atrial dilatation caused by mitral stenosis. This point is located just below bronchial narrowing. Sixth narrowing, called "Laimer narrowing," is located at second crossing point of esophagus and aorta. This point is located at plane corresponding to upper edge of 10th dorsal vertebral corpus. Laimer narrowing occurs in situation of aortic atherosclerosis. Just above this narrowing, a partial dilatation called "epiphrenic ampulla" or "Vorgamen de Luschka" is found. Last narrowing (and 4th classical narrowing) is made by esophageal hiatus that originates from right crus of diaphragm, and is located at the level of 11th dorsal vertebra and 40 cm after maxillary central incisor teeth; it is 1–1.5 cm in length and1.5–1.8 cm in width. This last narrowing is named "lower esophageal sphincter." Lower sphincter consists of a physiological sphincter mechanism made by muscle fibers of right crus of diaphragm; it provides an antireflux mechanism. When a person is not eating, esophageal lumen is closed above lower esophageal sphincter. Esophagus is primarily median and vertical, but has three slight curves located in neck, behind left bronchus, and at bifurcation of trachea (**Picture 1**).

Esophagus is located at left of midline at level of 1st dorsal vertebra, right of midline at level of 6th dorsal vertebra, and left of midline again at level of 10th dorsal vertebra. Thus, esophagus makes a reverse "S" all the way in front of vertebral column. These narrowings and curves are important landmarks for radiological and endoscopic investigation of abnormalities, cancer diagnosis, and stricture formation after swallowing of chemicals [2, 7].

Esophagus is anatomically divided into three parts: cervical esophagus, thoracic esophagus, and abdominal esophagus.

3.1. Cervical esophagus

Cervical esophagus starts at inferior margin of cricoid cartilage that corresponds to corpus of 6th cervical vertebra. This level is marked by a carotid tubercula named "Chasseing tubercula,"

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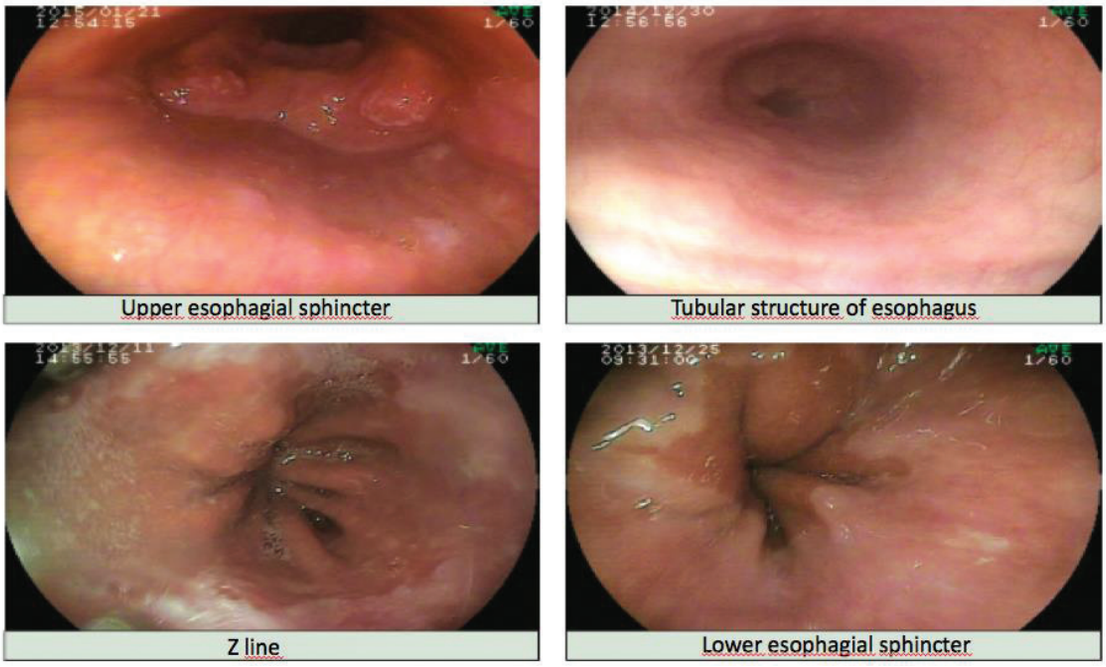

Picture 1. Endoscopic view of esophagus (with the permission of Turkish Surgery Association).

which is an important landmark in cervical esophagectomy. Cervical esophagus ends at inferior edge of first dorsal vertebra that comes up to a horizontal plane of jugular incisura of sternum. The endpoint is the starting point of upper mediastinum, and from this point it is thoracic esophagus. Cervical esophagus is 5–6 cm long, and its luminal diameter is 1.4–1.5 cm at its narrowest point.

