

Lymphatics of the Mediastinum, Esophagus and Lungs: Thoracic Surgeon's Point of View

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Abstract

The anatomy of the thoracic lymphatic system is very complex and not completely known yet. Thoracic malignancies, especially lung and esophageal cancers, are rapidly increasing as incidence. A good knowledge of the thoracic lymphatic system is very important in staging, diagnosis and treatment of these malignancies. The complete lymphadenectomy has a crucial role in both to achieve a correct postoperative stage and a complete resection of pathologic tissue. The article is a glimpse on the lymphatic anatomy of the thorax, as it should be known by surgeons involved in thoracic oncology.

Keywords: Thorax; Lymphatics; Mediastinum; Esophagus; Lungs; Thoracic surgery

Main Text

There are still many points in lymphatic embryology and anatomy to discover because of the limitation of exploratory methods that are available. The lymphatic vascular system is very complex and it hasn't been studied like the blood vascular system.

There are different lymphatic drainage pathways in the thorax that are relevant in the staging of thoracic malignancies: lung cancer, esophageal cancer, malignant mesothelioma, lymphomas and breast cancer. Each structure from which a thoracic primary tumor originates has a specific lymphatic spread that has to be known in order to be able to evaluate the spreading of the disease [1]. All these pathways are interconnected with each other and with the thoracic duct.

There are three main lymphatic ascendant pathways or lymph node chains described [2]: 1) *posterior parietal chain* that ascends along the vertebral column in the posterior mediastinum; 2) *anterior parietal chain* along the internal mammary vessels, and 3) *median visceral chain* along the esophagus, tracheobronchial tree and phrenic nerves

There is also a diaphragmatic lymphatic network which drains the diaphragm and establishes connections with above mentioned chains. The thoracic duct is the main lymphatic vessel in which all other lymphatic networks finally drains.

The *posterior parietal chain* ascends in the posterior mediastinum along the vertebral column and it gathers intercostal lymphatics which drain the chest wall, the posterior pleura and the posterior part of the diaphragm. On their course there are lymph nodes situated in the extrapleural fat adjacent to the rib heads. The drainage of this chain (both sides) is essentially ascendant, finishing in the thoracic duct or directly into the Pirogoff angle. They may also drain inferiorly and involve in this case the lymphatics within the gastro-hepatic ligament and celiac nodes.

The *anterior thoracic chain* ascends along the internal mammary vessels and drains the anterior chest wall, the anterior and lateral diaphragm and the medial breast. The internal mammary nodes are found in the intercostals spaces along the sternum and are usually present from the fifth intercostals space to the clavicles [1]. This chain, like the posterior one, can also drain inferiorly through the rectus

abdomen's muscle sheath to the sub diaphragmatic and sub peritoneal plexus and forward to the liver and retroperitoneal nodes. There are also connections between left and right anterior thoracic chains.

Both posterior and anterior chains, on the left and on the right side, communicate with the median visceral chain and also with each other by intercostals chains.

The *median visceral chain* is actually represented by lymphatics of intrathoracic organs and within the mediastinum. This median visceral chain gathers together a posterior para-esophageal chain, an anterior chain along the phrenic nerves and the most important, a median tracheobronchial chain that drains essentially the lung, but also the heart and the esophagus, better known by surgeons through the TNM classification used mainly for lung cancer.

Anatomic studies performed in the last decades [3] identified more clearly the lymphatic chains within the mediastinum, as it follows:

There are three lymphatic chains in the right upper mediastinum:

- Paratracheal lymph node chain corresponding to the stations superior 10R, 4R and 2R; this chain is located in an area bordered by the superior vena cava antero-laterally, the pericardium and the aorta on the left side, right brachiocephalic vein and the mediastinal pleura on the right side and by the trachea posteriorly.
- Tracheoesophageal chain corresponding to the station 3p and it is located in the tracheoesophageal groove.
- Right phrenic nerve chain corresponding to the station 3a located along the right phrenic nerve.

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Received January 27, 2014; **Accepted** February 20, 2014; **Published** September 20, 2014

How to cite: Bolca C. Lymphatics of the Mediastinum, Esophagus and Lungs: Thoracic Surgeon's Point of View. Journal of Surgery [Jurnalul de chirurgie] 2014; 10(2): 113-115 DOI: [10.7438/1584-9341-10-2-1](https://doi.org/10.7438/1584-9341-10-2-1).

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There are three lymphatic chains in the left upper mediastinum:

Preaortocarotid chain corresponding to the stations 5 and 6 is located in a triangle formed by the phrenic nerve anteriorly, the vagus nerve posteriorly, pulmonary artery inferiorly, all covered laterally by the mediastinal pleura and with a medial limit represented by ligamentum arteriosum.

Left superior bronchial recurrent chain is corresponding to the stations superior 10L, 4L and 2L. The boundaries are represented by the aortic arch superiorly, left main bronchus inferiorly, anterolaterally by the pulmonary artery and ligamentum arteriosum and medially by the trachea and the esophagus.

