THE STRUCTURAL BASES OF ACTIVE LYMPH FLOW IN HUMAN FOETUS THORACIC DUCT

Petrenko V.M.
I.I. Mechnikov State Medical Academy, St.-Petersburg, Russia

The thoracic duct consist of the row of lymphangions with muscle cuff between distal and proximal valves. The valves occur during the first half of the prenatal development of thoracic duct in human. During the second half of the development their maturation is underway – the enlargement of muscle cells together with the increase in their quantity leads to formation of the multi-layered muscle cuff of the duct lymphangions and with decreasing of the valves number.
Keywords: thoracic duct, valves, muscle cells, muscle cuff, lymphangion

Condition of the problem

The structural basis for lymph flow has been a subject of numerous studies, but mostly performed on mature humans and different mammals [1-8]. Valves divide lymphatic vessels to the lymphangions which have been defined as a intervalvar segment including muscle cuff between distal and proximal valves [4]. Muscle cuff contains the main part of lymphangion muscle cells and functions as a pump [3], connects with both valves of its lymphangion, intrinsic and extrinsic, by means of muscle bundles [4,5]. The prenatal development of human lymphatic systems did not attract enough attention of the lymphatic researchers due to the understandable difficulties to work with human tissues. Usually readers are referred to the “classical” studies [9-11] mostly focused on the problem of the lymphatic origin from veins or mesenchyme but without detailed morphological analysis of such development. According to O.F.Kampmeier [10] initially valves in the thoracic duct could be found in human embryos ~30 mm length, and they are determined as small thickenings of the duct endothelium. The formation of muscle layers in the thoracic duct wall begins during the middle of the prenatal month 5.

Material and methods

The work was carried out on 400 both sexes human embryoes and foetuses of 4-36 weeks old without pathology. Material was fixed in 10% solution of neutral formalin. Part of material was stained in paraffin with following production of serial longitudinal and transverse sections of 5-10 mkm in thickness. Sections were stained by hematoxylin and eosin, picrofuxine, azane, silver nitrate, orseinum. Thoracic ducts´ total preparations from some foetuses of 11-36 weeks were stained by gallocyanin.

Results

The paired thoracic duct could be determined in human embryos of 14 mm length (the beginning of week 7): during the formation of the paired jugular lymphatic sacs the thoracic subcardinal veins are excluded from blood circulation together with several other veins from the system of precardinal and postcardinal veins (**Fig. 1**). At this time the thoracic duct is localized between the thoracic postcardinal (azygos) vein and thoracic aorta at the levels of Th2-Th8 and it enters the bottom part of the jugular lymphatic sac. The connection site between the thoracic duct and jugular sac has duplication of the wall (initial valvar formation) and could be already determined in embryos 10-12 mm long (weeks 5.5-6). The thoracic duct finally exhibits lack of any connections with venous circulation other than its cranial part at the end of embryonic week 7 and possesses initially only tiny endothelial cell-containing wall which is much thinner than walls of veins surrounding it. First valves in the thoracic duct could be found at the end of embryonic week 8 (embryos 27-28 mm long): one valve is located in upstream diaphragmal part of the thoracic duct and its cysterna, another valve – in cranial downstream part of the duct near esophagus (**Fig. 2**). These valves with short cusps are still functionally incompetent – they are not able to close

completely the thoracic duct lumen and therefore to prevent the reversed lymph flow in the duct.