3.1.1. Surrounding structures

Esophagus runs in deepest fascial plane of neck, leaning between trachea anteriorly and vertebra posteriorly. Esophagus is attached to prevertebral fascia by sagittal septa, which forms retropharyngeal and retro-esophagial spaces.

Esophagus is covered by larynx and trachea anteriorly (**Figure 3**), but this covering is partial, and an open margin is found on left anterior side, which provides natural surgical access. Esophagus attaches with tracheoesophageal muscle fibers to trachea; it is easy to separate tracheoesophageal plane, except in pathological circumstances. Esophagus's closest structure is carotid artery anterolaterally, which lies 1–2 cm away from it. Inferior thyroid artery, thyroid lobes, and recurrent laryngeal nerves are other important contiguities of esophagus, and ductus thoracicus lies on left side of it. Esophagus connects prevertebral muscles, cervical vertebras, and prevertebral laminas posteriorly. Thoracic duct connects to left "Pirogoff angle," and it makes a slight connection to left side of esophagus.

3.1.2. Importance of surrounding structures

Sagittal septa, which forms retropharyngeal and retro-esophagial spaces, blocks the diffusion of abscess of this area to upper mediastinum, but abscess can diffuse via pretracheal space to the upper mediastinum and can cause a fatal complication. Pretracheal space is important in that it can be perforated, primarily during an esophagectomy.

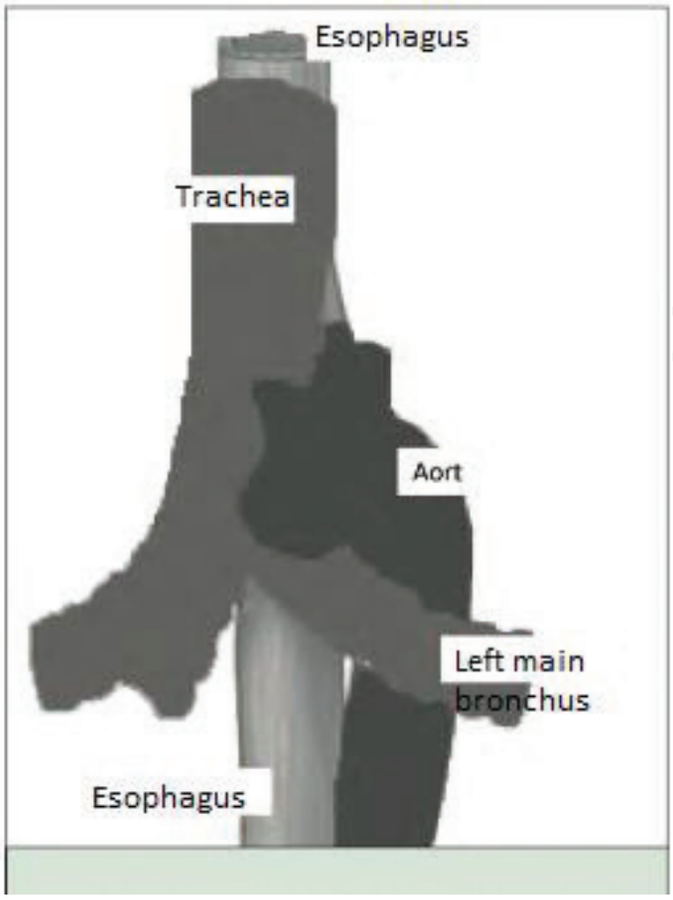

Figure 3. Placement of esophagus relative to other anatomic structures (with permission of Turkish Surgery Association).

Recurrent laryngeal nerve (RLN) lies in tracheoesophageal sulcus, and esophagus is close to this nerve, which is important in case of cervical esophagectomy. Injury of RLN causes unilateral difficulty in swallowing and hoarseness; bilateral injury causes closure of vocal cords in median position, and a tracheostomy becomes necessary. Especially on left side of esophagus, RLN is so close to esophagus that it is easy to injure a nerve with a careless dissection. Thus, dissection should be made close to esophageal muscle fibers to avoid this complication. As previously mentioned, thoracic duct connects to left Pirogoff angle, and it makes a slight connection to left side of esophagus. To avoid harm to thoracic duct, a careful dissection should be made, especially in cervical esophagectomy [8, 9].

3.2. Thoracic esophagus

Measuring 16–18 cm in length, thoracic esophagus is in upper and posterior mediastinum. Running from 1st to 11th dorsal vertebra, it does not fit concavity of vertebral column. However, it changes location to left gradually from start to end. At beginning, it is located between vertebral column and trachea, slightly left of midline and 5 cm left of vertebral column at level of diaphragmatic hiatus (**Figure 4**). Parietal sheet of pleura is tightly connected to both sides of vertebral column, and these connections cause esophageal-pleural recesses that make dissection of esophagus in thorax more difficult. Thus, if a pleural rupture occurs in this area during surgery, fixing rupture can present a challenge for surgeon [2].

