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Oesophageal surgical anatomy

Anatomia chirurgiczna przełyku

For surgical treatment of oesophageal cancers the knowledge of its anatomy is the most important. The topography of the oesophagus and its arterial vascularization as well as the lymphatic system should be taken into consideration.

OESOPHAGEAL ANATOMY AND TOPOGRAPHY

The knowledge of the oesophageal anatomy and topography should comprise the fact that it is adjacent to important organs, vessels and nerves. Thus the experience of the anatomic relations of this organ and its topography: the cervix, the mediastinum and abdominal cavity is necessary for performing successful oesophageal surgery.

Oesophagus is a muscular tube that can be moved and modelled by adjacent organs. It is strongly attached only in two places: in oesophago-pharyngeal anastomosis and in oesophageal hiatus of the diaphragm. It begins at the cervical level of the lower border of the cricoid cartilage (so-called "oesophageal mouth") which corresponds to sixth cervical vertebra (C_6). Next it descends lar-

gely through the superior and posterior mediastinum. It traverses the diaphragm at the level of the $Th_{10} - Th_{11}$ and is connected with the stomach in the cardia. In an adult of an average height it is about 23-26 cm long connecting the pharynx to the stomach and the distance from the incisive teeth to the oesophageal commencement is about 18 cm long (5, 6, 13).

The organization of tissues within the oesophageal wall contains four main layers (tunics) – 5, 8: 1. tunica mucosa; a) epithelium, b) lamina propria, c) lamina muscularis mucosae. 2. submucosa. 3. tunica muscularis externa. 4. adventitia.

Tunica mucosa is composed of the epithelium, lamina propria and lamina muscularis mucosae. At the gastro-oesophageal junction the stratified squamous epithelium is abruptly succeeded by simple columnar epithelium. Tunica mucosa forms numerous longitudinal folds, which close the oesophageal lumen by joining one another. Lamina propria is made of compact connective tissue often rich in thin collagen fibers and a net of elastic fibers.

Lamina muscularis of the mucosa is well developed in the oesophagus. It is composed of bundles of mainly longitudinal smooth muscle and a thin net of elastic fibers. The next layer – tunica submucosa is formed of fibrous tissue. It contains larger blood vessels, nerves and mucous glands.

Tunica muscularis externa has the usual outer longitudinal and inner circular layers. The longitudinal layer is generally thicker than the circular one. In the middle part of the oesophagus the bundles of smooth muscle fibers gradually replace the skeletal ones which, in the lower third part of that tunica become entirely replaced by smooth muscles.

The external layer of the oesophageal wall is the adventitia. It is built up of detached fibers of the connective tissue, which join the oesophagus with the neighbouring organs, due to which it is transferable and moveable only in some extent.

In oesophageal structure it is important to look at its distribution into three main parts. When diagnostic examinations: barium passage, endoscopy, endoscopic ultrasonography, CT, or NMR are used for localization of the primary oesophageal cancers, the organization of the organ needs to be unified. The oesophageal, surgical division, used nowadays is based on its anatomical topography and the description of the localization of the diagnosed tumors (9, 12, 15, 16, 17).

According to this division the oesophagus has two main parts: cervical and thoracic. The thoracic part is divided into three parts:

1. Cervical part of the oesophagus. The beginning of this part is in the lower end of the cricoideal cartilage, which is at the level of sixth cervical vertebra (C_6). It is descending 4-5 cm between trachea and the vertebral column and reaches the lower edge of the second thoracic vertebra, which is the level of jugular incisure, at a maximum distance of 18 cm from incisive teeth. As a result of the left-sided bend of this part of the oesophagus, the recurrent laryngeal nerve is located superficially and the right recurrent laryngeal nerve is covered with the trachea.

2. Thoracic part of the oesophagus. This part of the oesophagus has three main sections: upper, middle and lower:

a) The upper thoracic part of the oesophagus begins with the jugular incisure level (the lower edge of the second thoracic vertebra Th_2) and descends to the level of the trachea bifurcation i.e. to the lower edge of the sixth thoracic vertebra (Th_6). This place is situated about 24 cm from incisive teeth. This part at the front is covered with tracheal wall, which is loosely linked with connective tissue and smooth muscular fibers. The left recurrent laryngeal nerve, common carotid artery, subclavian artery and thoracic duct are situated on the left side of the oesophagus. It is hidden behind the trachea on the right side and the right recurrent laryngeal nerve does not touch its wall. The vagus nerve and the azygos vein arch cross the right wall of the oesophagus at the level of the tracheal bifurcation. Its anterior wall is connected with the left main bronchus in this place.