Left phrenic nerve chain corresponding to the station 3a located along the left phrenic nerve.

There are three lymphatic chains in the lower mediastinum:

- Inter tracheobronchial chain corresponding to the stations 7, 8, inferior 10R and 10L, located below the carina and bordered laterally by the main bronchi, posteriorly by the esophagus and anteriorly by the pulmonary artery and pericardium.
- A lymphatic chain on each side within the pulmonary ligament is corresponding to station 9
- There are aspects that are not yet clear regarding the limits between the mediastinal lymphatic stations. The limits between stations superior 10 and 4, between 4 and 2, between 5 and 6 or inferior 10 and 7 and 8 are still on debate. This is why, during lymphadenectomy for different thoracic malignancies, it is recommended to remove the entire lymphatic tissue and not only the nodes from different positions.

Esophageal Lymphatics

The lymphatic drainage of the esophagus is mainly longitudinal and intramural than segmental. There are lymphatic plexuses in every esophageal layer but the lymphatic network is abundant in the sub mucosal level and the lamina propria mucosae, and less developed in the muscular layer and in the adventitia. The dense sub mucosal lymphatic layer is uninterrupted and continues with the lymphatic sub mucosal layer of the pharynx and of the stomach. In general the upper two thirds of the esophagus drain cephalic and the lower third drains caudally towards the abdomen. The sub mucous lymphatic vessels are perforating the muscular layer creating connections with lymphatic plexuses at this level, and also with the Para esophageal lymph nodes. This sub mucous network frequently has direct connections with the thoracic duct [4] and also with the anterior phrenic chain [5] and the median tracheobronchial chain.

Standardized lymph node mapping systems were described, and the most frequently used is the one described by American Joint Committee on Cancer for the staging of esophageal cancer. This lymphatic map was developed on the system first described by Casson [6] and it uses the mediastinal node stations described previously for lung cancer [7] with modifications specific to esophageal cancer. These specific modifications are addition of stations from 15 to 20 and division of the station 8 in middle and lower Para esophageal nodes (Figure 1).

It is well known that incidence of lymph nodes metastases in esophageal cancer is influenced by factors such as depth of tumor invasion, tumor location and histology. There are differences (not yet completely elucidated) regarding lymph node spread for adenocarcinoma and squamous cell carcinoma of the esophagus also related with the topography of each of these two histologic types. As adenocarcinoma involves the lower esophageal third, usually drains downward and the squamous cell carcinoma, located in the two upper thirds, drains cephalic.

With a tumor limited to the sub mucosal layer the tumor cells will likely spread craniocaudally along the sub mucosal lymphatic plexus and involve nodes that are far from the tumor, for example cervical nodes. With a tumor that involves the muscular layer the possibility of mediastinal per esophageal nodes involvement is increased. The recent change of TNM classification for the N category is classified by the number of lymph nodes metastases and not the area where they are situated. Apparently, the second presented situation represents a more advanced stage of disease.

Pulmonary Lymphatic's

Even though there are some older descriptions of pulmonary lymphatic's, Rouvière [8] is credited with the first comprehensive description of lung lymphatic system; by selective injection of lymph vessels on 200 human specimens he managed to present the lymph nodes draining each lobe of the lung and he was the first that supposed the possibility of knowing the lymph node involvement based on the origin of the primary tumor. His drawings are still accurate today.

More studies were made in the 50's [9] and the 60's [10]. State of the art regarding description of the thoracic lymphatic system and the patterns of drainage was achieved nowadays by Riquet, who, with a constant interest and a life-long study in this subject, managed to present large and very valuable new information on this subject.

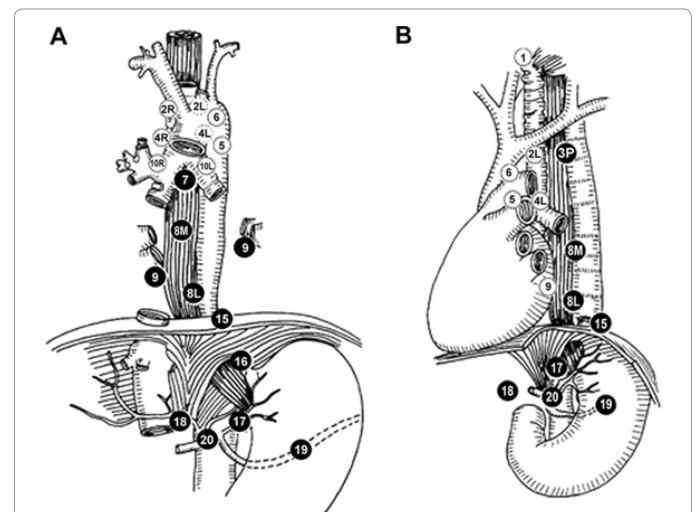


Figure 1: AJCC esophageal staging, nodal designation.

