Anatomy of the Thoracic Duct

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KEYWORDS

• Thoracic duct • Lymphatic capillaries • Vertebra
• Cisterna chyli

ANATOMY OF THE THORACIC DUCT

The thoracic duct is a major anatomic structure of the upper part of abdomen, chest, and the lower part of the neck. A precise knowledge of the anatomy of the duct is essential in the safe performance of any surgical procedures involving these areas.

Lymphatic capillaries are joined from the most remote parts of the interstitium by tissue channels, many of which are only a few tens of microns long. These channels form collecting systems that are many centimeters long and drain lymph from the initial lymphatic capillary into the venous system.[1] Lymphatic capillaries consist of single layers of flat endothelial cells, which are slightly larger and thinner than blood capillary cells. Basement membrane is absent or vestigial, which allows large molecules to permeate the wall easily.[2] Because of their greater permeability lymphatic capillaries are more effective than blood capillaries in removing protein-rich fluid from the intercellular spaces.

When the collected fluid enters the lymphatic vessels, it is called lymph. The lymphatic vessels also serve to transport proteins and lipids that are too large to cross the fenestrations of the absorptive capillaries of the small intestine. Before returning to the blood, lymph passes through lymph nodes, where it is exposed to the cells of the immune system.[3] The lymphatic vessels merge to create the thoracic duct, which drains the lymph toward the venous system at the base of the left part of the neck at a volume estimated to be 1.38 mL/kg of the body weight per hour.[4] Because of this large volume of lymph, understanding the complex anatomy of the thoracic duct is key to preventing traumatic chylothorax.

EMBRYOLOGY

The lymphatic system begins forming in the human embryo during the sixth week of development when the embryo is about 10 mm in length. These first lymphatics are blunt buds, which are located near the internal jugular veins at the root of the neck.[5] At the end of the embryonic period, there are 6 primary lymph sacs: 2 jugular lymph sacs, 2 iliac lymph sacs, 1 retroperitoneal lymph sac, and 1 cisterna chyli (**Fig. 1**). Lymphatic vessels develop in a manner similar to blood vessels and join the lymph sacs.[6] Linkage of the jugular lymph sacs with the cisterna chyli, the abdominal origin of the thoracic duct, is initially in the form of a bilateral system of lymphatic trunks, connected with one another across the midline by numerous collateral anastomoses. Of these trunks, the inferior portion of the right trunk and the superior portion of the left trunk, together with a diagonal anastomosing channel at the level of T4-T6 segments, forms the definitive thoracic duct[7]; the rest of the ducts regress with time. Except for the superior part of the cisterna chyli, the lymph sacs are transformed into groups of lymph nodes during the early fetal period.[6] The uppermost lymph node to form is generally called the Virchow node and is located at or near the jugulosubclavian venous junction.[8]

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Thorac Surg Clin 21 (2011) 229–238
doi:10.1016/j.thorsurg.2011.01.002

