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ANATOMICAL VARIATIONS OF THE THORACIC DUCT: A PRELIMINARY REPORT IN ADULT AND FETAL SPECIMENS

M. Amore, R. Bernárdez, R. Enríquez, S. Granja, H. Romeo

Laboratory of Vascular Anatomy (MA) and Laboratory of Cadaveric Processing and Biosecurity (RB,RQ,SG), III Chair of Anatomy, Faculty of Medicine, University of Buenos Aires, and Laboratory of Animal Models and Experimental Microsurgery (MA,HR), School of Medicine, BIOMED UCA-CONICET, Pontifical Catholic University of Argentina, Buenos Aires, Argentina

ABSTRACT

The study aim is to evaluate anatomical variations of the thoracic duct using a specialized sequential injection procedure. The different types, frequencies, and anatomical topography were recorded and evaluated using 12 adult and 16 fetus specimens. By employing a perfusion pump device, cadavers were sequentially perfused with acrylic colored latex first through the internal marginal vein, then the thoracic duct at the interazygous-aortic recess, and finally through the posterior tibial artery. After perfusion, thoracic ducts were identified, partially dissected, and cadavers fixed by soaking in an aqueous solution of 5% formalin (v/v). Finally, further dissection and detailed photography were performed. Plexus shapes at different levels were clearly evident in 80% of the adult specimens. Whereas the presence of the cisterna chyli was detected in 100% of fetuses as an ampule dilatation at the beginning of the thoracic duct, in only one adult specimen was a dilatation found at the lumbar lymphatic trunk level. Functionally it is not known whether these modified anatomical features (plexus shapes) have served to compensate (as a derivative pathway) for lymphatic hypertension in life as a reflection of lymphatic system challenges and subsequent growth in the adult specimens.

Keywords: thoracic duct, cisterna chyli, derivative pathways, sequential perfusions

Normally the flow of chyle originates in the chyliferous vessels of the ileum/jejunum and flows through sequentially bigger lymphatic vessels to the cisterna chyli and the thoracic duct, eventually ending in the venous circulation through the left jugular-subclavian venous junction.

The thoracic duct is a part of the main lymphatic collector system. It transports between 2 and 4 liters of systemic lymph plus chyle daily. The duct is formed by the union of two lumbar lymph trunks and the gastrointestinal lymph trunk at the level of the lumbar vertebrae I and II. The dilated ampulla, resulting from this union, is named the cisterna chyli (also known as the cistern or reservoir of Pecquet after its discoverer) (1). The white lymph fluid filled with chyle joins with interstitial systemic lymph in the cisterna chyli and from there is no longer milky white, but turns an opalescent color.

The thoracic duct ascends to the posterior mediastinum and at the cervical level ends through the posterior wall of the left jugular subclavian venous junction directly or indirectly through interposed lymph nodes. The duct presents a length that ranges from 35 to 45 cm with a diameter fluctuating in between 2 to 4 mm in adults (1-7).

Anatomical variations found in the thoracic duct are attributed to embryologic development. It starts as a paired structure, consisting of both left and right trunks that are joined by numerous anastomoses. Despite this origin, the definitive thoracic duct generally comprises only the lower portion of the right trunk along with a transverse anastomosis and the upper portion of the left trunk. The persistence of both trunks is known as full replication and found only in 1.4% of cases. More commonly, a partial duplication is observed in 10 to 20% of the cases when the two top halves persist and the left lower portion normally regresses causing the thoracic duct to split into a V-shape, leading to both venous angles. There is another variety of partial duplication that is generally restricted to the thoracic section of the duct. It takes place when a segment of the left lower trunk anastomosis transversely towards the right side and is conserved (8-11).

Given that the human thoracic duct displays a high degree of anatomical variations, in the present preliminary report we aimed to evaluate these morphological deviations regarding its nature, frequency, and the portion of the duct involved by employing a novel descriptive anatomical technique.

