

## SEGMENTARY CONSTRUCTION AS CONSTITUTION OF LYMPHATIC SYSTEM

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Lymphatic system consists of segments of two types – general (systemic or periarterial) and special (own, local or intervalvar). The segments organize all reactions of the system on influences of its environment including pushes of lymph flow.

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**Keywords:** lymphatic system, segment, valve, artery

It is known many facts about structure of lymphatic system (LSy) in man and animals [2, 5, 6]. It is proposed mush models of function of LSy as part of cardiovascular system, but mainly of lymphatic vessels (LV) – lymphatic hearts by L. Ranvier or lymphangions as valvar segments, functional units of LV according E. Horstmann and H. Mislin [1, 4, 6]. These models characterize organization of LSy in different aspects, but generally accepted conception about organization of LSy at whole is absent. In this article I want to point on common in structure of all sections of lymphatic bed (LB) independently from their regional and organic belonging, in order to establish the main principle of general construction of LSy in mammals.

**Topographico-genetic features of LB.** LV and lymph nodes (LN) usually lie about blood vessels. And this is not accidentally. Primary veins always accompany arteries of embryo, part of its veins are turned off blood flow with formation of primary LV. Blood vessels invaginate in lumen of these LV with anlage LN in fetuses. External wall of marginal sinus in anlage of LN (wall of maternal LV) transformates into capsule of LN (~ wall of definitive LV), internal wall of marginal sinus of LN is infiltrated by lymphocytes, which migrate from blood microvessels of stromal anlage of LN (invagination in lumen of maternal LV) [5]. Arteries with the most high blood pressure, the most thick and compact walls among all vessels:

1) dominate in interactions with veins and LB, contact (fragmentation of embryonic vessels and direct massage of definitive vessels) and distant (over capillaries and tissue channels, blood supplying of tissues and organs in environment of LB as its external cuff – lymphization and «undirect» massage of LB);

2) more stable to pressure of surrounding organs and as pivot preserve stability of vascular bundles.

Definitive microcirculatory bed, as primary vascular bed in early embryos, has net-form architecture, comparatively thin, gentle differentiative walls. Most large, magistral arteriolar and venulae, their branches and tributaries divide mesentery on microdistricts

of microcirculatory bed. Terminal arteriolar come off outline of the microdistricts. Their outline vascular bundles include LV of I order. The LV lie offer on their outlying area, at one or both sides from magistral venulae, and lymphatic capillaries – on the outside of balls of blood capillaries. Lymphatic capillaries fuse into lymphatic postcapillaries, which move towards the outline vascular bundle of the microdistrict, offer along collective venulae. LB has similar construction in organs with multilayers structure. Thus all LB, beginning from its roots, lie collaterally to the blood vessels. In definitive microcirculatory bed LV accompany offer venulae as in anlage of LB in embryo.

After bounds of organs large LV more and offer are orientated on aorta and its branches: thoracic duct and its roots, lumbar trunks, pass along descending aorta, vascular bundles of all main parts (regions) of human or animal body and to all organs form about aortic branches and their branchings. That construction of cardiovascular system, and LSy as its part, originates already in embryos (Fig. 1): branches of dorsal aorta grow to somites, adjoining parts (segments) of neural and intestinal tubes, their derivatives; drainage vessels, venous and lymphatic, are orientated on these branches of arterial tree.

**Morfogenetic folding adaptation of LB** – formation of valves: periodic knocks against of lymph anti-flows cause repeated local lymphodynamic strokes and overstretching of walls of LB, arising and increasing of their residual deformations with look as circular folds [6]. Valves limit lymph flow back and thus prevent destructive lymphodynamic strokes. As long ago as XIX centure A.Haller observes rythmical contractions of segments of LV between neighbouring valves and voices supposition, that such segments present lymph pumps. At this time L. Ranvier describes lymph hearts in LV of mammals. According E. Horstmann a. H. Mislin, they are valvar segments or lymphangions, functional units of LV: distal valve limits lymph flow back, more proximal muscular cuff supports direct lymph flow. I think, that lymphangions are intervalvar segments of

LV, which include both neighbouring valves of the segment, entrance and exit, because lymphangions function only with participation of both their neighbouring valves (Webb R, 1932) [6], as industrial pump. What is more, LB has segmentary construction on all extent.

