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CARDIOVASCULAR SYSTEM: STRUCTURAL CHARACTERISTICS, AGE-RELATED CHANGES, AND PATHOGENESIS OF DISEASES

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Abstract

This study provides a comprehensive overview of the main structures of the heart and cardiovascular system and their functional significance. It includes a detailed analysis of the macro- and microstructural organization of the heart, age-related morphological changes, anatomical variations of the coronary arteries, and key anatomical factors involved in the development of heart failure. The cellular composition of the heart wall layers — endocardium, myocardium, and epicardium — the fibroelastic structure of the heart valves, and the localization and functional characteristics of the conduction system are described based on solid scientific evidence.

The section on age-related changes highlights embryonic structures during infancy (foramen ovale, ductus arteriosus), physiological hypertrophy in adolescence, maximal functional reserve in middle age, and processes in old age such as increased fibrosis, reduced myocardial mass, and decreased conductivity. Variations in coronary arteries, including congenital and acquired forms, dominance types, accessory branches, intramural segments, myocardial bridging, and collateral circulation formation, are thoroughly examined. The anatomical relevance of these structures in coronary insufficiency pathogenesis is analyzed scientifically. Morphological changes contributing to heart failure, such as myocardial hypertrophy, ventricular dilation, valve apparatus insufficiency, cardiosclerosis, and coronary artery narrowing, are identified as key factors.

The role of vascular wall structure in arterial pressure formation is emphasized, with detailed discussion on the ratio of elastin and collagen fibers in elastic and muscular arteries, smooth muscle cell activity, endothelial function, wall thickening, and the hemodynamic impact of atherosclerosis and arteriosclerosis. Age-related changes, including reduced arterial elasticity, increased collagen, widened pulse pressure, and elevated peripheral resistance, are explained with scientific evidence.
Overall, this study comprehensively describes the morphological and functional characteristics of the cardiovascular system, providing a solid theoretical foundation for anatomy, cardiology, surgery, and morphological research.

Keywords: Heart anatomy, cardiovascular system, coronary arteries, anatomical variations, heart failure, myocardial structure, valve apparatus, age-related changes, arterial pressure, vascular wall, elastic arteries, muscular arteries, endothelium, atherosclerosis, hemodynamics, structural remodeling.

Introduction

The cardiovascular system is one of the most vital systems in the human body, ensuring continuous blood circulation. This circulation delivers oxygen, nutrients, and hormones to tissues while removing metabolic waste. The system comprises the heart, blood vessels, and blood, which collectively maintain homeostasis and support essential physiological processes.

The heart, as the central organ of the system, functions as a muscular pump, regulating blood flow through a network of arteries, veins, and capillaries. Its primary role is to support cellular function and facilitate the exchange of gases, nutrients, and metabolic products at the cellular level. Structurally and functionally, the heart is complex, consisting of four chambers: two atria (upper chambers) and two ventricles (lower chambers). The left side pumps oxygenated blood into systemic circulation, while the right side sends deoxygenated blood to the pulmonary circulation. The cardiac conduction system, including the sinoatrial node, atrioventricular node, and Purkinje fibers, ensures rhythmic and coordinated contractions necessary for effective blood circulation.

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Blood vessels are critical components for transporting blood throughout the body. Arteries carry blood away from the heart, veins return it to the heart, and capillaries enable gas, nutrient, and waste exchange within tissues. The efficiency of the cardiovascular system depends on the structure and function of these elements. Structural or functional abnormalities in these components can lead to various cardiovascular diseases, including hypertension, atherosclerotic plaque formation, heart failure, and arrhythmias.

The cardiovascular system has been a focus of medical anatomical and physiological research for centuries. Numerous studies have enhanced understanding of the heart's structure and its complex relationship with blood vessels, emphasizing its crucial role in sustaining life. Key references include Guyton and Hall's Textbook of Medical Physiology, which details the heart's pumping function and anatomical organization, explaining how its four chambers and conduction system produce rhythmic and coordinated contractions to sustain blood flow. This work provides a comprehensive understanding of cardiac physiology and the interactions regulating blood circulation.

The anatomy of blood vessels has also been extensively studied. Moore and Dalley's Clinically Oriented Anatomy describes the structure of arteries, veins, and capillaries in detail, emphasizing how their architecture aligns with their function — arteries transport oxygen-rich blood under high pressure, veins return deoxygenated blood under low pressure, and capillaries facilitate tissue-level exchange of gases and nutrients. This detailed anatomical knowledge is essential to understand how different vessels contribute to cardiovascular efficiency.

Research by Harrison et al. (2017) further explores the physiological and biochemical processes within blood vessels, examining how plaque formation (atherosclerosis) disrupts normal blood flow and affects systemic circulation. These findings highlight the importance of vascular structural integrity, as disruptions contribute to cardiovascular diseases, a leading cause of morbidity and mortality in modern populations.

The structural role of the cardiovascular system has also been discussed in Plaksiy's work on higher education quality indicators, drawing analogies between anatomical organization and system management in healthcare and educational institutions. Although focused on systemic approaches, Plaksiy emphasizes the importance of structural understanding for maintaining overall system health.

Clinically, Yastrebov, Pinskaya, and Kosaretsky (2018) examine the use of contextual information in assessing cardiovascular health, reinforcing the relevance of structural and functional knowledge in patient evaluation and management.