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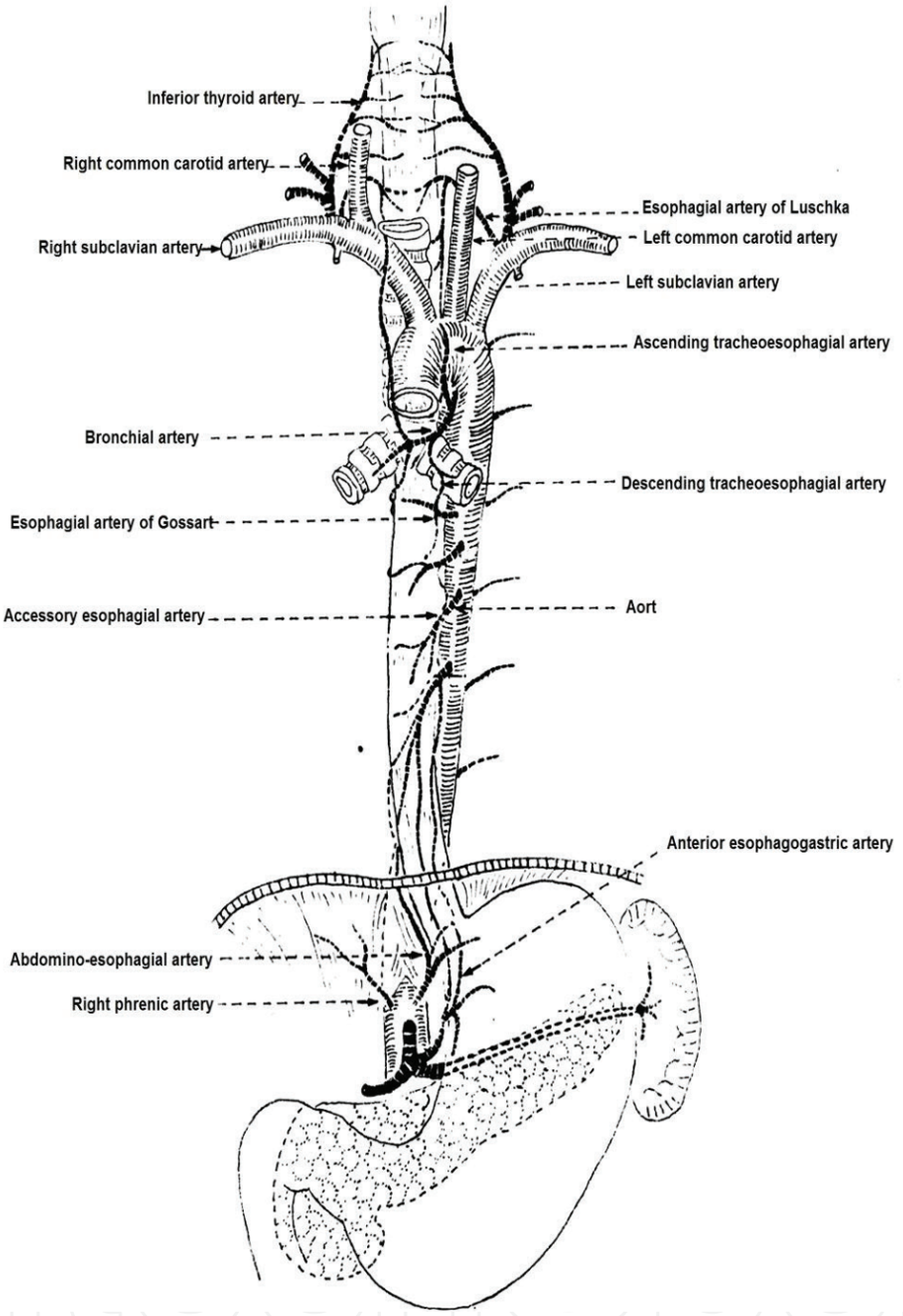

Figure 4. Arteries of Esophagus.

As previously discussed, esophagus within thoracic cavity contains three classical narrowings, two conditional narrowings, and two curves.

3.2.1. Surrounding structures

Most important and challenging structure in this region is thoracic duct, which lies behind esophagus throughout thorax. Thoracic duct is located slightly apart from esophagus in inferior third part of thorax, but it comes closer as esophagus goes upward. Trachea, aortic arch, right pulmonary artery, left main bronchus, plexus of esophagus, pericardium, left atrium, and

anterior vagus nerve are found anterior to esophagus. At posterior side, esophagus connects to vertebral column, longus colli muscle, posterior intercostal arteries, azygos vein, hemiazygos vein, anterior wall of aorta, posterior vagal nerve, and pleura. Aortic arch, left subclavian artery, left inferior laryngeal nerve, left vagus nerve, thoracic ductus, and thoracic part of aorta are located on left side of esophagus. Azygos vein, pleura of mediastinum, right main bronchus, and right vagus nerve are located on right side.