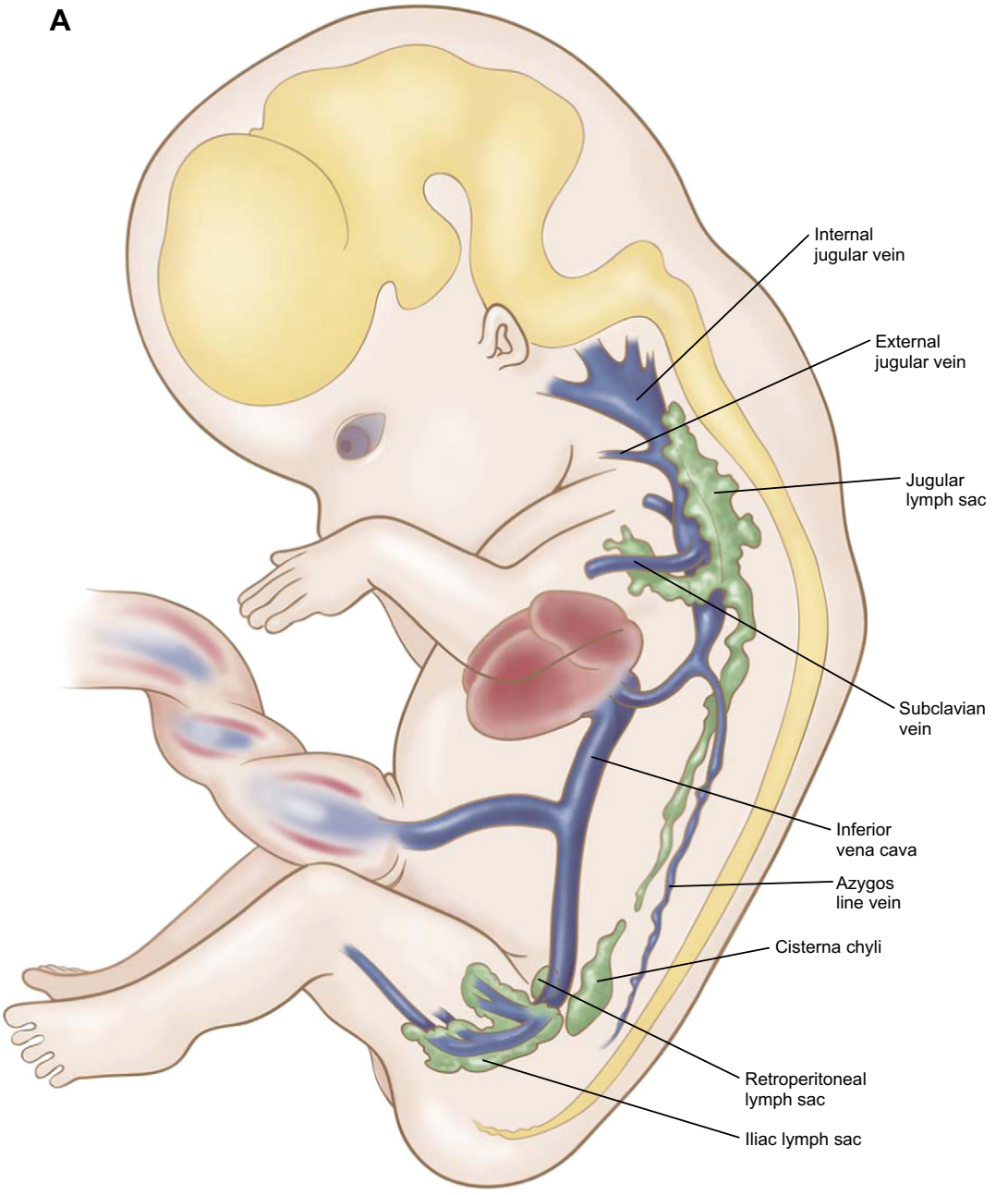

Fig. 1. Development of the lymphatic system. (*A*) Left side of an 8-week embryo showing the primary lymph sacs. (*B*) Ventral view of the lymphatic system at and after 9 weeks' gestation, showing the paired thoracic ducts and the regression of the left duct. *(Adapted from* Moore KL, Persaud TVN. The developing human. 7th edition. Philadelphia: WB Saunders; 2003; with permission.)

CISTERNA CHYLI AND ABDOMINAL LYMPH TRUNKS

The 4 main abdominal lymph trunks converge to form an elongated arrangement of channels referred to as the abdominal confluence of lymph trunks or the cisterna chyli (see **Fig. 1**). To further complicate matters, this group of channels may have a simple ductlike structure or may be duplicated, triplicated, or plexiform.[9] A fusiform area of dilatation in the lymphatic channels, which extends 5 to 7 cm in the caudocephalad direction,