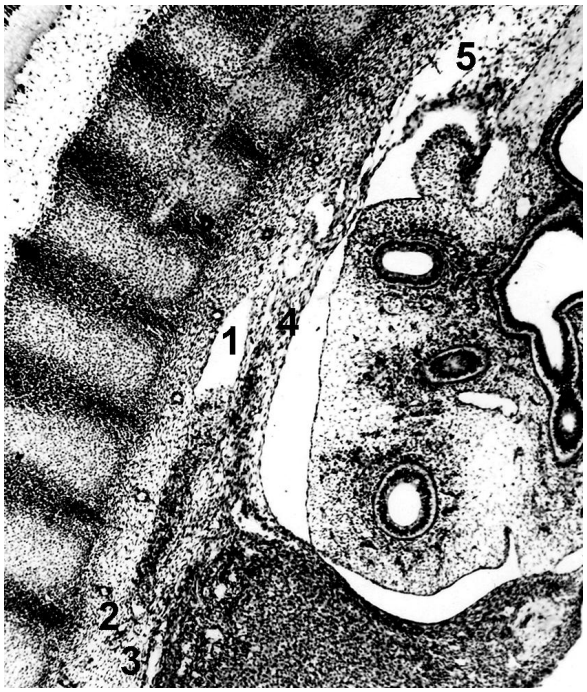


Fig. 1. Human embryo 14 mm of length (beginning of week 7), saggital section: 1 – postcardinal (azygos) vein; 2 – supracardinal (ascending lumbar) vein; 3 – superior mesocardinal vein; 4 – thoracic subcardinal vein / thoracic duct; 5 – jugular lymphatic sac. Hematoxylin / eosin staining. Light microscopy, magnification – 50X.

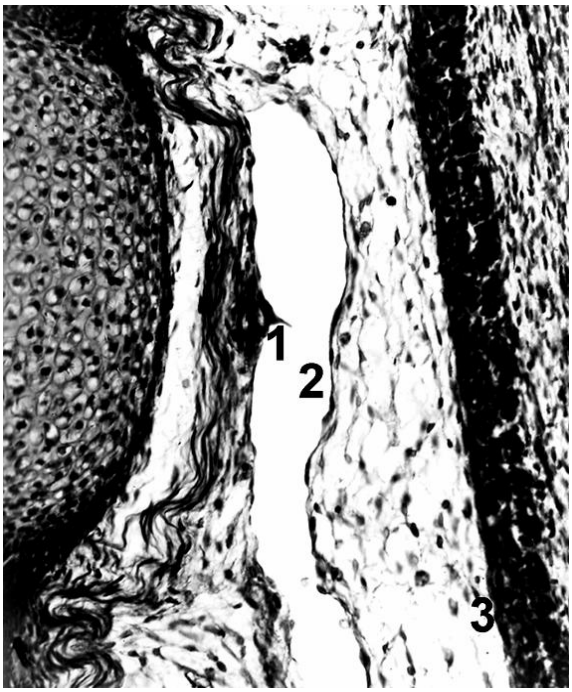


Fig. 2. Human embryo 28 mm of length (week 8), saggital section: 1 – thoracic duct valve; 2 – endothelial layer of the thoracic duct; 3 – esophagus. Hematoxylin / eosin staining. Light microscopy, magnification – 400X.

During the embryonic month 3 the thickening of the thoracic duct can be observed – the connective tissue forms adventitial layer of the duct and enters into thoracic duct's valves, which could be clearly divided into thick basement and tiny endothelial cusp (**Fig. 3**). The length of the valve cusps progressively increases, their tips contact together and elongate in downstream direction forming the valve sinuses (spaces between the thoracic duct wall and valve cusps). Therefore at this age of embryonic development the intervalvular segments of the thoracic duct could be already determined. During the month 4 the thickness of the adventitial layer significantly increases and it could be divided on two layers: the thin subendothelial layer, which is full of thin reticular fibers, and the thicker outer layer, which is rich by blood capillaries, thick reticular and collagen fibers. The muscle cells are mostly located in between of subendothelial and outer adventitial layer of the duct and could be determined as earlier as in the ending of month 3 or beginning of month 4 (**Fig. 4 A**). The number of valves increases but varies individually from 10 to 16. Valve cusps are getting longer and thicker with more curved shape, valve sinuses are also getting deeper although from outside of duct the borders between adjacent lymphangions are not well defined, so the thoracic duct is mostly cylindrical by its shape. During month 5 the layer of myocytes is still interrupted, and mostly single myocytes or small groups of them could be determined in the thoracic duct wall (**Fig. 4B**). Together with thin elastic fibers the myocytes form a thin medium layer of

the duct. Thick outer layer of the duct consists of axially oriented bundles of thick collagen fibers and elastic fibers. The number of valves varies between 25 and 35/ duct. However the shape of the majority of lymphangions remains cylindrical, only few of them in cervical and upper thoracic parts of the duct are getting elliptical shape. On the border between such lymphangions the thoracic duct is much narrower. In foetuses of months 6-7 the increase in number and enlargement of myocytes is continued, the short myocytes bundles of almost axial orientation could be found in the subendothelial and outer layers of the duct. In foetuses of months 8-9 muscle cell layers may be clearly separated for three