3.2.2. Importance of surrounding structures

Close proximity of upper two-thirds of esophagus to thoracic duct increases risk of thoracic duct injury in middle and upper mediastinal dissection of esophagus; thus, careful dissection should be performed in this area.

At a level of diaphragmatic hiatus, a soft areolar tissue connects esophagus to diaphragmatic cruses, and a slight concave area called "portal concavity" allows formation of a hiatal hernia.

The area between aortic arch and esophagus is comprised of aorticoesophagial muscle fibers that include large vessels; dissection of this area is fairly simple, except in the case of tumor invasion. If tumoral invasion occurs among these large vessels, removal is challenging and dangerous.

Upper mediastinum becomes narrower above aortic arch, and esophageal tumors can easily infiltrate left recurrent laryngeal nerve and respiratory system; however, aortic arch and azygos vein block tumors in these areas to infiltrate lower parts of mediastinum.

Lower parts of thoracic esophagus are surrounded by soft areolar tissue. Here esophagus is not touching adjacent organs and descends slightly away from the vertebral column, making dissection and resection easier and tumor infiltration more difficult in this area.

Two weak areas in esophagus that can be vulnerable to pulsing diverticula are upper and lower parts of a cricoid muscle. In addition, another weak area is located on left posterior esophageal wall, very close to diaphragmatic hiatus, spontaneous rupture of esophagus can occur [2, 10].

3.3. Abdominal esophagus

Abdominal esophagus is 1–2.5 cm long and is topographically located at 11thvertebral plane posteriorly. The plane passes through 7th rib cartilage and sternum anteriorly. It passes through esophageal hiatus of diaphragm, which is comprised of muscular fibers of right crus. The anterior side is longer than posterior side of esophagus because diaphragmatic crura are oblique. Anterior and lateral sides are partially covered by visceral peritoneum, and posterior side is nonperitoneal side. Three ligaments connect esophagus to spleen, liver, and diaphragm. They are hepatogastric ligament, gastrosplenic ligament, and gastrophrenic ligament.

3.3.1. Surrounding structures

Following structures are located near abdominal esophagus: posterior side segment of two-thirds of liver, left vagus nerve and esophageal plexus anteriorly, left and right crus of diaphragm, aorta and left inferior phrenic artery posteriorly, caudate lobe of liver at the right side, and fundus of stomach at left side.

Esophageal hiatus is located on right side of midline and is 2 cm in diameter. Topographically, it is located at 10th vertebral plane. Before reaching hiatus, esophagus dilatates at a place called "epithetic ampulla" that is delaying point of morsel when swallowing during radiologic examinations.

Esophagus ends at a place called "cardia of stomach." Right side of esophagus continues as lesser curvate of stomach, and left side angles with greater curvate of stomach, forming "angle of Hiss." A mucosal tongue that descends into stomach is called "Gubaroff valvula." Hiss angle and Gubaroff valvula are important in antireflux mechanism [11].

Phrenoeosophagial ligament is primary part of antireflux mechanism that includes Gubaroff valvula and angle of Hiss (**Figure 5**). This ligament consists of subpleural fascia, pleura,