b) The middle thoracic part of the oesophagus spreads from the level of the tracheal bifurcation (lower edge of Th_6) to the middle of the distance between the bifurcation and the gastro-esophageal junction (lower edge of the eighth thoracic vertebra Th_8). It is about 32 cm from incisive teeth. The posterior and a part of the anterior wall of the oesophagus is covered with right parietal pleura and in this part the oesophagus is withdrawing from the vertebral column. The presentation of strict connection between the oesophagus and the posterior wall of pericardium, which divides it from the left cardiac atrium is very important for surgical practice. The aorta is placed between the oesophagus and the left side of the vertebral column at the level of sixth thoracic vertebra. In this area the posterior surface of the oesophagus most frequently crosses the hemiazygos vein and sometimes also the thoracic duct.

c) The lower part of the thoracic oesophagus, about 8 cm long (including its abdominal part) is named the distal part of the oesophagus. It begins at the middle part of the distance from tracheal bifurcation (the level of Th_8) and the gastro-esophageal junction level of (Th_{10}-Th_{11}), which is located about 32-40 cm from incisive teeth. This part of the oesophagus has beginning at the place,

where it enters the oesophageal hiatus of diaphragm. This is usually called diaphragmatic. The oesophagus and the aorta behind it are surrounded with diaphragmatic muscular fibers shaped like an eight.

ARTERIAL SUPPLY OF THE OESOPHAGUS

The increasing number of the oesophageal resections has confirmed that very important problems are caused by anastomotic leakage. Good blood supply in the oesophageal stump and the transplant is the most important for surgical success (7, 14). For that reason the knowledge of the arterial supply of the oesophagus is very important too.

The cervical part of the oesophagus is supplied via the paired superior and inferior thyroid arteries, which derive from the right and left common external artery and from the thyrocervical trunk and the subclavian artery. The trachea and the cervical part of the oesophagus are mainly supplied by inferior thyroid arteries, which have a 2-3 cm long branch each, called the tracheo-esophageal grove. They descend on each side medially and caudally until they reach the tracheo-oesophageal recess. The vessels on both sides are anastomosed along the trachea and with two or three branches they penetrate the periesophageal tissue branching again before they reach the oesophageal wall into vessels of less than 500 μm luminal diameter (21). Variants such as direct oesophageal branches from the subclavian artery, the superior thyroid artery, the thyroidea ima and common carotid artery are infrequent and rather insignificant (18, 21).

The thoracic part of the oesophagus receives blood from two origins (18, 19). The four unpaired tracheo-bronchial arteries, which derive from aortic arch in a bundle, are the first and the most important of those sources. They subsequently ramify into the oesophageal wall with numerous small branches, which divide within the organ into vessels of 350-500 μm in diameter. The broncho-oesophageal arteries often come out of the antero-lateral surface of the descending aorta 1-3 cm caudally to the vascular bundle. All vessels of the oesophagus are straight and short (less than 1.5 cm long) – 18, 19. Arterial branches of intercostal arteries seem to have little significance for the arterial supplementation of the oesophagus (19). The other origin of the blood supply in this part of the oesophagus is created by one or – rarely – two unpaired oesophageal arteries – of 1-2 mm in diameter – branching out of the descending aorta. If they are already present, they descend towards the oesophagus and divide into the ascending and descending branches.

The vascularization of the abdominal part of oesophagus is the most stable and comes from the left gastric and the splenic arteries, which derives from the celiac trunk. Branches of the left gastric artery (up to 11) supply the anterior and right part of the oesophageal wall, while the splenic artery supplies its posterior and left part (5, 18).

OESOPHAGEAL VESSELS AND LYMPH NODES

The system of vessels and lymph nodes, which carry the lymph from the oesophagus forms a complicated structure spreading extensively from the cervix, through the mediastinum to the upper level of the abdominal cavity. In the oesophageal wall we can distinguish the lymph rate of the mucosal, the submucosal and the muscular tunics, as well as two plexuses of lymphatic vessels: submucosal and muscular (10). The adventitial plexus is not always present (11). The lymph rate of the mucosal tunica situated in the lamina propria consists of the layer of the numerous tightly vessels, from which small vessels forming the submucosal plexus are next derived. The plexus connects the lymph with the lymph reties and thus it is the basic way of the outflow of the lymph from the oesophagus (10, 11). Efferent lymph vessels cross the oesophageal wall and lead to regional lymph nodes.

The lymphatic retie of the muscular tunica of the oesophagus consists of three layers of lymphatic vessels: in the circular and longitudinal muscles, and in the tissue between the layers. An intramuscular plexus is formed from these vessels and joins both the submucosal and the adventitial plexus. The outflow of the lymph to regional lymph nodes or to the lymph nodes situated above and underneath can take place (2, 3, 4, 22). Owing to many intramural anastomoses many lymph vessels of the oesophagus are also linked to the vessels of the adjoining organs: the pharynx, the trachea, the bronchi, the lungs, the stomach and the liver (10, 11, 23, 25). The following regional lymph nodes are usually distinguished for the particular parts of the oesophagus:

1. The cervical part – deep cervical lymph nodes (including the lymph nodes around the recurrent laryngeal nerve) and supraclavicular lymph nodes.