(1) *Supraclavicular nodes* - Above sterna notch and clavicles; (2R) *Right upper paratracheal nodes* - Between intersection of caudal margin of innominate artery with trachea and the apex of the lung; (2L) *Left upper paratracheal nodes* - Between top of the aortic arch and apex of the lung; (3P) *Posterior mediastinal nodes* - Upper paraesophageal nodes, above tracheal bifurcation; (4R) *Right lower paratracheal nodes* - Between intersection of caudal margin of innominate artery with trachea and cephalic border of azygous vein; (4L) *Left lower paratracheal nodes* - Between top of aortic arch and carina; (5) *Aortopulmonary nodes* - Subaortic and para-aortic nodes lateral to the ligamentum arteriosum; (6) *Anterior mediastinal nodes* - Anterior to ascending aorta or innominate artery; (7) *Subcarinal nodes* - Caudal to the carina of the trachea; (8M) *Middle paraesophageal lymph nodes* - From the tracheal bifurcation to the caudal margin of the inferior pulmonary vein; (8L) *Lower paraesophageal lymph nodes* - From the caudal margin of the inferior pulmonary vein to the esophagogastric junction; (9) *Pulmonary ligament nodes* - Within the pulmonary ligament; (10R) *Right tracheobronchial nodes* - From cephalic border if the azygous vein to the origin of RUL bronchus; (10L) *Left tracheobronchial nodes* - Between carina and LUL bronchus; (15) *Diaphragmatic nodes* - Lying on the dome of the diaphragm, and adjacent to or behind the crura; (16) *Paracardial nodes* - Immediately adjacent to the gastroesophageal junction; (17) *Left gastric nodes* - Along the course of the left gastric artery; (18) *Common hepatic nodes* - Along the course of common hepatic artery; (19) *Splenic nodes* - Along the course of splenic artery; (20) *Celiac nodes* - At the base of the celiac artery.

The *lobar and (sub)segmental nodes* (11 to 14) are not figured.

(from Casson AG, Rusch VW, Ginsberg RJ, Zankowicz N, Finley RJ. Lymph node mapping of esophageal cancer. *Ann Thorac Surg.* 1994; 58: 1569-1570 – with permission from Elsevier)

Lymphatic capillaries of the lungs originate in the connective tissue between the alveolar walls and the interlobular, pleural, peribronchial and perivascular sheets [11]. More capillaries form lymphatic collecting vessels called collectors, which contain unidirectional valves and smooth muscle in their walls.

Along their course in the lung or in the mediastinum toward the venous blood circulation, most of the lymphatic collectors flow into lymph nodes which are an important part of the lymphatic system. Those structures form pathways named "lymph node chains" which terminates into the blood circulation by connecting directly with the cervical venous confluence, indirectly via the thoracic duct, or both.

The number, size and location of the lymph nodes along collectors are very variable among individuals and within the same individual. This variability must be remembered during treatment for thoracic malignancies. These lymph node chains can also present anastomoses with neighboring channels [12].

Lymphatics of the lung are represented by a visceral pleural network and a peribronchovascular or parenchymal network. The pleural collectors course over the visceral pleura towards the pulmonary hilum where they anastomose with the parenchymal collectors, or they can go further and enter directly into the mediastinum [13] - a good explanation of skip metastasis. Multiple lymphatic parenchymal channels anastomose with each other and drain sequentially into the intrasegmental, intersegmental, lobar and finally, hilar lymphatic nodes. Here, after anastomosis with the plural collectors they drain into the mediastinum.

Studies performed on lung cancer in various locations within the lung show that nodal pathways are dependent on the lobar origin of the tumor. Malignant lesions on the right upper lobe drain preferentially into the paratracheal lymph node chain and anterior mediastinal lymph nodes. Right middle and lower lobes drains usually into the subcarinal nodes and secondary into the paratracheal lymph node chain and anterior mediastinal lymph nodes. The tumors in the left upper lobe drain more frequently into the preaortocarotid chain and left lower lobe tumors drain into the subcarinal and left superior bronchial recurrent chain.

However, mediastinal metastases may occur in any of the mediastinal lymph nodes regardless the tumor origin, due to multiple connections between lymphatic channels. The hilar nodes also can be bypassed and mediastinal metastases may occur without hilar involvement, aspect that is more often encountered in the tumors involving the upper lobes. Rarely, direct passage from the parenchymal lymphatics and the thoracic duct allows the spread into the systemic circulation of metastatic cells without mediastinal node involvement. Bronchial lymphatics from both lungs usually remain ipsilateral, but they may sometimes connect with the contralateral mediastinum after crossing over at the level of lower trachea and subcarinal space [14].

In conclusion, surgical anatomy and the physiology of the lymphatic system is very important to be known by the surgeons involved in the diagnosis and treatment of thoracic malignancies, as the lymphadenectomy has a crucial role in both to achieve a correct postoperative stage and a complete resection of pathologic tissue. Removal of the lymphatic chains is a must in oncologic surgery of the thorax, even though, there still are gaps in proving the advantages in survival that a complete lymphadenectomy could bring.

Conflict of interest

The author has no conflict of interest to disclose.

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