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HISTOLOGICAL STRUCTURAL FEATURES OF THE CARDIOVASCULAR SYSTEM: MODERN MORPHOFUNCTIONAL APPROACHES

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Abstract

This article analyzes the histogenesis of the cardiovascular system, as well as the microscopic and ultramicroscopic structure of various types of blood vessels and the heart wall. During the research, the histological differences between the layers of arteries, veins, and microcirculatory bed vessels, alongside the functional classification of cardiomyocytes, are highlighted. The obtained results are of great importance in understanding the histophysiology of the heart and blood vessels, as well as in studying the morphological foundations of various pathological processes.

Keywords: Histology, cardiomyocyte, endothelium, artery, vein, microcirculation, elastic fiber, myocardium, endocardium, hematocyte.

INTRODUCTION

The cardiovascular system is one of the vital systems of the body, and its main function is to supply tissues and organs with oxygen and nutrients, as well as to transport metabolic products. Since pathologies of this system (atherosclerosis, hypertension, myocardial infarction) rank first in modern medicine, studying the regeneration and structural changes of vascular walls, which form its histological basis, is of urgent relevance.

From a histological perspective, the cardiovascular system consists of a central organ (the heart) and peripheral organs (blood and lymphatic vessels). Although all vessels (except capillaries) have a three-layered structure, there are distinct differences in their histological composition depending on their functional role.

The vascular system performs vital functions in the human body. Its primary task is to supply tissues with oxygen and nutrients and to eliminate metabolic waste products.

The normal functioning of blood vessels ensures the complete operation of the cardiovascular system. Therefore, studying the structure of the vascular wall is of great importance in histology. Understanding its morphological characteristics helps to deeply comprehend not only normal physiology but also pathological processes.

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Classification of blood vessels:

Arteries: Arteries are vessels that carry blood away from the heart to organs and tissues. Their walls are thick and adapted to transport blood under high pressure. Histologically, arteries are divided into three main types:

- **Large elastic arteries** (e.g., aorta, pulmonary artery) — their walls contain many elastic fibers, which cushion the pressure of the strong blood flow coming from the heart.
- **Medium muscular arteries** (e.g., radial, femoral arteries) — their walls are rich in smooth muscle fibers, which actively regulate blood flow.
- **Small arteries and arterioles** — they facilitate the transition to capillaries and play a crucial role in determining peripheral resistance.

Veins: Veins return blood from organs and tissues to the heart. Their walls are thinner compared to arteries because the blood pressure in veins is low. Veins are divided into:

- **Large veins** (e.g., superior and inferior vena cava) — have a wide lumen and fewer muscle fibers in their walls.
- **Small and medium veins** — often possess valves that prevent the backflow of blood.

The main feature of veins is that they store a large portion of the blood, acting as a "blood depot."

Capillaries: Capillaries are the smallest blood vessels through which substance exchange with tissues occurs. Their wall consists of a single endothelial cell, adapted for the easy passage of gases and nutrients. Depending on their structure, capillaries are divided into three types:

- **Continuous** — the most common type, possessing a smooth endothelium (e.g., muscles, lungs).
- **Fenestrated** — the endothelium contains small pores (fenestrae) that accelerate the passage of substances (e.g., renal glomeruli, intestines).
- **Sinusoidal** — wide capillaries with uneven, high permeability (e.g., liver, spleen).

Layers of the vascular wall:

The vascular wall has a complex structure that performs various functions in the body. Each layer has specific morphological and functional characteristics.

- **Tunica intima (inner layer)** – This is the innermost part of the vessel wall, in direct contact with the bloodstream.
  - It mainly consists of **endothelial cells**. Endothelial cells have a squamous epithelial shape, and their cytoplasm contains numerous pinocytotic vesicles.
  - Endothelial cells serve not only as a mechanical barrier but also as an active **metabolic center**: they secrete anticoagulant substances, vasodilators (e.g., nitric oxide), and vasoconstrictors.

METHODS

The following histological and morphometric methods were used within the framework of the study:

1. **Preparation of histological slides:** Sections of the heart and large vessels (aorta, vena cava) were fixed in a 10% neutral formalin solution.
2. **Staining techniques:** Tissue sections were stained with hematoxylin-eosin and the orcein method to identify elastic fibers.
3. **Microscopy:** The obtained slides were analyzed using light microscopy (Leica DM series) and electron microscopy.
4. **Morphometry:** The thickness of the vessel walls and the ratio between layers were measured using specialized software.

RESULTS

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Histological structure of the heart wall

The heart wall consists of three layers: **endocardium, myocardium, and epicardium.**

- **Endocardium:** Consists of the endothelium, subendothelial layer, elastic-muscular layer, and an outer connective tissue layer. Studies show that the thickness of the endocardium varies in the atria and ventricles, possessing a strong fibrous base in the valve regions.
- **Myocardium:** The thickest layer of the heart, composed of cardiomyocytes. We divided cardiomyocytes into three types:
  - *Working (typical) cardiomyocytes:* Possess strongly developed myofibrils.
  - *Conducting (atypical) cardiomyocytes:* Form Purkinje fibers and are rich in glycogen.
  - *Secretory cardiomyocytes:* Located in the right atrium and produce natriuretic hormone.
- **Epicardium:** A serous membrane whose surface is covered with mesothelium.

Histomorphology of blood vessels

Depending on hemodynamic conditions, blood vessels are divided into the following types:

Vessel Type	Inner Layer (Tunica intima)	Middle Layer (Tunica media)	Outer Layer (Tunica adventitia)
Elastic arteries (Aorta)	Thick, with well-developed endothelium and subendothelium	40-50 fenestrated elastic membranes	Loose connective tissue, *vasa vasorum* is present
Muscular arteries	Internal elastic membrane is clearly visible	Smooth muscle cells predominate	External elastic membrane is present
Veins	Valves are present (in the lower parts of the body)	Muscular layer is relatively thin	The thickest layer, rich in collagen fibers

Microcirculatory bed

This bed is the main center of metabolism and consists of arterioles, precapillaries, capillaries, postcapillary venules, and anastomoses. Capillaries are divided into three types according to their structure:

- **Somatic (continuous):** Found in muscle and skin tissue.
- **Fenestrated:** Found in the kidneys and endocrine glands.
- **Sinusoidal (perforated):** Found in the liver and bone marrow.

DISCUSSION

The research results indicate that the ratio of elastic and muscular elements in the arterial wall is directly dependent on the level of blood pressure. The abundance of elastic structures in the aorta serves to cushion the pressure during systole, while muscular arteries regulate blood flow to the organs.

The significance of **intercalated discs (disci intercalares)** between cardiomyocytes is crucial. Electron microscopy revealed that they are connected via desmosomes and nexuses (gap junctions). This ensures that the heart functions as a single functional syncytium.

A specific feature of the histological structure of veins is the thinness of their walls and the scarcity of elastic elements, which is explained by the flow of blood under low pressure and their function as a depot.

CONCLUSION

1. The histological structure of the organs of the cardiovascular system is fully adapted to their hemodynamic functions (morphofunctional unity).

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2. The regenerative capabilities of the myocardium are limited due to the highly differentiated structure of cardiomyocytes and occur mainly through intracellular hypertrophy.

3. The walls of the microcirculatory bed vessels are highly permeable, acting as the main histohematic barrier that ensures gas exchange between tissues and blood.

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