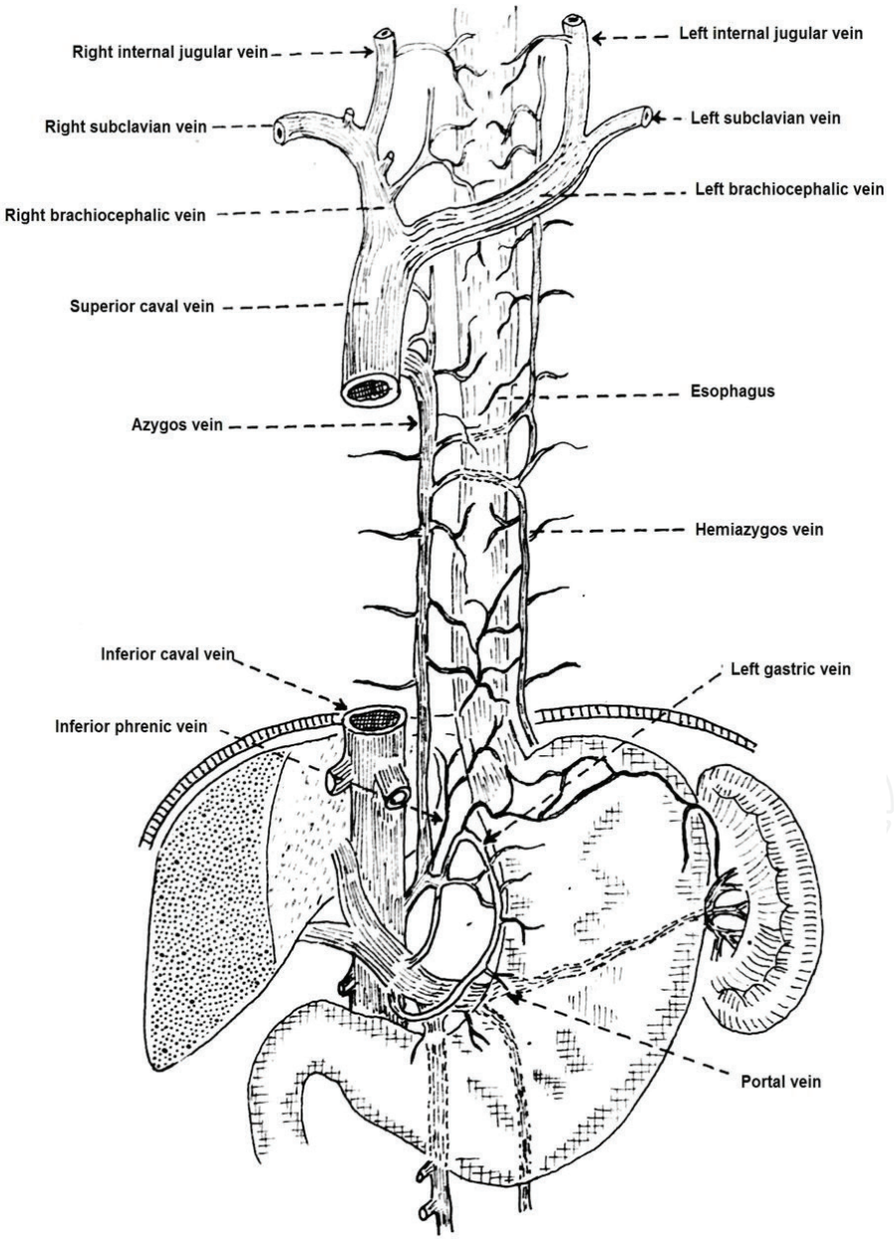

Figure 5. Veins of Esophagus.

phrenoesophageal fascia, and transverse fascia of abdomen and peritoneum. Fibers of this ligament that reach upward are called "Juvara fibers"; downward fibers are called "Rouget fibers." Phrenoesophageal ligament resists vigorous abdominal pressure that pushes stomach to intrathoracic cavity, but it allows esophagus to move upward and downward while swallowing. This ligament makes gastroesophageal junction both flexible and tight [12, 13].

4. Connections that stabilize esophagus

Fibrotic membrane that attaches esophagus to vertebral column is called "Bouteiller membrane." This membrane is tight over diaphragmatic hiatus and limits extreme movements of esophagus. However, under hiatus, membrane is loose and long. Phrenogastric ligament lies between diaphragm and cardia of stomach and both vagus nerves. Vagus nerves hang esophagus to thoracic cavity; thus, cutting vagus nerves elongates esophagus 4–5 cm [2].

4.1. Arteries of esophagus

Inferior thyroid artery provides primary arterial flow to the cervical esophagus, and subclavian artery, main carotid artery, vertebral arteries, ascendant pharyngeal artery, superficial cervical artery, and costocervical trunk are other arterial blood flow providers to cervical esophagus. Thoracic portion of esophagus takes blood flow from aorta, bronchial arteries, and right intercostal arteries. The abdominal esophagus is fed by left gastric artery, short gastric arteries, and descending branch of left phrenic artery. Inferior thyroid artery supplies arterial blood flow to cervical portion of esophagus (**Figure 6**). An excessively low resection of cervical esophagus causes devascularization to this area. In addition, aggressive resection and mobilization or laceration of bronchial artery, or cutting recurrent branches of left gastric artery and inferior phrenic artery causes devascularization at level of tracheal carina. Esophageal arterial blood flow is extremely rich and adequate for anastomosis, but a poor blood supply or careless or over aggressive dissection can cause anastomotic leakage in esophagus [14–16].