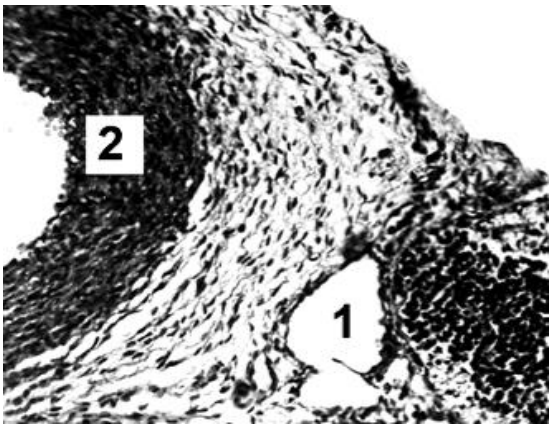
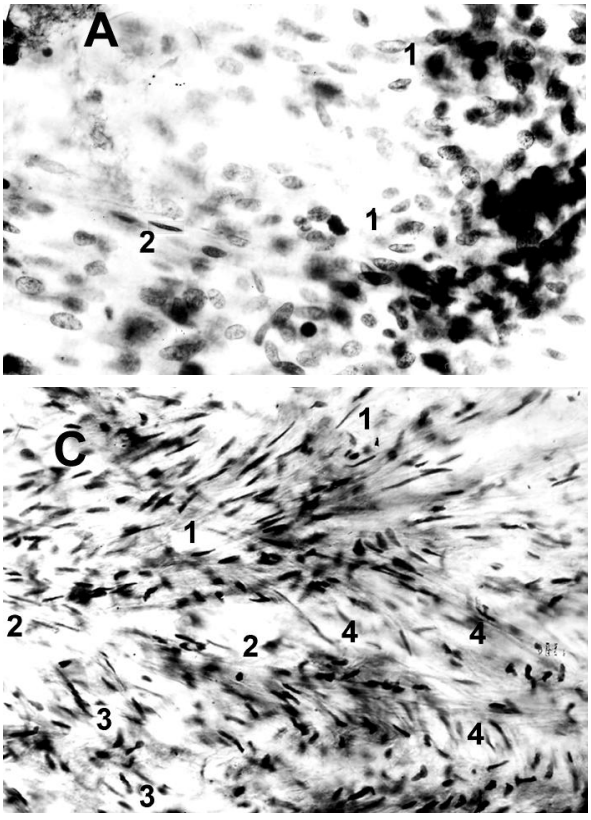


Fig. 3. Human foetus 61 mm of length (week 10.5), cross section: 1 – thoracic duct valve; 2 – aorta. Hematoxylin/eosin staining. Light microscopy, magnification – 120X



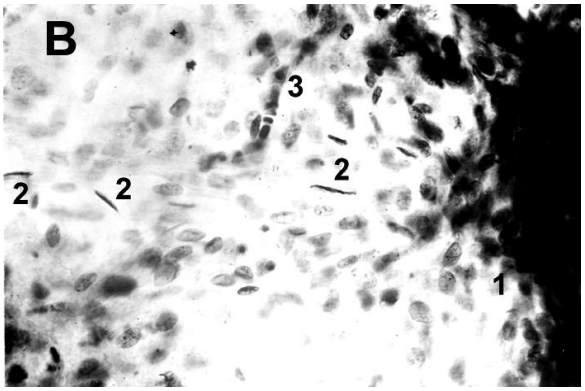


Fig. 4. Thoracic duct in human foetuses of week 11.5 (A); 20 (B) and 33 (C), total preparations. A and B:1 – valve; 2 – myocytes; 3 – blood capillary. C: 1, 2, 3, 4 – myocytes bundles in muscle cuff of lymphangion. Gallocyanin staining. Light microscopy, magnification: A, B – 400X; B – 250X