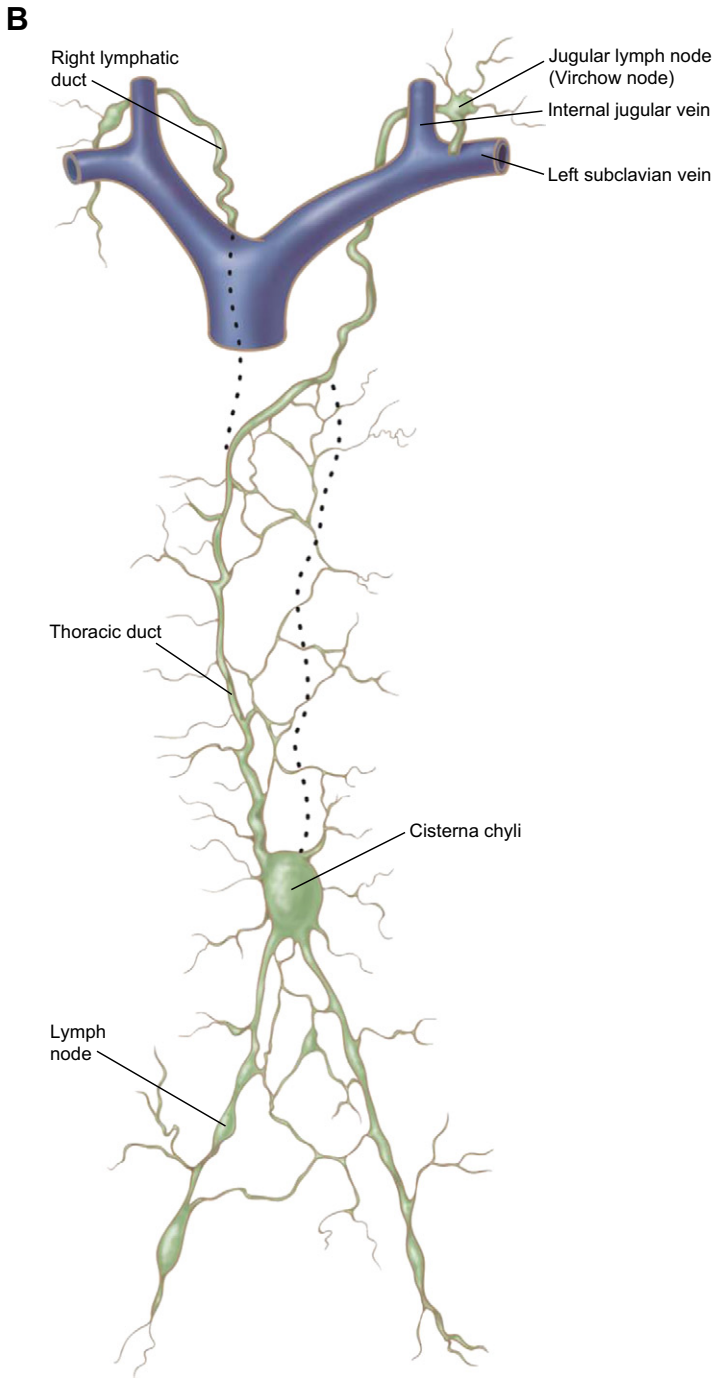

Fig. 1. (*continued*)

has been reported in 53% of lymphangiographic studies,[10] 50% of autopsies,[11] and 15% of abdominal magnetic resonance imaging studies.[12]

The cisterna chyli is generally found along the vertebral column at the L2 level, but it may also be found anywhere between T10 and L3, generally to the right of the aorta.[4] The medial edge of the right crus of the diaphragm lies anterior to the abdominal confluence of lymph trunks. The confluence receives the right and left lumbar trunks and the intestinal lymph trunks.[9] The right and left lumbar trunks deliver lymph from the abdominal

wall below the levels of navel, pelvis, kidneys, and adrenal glands. The intestinal trunk receives lymph and chyle from the parts of the gastrointestinal tract supplied by the celiac and superior mesenteric arteries. The intercostal trunks either enter the upper part of the cisterna chyli or empty directly into the origin of the thoracic duct.[13] The lymph accumulated in the cisterna chyli is suctioned upward in the chest through the thoracic duct.

The intimate relationship of the cisterna chyli and abdominal lymph trunks with the abdominal aorta may lead to injury during aortic surgery, particularly during dissection performed around