MATERIAL AND METHODS

A total of 28 cadavers were examined comprising 12 adults (8 male and 4 female) aged between 50-80 years and 12 fetuses between 35 and 40 weeks of development. All cadavers were injected with a solution of natural acrylic pigmented latex diluted in distilled water. The injection sequence starts through the internal marginal vein, continuing with perfusion over the interazygous-aortic recess to reach the thoracic duct, and completing with an arterial perfusion through the posterior tibial artery. Before each perfusion step, the colored latex material contained in the venous vessels must to be forged at the left venous angle (also known as Pirogoff's angle) in order to block the progression of latex coming from the thoracic duct. The same procedure of hardening of latex material inside the thoracic duct was applied before perfusion through the arteries. The surgical approach to the thoracic duct consisted of a lateral right thoracotomy to reach the interazygous-aortic recess and introduction of an Abbocath-T catheter of 16/24 G (Abbot, Santa Clara, CA) depending upon adult or fetal specimen size. The cathe-ters employed in the different and sequential blood vascular and lymphatic perfusions were connected to a peristaltic perfusion pump device (APEMA PC II, APEMA S.R.L., Argentina) that delivers a rate of 150 ml/h. Prior to the infusion of latex, specimens were slowly perfused with 10% hydrogen peroxide (v/v). Following latex infusion, specimens were fixed by immersion in a 5% formalin (v/v) solution for 7-14 days (depending whether fetus or adult specimens) and then cleared with 100% hydrogen peroxide for 24 hr as previously reported. Finally, preserved cadavers were carefully dissected, anatomical structures identified, and photo documented by employing a Olympus Stylus 1 12Mp 10.7x3" digital camera (12-14).

The cadaveric material employed in the present study is owned by the Vascular Anatomy Laboratory at the III Chair of Anatomy, Faculty of Medicine, University of Buenos Aires.

RESULTS

The thoracic duct was evaluated with a focus on anatomical modifications found at: the origin of the duct such as the presence of the cisterna chyli; the lumbar lymphatic trunks; the gastrointestinal trunk; and its terminus in adult specimens (*Fig. 1*).

Plexus shape distributions and derivative pathways of the thoracic duct were found in 80% of adults specimens and were most frequently observed at the origin of the duct (*Fig. 1a-b*). Interestingly, and in contrast to adults, 100% of the fetal specimens display

