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Thoracic duct variations may complicate the anterior spine procedures

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Abstract The aim of this study is to localize and document the anatomic features of the thoracic duct and its tributaries with special emphasis on the spinal surgery point of view. The thoracic ducts were dissected from nine formaldehyde-preserved male cadavers. The drainage patterns, diameter of the thoracic duct in upper, middle and lower thoracic segments, localization of main tributaries and morphologic features of cisterna chyli were determined. The thoracic duct was detected in all cadavers. The main tributaries were concentrated at upper thoracic (between third and fifth thoracic vertebrae) and lower thoracic segments (below the level of ninth thoracic vertebra) at the right side. However, the main lymphatic tributaries were drained into the thoracic duct only in the lower thoracic area (below the level of the tenth thoracic vertebra) at the left side. Two major anatomic variations were detected in the thoracic duct. In the first case, there were two different lymphatic drainage systems. In the second case, the thoracic duct was found as bifid at two different levels. In formaldehyde preservation, the dimensions of the soft tissues may change. For that reason, the dimensions were not discussed and they may not be a guide in surgery. Additionally, our study group is quite small. Larger series may be needed to define the anatomic variations. As a conclusion, anatomic variations of the thoracic duct are numerous and must be considered to avoid complications when doing surgery.

Keywords Thoracic duct · Anatomy · Spine surgery · Complication · Variation

Introduction

The thoracic duct is the primary lymphatic vessel and it collects the lymphatic fluid from all the minor lymphatic vessels. Its distal dilated origin is known as cisterna chyli and it is usually located on the anterior surface of the first or second lumbar vertebra. It extends superiorly and usually drains into the left subclavian vein [3, 7]. Thoracic duct injury and chylous leakage is a rare complication in spine surgery. However, lymphatic injury after spinal operations [10, 12, 17] or blunt abdominal traumas [1] have been reported. Although the anatomic variations of the main trunk of the thoracic duct and its tributaries are well documented for thoracic surgery [13], the importance of the anatomic features for spinal operations is not sufficiently emphasized. Some radiographic methods were described in English literature to visualize the thoracic lymphatic system like sonography [18], computerized tomography [4], magnetic resonance lymphography [16] and magnetic reso-

nance imaging [2, 11]. These methods are not useful in practice. For that reason, the surgeon who wants to perform anterior surgery should notice the lymphatic system.

The aim of this study is to localize and document the anatomic features of the thoracic duct and its tributaries with special emphasis on the spinal surgery point of view.

Materials and methods

The thoracic ducts were dissected from nine formaldehyde-preserved male cadavers. The subjects were placed in supine position. Chest wall was opened with bilateral incision at the medial axillary line. The two clavicles were disarticulated and diaphragmatic attachments were freed. The incision was extended to the iliac wings and both the anterior chest wall and the abdominal wall were removed. Thoracic and abdominal organs were removed with fine dissection. Vascular structures were left intact and retracted.

The drainage patterns, diameter of the thoracic duct at the level of the 5th thoracic (midpoint of the fifth thoracic vertebral body), the 9th thoracic (midpoint of the ninth thoracic vertebral body) and the 12th thoracic vertebrae (midpoint of the 12th thoracic vertebral body), localization of main tributaries and morphologic features of cisterna chyli were determined. The position of thoracic duct with respect to the vertebra and relationships with the azygos vein were ascertained. Mean values, medians and quartiles were calculated as descriptive measures to define variations.

Results

The thoracic duct was detected in all cadavers. The main tributaries were located in upper thoracic (between the third and fifth thoracic vertebrae) and lower thoracic (between the 9th and 12th thoracic vertebrae) segments at the right side. However, the main lymphatic tributaries were drained into the thoracic duct only in the lower thoracic area at the left side. Localization of the main tributaries is shown in Table 1.

The mean diameter of the thoracic duct at the 5th, 9th and 12th thoracic vertebrae was 2.3 ± 0.8 mm, 2.6 ± 0.8 mm and 3.3 ± 0.6 mm, respectively.

In eight of the nine cases, the thoracic duct was located in the midline at the thoracolumbar junction level, while in one case it looked like as if the duct had covered the right and left sides of the spine like a web. In six of these eight cases, the duct was tending to rotate to the left side at the levels between the fourth and seventh thoracic vertebrae. However, the thoracic duct was passed to the left side at or below the tenth thoracic vertebra in two cases. In these cases, it was found that the duct was placed on the left side of the vertebrae at the middle and upper thoracic segments. In one case, thoracic duct had covered both the right and left side of the spine.