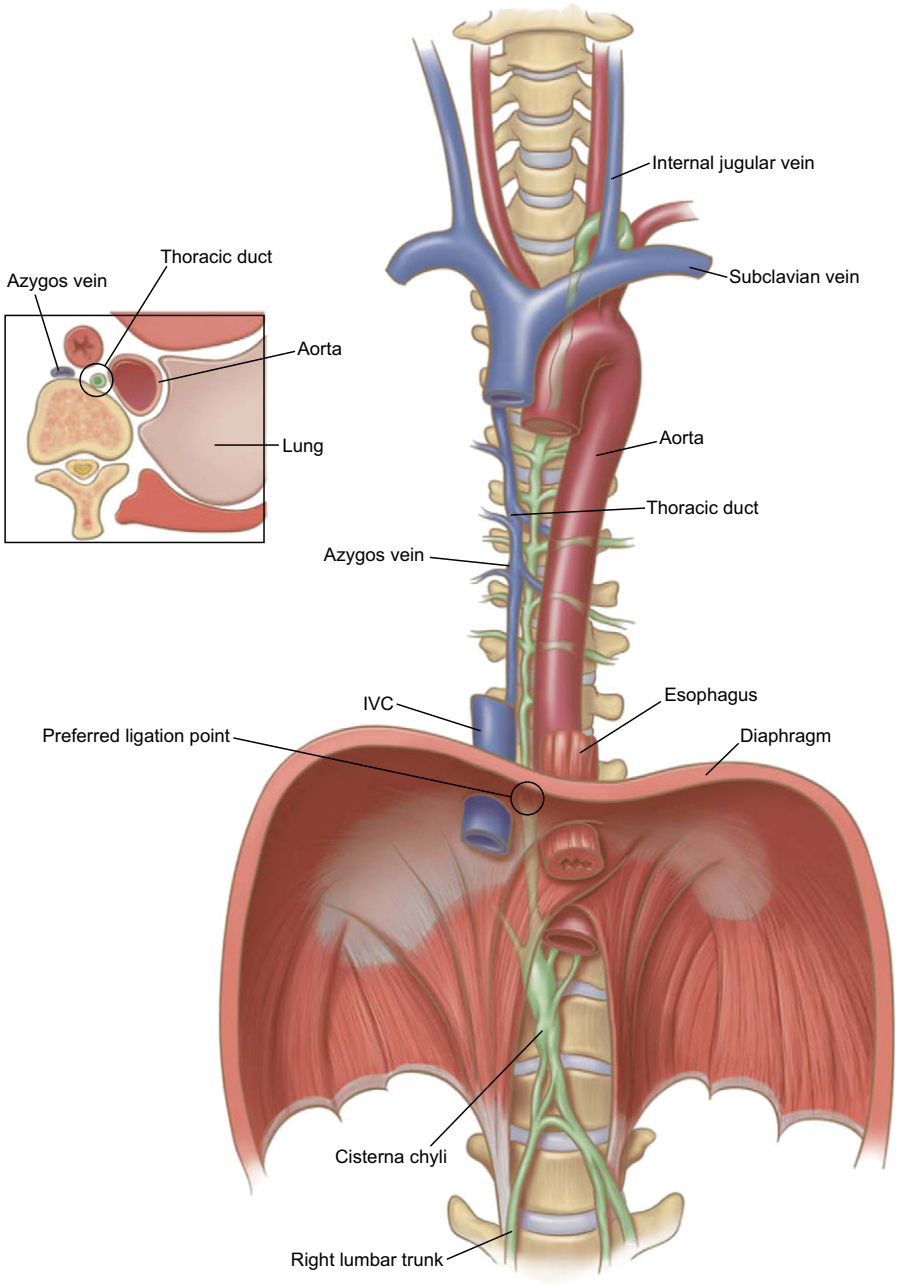

Fig. 2. Surgical anatomy of thoracic duct showing the preferred point of thoracic duct mass ligation in the surgical treatment of chylothorax. IVC, inferior vena cava.

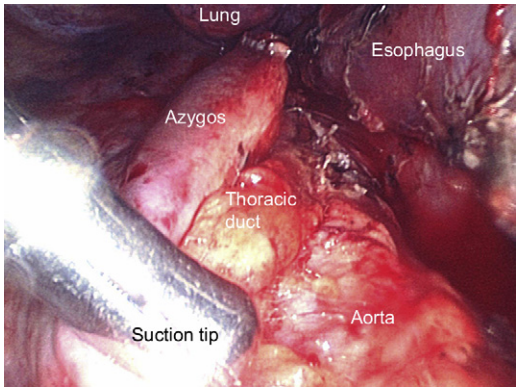

Fig. 3. Location of the thoracic duct in midthoracic cavity after division of the azygos vein during a minimally invasive esophagectomy (the esophagus has been mobilized interiorly in this figure).

the aorta above the level of the celiac axis. The large caliber of the trunks coupled with the volume of lymph flowing through them can lead to problematic chylous (lymphatic) ascites.[9]

THORACIC DUCT

The thoracic duct is the largest lymphatic channel in the body, measuring 38 to 45 cm in length and 2 to 5 mm in diameter. It extends from L2 to the base of the neck (**Fig. 2**). This duct collects lymph from the entire body except from the right sides of the head and neck, right upper hemithorax, and the right upper extremity that are mainly drained by the right lymphatic trunk.[13]

The thoracic duct contains a well-developed basement membrane and has 3 layers within its wall: intima, media, and adventitia. The media consists of smooth muscle fibers supported by connective tissue containing elastic fibers, which contract periodically to aid the lymph flow. The thoracic duct and all lymphatic channels, except the smallest ones, have valves. These valves are more numerous and closer together than the valves of veins. The valves are so close that a distended lymphatic vessel may appear beaded because of dilated sections between the valves.[2]