layers in a muscle cuff of the duct. Thin subendothelial layer contains the thin elastic fibers and few myocytes. Medium layer consists of majority of the ducts' myocytes with mostly circular orientation (**Fig. 4C**). Muscle bundles together with elastic and collagen fibers can cross together and form up to two layers of bundles. The thickest outer layer of the duct consists of numerous bundles of the different fibers, in between of which are subaxially and axially oriented bundles of myocytes (1-2 rows of cells) and blood capillaries are located. The number of the thoracic duct valves at the foetal age of the 8-9 mo diminishes to ~20/ duct. In valvular parts of the thoracic duct its wall is thicker and mus-

cle cell layers are not as well organized as described above for muscle cuffs parts of the duct. Myocyte-to-myocyte contacts could be determined in valvular areas, promoting the muscle cell contacts between adjacent lymphangions. Lymphangions which are typically elliptical by shape could be determined along all of the thoracic duct.**Conclusion**

The structural basis of the active lymph transport in the thoracic duct could be found already during the first half of the prenatal development in humans. The first valves with short cusps are appeared in embryonic period, the first muscle cells – in early foetus period with the increasing of valves number and their cusps length. The development of the competent valves and intervalver segments in thoracic duct occurs at the same time creating the ground for effective undirectional net lymph flow. At the end of the first half of the prenatal development primitive muscle cuff is formed already in the thoracic duct lymphangions which number is maximum. During the second half of the development the maturation of these basic elements of lymphatic pumping is underway – the enlargement of muscle cells together with increases in their quantity leads to formation of the multi-layered muscle cuff in the thoracic duct lymphangions with more and more thick muscle net in the cuff middle layer and with decreases of the number of the valves. Prenatal maturation of the thoracic duct leads to the changes in its shape. As closer to the birth, as more muscle cells could be found in the walls of the thoracic duct, and as more the shape of lymphangions changes from simplified cylindrical to elliptical, forming the narrowest parts of the thoracic duct near their valve basements and widest parts – close to the intraluminal edges of the valve cusps.

References

1. El Zawahry, M.D., et al., A study of the gross, microscopic and functional anatomy of the thoracic duct and the lympho-venous junction. Int Surg, 1983. 68 (2): p. 135-8.

2. Lee, S.H., H.J. Wen, and C.L. Shen, Ultrastructure of the monkey thoracic duct and the cisterna chyli. J Anat, 1993. 182 (Pt 2): p. 205-12.

3. Mislin, H., The Lymphangion. In: Lymphangiology. Stuttgart–New-York, Schaffauerverlag, 1983, p. 165-175.

4. Petrenko, V.M., Morphological bases of segmentary organization of active lymph outflow from organs. European Journal of natural history, 2006. 1: p.32-35.

5. Petrenko, V.M., Lymph node in the segmentary organization of lymph flow. European Journal of natural history, 2006. 2: p.134-136.

6. Petrenko, V.M., Smooth myocytes in the thoracic duct valves // European Journal of natural history, 2007. 5: p.66-67.

7. Shimada, K. and I. Sato, Morphological and histological analysis of the thoracic duct at the jugulosubclavian junction in Japanese cadavers. Clin Anat, 1997. 10 (3): p. 163-72.

8. Kajava, Y., Zur microscopishchen Anatomie des Ductus thoracicus und der Trunci lymphatici des Menschen (In German). Acta Soc. Med. Fen., 1921. III (1): p. 1-24.

9. Sabin, F.R., On the development of the lymphatic system in human embrios, with consideration of the morphology of system as a whole. Amer. J. Anat., 1909. 9: p. 43-91.

10. Kampmeier, O.F., Evolution and comparative morphology of the lymphatic system, ed. C.C. Thomas. 1969, Springfield, IL. 620.

11. van der Putte, S.C., The development of the lymphatic system in man. Adv Anat Embryol Cell Biol, 1975. 51 (1): p. 3-60.