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MORPHOLOGICAL ASPECTS OF THE HEART: STRUCTURE, FUNCTION AND PATHOLOGICAL CHANGES

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Abstract. This article explores the morphological structure of the heart, its histological layers, their functional significance, as well as changes occurring under various pathological conditions. Based on anatomical and histopathological analysis, the morphological foundations of heart diseases are explained. Moreover, structural analysis of cardiac tissues using modern morphological research methods such as immunohistochemistry, electron microscopy, and 3D reconstruction is presented.

Keywords:cardiac morphology, myocardium, endocardium, epicardium, histology, fibrosis, cardiomyocyte, pathomorphology.

INTRODUCTION

The heart is one of the most vital organs of the human body, and its morphological structure directly ensures its physiological functions. The latest achievements in anatomy and histology have enabled a deeper study of the structural and cellular characteristics of cardiac tissues. This article systematically analyzes the normal morphological structure of the heart and the changes observed under pathological conditions. The heart is a four-chambered organ consisting of two atria and two ventricles. The heart wall is composed of three main layers[1,2]:

1. **Endocardium** – the innermost layer lining the heart chambers. It is covered with endothelial cells and rich in elastic fibers.
2. **Myocardium** – the main muscular layer of the heart. Cardiomyocytes are the specialized cells of cardiac muscle tissue.
3. **Epicardium** – the outer serous layer of the heart, which, together with the pericardium, encloses the heart.

The **endocardium**, lining the inner surface of the heart chambers, also contributes to the structure of the heart valves. Its inflammatory and degenerative changes (e.g., endocarditis, valvular fibroelastosis) are associated with clinical conditions such as valvular insufficiency or stenosis. Morphological deformities of the valves directly affect cardiac hemodynamics and lead to the development of heart failure.

The **epicardium** and **pericardium** cover the heart from the outside and provide free movement of the heart, reducing friction. Pathological processes in the pericardial layers, such as pericarditis or pericardial effusions, exert excessive mechanical pressure on the contractility of the heart. From a morphological perspective, pericardial inflammatory infiltration, fibrosis, or accumulation of exudate can lead to impaired diastolic function of the heart.

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HISTOLOGICAL STRUCTURE OF CARDIAC TISSUES

Cardiomyocytes – Cardiomyocytes are interconnected through intercalated discs, which play a crucial role in conducting electrical impulses. These cells contain a large number of mitochondria, enabling the continuous contraction of the heart.

Conduction tissue system – The heart's conduction system includes the sinoatrial node, atrioventricular node, bundle of His, and Purkinje fibers. These structures regulate the heart rhythm.

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Interstitial tissue – Located between myocardial cells, the interstitial tissue is composed of fibroblasts, capillaries, and immune cells. It plays a role in maintaining cardiac homeostasis[3,4].
Morphological changes in pathological conditions –In myocardial infarction, a necrotic core forms, the inflammatory response is activated, and infiltration by macrophages and neutrophils is observed. In the later stage, fibrous tissue forms.
In hypertrophic cardiomyopathy, hyperplasia of cardiomyocytes and enlargement of nuclei are characteristic.
In dilated cardiomyopathy, the heart chambers are dilated, cardiomyocytes are stretched, and contractility is reduced.
Myocarditis is characterized histologically by inflammatory cell infiltration, edema, necrosis, and interstitial fibrosis.
Endocarditis and epicarditis – Infectious and autoimmune conditions lead to inflammatory infiltrates, thrombotic masses, edema, and fibrosis in the inner (endocardium) and outer (epicardium) layers of the heart.

MODERN MORPHOLOGICAL RESEARCH METHODS

1. **Immunohistochemistry** – The state of cardiac cells is assessed using markers such as troponin, actin, and desmin.
2. **Electron microscopy** – Ultrastructural changes are evaluated, particularly the condition of mitochondria and the structure of intercalated discs.
3. **Genomic and transcriptomic studies** – Genetic SNPs and RNA profiles that predispose to heart diseases are identified.