4.2. Veins of esophagus

Venous system of esophagus begins at submucosal plexus, which perforates muscular layer and empties into azygos system. Cervical portions of venous drainage empty into inferior thyroid veins. Thoracic portion's venous drainage empties into azygos vein, right brachiocephalic vein and, rarely, vertebral veins on right side, and hemiazygos vein, left brachiocephalic vein and, rarely, vertebral veins on left side. Venous drainage of abdominal portions empties primarily into left gastric veins. Other veins that drain esophageal venous plexus are short gastric veins, splenic vein, left gastroepiploic vein, and branches of an inferior phrenic vein. Lower esophageal veins connect to superior caval venous system by azygos and hemiazygos veins with multiple shunts, and other multiple shunts are located between inferior caval system and lower esophagus (**Figure 7**). Retrograde flow of esophageal venous system causes venous dilatation and varices, and these varices can cause fatal bleeding [2, 14, 17].

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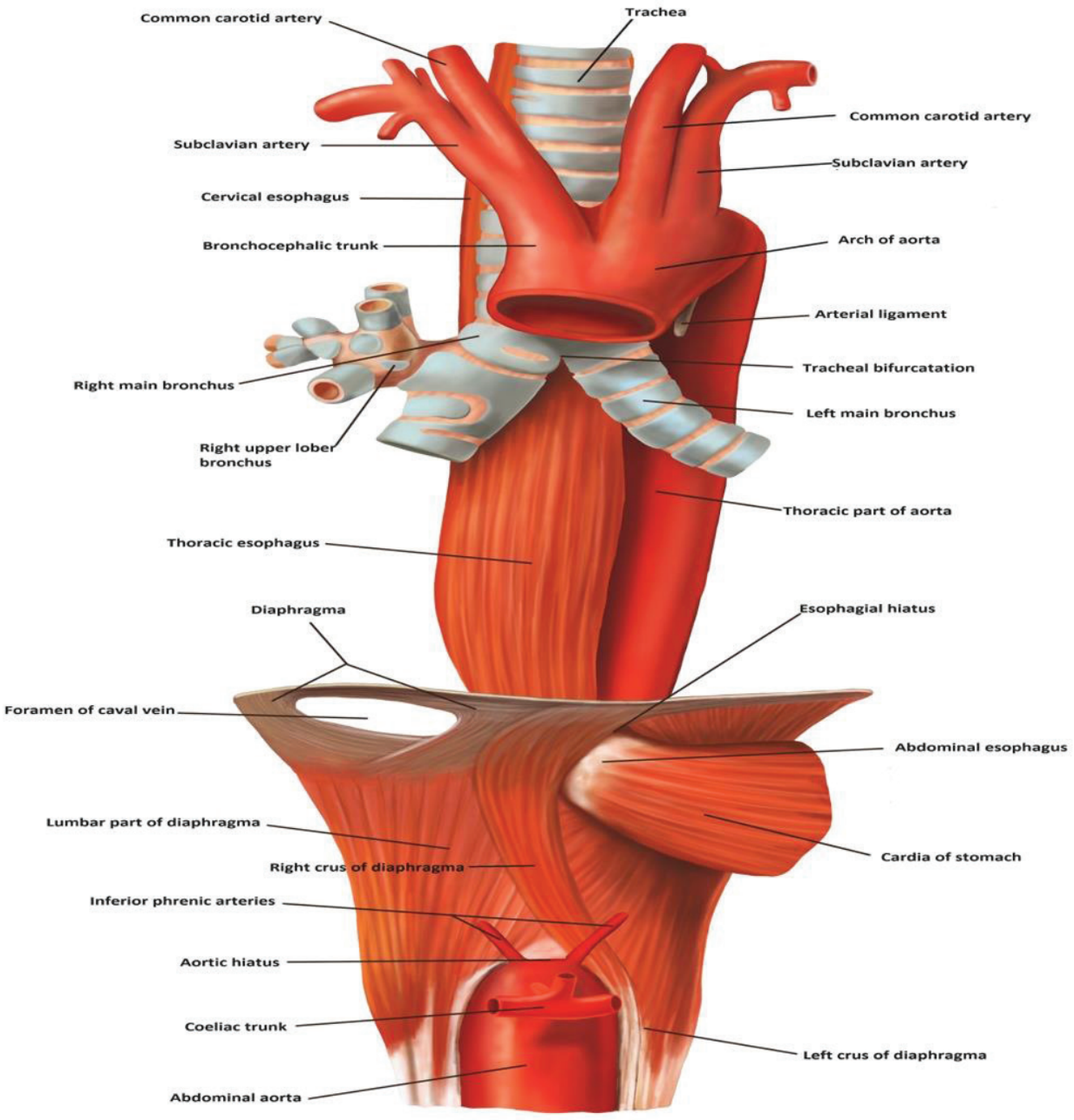

Figure 6. Relation among esophagus, diaphragm, and aorta (with permission from Turkish Surgery Association).