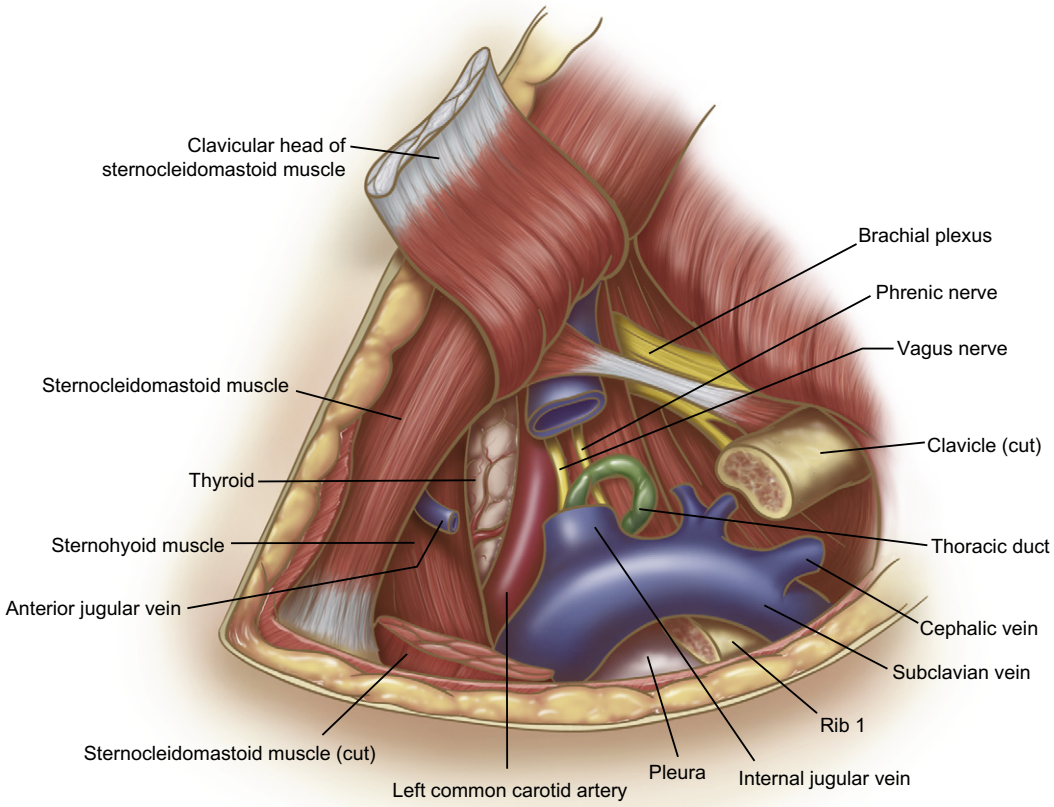

Fig. 4. Termination of the thoracic duct. Note the thoracic duct curving anteriorly to drain into the junction between the internal jugular and left subclavian veins.

The origin of the thoracic duct starts at the superior pole of the cisterna chyli, traverses the aortic hiatus of the diaphragm (see **Fig. 2**), and then ascends the posterior mediastinum, to the right of the midline, between the descending thoracic aorta on the left and the azygos vein on the right (**Fig. 3**). The vertebral column and the right intercostal arteries lie posterior to the thoracic duct. The diaphragm and esophagus are anterior. A recess of the right pleural cavity may separate the duct and the esophagus.

At the T5 level, the duct gradually inclines to the left, enters the superior mediastinum, and ascends toward the thoracic inlet along the left edge of the