Table 1 Localization of thoracic duct tributaries according to the vertebral levels

	Localization of tributaries	
	Right	Left
1	T5, T9	T7–8[a], T10, T11–12[a]
2	T5	T10, T10–11[a], T12
3	T4–5[a], T5, T9–10[a], T10	–
4	T4	T10, T11, T12
5	T3–4[a], T11–12[a], T12	T10, T10–11[a]
6	T9, T10-11[a], T11, T11[b]	T10-11[a] ,T11-12[a]
7	T4, T10, T11–12[a]	T7, T10–T11[a]
8	T9, T10–11[a], L1	T4, T11, T11–12[a], L1
9	–	T10

T Thoracic, *L* Lumbar
[a]Tributaries were located at the intervertebral disc level
[b]Two tributaries were found at the same vertebral level

Cisterna chyli was detected in eight of the nine cases. The mean diameter of cisterna chyli was 7.1 ± 2.0 mm and the mean length was 16.9 ± 3.3 mm. Three lymphatic vessels had formed the cisterna chyli. It was located in the 12th thoracic and the 1st lumbar vertebra in seven cadavers. In one case, cisterna chyli was found to be more caudally and it was extended to the inferior endplate of the third lumbar vertebra. In one of these nine cases, cisterna chyli was not detected.

The thoracic duct was found between the aorta and the azygos vein. It was superficial according to the azygos vein, but in one case a main tributary was turned around (had surrounded) the vein and was placed between vertebral body and the azygos vein.

Two major anatomic variations were detected in the thoracic duct. In the first case, there were two different lymphatic drainage systems. Left ascending branches had formed the main duct and this vessel had formed the ring shape in the middle thoracic segments. Inferior and right tributaries had joined at the thoracolumbar junction and formed the right ascending trunk. A thick lymphatic branch originating from the posterior wall of the thorax was detected at the level of the ninth thoracic vertebra. This major branch joined with the right trunk. These two drainage systems of the lymphatics covered the vertebral bodies between the 7th and the 12th thoracic vertebrae. The two systems had joined and formed a single thoracic duct above the fifth thoracic vertebra (Fig. 1a, b). Cisterna chyli was not observed in this case. In the second case, the thoracic duct was found as bifid at two different levels. It was looped and formed as a

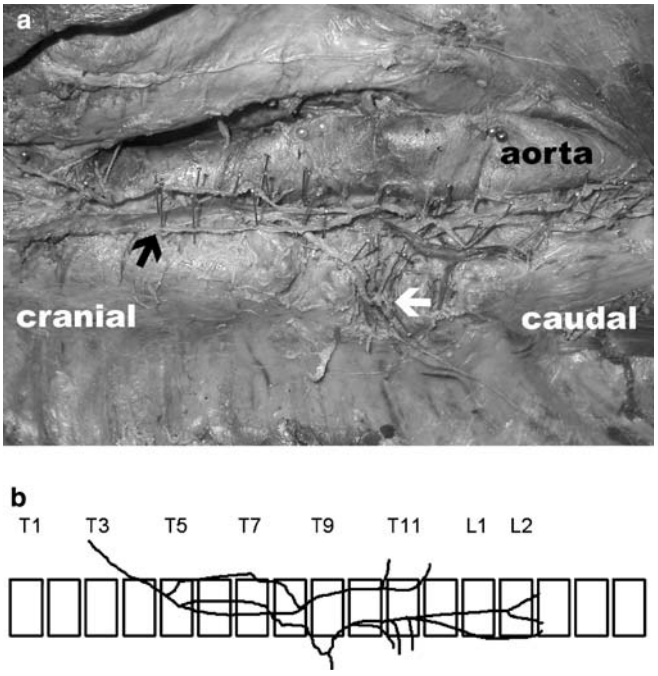

Fig. 1 The photograph (**a**) and the schematic diagram (**b**) of the double lymphatic drainage system. *White arrow* in Fig. 1a indicates the thick branch originating from the posterior chest wall. *Black arrow* indicates one of the main trunks, which was damaged during dissection. Note that the lymphatic system covers the inferior thoracic spine

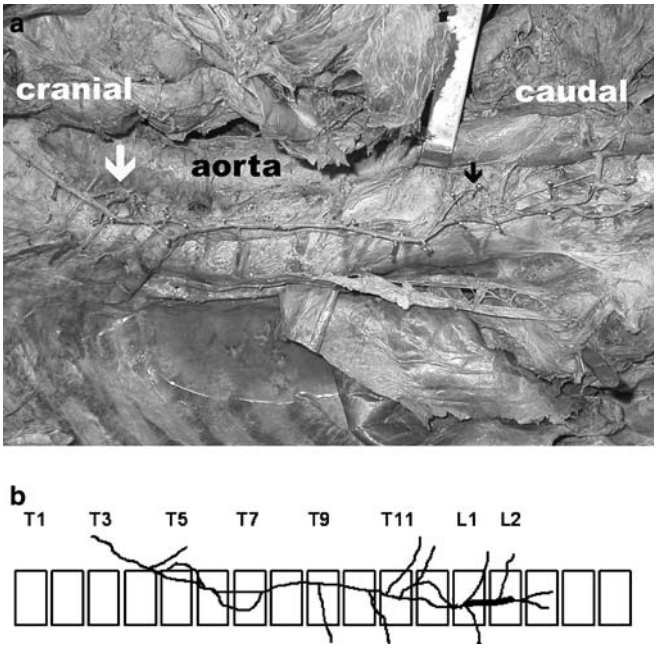

Fig. 2 The thoracic duct with ring formation and its tributaries can be seen on the photograph (**a**) and the diagram (**b**). *White and black arrows* in Fig. 2a show the lymphatic network at the upper and lower thoracic segments

ring shape at the upper thoracic segments and the thoracolumbar junction (Fig. 2a, b).