4.3. Lymphatics of esophagus

Lymphatics are located in every layer of esophagus, but primarily at lamina propria, forming a giant network system. Cervical lymphatics empty internal jugular lymph nodes and upper tracheal lymph nodes. An internal jugular lymphatic system that forms deeper cervical lymphatic system connects with lymphatic duct at right side and thoracic duct at left side.

Lymphatics of thoracic esophagus empty posterior parietal, diaphragmatic, tracheal, tracheobronchial, retrocardiac, and infracardiac lymph nodes.

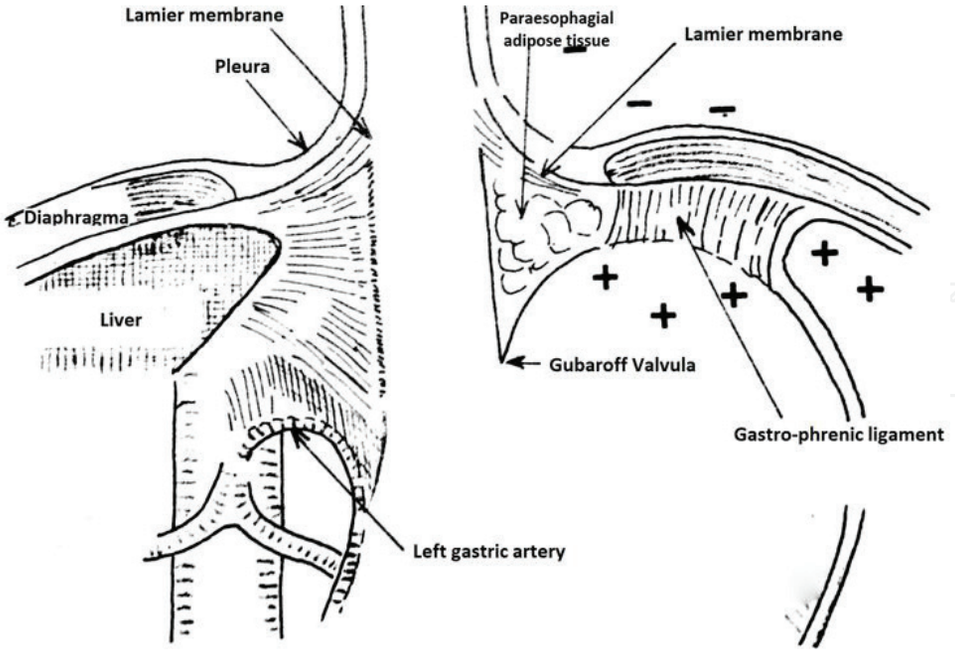

Figure 7. Anti-reflux mechanism of esophagus.

Abdominal parts of lymphatic system empty left gastric, paracardiac lymph nodes, and all these nodes connect to coeliac lymph nodes. Coeliac lymph nodes empty cisterna chyli or thoracic duct.

Posterior parietal lymph nodes include posterior mediastinal and intercostal lymph nodes and connect with thoracic duct or right lymphatic duct. Only posterior part of diaphragmatic lymph nodes are connected to esophageal lymphatic system, and these lymph nodes empty to posterior parietal lymph nodes.

Tracheal or paratracheal lymph nodes are located on two sides of trachea, and tracheobronchial lymph nodes are located around bifurcation of trachea. Tuberculosis, which causes necrosis and fibrosis of tracheobronchial lymph nodes, forms traction diverticula of esophagus. These two lymphatic systems form a broch mediastinal lymphatic chain that empties to thoracic duct or right lymphatic duct (**Figure 8**) [18, 19].

4.4. Innervation of esophagus:

Parasympathetic and sympathetic nerves form esophageal innervation, carrying stimuli to esophageal muscles, glands, veins, and arteries.

4.4.1. Parasymphatic innervation

Parasympathatic fibers that innervate pharynx and upper part of esophagus come from ambiguous nuclei of brain. Esophageal innervation is primarily accomplished by vagus nerves, which end at dorsal vagal nuclei of brain. Cervical esophagus takes thin fibers from both recurrent laryngeal nerves. Both left and right recurrent laryngeal nerves arise from vagus nerves, but on left side, a recurrent laryngeal nerve is closer to aortic arch. On right side,