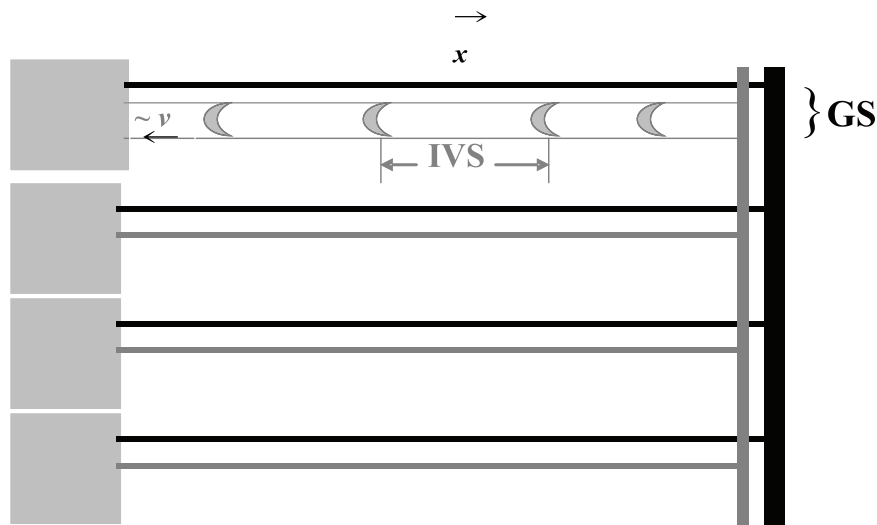


Fig. 1. Segmentary morphogenesis of lymphatic bed (scheme): gray squares – somites and their derivatives; gray lines – lymphatic vessels and their walls; black lines – arteries; IVS – intervalvar (special) segment;  $\sim v$  – oscillations (of speed) of lymph flow with connection of functional activity of somite and their derivatives, including oscillations of tissue fluid production, valves are on the way of reverse lymph flow; *GS* – general segment (of lymphatic system);  $x$  – place of own segment of lymphatic bed about main (segmentary) artery of general segment, direct of its growth determines topography and state of lymphatic bed in composition of general segment. Morphogenesis of lymphatic bed is described by formulæ of its work ( $A = 1/2 mv^2 + 1/2 kx^2$ ) as derivate of kinetic and potential energy of developing system

Valves divide LB on intervalvar segments with different structure: lymphatic postcapillaries consist of unmuscular intervalvar segments, which organize passive lymph flow out network of lymphatic capillaries; LV consist of muscular intervalvar segments or lymphangions, which may be contract themselves by deficit of energy of extravasal factors and actively move lymph to veins; LN is nodal or lymphoid lymphangion, it regulates as volume speed of lymph flow so composition of lymph. All intervalvar segments of LB have common structure: between entrance and outlet valves there is unvalvar part, but with different construction. The wall of lymphatic postcapillary consists of endothelium and (often) connective tissue. The wall of LV includes yet smooth myocytes, the wall of LN (internal wall of nodal sinus) – lymphoid tissue. The border valve belongs to both neighbouring intervalvar segments (wall of LB is uninterrupted). The cusps of closed valve divide lumen of neighbouring intervalvar segments on the autonomic compartments. Their dilatation by filling of lymph induces passive contract of intervalvar segment (pressure of surrounding tissues – external cuff of LB), and stretching of its walls – ac-

tive contract (muscular cuff of lymphangion). Segmentary principle of construction extends on network of lymphatic capillaries. Mobile intercellular contacts of endothelium are maken and function as minivalves [3] on entrance of lumen of lymphatic capillary: they level variable current of fluid between tissue channels and lymphatic capillary and thus regulate filtration of tissue fluid in lumen of lymphatic capillary (lymphization).