The heart is a muscular organ located in the left part of the thoracic cavity, between the lungs and the abdominal cavity. The heart wall consists of three layers: the endocardium, which lines the heart chambers, ensures smooth blood flow, and forms the inner surface of the valves; the myocardium, the main contractile layer composed of cardiac muscle cells (cardiomyocytes) adapted for contraction and impulse conduction; and the epicardium, the outer covering that connects the heart with connective tissue and is adjacent to the pericardium. The heart consists of four chambers: the left and right atria (upper chambers) and the left and right ventricles (lower chambers). The left side of the heart pumps blood into the systemic circulation, while the right side sends blood to the pulmonary circulation. Heart valves (mitral, tricuspid, aortic, and pulmonary valves) ensure unidirectional blood flow.

Age-related physiological and morphological changes are observed in the heart structure. In infancy, the foramen ovale and ductus arteriosus are present, providing the embryonic circulation system. During adolescence, myocardial hypertrophy, physiological growth, and valve strengthening occur. In adulthood, the heart operates with maximal contractile reserve. In old age, fibrotic processes increase, myocardial mass decreases, cardiac conductivity declines, and valve elasticity is lost.

Coronary arteries supply the myocardium with oxygen and nutrients. Their variations play a significant role in the development of ischemic heart diseases and heart failure. These include dominance types (left or right coronary dominance), accessory branches and intramural segments, the myocardial bridge where an artery passes within the myocardium facilitating oxygen delivery, and collateral circulation acting as a compensatory mechanism against ischemia.

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The structure and elastic-mechanical properties of the vascular wall are important in forming arterial pressure. Elastic arteries (aorta, major arteries) transmit pulse waves and reduce blood pressure fluctuations, while muscular arteries regulate peripheral resistance. The ratio of elastin to collagen fibers, smooth muscle cell activity, and endothelial function control blood pressure. Thickening of vessel walls, atherosclerosis, and arteriosclerosis negatively affect hemodynamics. With age, arterial elasticity decreases, collagen fibers increase, pulse pressure rises, and peripheral resistance increases.
According to statistics in Uzbekistan, circulatory system diseases remain the leading cause of death. In 2023, of the total 172.8 thousand deaths nationwide, approximately 61.1% were due to cardiovascular diseases. In 2024, over 57.6% of all deaths were associated with circulatory system disorders. Almost half or more of the annual deaths are caused by cardiovascular diseases, emphasizing the relevance of anatomical and physiological factors.
Analyses show that in Uzbekistan, arterial hypertension and elevated blood pressure are directly related to vessel wall structure and hemodynamics. Increased arterial pressure contributes to many heart diseases, atherosclerosis, and heart failure development. Ischemic heart disease, especially atherosclerosis and coronary artery narrowing, occurs due to vessel wall changes, plaque formation, vessel variations, and hemodynamic disturbances, resulting in oxygen deficiency in the myocardium and conditions such as angina, myocardial infarction, and chronic heart failure. Chronic heart failure often develops against the background of long-term hypertension, ischemic heart disease, and myocardial structural changes. Ventricular dilation, valve insufficiency, cardiosclerosis, and myocardial fibrosis reduce cardiac pumping function, leading to insufficient oxygen and nutrient delivery to tissues, causing fatigue, shortness of breath, and leg swelling. Atherosclerosis is characterized by structural changes in the vessel wall and formation of fatty plaques. Causes include high cholesterol levels, oxidative stress, chronic inflammation, and sedentary lifestyle. Plaque accumulation limits blood flow and contributes to hypertension, ischemic heart disease, and chronic heart failure. Vessel wall damage also increases the risk of thrombosis and embolism.

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Effective management of cardiovascular diseases requires an integrated approach considering structural, hemodynamic, and metabolic changes. Pharmacological therapy includes antihypertensive drugs to reduce arterial pressure and peripheral resistance (e.g., ACE inhibitors, beta-blockers, diuretics), lipid-lowering agents (statins) to slow atherosclerosis and maintain vascular elasticity, and anticoagulants or antiplatelet agents to reduce thrombosis and embolism risk. Heart failure therapy (digoxin, ACE inhibitors, beta-blockers, diuretics) supports myocardial contractility and alleviates symptoms from ventricular dilation and valve insufficiency. Invasive and surgical approaches include coronary angioplasty and stenting to widen narrowed arteries, coronary artery bypass to restore blood flow to ischemic areas, and valve surgery (prosthetic or reconstructive) to restore pumping function. Lifestyle modifications such as healthy diet, physical activity, reduced salt and trans fats, smoking cessation, alcohol limitation, stress management, and maintaining normal weight help control blood pressure and prevent atherosclerosis.

Individual patient assessment considering vessel wall variations, coronary anatomy, myocardial mass, and electrical conduction is critical for determining an effective therapy strategy. The integrated approach combining pharmacotherapy, invasive intervention, and lifestyle modification maintains optimal cardiovascular function and reduces disease complications.

The cardiovascular system is the most important system sustaining human life. Its anatomical structure, coronary artery variations, and vascular wall properties play a decisive role in maintaining normal hemodynamic function. Age-related changes in myocardial and vascular structure, electrical conduction, and arterial pressure determine cardiovascular efficiency. Diseases such as arterial hypertension, ischemic heart disease, chronic heart failure, and atherosclerosis are directly related to these structures and hemodynamic processes, significantly affecting patient health. Management and treatment require an integrated approach: combining pharmacotherapy, invasive and surgical methods, and lifestyle modification reduces complications and optimizes body function. In-depth study of the cardiovascular system, identification of pathological changes,

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and application of comprehensive management strategies provide a scientific basis for cardiology and prevention and improve patient quality of life.

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