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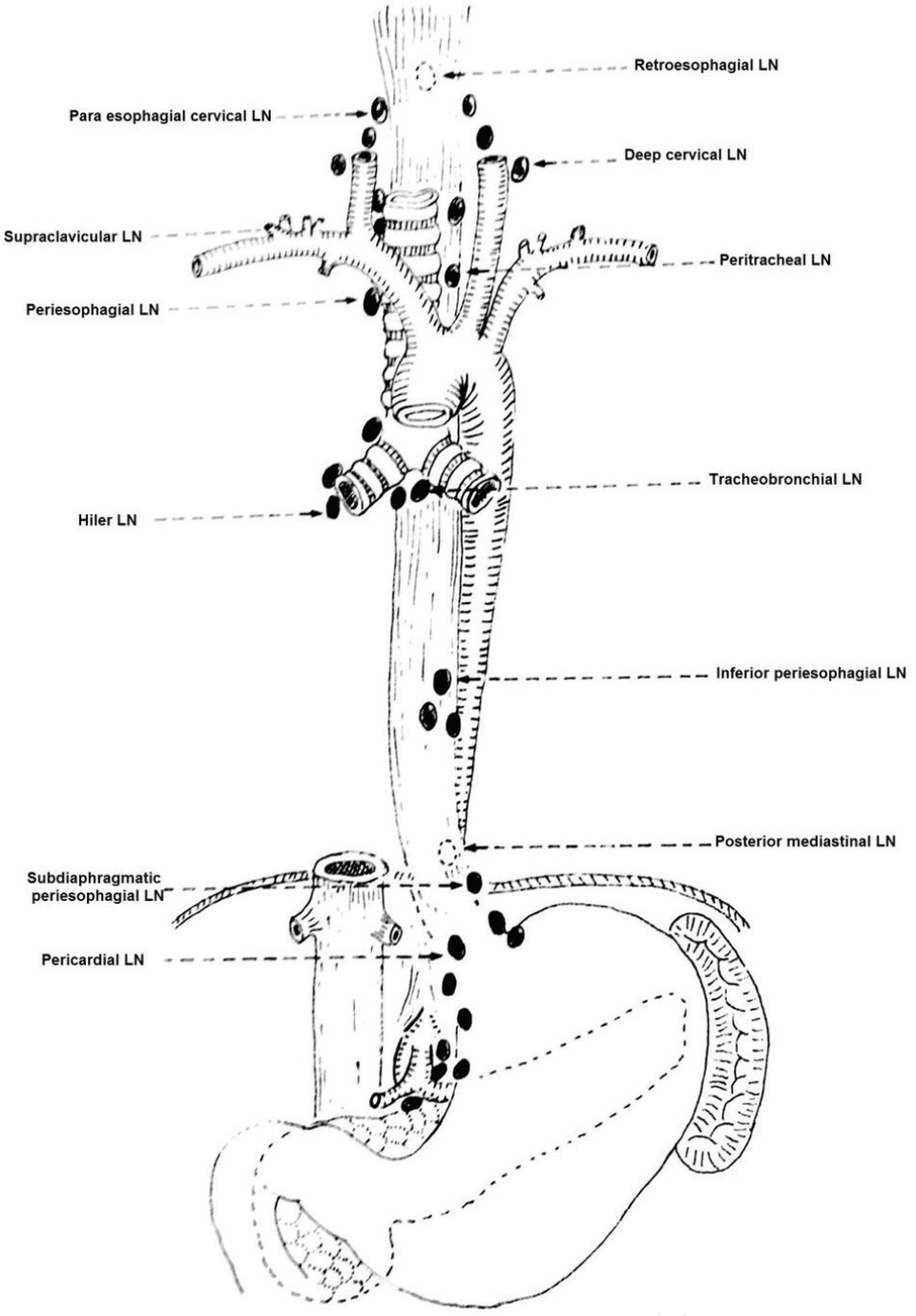

Figure 8. Lymphatics of esophagus.

it is closer to subclavian artery. Finally, left and right recurrent laryngeal nerves run in sulcus between trachea and esophagus. The thoracic esophagus is primarily innervated by vagus nerves, but the upper part of thoracic esophagus takes some fibers from left recurrent laryngeal nerve. Vagus nerve fibers form two to four branches under tracheal bifurcation, and these nerve branches are located on anterior face of esophagus at level of posterior mediastinum. Near esophageal hiatus, these nerve branches unite and form two vagal trunks of esophagus.

Variation of vagal trunks is important during vagotomy. A surgeon should be aware of these variations and be careful because more than one branch can be found in anterior or posterior vagal trunk or both.

4.4.2. Sympathetic innervation

The upper part of esophagus is innervated by pharyngeal plexus, which is fed by upper cervical ganglions, middle cervical ganglions, and sympathetic trunks of vertebral ganglions while running downward. Superior parts of the thoracic esophagus are innervated by stellate ganglion and subclavian ansa. Lower parts of thoracic esophagus are innervated by greater splanchnic nerves that end at coeliac plexus. Left greater splanchnic nerve and right inferior phrenic nerve innervate abdominal esophagus [20, 21].

Author details

Murat Ferhat Ferhatoglu* and Taner Kıvılcım

*Address all correspondence to: erhatferhatoglu@gmail.com

General Surgery Department, Okan University, Istanbul, Turkey

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