LSy may be present as chain of intervalvar segments. Their construction become complicated progressively in orthograd direction (Fig. 2): the endothelium of lymphatic capillary are supplemented by its folds (valves) and adventitia in the walls of lymphatic postcapillary, smooth myocytes – in the walls of LV, lymphoid tissue – in the walls of LN. This hierarchy in structure of definitive LSy recapitulates the main stages of development of LSy with connection with organogenesis (growth of functional loading on LB) in evolution and ontogenesis of vertebrates. Thus human thoracic duct:

1) has endothelial walls in embryos of 7-8 weeks, first valves with short cusps – in embryo of 8 week;

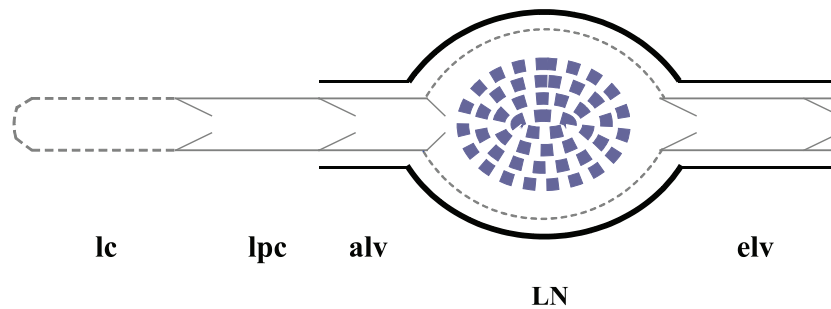


Fig. 2. Lymphatic system as chain of intervalvar segments with progressively complicated construction of their walls (scheme): lc – lymphatic capillary with endothelial wall, dotted line symbolizes mobile intercellular contacts, they function as minivalves on entrance into unmuscular intervalvar quasi-segment; lpc – lymphatic postcapillary, where typical, intraluminal valves appear (unmuscular intervalvar segment); alv, elv – afferent and efferent lymphatic vessels, thick black line symbolizes muscular layer in their walls (muscular intervalvar segments or lymphangions); LN – lymph node as nodal or lymphoid lymphangion, its walls contain lymphoid tissue

2) acquires thin adventitial coat and several valves with long cusps, which cut up the lumen during their closing in fetuses of 3 month;

3) become unpaired with beginning of division of its thickening wall on definitive layers including smooth myocytes from ending 3d – beginning 4<sup>th</sup> months [5].

LN is part of uninterrupted lymphatic tract: walls and lumen of afferent LV pass into capsule and sinuses of LN, which continue into walls and lumen of efferent LV. Their muscular layers interconnected too. LN is one of lymphangions in network of extraorganic LB. On structure and function capsule of LN is mus-

cular cuff of nodal lymphangion, in connective tissue of which lymphocytes instil [6]. As in evolution of vertebrates, so in ontogenesis of man and mammal animals LN form at last among all sections of LB, on the base of LV, but with participation of arteries and veins, which invaginate in lumen of LV. Then it is originated lymphoid parenchyma of LN as local transformation of the wall of maternal LV (Fig. 3): monocytes (→ macrophages) and lymphocytes pass from blood microvessels of the invagination (stromal anlage of LN) into its intervacular connective tissue which grow up as lymphoid tissue into lumen of the LV [5].