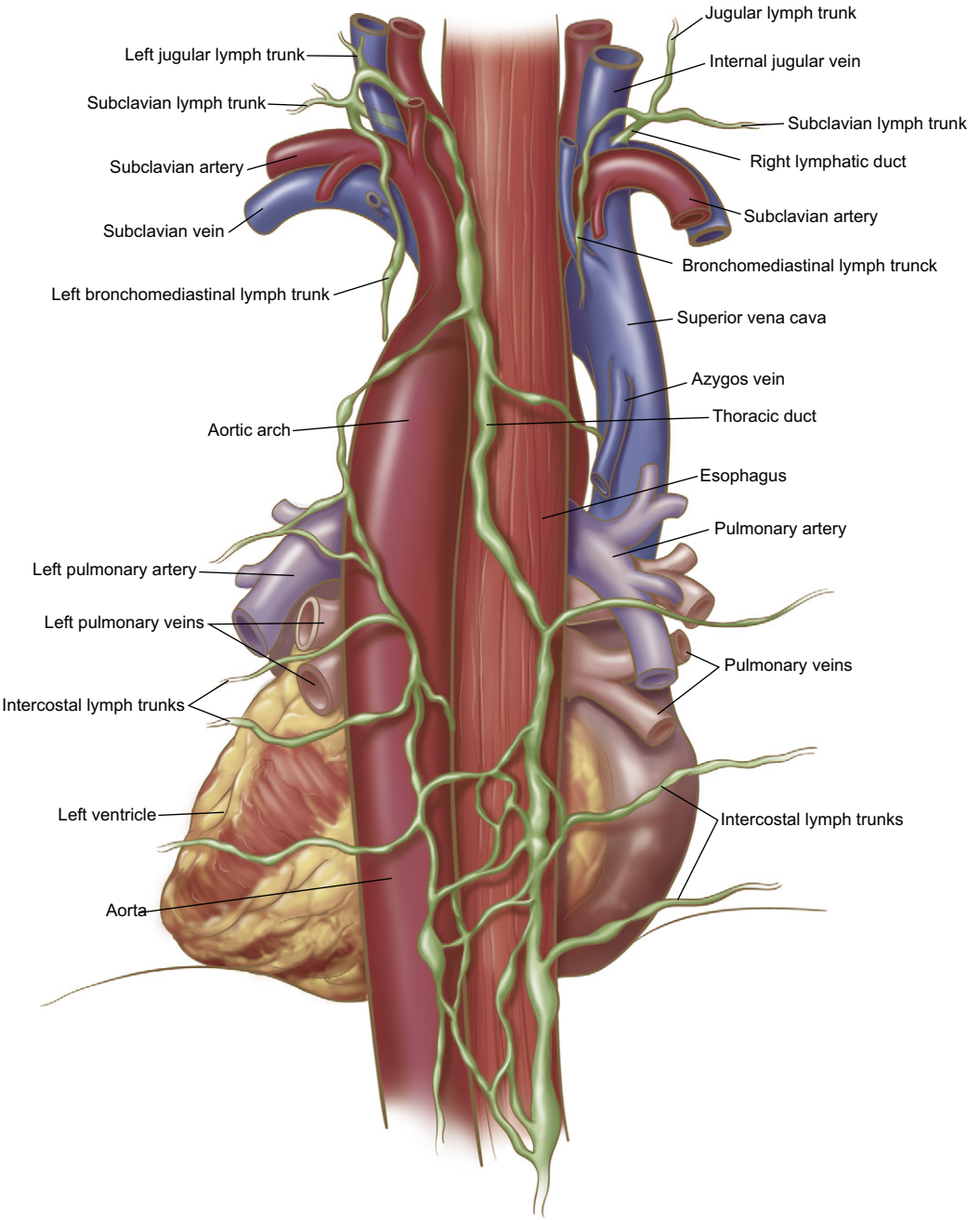

Fig. 5. Posterior view of the thoracic duct and its tributaries Note that the remnant of the right lymphatic duct in the neck forms from the union of 3 lymphatic trunks: right jugular, right subclavian, and right bronchomediastinal trunks.

esophagus. In this part of its course, the duct is first crossed anteriorly by the aortic arch and then runs posterior to the initial segment of the left subclavian artery, in close contact with the left mediastinal pleura. Passing into the neck, the thoracic duct arches laterally at the level of the transverse process of the C7 vertebra. Its arch rises 3 or 4 cm above the clavicle (**Fig. 4**). The duct passes posterior to the left common carotid artery, vagus nerve, and internal jugular vein. Finally, the duct descends anterior to the first part of the left subclavian artery, and after receiving branches from the left sides of the head and neck and from the left upper limb, it most commonly ends by opening into the junction of the left subclavian and internal jugular veins. The duct may also open into either of the great veins, near the junction, or it may divide into several smaller vessels, each terminating individually in the venous system.

The thoracic duct is 0.5 cm in diameter at its abdominal origin. It diminishes in caliber at the midthoracic level but grows to 0.5 cm again before its termination into the jugular vein.[9] The thoracic duct is dilated in several clinical conditions, such as cirrhosis with portal hypertension and right-sided heart failure.[14–17]

Although the diameters of the common bile duct and the pancreas increase during aging, the diameter of the thoracic duct does not seem to do so.[18]

Several tributaries join the thoracic duct at various places along its length (**Fig. 5**). Bilateral descending thoracic lymph trunks from intercostal lymph nodes of the lower 6 or 7 intercostal spaces on both sides traverse the aortic hiatus and join the lateral aspects of the thoracic duct in the abdomen immediately after its origin. Bilateral ascending lumbar lymph trunks from the upper lateral aortic nodes ascend and pierce their corresponding diaphragmatic crura and then join the thoracic duct at various levels within the thorax.

The upper intercostal trunks drain the intercostal nodes in the upper 5 or 6 left intercostal spaces. The left subclavian trunk usually joins the thoracic duct but may open independently into the left internal jugular vein. The left bronchomediastinal trunk occasionally joins the thoracic duct as well but usually has an independent venous opening.[9]

Some thoracic duct tributaries may directly drain lymph from an organ without crossing any lymph node along their course (anodal route). This anodal route has been observed for the diaphragm, the esophagus, and the lower lobes of the lungs.[19] Direct lymphatic drainage of the