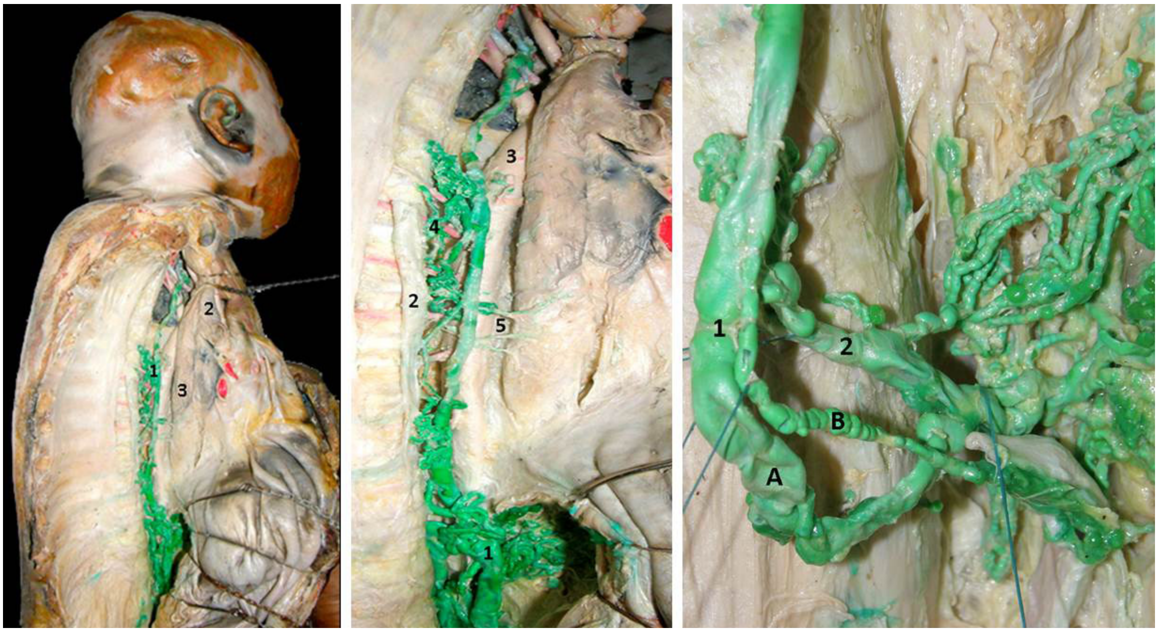

Fig. 1. Photographs of adult specimens showing a panoramic view of the thorax in a longitudinal section. (a) In the posterior mediastinum, the thoracic duct (1, green), trachea (2) and esophagus (3) is highlighted. In an amplified view (b), the interazygos-aortic recess displays the beginning of the thoracic duct (1, green), azygos vein (2), thoracic aorta artery (3), plexus shape or derivative lymphatic vessels (4), and lymphatic vessels draining into the thoracic duct (5, green). An amplified view of the lower thoracic duct (c) displays the origin of the thoracic duct showing the confluence of lumbar lymphatic trunks (A, right; B, left) and the gastrointestinal trunk (3).

ampule dilation at the origin of the thoracic duct (*Fig. 2a*).

In only one adult specimen a dilatation of the left lumbar lymphatic trunk that could be confused as a cisterna chyli was observed. Although no total duplications were observed, a few partial duplications were detected at the cervical level in adults (*Fig. 2b*). In all specimens, the termination of the thoracic duct at the level of the joint union between the left internal jugular vein and the subclavian vein was observed directly or indirectly with interposition of lymph nodes (*Fig. 3*).

DISCUSSION

The technique of sequential injection using a perfusion pump at a slow rate permitted the complete identification of the thoracic duct as well as the lymphatic trunks that give rise to it. In fact, this retrograde and anterograde double injection method allowed the elucidation and differentiation of lymphatic vessels that originated in the hepatic, jejunum-ileum, and esophageal regions. In regard to the esophageal region, lymphatic vessels at that level were found to run in a transverse manner and established direct connections with the thoracic duct.

The first injection-perfusion in the sequential procedure was performed directly through the venous system, and the subsequent hardening of the injected latex material resulted in the crucial step of the technique. This hardening constitutes an effective barrier to stop the progression of subsequent injection material injected at level of the Pirogoff's angle during the filling of the thoracic duct. The procedure following the sequence of venous-lymph-arterial vessels completely avoided mixture of latex colors

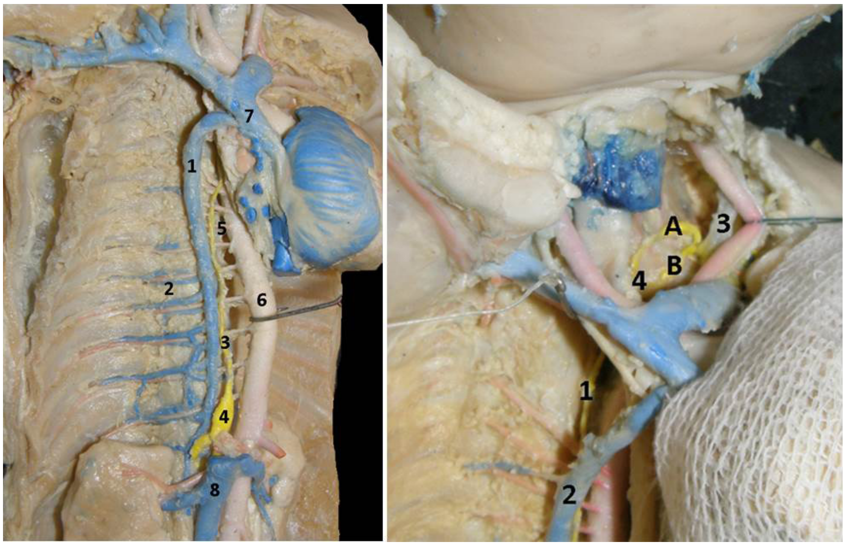

Fig. 2. (a) An amplified view of the thorax of an adult specimen in longitudinal section highlights the azygos vein (1, pale blue), intercostal veins (2, pale blue), thoracic duct (3, pale yellow), cisterna chyli (4, pale yellow), intercostal arteries (5), thoracic aorta artery (6, pale pink), superior vena cava (7, pale pink) and the inferior vena cava (8, pale blue). An amplified view of the cervical region from an adult specimen displays the thoracic duct (1, yellow), azygos vein (2, pale blue), left internal jugular vein (3), and bifurcation of the thoracic duct in trunks A and B (4).

