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HISTOLOGICAL STRUCTURE AND MORPHOFUNCTIONAL CHARACTERISTICS OF BLOOD VESSEL WALLS: A MODERN ANALYSIS

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Abstract This article highlights the histological structure of blood vessels (arteries, veins, and the microcirculatory bed) and their morphofunctional characteristics. The changes in the vessel wall layers (intima, media, adventitia) depending on hemodynamic parameters, as well as the histophysiological significance of endothelial cells, are analyzed. The obtained data serve to understand the mechanisms of vascular pathologies (atherosclerosis, hypertension) and to strengthen the fundamental basis in modern medicine.

Keywords: Histology, blood vessels, endothelium, intima, media, adventitia, artery, vein, capillary, microcirculation.

INTRODUCTION

The blood vessels constitute a complex morphofunctional system that ensures the continuous circulation of blood, tissue trophism, and substance exchange in the body. In modern histology, blood vessels are considered not merely as blood-carrying tubes but as active endocrine and metabolic organs that directly regulate blood pressure, blood coagulation processes, and tissue homeostasis.

Based on their histological structure, all blood vessels (except capillaries) consist of three main layers: the inner (*tunica intima*), middle (*tunica media*), and outer (*tunica externa* or *adventitia*). The ratio of tissue elements (smooth muscle cells, elastic, and collagen fibers) in these layers varies sharply depending on the hemodynamic conditions of the vessel, namely the level of blood pressure and flow velocity. The main objective of the study is to systematically analyze the relationship between the structural elements and functional tasks across different types of blood vessels.

METHODS

Functional significance of the blood vessel wall:

- **Maintaining and regulating blood pressure:** * Muscle fibers in the arterial wall contract and relax, altering the vessel diameter. This regulates peripheral resistance and blood pressure.

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- Thanks to elastic fibers, the systolic shock of the heart is cushioned, and blood flow continues uninterrupted even during diastole.

- **Participation in nutrient and gas exchange:** * Oxygen and nutrients are delivered to all tissues through capillaries, and waste products are removed.
  - Through this process, tissue metabolism is ensured, and the normal physiological activity of the body is maintained.
- **Changes associated with pathologies:**
  - *Atherosclerosis:* As a result of the accumulation of cholesterol plaques in the inner layer (intima), the vessel lumen narrows, and blood flow is disrupted.
  - *Varicose veins:* Due to the failure of valves in the veins, blood flows backward, causing the veins to dilate.
  - *Hypertension:* Due to the hypertrophy of the muscle layer in the arteries and a decrease in elasticity, blood pressure remains consistently high.

Conclusion [Sub-section]: The histological structure of the blood vessel wall plays a crucial role in ensuring normal hemodynamics and metabolic processes in the body. The specific morphological features of the *tunica intima*, *tunica media*, and *tunica adventitia* layers are vital in regulating blood pressure and facilitating oxygen and nutrient exchange. Morphological differences between arteries and veins determine their functional adaptability, while capillaries ensure direct substance exchange with tissues. At the same time, pathologies such as atherosclerosis, hypertension, and varicose veins are closely related to the histological changes occurring specifically in the blood vessel wall. Thus, an in-depth study of the structure of the blood vessel wall is a relevant scientific direction for clinical medicine and practical diagnostics.

To study the architecture of the blood vessel wall, complex histological and morphometric methods are used:

1. **Fixation and slide preparation:** Sections of large and medium blood vessels (aorta, femoral artery, inferior vena cava) and microcirculatory bed vessels are fixed in a 10% neutral formalin solution and embedded in paraffin blocks.
2. **Staining techniques:** To evaluate the general morphological picture, the preparations are stained with hematoxylin-eosin. The orcein (or Weigert's method) is used to identify elastic fibers in the vessel wall, while the Van Gieson method is utilized to differentiate collagen fibers.
3. **Microscopy:** Histological preparations are analyzed using a light microscope (magnifications x100, x400, x1000) and an electron microscope to study the ultramicroscopic structure of the endothelium (pinocytotic vesicles, fenestrae).