The thoracic duct was drained into the left subclavian vein in all nine cadavers.

Means, medians and quartiles of the thoracic duct diameter and cisterna chyli measurements are shown in Table 2.

Discussion

The thoracic duct is the main collecting vessel of the lymphatic system. It drains three-quarters of the lymph in the body into the venous bloodstream. Classically, the duct originates from the cisterna chyli, which is usually located at the level of the first and the second lumbar vertebrae. It enters the thoracic cavity via the aortic hiatus and ascends between the aorta and the azygos vein. In the thorax, the thoracic duct lays on the anterior surface of the vertebral bodies and drains into the junction of the left subclavian internal jugular veins [3]. However, there may be considerable anatomic variations of the thoracic duct [7, 8, 13, 15, 16].

Chyle is generated in the lymphatic system of the small intestine as a product of fat digestion and transported via the cisterna chyli to the thoracic duct. Thoracic duct and cisterna chyli injuries may cause chylous leakage which is manifested clinically as a chylothorax or chyloperitoneum. Treatment of chylous leakage should be directed toward a decrease in the formation of chyle through a low-fat diet, drainage of the fluid and adequate supportive therapy. If the drainage does not cease, or if the patient shows signs of metabolic complications, an operation is recommended to find the source of the leakage [14].

Thoracic duct injuries are not common. It is reported after blunt abdominal traumas [1], vertebral fractures [17] or as an iatrogenic complication following anterior spine surgery [6, 9, 10, 12, 14] or cervical dissectomies [5]. The variable anatomic course of the thoracic duct has been reported as the reason for its injuries associated with spinal lesions [17]. The real frequencies of the thoracic duct injuries may have been underestimated because some of them were considered as asymptomatic [9]. However, chylous leakage in the thoracic cavity may complicate the primary disease and the treatment period might be prolonged.

Although the anatomical variations of the thoracic duct has been described in detail in the large series in the literature [7, 13], its importance for the anterior thoracolumbar spine exposures was not stressed. Riquet et al. performed an anatomical study on 530 cadavers to identify the tributaries from intrathoracic organs to the thoracic duct. They observed the main

Table 2 Means, medians and quartiles of the thoracic duct and cisterna chyli measurements

	Mean (mm ± SD)	Median (mm)	25th percentiles	50th percentiles	75th percentiles
Thoracic duct at T5 level	2.3 ± 0.8	2.1	1.8	2.1	2.9
Thoracic duct at T9 level	2.6 ± 0.8	2.3	2	2.3	3.2
Thoracic duct at T12 level	3.3 ± 0.6	3.6	2.7	3.6	3.9
Length of cisterna chyli	16.9 ± 3.3	15.8	14.5	15.8	18.4
Diameter of cisterna chyli	7.1 ± 2.0	6.4	5.4	6.4	8.7

SD Standard deviation

tributaries from the right lung, left lung, the heart, the esophagus and the diaphragm. All tributaries were detailed and grouped according to the visceral organs [13]. Although this excellent study was performed in a large group and the tributaries were defined in detail, anatomic properties of the main trunk and localization of the tributaries according to the vertebrae were not identified. In our study, connection of tributaries to the main trunk was recorded according to the vertebral levels. On the right side, the tributaries were concentrated at the upper thoracic segments and thoracolumbar junction. Nevertheless, the lymphatic tributaries were located between the 7th and the 12th thoracic vertebrae at the left side. Left thoracotomy is the generally preferred method for reaching the spine. For that reason, this tributary concentration at the left side may complicate the left thoracotomy at lower thoracic segments. The surgeon should be aware of the anatomic variations.

Jdanov has described the anatomic variations of the thoracic duct, main tributaries, cisterna chyli and the drainage patterns. In his study, five different types of thoracic duct were described. All types were located at the midline or slightly left side and only one main drainage system was defined [7]. In our study, two different anatomic variations were found, one of which was not published previously. In the first case, there were two different drainage systems and the cisterna chyli was not present. The tributaries and the main trunks had covered the spine at the lower thoracic segments. In the second case, the thoracic duct was bifid and had formed a ring shape around the vertebrae. In these cases, the ducts were found at unusual locations. Due to these variations, the thoracic duct may become more vulnerable unless the surgeon keeps it in mind.

There are some drawbacks and limitations in our study. Firstly, formaldehyde-preserved cadavers were used for dissection. In formaldehyde preservation, the dimensions of the soft tissues can change. For that reason, the dimensions were not discussed in the study and they may not be a guide in surgery. Secondly, our study group is quite small. Larger series may be needed to define the anatomic variations. However, thoracic and lumbar viscera can be damaged after thoracic duct dissection and these organs cannot be used for further studies. On the other hand, it is very hard to find a cadaver in our country because of social and cultural reasons.

As a conclusion, a thorough understanding of the anatomy of the thoracic duct is essential to prevent the complication of chylothorax. Anatomic variations of the thoracic duct are numerous and must be taken into account to avoid complications when doing surgery.

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