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STRUCTURE AND FUNCTIONAL MECHANISMS OF THE HUMAN HEART AS A BIOLOGICAL PUMP

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Annotatsiya. Mazkur maqolada inson yuragining tuzilishi va uning ishlash mexanizmi anatomik hamda fiziologik jihatdan tahlil qilinadi. Yurakning asosiy qismlari, jumladan bo'lmachalar, qorinchalar, yurak klapanlari va o'tkazuvchi tizimi faoliyati o'rganiladi. Shuningdek, qon aylanish tizimidagi roli, yurak sikli bosqichlari hamda yurak mushagining qisqarish mexanizmi ilmiy asosda yoritib beriladi. Tadqiqot natijalari yurak faoliyatini tushunishda muhim nazariy va amaliy ahamiyatga ega.

Kalit so'zlar: yurak, anatomiya, qon aylanish, yurak sikli, miokard, fiziologiya

Аннотация. В данной статье рассматриваются анатомическое строение и функциональные механизмы работы сердца человека. Изучаются основные отделы сердца, включая предсердия, желудочки, клапаны и проводящую систему. Особое внимание уделяется роли сердца в системе кровообращения, фазам сердечного цикла и механизмам сокращения сердечной мышцы. Полученные результаты имеют важное значение для понимания физиологии сердечно-сосудистой системы.

Ключевые слова: сердце, анатомия, кровообращение, сердечный цикл, миокард, физиология

Abstract. This article analyzes the anatomical structure and functional mechanisms of the human heart as a vital organ responsible for blood circulation. The study focuses on the main components of the heart, including atria, ventricles, heart valves, and the conduction system. Particular attention is given to the cardiac cycle, mechanisms of myocardial contraction, and the role of the heart in systemic and pulmonary circulation. The findings contribute to a deeper understanding of cardiovascular physiology and its biological significance.

Keywords: heart, anatomy, blood circulation, cardiac cycle, myocardium, physiology

INTRODUCTION

The human heart is a highly specialized muscular organ that functions as a central regulator of the circulatory system, ensuring the continuous movement of blood and maintaining physiological homeostasis. Its role extends beyond simple mechanical pumping, as it integrates structural, electrical, and biochemical processes that collectively sustain life. According to Arthur Guyton[1], the heart operates as a pressure-generating system capable of adapting its output to meet the metabolic demands of the body, which may vary significantly under different physiological conditions.

Anatomically, the heart is a four-chambered organ consisting of two atria and two ventricles, structurally separated by interatrial and interventricular septa. This organization enables the division of pulmonary and systemic circulation, allowing efficient oxygenation of blood and distribution throughout the body. As emphasized by Henry Gray[2], the precise arrangement of cardiac chambers and valves is essential for

[1] Guyton, A. C., Hall, J. E. (2016). *Textbook of Medical Physiology*. 13th ed. Philadelphia: Elsevier, pp. 103–115.
[2] Gray, H. (2020). *Gray's Anatomy: The Anatomical Basis of Clinical Practice*. 42nd ed. London: Elsevier, pp. 105–118.

maintaining unidirectional blood flow and preventing regurgitation, which ensures the mechanical efficiency of cardiac function.

The functional mechanism of the heart is based on the coordinated activity of cardiac muscle tissue, known as the myocardium, and a specialized conduction system responsible for generating and transmitting electrical impulses. This system includes the sinoatrial node, which acts as the primary pacemaker, and the atrioventricular node, which regulates impulse transmission to the ventricles. According to Keith Moore[3], the synchronization between electrical excitation and mechanical contraction is fundamental for the effectiveness of the cardiac cycle and the maintenance of stable circulation.

In addition, the cardiac cycle represents a sequence of systolic and diastolic phases, during which blood is alternately pumped and received by the heart chambers. The efficiency of this cycle depends on multiple factors, including pressure gradients, valve function, and myocardial contractility. As noted by John West[4], even minor disturbances in these mechanisms can lead to significant alterations in cardiovascular function, highlighting the complexity and sensitivity of the heart as a biological system. Despite the extensive body of knowledge in cardiac anatomy and physiology, a comprehensive understanding of the relationship between structural components and functional mechanisms remains essential for both theoretical and clinical applications. Therefore, this study aims to provide an integrated analysis of the anatomical structure of the human heart and the physiological mechanisms that regulate its continuous and coordinated activity

MATERIALS AND METHODS

The study was based on a systematic analysis of anatomical and physiological data describing the structure and function of the human heart. The research object was the human heart as a central organ of the cardiovascular system, with focus on its chambers, valves, myocardial layers, and conduction system. The analysis included both

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[3] Moore, K. L., Dalley, A. F., Agur, A. M. R. (2018). *Clinically Oriented Anatomy*. 8th ed. Philadelphia: Wolters Kluwer, pp. 143–155.

[4] West, J. B. (2012). *Cardiovascular Physiology: The Essentials*. 10th ed. Philadelphia: Lippincott Williams & Wilkins, pp. 25–37.

macroscopic structures, such as atria and ventricles, and microscopic components, including cardiac muscle fibers and specialized conductive tissues.