RESULTS

Histology of arteries

Arteries are vessels that carry blood from the heart to tissues. Depending on the structure of the middle layer in their wall, they are divided into 3 types:

- **Elastic arteries (Aorta and pulmonary trunk):** Their middle layer (*tunica media*) consists of 40-50 complete (fenestrated) elastic membranes. This allows them to withstand high blood pressure during cardiac systole and ensure continuous blood flow.
- **Muscular arteries (Most medium and small arteries):** In the middle layer, smooth muscle cells are arranged in a circular (spiral) manner, coordinating the blood supply to organs through contraction. Internal and external elastic membranes are clearly visible.
- **Mixed (muscular-elastic) arteries (Carotid, subclavian arteries):** Smooth muscle cells and elastic fibers are located in approximately equal proportions in the middle layer.

Structure of the microcirculatory bed

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The microcirculatory bed is a system where direct substance exchange occurs between tissues and blood. It includes the following components:

- **Arterioles:** The "faucets" of blood flow, containing 1-2 layers of smooth muscle cells in their wall. They are considered the main peripheral barrier determining arterial blood pressure.
- **Capillaries:** Their wall consists of only a single layer of endothelium, a basal membrane, and pericytes. According to the structure of the endothelium, capillaries are divided into 3 types:

1. *Continuous (somatic):* The basal membrane and endothelium are intact (muscles, brain tissue, lungs).
2. *Fenestrated (visceral):* There are 60-80 nm pores (fenestrae) in the endothelium (renal glomeruli, endocrine glands, intestinal villi).
3. *Sinusoidal:* Wide lumen, the basal membrane is discontinuous or absent (liver, spleen, red bone marrow).

- **Venules:** Thin-walled vessels that collect blood from capillaries. They are further divided into postcapillary, collecting, and muscular venules. The passage of leukocytes from the blood into the tissue (diapedesis) mainly occurs in postcapillary venules.

Histology of veins

Veins return blood from organs to the heart. Because blood pressure is low and flow velocity is slow in them, their walls are thinner compared to arteries, and the muscle tissue in the middle layer is less developed.

- **Non-muscular (fibrous) veins:** Bone tissue, meninges, retinal veins. Their walls are fused to surrounding tissues and do not lose their shape.
- **Muscular veins:** Depending on their location in the body, muscle elements are developed to varying degrees. Particularly, in the veins of the lower half of the body (legs), smooth muscle is well developed in the wall, and their inner layer contains valves (*valvulae*) that prevent the backflow of blood.

DISCUSSION

Analyses show that each layer of the blood vessels performs a specific morphofunctional task. The endothelium, which is the main cell of the *tunica intima*, is not merely a covering epithelium. In modern histology, the endothelium is recognized as a massive endocrine organ that prevents blood coagulation (producing prostacyclin, nitric oxide), regulates vascular tone (endothelin), and participates in inflammatory reactions.

The *tunica externa* (adventitia) of arteries and veins consists of loose fibrous connective tissue, and the vessels' own blood vessels (*vasa vasorum*) and nerve plexuses (*nervi vasorum*) that nourish the walls of large vessels are located precisely in this layer. The thicker adventitia of veins limits their tendency to over-expand and ensures they fulfill their function as a "blood depot."

The provision of the histohematic barrier (blood-brain, blood-thymus barriers) in the capillary wall specifically by the endothelium and its continuous basal membrane is a crucial mechanism in protecting organs from immunological and toxic influences.

CONCLUSION

1. The histological structure of the blood vessel system is strictly adapted to its hemodynamic conditions (blood pressure, flow velocity), ensuring continuous exchange between blood and tissues.
2. The ratio of elastic and muscle tissues in the arterial walls changes as the distance from the heart increases, reflecting the vessels' properties to cushion and regulate blood flow.

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3. The structural polymorphism of the microcirculatory bed endothelium (continuous, fenestrated, sinusoidal) is directly related to the functional specificity of organs (filtration, secretion, hematopoiesis).

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