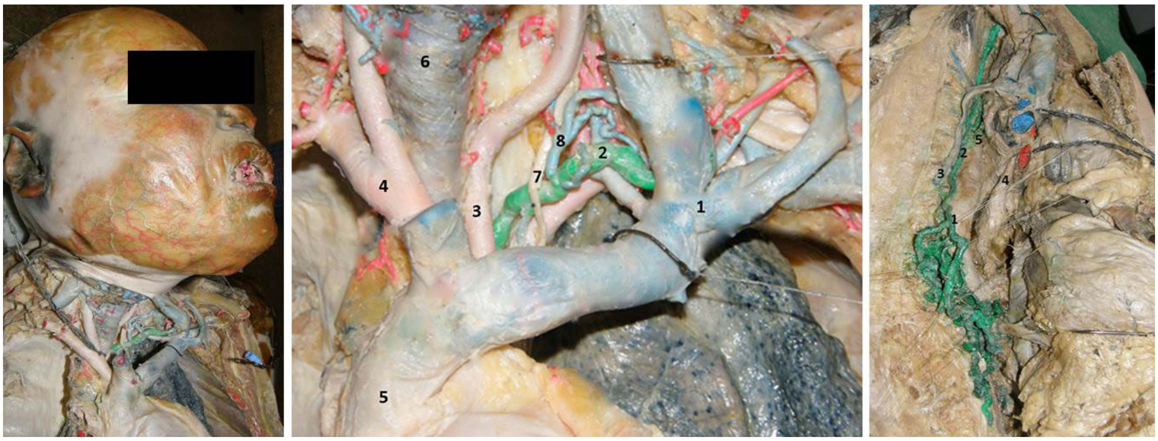

Fig. 3. Photographs of a fetal specimen showing panoramic (a) and amplified views (b) of the cervical region highlighting the terminus of the thoracic duct visualized at the venous angle or Pirogoff's angle (1, pale blue), thoracic duct (2, pale green), left common carotid artery (3, pale pink), brachiocephalic artery (4, pale pink), superior vena cava (5, pale blue), trachea (6), left vagus nerve (7, white), and a lymphatic collector (8). A longitudinal section of the thorax displaying the posterior mediastinum (b) highlights the lumbar lymphatic trunks (1, pale green), thoracic duct (2, pale green), azygos vein (3, pale blue), esophagus (4), and the paraesophageal lymphatic vessels (5, pale green). The formation of a plexus as well as derivative pathways in the thoracic duct are not seen in fetal specimens.

allowing efficient visualization of all anatomical compartments. The technique was not only useful to assess the relationship between the thoracic duct and posterior mediastinum organs but it also defined their anatomical variations.

In adults, the plexus shape of thoracic duct is frequently identified. This could be used as an argument to explain the generation of derivative pathways or alternative compensatory lymphatic circulation routes that appeared after operations that involve clipping or ligatures of the duct. From a pathophysiological perspective, the compensatory capacity of these plexuses may explain in some cases the absence of clinical manifestation secondary to lymphatic/chylous hypertension. Whether their existence was congenital or as a result of stimulation due to some form of lymphatic obstruction is unclear from our limited number of specimens. Interestingly, plexus shape variations are completely absent in the fetal specimens. Therefore, we are tempted to speculate that both derivative pathways and plexus shape variations of thoracic duct start to develop either as a consequence of upright position in adulthood where the lymphatic pressures radically change (15) (supported by recent evidence reporting changes in cisterna chyli size due to postural effects) (16) or due to lymphangiogenic growth in response to lymphatic system insults/obstruction in post-fetal life.

Finally, our results on the anatomic variations of the thoracic duct are compatible with the appearance of derivative lymphatic circuits observed during some pathophysiological conditions employing modern diagnostic techniques such as transnodal lymphography (17), which adds validity to both techniques.

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Horacio Romeo, PhD
Miguel A. Amore, MD
Laboratory of Animal Models and Experimental Microsurgery
School of Medicine, BIOMED UCA-CONICET
Pontifical Catholic University of Argentina
Alicia Moreau de Justo 1500, 4th floor
C1107ADF CABA, Argentina
Tel./fax: +54 11 4349 0200
E-mail: Horacio_romeo@uca.edu.ar (HR)
mamore@fmed.uba.ar (MA)