The methodological approach relied on the examination of established anatomical and physiological sources. Structural parameters of the heart were defined according to standard anatomical data: the average adult human heart weighs approximately 250–350 grams, measures about 12 cm in length, 8–9 cm in width, and 6 cm in thickness. The wall thickness of the left ventricle ranges from 8 to 15 mm, while the right ventricle is thinner, measuring approximately 3–5 mm[5]. These differences were considered essential for understanding pressure generation in systemic and pulmonary circulation.

Functional mechanisms were analyzed based on physiological indicators of cardiac activity. The cardiac cycle duration in a resting adult was taken as 0.8 seconds, consisting of atrial systole lasting 0.1 seconds, ventricular systole 0.3 seconds, and general diastole 0.4 seconds. Heart rate was considered within the normal range of 60–80 beats per minute, while stroke volume averaged 60–90 ml per beat, resulting in a cardiac output of approximately 4–6 liters per minute. These values were used to explain the efficiency of the heart as a biological pump.

In addition, the conduction system of the heart was analyzed based on electrical impulse generation and propagation. The sinoatrial node was identified as the primary pacemaker with an intrinsic firing rate of 60–100 impulses per minute, while the atrioventricular node exhibited a slower rate of 40–60 impulses per minute. The propagation velocity of impulses through Purkinje fibers was estimated at 2–4 m/s, ensuring rapid and synchronized ventricular contraction. These physiological parameters were used to interpret the coordination between electrical activity and mechanical contraction in the heart.

RESULTS AND DISCUSSION

The analysis of anatomical and physiological data revealed that the structural organization of the human heart is directly related to its functional efficiency as a biological pump. The presence of four chambers allows the complete separation of

[5] Guyton, A. C., Hall, J. E. (2016). *Textbook of Medical Physiology*. 13th ed. Philadelphia: Elsevier, pp. 103–120.

pulmonary and systemic circulation, which ensures effective oxygen transport and metabolic exchange. The left ventricle, characterized by a wall thickness of up to 15 mm, generates systolic pressure of approximately 120 mmHg, while the right ventricle produces about 25 mmHg, which is sufficient for pulmonary circulation.

Table 1. Structural and functional parameters of the human heart

Parameter	Value (average)	Functional significance
Heart weight	250–350 g	Determines overall pumping capacity
Heart length	10–12 cm	Anatomical size indicator
Left ventricle wall thickness	8–15 mm	High pressure generation (systemic circulation)
Right ventricle wall thickness	3–5 mm	Low pressure (pulmonary circulation)
Stroke volume	60–90 ml	Blood ejected per beat
Heart rate	60–80 bpm	Determines cardiac rhythm
Cardiac output	4–6 L/min	Total blood circulation efficiency
Cardiac cycle duration	0.8 s	Coordination of systole and diastole

The data presented in Table 1 indicate that anatomical parameters are closely linked to physiological performance. For example, the greater thickness of the left ventricular wall allows the generation of higher pressure required for systemic circulation, while the thinner right ventricle is adapted to pulmonary circulation with lower resistance. The study also demonstrated that heart valves regulate unidirectional blood flow based on pressure gradients. Proper valve function ensures efficient ejection of an average stroke volume of approximately 70 ml per beat. In addition, the conduction system maintains synchronization of myocardial contractions, with impulse generation in the sinoatrial node and rapid propagation through Purkinje fibers, reaching speeds of up to 4 m/s.

The cardiac cycle, lasting approximately 0.8 seconds, integrates electrical and mechanical processes, ensuring stable blood circulation. During systole, blood is ejected into major arteries, while diastole allows ventricular filling and myocardial recovery.

The coordination of these phases is essential for maintaining adequate cardiac output and tissue perfusion. Overall, the results confirm that the efficiency of the human heart depends on the precise interaction between its anatomical structure and physiological mechanisms, highlighting its role as a highly regulated biological system.

CONCLUSION

The present study confirms that the human heart functions as a highly efficient and well-coordinated biological pump, whose performance is determined by the close interaction between its anatomical structure and physiological mechanisms. The four-chambered organization of the heart ensures the separation of pulmonary and systemic circulation, allowing effective oxygen delivery and metabolic exchange throughout the body.

It was established that structural features such as ventricular wall thickness are directly related to functional demands. The left ventricle, with its greater thickness, generates high pressure required for systemic circulation, while the right ventricle operates under lower pressure conditions suitable for pulmonary circulation. In addition, heart valves play a crucial role in maintaining unidirectional blood flow, preventing backflow and ensuring stable hemodynamics.

The study also highlights the importance of the cardiac conduction system in regulating heart activity. The generation and propagation of electrical impulses ensure synchronized myocardial contraction, which is essential for maintaining an effective cardiac cycle. The coordination of systole and diastole enables the heart to maintain a stable cardiac output of approximately 4–6 liters per minute under normal physiological conditions. Overall, the findings demonstrate that the efficiency of the human heart depends on the precise integration of structural components, electrical activity, and mechanical processes. Understanding these mechanisms provides a scientific basis for further studies in cardiovascular physiology and contributes to the improvement of clinical approaches to heart-related diseases.

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