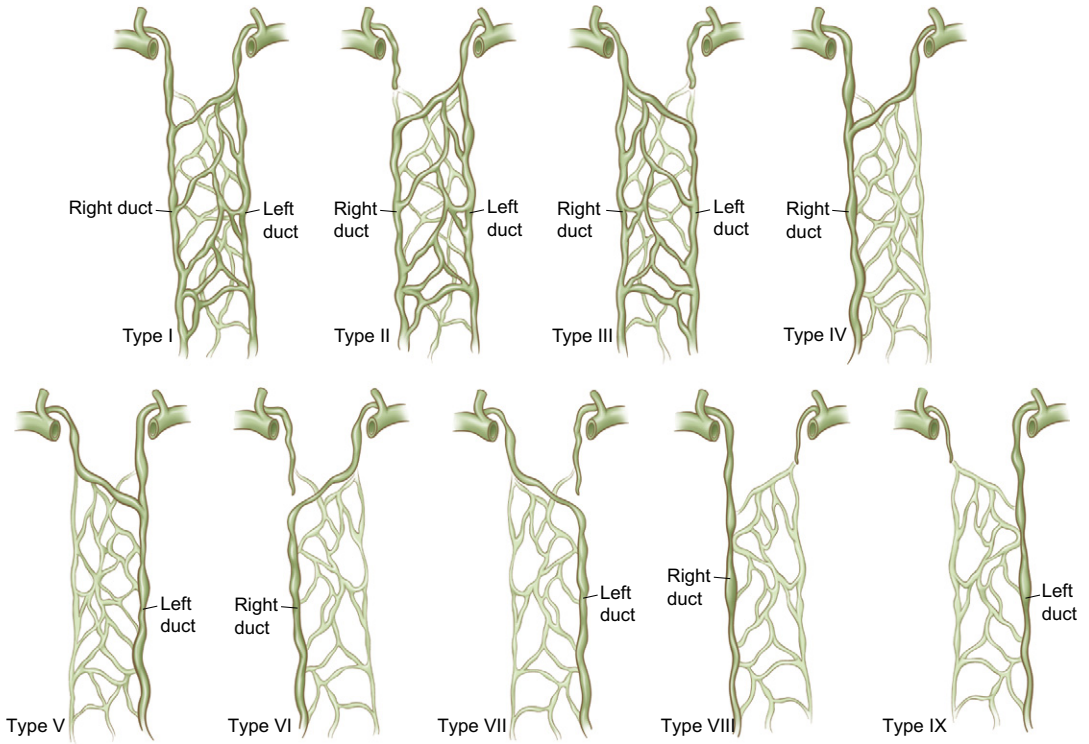

Fig. 6. Variations in the development of the thoracic duct. The most common types are Type VI at 63% and Type II at 27%. (*Adapted from* Davis HK. A statistical study of the thoracic duct in man. Am J Anat 1915;17:211–44; with permission.)

esophagus into the thoracic duct has also been identified macroscopically in as many as 19.8% to 22.7% of cadavers.[20–22] The drainage pattern may play an important role in the prognosis of cancers involving these organs and may help explain the poor prognosis of esophageal cancer and the possibility of distant metastases in non–small cell lung cancer, even when there is no lymph node involvement.

RIGHT LYMPHATIC TRUNK

The right lymphatic trunk in the neck typically forms from the union of 3 lymphatic trunks: right jugular, right subclavian, and right bronchomediastinal trunks (see **Fig. 5**). The right bronchomediastinal trunk is regarded as the vestigial portion of the cranial segment of the embryologic right thoracic duct. It receives lymphatic drainage from the right lung, lower part of the left lung, and right side of the diaphragm; most of the drainage from the heart; and some drainage from the right lobe of the liver.[13] The right lymphatic trunk has a variable anatomy, including a doubling of the duct and left-sided, right-sided, or bilateral termination.

ANATOMIC VARIATIONS OF THE THORACIC DUCT

Although a thorough understanding of the anatomy of the thoracic duct is essential when performing procedures within the thoracic cavity to prevent the complication chylothorax, the "textbook" anatomy of the thoracic duct is found in only 50% of individuals. In the other 50% of cases, the thoracic duct anatomy may vary considerably.

Variations in Origin

As described earlier, the right and left lumbar lymphatic trunks arise from several roots and converge to form the thoracic duct. The junction lies between L2 and T12 vertebrae. A cisterna chyli is present when the junction is low at the level of the lumbar vertebral bodies. When the junction is higher than the 12th vertebra, there may be dilation of both lumbar trunks, which perhaps represents the unfused lateral primordia of the cisterna, or there may be no trace of a cisterna. A cisterna is present in about 50% of adults examined.[7]