2. The thoracic part – upper and lower tracheo-bronchial lymph nodes and mediastinal posterior lymph nodes.

3. The abdominal part – lymph nodes near the stomach cardia, the less gastric curve lymph nodes and the lymph nodes of the celiac plexus.

Some vessels deriving from regional lymph nodes can lead directly to the mediastinal trunk or to the thoracic duct (10, 11).

In order to simplify the identification and possibly, the dissection of lymph nodes, the Japanese Society for Esophageal Diseases has created an anatomical map of the oesophageal lymphatic system (15). The present classification groups lymph nodes in seven regions and is a modification of the formerly used system (2, 3). According to the classification the following groups of oesophageal lymph nodes are specified:

I. Cervical bilateral lymph nodes; a) deep lateral lymph nodes – also called the lymph nodes of the accessories nerve, because of location near the nerve, b) deep external lymph nodes – situated laterally to the internal jugular vein. The group also comprises supraclavicular lymph nodes, c) deep internal lymph nodes – also called the lymph nodes of the recurrent laryngeal nerve, situated medially to the internal jugular vein. The upper part associated with the recurrent laryngeal nerve is linked to the lower part located in the thorax. Thus the part is called the tracheo-cervical region.

II. Mediastinal lymph nodes;

1. Lymph nodes of upper mediastinum; a) lymph nodes of laryngeal recurrent nerves – in the right side there are several lymph nodes along the right laryngeal recurrent nerve forming a loop under the subclavian artery. On the left side, because of a different topography of the left laryngeal recurrent nerve, they are located along the trachea; b) paratracheal lymph nodes – on the right side located along the right vagus nerve and of the left – they correspond to the lymph nodes of the left laryngeal recurrent nerve; c) lymph nodes of the brachiocephalicus trunk belong to the lymph nodes of the thoraco-cervical region and are located in the front and medially to the vagus nerve in the place where it crosses the brachiocephalicus trunk; d) paraesophageal lymph nodes – their location in the upper mediastinum is problematic. On the left it is difficult to differentiate between then and the paratracheal lymph nodes or the lymph nodes of the left laryngeal recurrent nerve. This group comprises lymph nodes located in the mediastinum and along the aorta too; e) Lymph nodes of the aortic arch – several lymph nodes located beneath the aortic arch. They are connected with the lymph nodes of the left laryngeal recurrent nerve on the left side and the tracheo-bronchial lymph nodes.

2. Lymph nodes of the middle mediastinum; a) lymph nodes of the tracheal bifurcation, called the nodes of the carina – are located in the place where the tracheal bifurcates into two bronchi; b) lymph nodes of pulmonal hills – situated bilaterally in the terminal parts of the bronchi; c) paraesophageal lymph nodes –

the lymph nodes located irregularly along the aorta and the thoracic trunk belong to this group.

3. Lymph nodes of the lower mediastinum; a) diaphragmatic lymph nodes – located near the oesophageal hiatus of the diaphragm, both in the front of the oesophagus and in the phrenoesophageal angle. They are connected with the lymph nodes of the gastric cardia; b) paraesophageal lymph nodes – they are linked with aorta and the thoracic duct in this part.

III. Epigastric lymph nodes; a) lymph nodes of the gastric cardia – located bilaterally to the cardia – regarded as the group, because they are situated near the uppermost branch of the left gastric artery; b) lymph nodes of the less gastric curve – situated in the fat tissue along the joined left and right gastric arteries. Most of the lymph nodes are located along the upper part of the less gastric curve; c) lymph nodes near the left gastric artery – located between the commencement of the left gastric artery and the less gastric curve; d) lymph nodes of the celiac plexus – a group of lymph nodes located around the short celiac trunk; e) lymph nodes of the common hepatic artery situated along that artery.

It has to be emphasized that the above mentioned classification of the lymphatic system, proposed by Japanese authors and applied in clinical practice, is not complacent with the anatomical classification (86). The names of specific lymph nodes groups according to both classifications are presented in Table 1.

Table 1. Classification of lymph nodes resected in the oesophageal cancer surgery – surgical classification acc. to Akiyama et al. and anatomical classification acc. to Nomina Anatomica 1989 (20).