SCIENTIFIC DISCUSSION AND ANALYSIS

The relationship between the morphological structure of the heart and its functional state lies at the intersection of cardiology and morphology as an important scientific issue. Understanding the structural components of cardiac tissues in their normal state, their spatial relationships, and the interactions at the cellular and tissue levels is essential for ensuring optimal heart function[5,6]. Therefore, this article provides a comprehensive analysis of the main components of cardiac morphology — the endocardium, myocardium, and epicardium — and examines their physiological and pathological changes on a scientific basis.
The myocardium is the main contractile layer of the heart wall and consists of specialized muscle fibers known as cardiomyocytes**.** Cardiomyocytes differ from other muscle tissues in the body in terms of nuclear count, sarcomere arrangement, presence of intercalated discs, mitochondrial density, and energy processes. In particular, sarcomere activity in the heart directly ensures the mechanical function during systole and diastole. The cardiac conduction system — including the sinoatrial node, atrioventricular node, bundle of His, and Purkinje fibers — is composed of specially modified myocardial cells and forms the physiological basis of heart rhythm. Morphological analysis of this system is crucial for understanding the pathogenesis and morphogenesis of cardiac arrhythmias. Pathological damage to the conduction system — such as fibrosis, sclerosis, or post-myocarditis destruction — can lead to rhythm disturbances.
Among pathological changes observed in the myocardium, the most common is myocardial infarction, which develops as a result of ischemic heart disease. Necrosis, inflammation, and subsequent fibrosis in the infarct zone alter the morphological and mechanical properties of the heart wall. Electron microscopy reveals mitochondrial swelling, degradation of actin-myosin filaments, and disruption of cellular membranes.
Immunohistochemical studies help determine the expression levels of markers in cardiomyocytes — such as troponin**,** natriuretic peptides**,** actin, and myosin — and uncover the molecular basis of structural changes in the heart. Additionally, regenerative processes in the heart — particularly the

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activity of cardiac progenitor cells and fibroblasts, angiogenesis (formation of new capillaries), and the degree of collagen synthesis — play an essential role in evaluating tissue remodeling caused by pathological conditions.

Studying morphological changes in cardiac tissues is significant not only for diagnosing and treating diseases but also for their prevention. Especially through modern genomic and proteomic research, genetic polymorphisms predisposing to heart disease are being identified[7,8]. This paves the way for personalized prevention and therapy of cardiac conditions based on individual genetic characteristics.

In general, a comprehensive study of the heart's morphological structure and in-depth analysis of pathological changes allows a scientific understanding of the causes, development stages, and consequences of cardiovascular diseases. This provides a critical scientific foundation for accurate diagnosis, effective treatment strategies, and advanced rehabilitation methods in clinical practice.

CONCLUSION

The morphological structure of the heart and its alterations under pathological conditions require thorough scientific analysis. Modern morphological and molecular technologies contribute significantly to improving the diagnosis and prognosis of cardiac diseases. A deep understanding of the histological changes in each layer of the heart forms the basis for developing individualized therapeutic approaches in the future.

The structural organization of the heart and its various physiological and pathological alterations carry significant scientific and practical importance for the anatomical, histological, pathomorphological, and clinical branches of medicine. The layered structure of the heart wall — including the endocardium, myocardium, and epicardium — each with its specific cellular composition and function, ensures the continuous and efficient functioning of the heart.

CONCLUSION

In this article, the morphological analysis of cardiac tissues was conducted using modern methods. Particular attention was given to the structural-functional relationship of cardiomyocytes in the myocardium, the histological details of the components of the conduction system, and the role of interstitial tissue in inflammatory and fibrotic processes.

Morphological changes observed in pathological conditions — such as myocardial infarction, cardiomyopathies, myocarditis, endocarditis, and epicarditis — are among the primary factors leading to impaired cardiac function. These changes are mainly characterized by cellular necrosis, inflammatory infiltration, fibrosis, and degeneration of muscle fibers. In addition, structural disorders within the cardiac conduction system serve as the morphological basis for arrhythmias and rhythm disturbances[9].

Modern morphological research methods — including immunohistochemistry, electron microscopy, and molecular and genetic analyses — enable an in-depth examination of the fine structure of cardiac tissues, their cellular state, and pathological alterations. These advances support early diagnosis, differential diagnosis, and the development of individualized therapies for cardiac diseases.

From this perspective, a deep and systematic investigation of morphological changes in the heart is crucial not only for scientific research but also for clinical practice. The expansion of morphological knowledge forms a solid scientific foundation for innovative approaches in cardiology, the development of new treatment methods, and strategic efforts to reduce the prevalence of heart diseases.

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