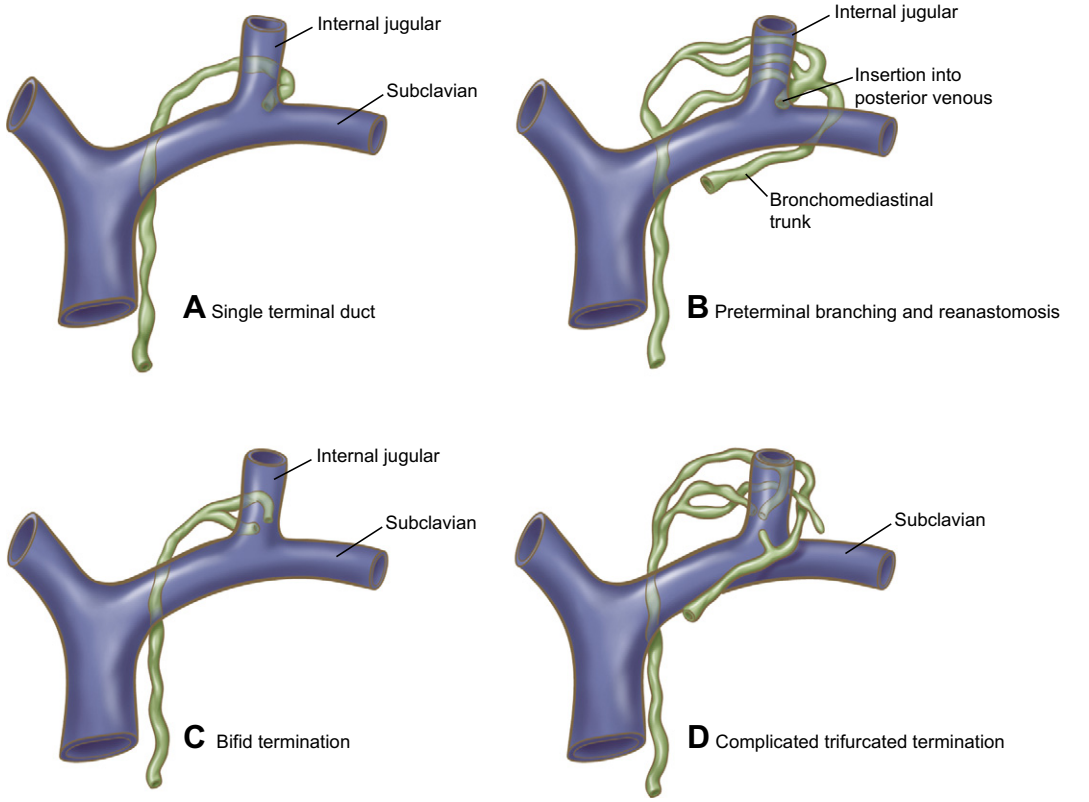

Fig. 7. Variations in termination of the thoracic duct. (*A*) Typical termination of the thoracic duct (single terminal duct). (*B*) Preterminal branching and reanastomosis of the thoracic duct. (*C*) Bifid termination. (*D*) Complicated trifurcated termination.

Variations in Anatomy

In 1915, Davis[11] first proposed 9 types of anatomic variations of the thoracic duct (**Fig. 6**). These variations depend on which portion of the embryonic thoracic duct atrophies and disappears and which portion continues to develop. In the anatomic study by Davis, which was based on the dissection of 22 cadavers, it was found that the most frequent anatomic variation of the thoracic duct is a doubling of the lower part of the duct caused by the persistence of both right and left trunks. Even when a single trunk has formed, the contralateral trunk is usually not completely absent and is connected by numerous cross-anastomoses to the main trunk. In addition, the thoracic duct may itself break into a plexus of lymphatic vessels, which reunite to form a single channel higher in the thorax.[7] In a larger series, the incidence of doubling was reported between 39% and 47%.[4] Complete bilateral thoracic ducts with coexistent persistent left superior vena cava[23] and termination of the thoracic duct in the azygos system are some examples of rare variations reported in the literature.[4]

Variations in Termination

The thoracic duct empties into the left great veins of the neck in 92% to 95% of cases, on the right side of the neck in 2% to 3% of cases, and bilaterally in 1.0% to 1.5% of cases.[24] The duct can have a superior extension above the clavicle, as much as 5 cm in 8.3% of cases, that predisposes it to surgical damage.[25] The thoracic duct terminates in the venous system as a single vessel in 68% to 87.5% of cases, as 2 ducts in 8.33% to 25% of cases, and as 3 terminal branches in 4.2% to 7% of cases (**Fig. 7**).[13,25] In about 20% of cases, thoracic ducts show branching and reanastomosing patterns before termination.[25]

The final termination patterns of the thoracic duct vary greatly. According to different observers, the final drainage site of the terminal branches of the thoracic duct is the junction of the left subclavian and internal jugular veins in about 7.5% to 64.3% of cases, the internal jugular vein in 4.8% to 85% of cases, the external jugular vein in 7.1% to 28% of cases, and the subclavian vein in 3.6% to 57.1% of cases.[9,13,25–28]

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