The name of the lymph nodes group	Surgical classification	Anatomical classification
Cervical lymph nodes	deep lateral lymph nodes Ia	nodi lymphatici cervicales laterales superficiales
	deep external lymph nodes Ib	nodi lymphatici cervicales laterales profundi – iugulares laterales – iugulares anteriores; – nodus iugulodigastricus; – nodus iuguloomohyoideus; – supraclaviculares
	deep internal lymph nodes Ic	nodi lymphatici cervicales anteriores profundi: prelaryngeales, pretracheales, paratracheales

Upper mediastinum	lymph nodes of the recurrent laryngeal nerves II1a	nodi lymphatici mediastinales posteriores paratracheales
	paratracheal lymph nodes II1b	nodi lymphatici mediastinales posteriores paratracheales
	lymph nodes of the brachiocephalicus trunk II1c	noduli limphatici mediastinales posteriores tracheobronchiales superiores
	paraesophageal lymph nodes II 1d	nodi lymphatici mediastinales posteriores iuxtaesophageales pulmonales
	lymph nodes of the aortic arch II1e	noduli lymphatici mediastinales anteriores (nodus ligamenti arteriosi)
Middle mediastinum	lymph nodes of the tracheal bifurcation II2a	noduli lymphatici mediastinales posteriores tracheobronchiales inferiores
	lymph nodes of pulmonal hills II2b	noduli lymphatici mediastinales posteriores tracheobronchiales superiores
	paraesophageal lymph nodes II2c	nodi lymphatici mediastinales posteriores
Lower mediastinum	diaphragmatic lymph nodes II3a	nodi lymphatici phrenici superiores
	paraesophageal lymph nodes II3b	nodi lymphatici mediastinales posteriores
Epigastric lymph nodes	lymph nodes of the gastric cardia IIIa	annulus lymphaticus cardiae
	lymph nodes of the less gastric curve IIIb	nodi lymphatici gastrici dextri et sinistri
	lymph nodes near the left gastric artery IIIc	nodi lymphatici gastrici sinistri
	lymph nodes of the celiac plexus IIId	noduli lymphatici celiaci
	lymph nodes of the common hepatic artery IIIe	nodi lymphatici celiaci et hepatici

WAYS OF CANCER ADVANCEMENT

The knowledge of the anatomic structure of the arterial and lymphatic systems is essential for understanding the ways of oesophageal cancer advance-

ment. The cancer is a primarily infiltrating neoplasm. It spreads by infiltrating the oesophageal wall both in the longitudinal axe (local spread) and in the transversal axe (regional spread). It also spreads through the lymphatic and blood systems (system spraed). The neoplasm advances relatively fast beyond the muscular layers infiltrating mediastinal area due to lack of tunica serosa which is a biological barrier to neoplastic spread. Tumors of the upper third part of the oesophagus may invade cervical arteries, the pleura, recurrent laryngeal nerves or the trachea. Neoplasms of the middle third part of the oesophagus may infiltrate the trachea and the left main bronchus, the aortic arch, hemiazygos vein, the pleura and the right lung. Cancers of the lower third part of the oesophagus most frequently infiltrate the pericardium, the descending aorta and the left pleura. According to W u et al. (24) the development of oesophageal cancer follows the phases:

1. Initial phase. In this period dysplastic changes and increased cornification of squamous cell are observed.

2. Evolution phase. The cancer infiltrates deeper layers and crosses the basement membrane of the oesophageal epithelium.

3. Manifest phase. The cancer infiltration does not cross the tunica adventitia of the oesophagus, but metastasizes through the lymphatic system.

4. Terminal phase. The cancer crosses the oesophageal wall and infiltrates the adjacent organs. Metastases in the lymphatic system are present.

It was in 1903 when Sakata (2) found that the lymphatic system in the oesophageal wall forms long main canals in the submucosal membrane. The lymph flows in both directions along the organ's axis. The system is connected with the adventitious network by small trunks (transverse to the muscular layer). Clinical research shows that the lymph from above the tracheal bifurcation flows mainly in the cranial direction and beneath the carina it flows towards the chyle cistern. The flow in the area of the tracheal bifurcation seems to be a two-way one (2, 3, 22). It can change as a result of the vessel occlusion by cancer infiltration, which explains the reverse spreading of the cancer. The knowledge of those acts and of the anatomy of the lymphatic system explains the phenomenon of the extensive spreading of cancer from a small focus under the unchanged mucosal membrane and of the neoplasm relapse in the anastomosis (261). Clinical observations carried out by Akiyama (1) showed a possibility of metastases in the lymphatic system of the cervix, the mediastinum and in the epigastrium – irrespective of the initial location of the cancer.

The liver is the place where most metastases, which spread through the blood system are located, especially in the case of tumors of the lower and middle

parts of the oesophagus (17). Other organs where metastases occur are lungs, bones, adrenal glands and the brain.

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STRESZCZENIE

Autorzy przedstawiają współczesną anatomię przełyku. Szczególną uwagę skupiają na problemach związanych z chirurgicznym leczeniem nowotworów przełyku. Podkreślają rolę znajomości Klasyfikacji Japońskiej układu chłonnego przełyku w zrozumieniu dróg szerzenia się raka przełyku.