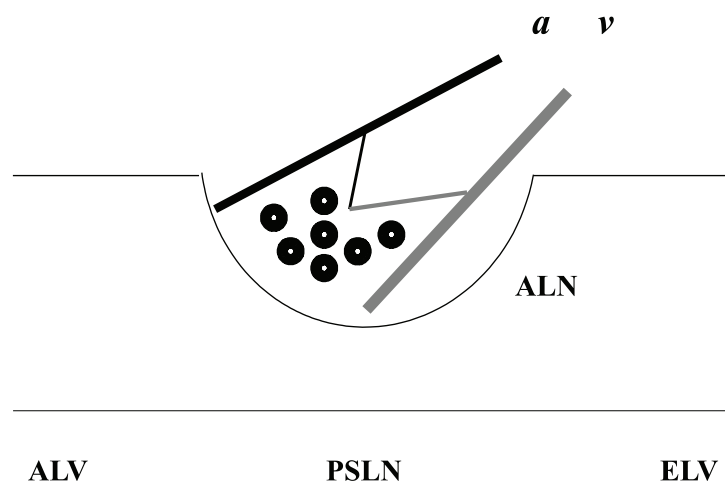


Fig. 3. Anlage of lymph node (ALN – scheme): a, v – artery and vein, they invaginate into lumen of lymphatic vessel, which divides on three segments, ALV, ELV and PSLN – afferent and efferent lymphatic vessels and primary marginal sinus of lymph node. PSLN is local narrowing of lumen of maternal lymphatic vessel in its part, where invagination of its wall with a, v (stromal ALN) grow up and transformate into ALN with lymphoid tissue

**Classification of segments of LSy.** Segmentary organization of all LB is defined as structure of its walls (valves), so its topography (branching artery). Therefore I divide all segments of LSy on two groups:

1) general (common for LB and blood bed) or systemic;

2) special, own or local.

I discern two types of general, periarterial segments of LSy:

1) central, paraaortic (lymphatic ducts and their parts and roots);

2) peripheral, subaortic, including

2a) regional or topographo-anatomical (usually about primary branches of aorta);

2b) organic, anatomical or subnodal (near the organ, in basin of its regional LN of I order);

2c) microorganic, microanatomical or paraarteriolar (in microdistricts of microcirculatory bed in organ – LV I order and their roots);

2d) root, primary or subarteriolar – lymphatic postcapillaries and their roots in modules and microdistricts of microcirculatory bed.

I divide special segments of LSy on unmuscular and muscular intervalvar segments, lymphangions – on vascular and nodular. Structure of own segments of LSy becomes complicated in orthograd direction:

1) at level of tissues in organs (in the places of lymphization) there are root general segments, they consist of unmuscular intervalvar segments;

2) on exit of organs and their coats (on withdrawal from vis a tergo) lymphangions appear;

3) at level of regional general segments lymphoid or nodal lymphangions supplement vascular lymphangions by means of including lymphoid tissue in the intima.

**Integration of segments of LSy.** The own segments of LSy unite with another components of general segments of LSy (and corresponding neuro-vascular segments of body at whole) by means of loose connective tissue, which may be transformates into lymphoid tissue in LN. In the walls of LB it may be distinguish own or segmentary apparatus (intervalvar segments) and oversegmentary apparatus of bipartite connections with surrounding tissues. The own apparatus includes inner layers of LB wall: in lymphatic capillaries and postcapillaries – endothelium, in LV and LN – intima (including lymphoid tissue in LN) and

media. The intervalvar segments of LV and LN are surrounded by common case of uninterrupted adventitia. Connective tissue fibers entwine in superficial layers of LB adventitia uniting wall of LB with surrounding tissues and organs – mechanic drives of external cuff of tissue (extralymphatic) pump.

### Conclusion

Constitution or general construction LSy, which determines its reactions on all influences of surroundings including pushes of lymph flow, is in the segmentary construction of all parts and sections of LSy. Its organization includes folding structure of LB walls, causing by fluctuations of lymph flow [6], and quasi-segmentary connection of LB with arteries. Topographo-anatomical segmentation of LB arises in embryos [5] and reflects external connections LB with its surroundings – source of extravasal factors of lymph flow. Functional, intervalvar segmentation of LB arises in fetuses and corresponds to impulsed lymphization in organs and partial lymph flow out organs, that causing cyclic organization of vital activity of cells and tissues. In condition of deficit of own lymph flow energy LB intervalvar segments organize passive and supplementary active moving of lymph from organs to veins. Structure and regimen of function of LB intervalvar segments are determined by their topography: at each level of general segmentation, branching of the main artery of systemic segment LB is divided on intervalvar segments with different construction of their walls. It corresponds to fluctuations of functional activity of surroundings: the metabolic activity of draining organs (lymphization as piston of tissue pump) and mechanic pressure of adjacent organs (external cuff of tissue pump).

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