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BIOPHYSICAL STRUCTURE OF BLOOD

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Abstract:

This article comprehensively analyzes the biophysical structure of blood, its components, and its main physicochemical properties. The composition of blood, consisting of plasma and formed elements, as well as important indicators such as viscosity, density, osmotic pressure, and oncotic pressure, are scientifically described. In addition, the rheological properties of blood, namely its behavior as a non-Newtonian fluid, the deformability of erythrocytes, and its role in microcirculation, are examined. The transport, protective, regulatory, and thermoregulatory functions of blood are also analyzed from a physical perspective. The results of the study demonstrate the important role of blood biophysical parameters in maintaining physiological balance, early disease detection, and modern clinical diagnostics.

Keywords: Blood, plasma, erythrocyte, biophysics, viscosity, rheology, hemodynamics, osmotic pressure, oncotic pressure, microcirculation, hematocrit

1. INTRODUCTION

Blood is one of the main internal environments of the human body and ensures the continuity of all vital processes. It transports oxygen, nutrients, hormones, enzymes, and metabolic products throughout the organism. In addition, blood plays a significant role in immune defense, thermoregulation, and maintenance of homeostasis.

Biophysics studies the physical, mechanical, and hydrodynamic properties of blood. Blood is a complex dispersed system whose structural components interact closely with one another. Changes in the physical properties of blood directly affect cardiovascular activity, tissue oxygenation, and overall metabolic processes.

Today, the increasing prevalence of cardiovascular diseases, diabetes mellitus, hypertension, and hematological disorders highlights the need for deeper investigation of blood biophysics. Therefore, the study of the biophysical properties of blood is considered one of the most relevant directions of modern medicine.

2. RESEARCH METHODOLOGY

This study employed theoretical analysis, literature review, comparison, generalization, and systematization methods. Scientific sources in medical physiology, biophysics, hemodynamics, and rheology were analyzed to examine the principal biophysical parameters of blood.

Additionally, theoretical concepts related to blood density, viscosity, osmotic pressure, and rheological state used in clinical practice were studied, and their physiological as well as pathological significance was evaluated.

3. MAIN PART

3.1. Composition and Structure of Blood

Blood consists of two main components: plasma and formed elements.

Plasma is the liquid part of blood, containing approximately 90–92% water. The remaining part consists of proteins, glucose, lipids, mineral salts, hormones, and enzymes. Plasma plays an important role in transport and metabolic processes.

Formed elements include:

- **Erythrocytes** – cells responsible for transporting oxygen and carbon dioxide;
- **Leukocytes** – major cells of the immune defense system;
- **Thrombocytes (platelets)** – cellular fragments involved in blood clotting.

The normal ratio of these components ensures proper functional activity of blood. Hematocrit is an important laboratory indicator reflecting the proportion of formed elements in blood.

3.2. Physical Properties of Blood

The main physical properties of blood include density, viscosity, surface tension, osmotic pressure, and oncotic pressure.

Viscosity is the resistance of blood to flow and depends on hematocrit level, plasma protein concentration, and temperature. Increased viscosity slows circulation and imposes additional workload on the heart.

Density varies according to the amount of cellular components and dissolved substances in blood. Under normal conditions, blood density is higher than that of water.

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Surface tension contributes to stable blood movement within capillaries. These indicators are essential for maintaining physiological equilibrium.

3.3. Rheological Properties of Blood

Rheology studies the flow and deformation properties of blood. Blood is not a simple Newtonian fluid but a **non-Newtonian fluid**, meaning that its viscosity changes depending on flow velocity.

The rheological properties of blood are influenced by:

- hematocrit level;
- erythrocyte elasticity;
- plasma protein concentration;
- temperature;
- vessel diameter;
- flow rate.

The deformability of erythrocytes allows them to pass through narrow capillaries. If this property decreases, microcirculation becomes impaired and hypoxia develops.

In diseases such as diabetes mellitus, atherosclerosis, and hypertension, blood rheology may significantly change.

3.4. Osmotic and Oncotic Pressure

Osmotic pressure is generated by all dissolved substances in plasma and regulates the exchange of water between cells and extracellular fluid. It maintains fluid balance between the intracellular and extracellular environments.

Oncotic pressure is mainly produced by proteins such as albumin. It retains fluid within blood vessels and prevents excessive fluid accumulation in tissues.

When albumin concentration decreases, fluid leaves the vessels and edema develops. This condition is common in liver diseases, kidney failure, and protein deficiency.

3.5. Hemodynamic Processes

Hemodynamics studies the movement of blood through vessels as a result of heart contractions. The following factors influence this process:

- force of cardiac contraction;
- heart rate;
- elasticity of blood vessels;
- peripheral resistance;
- blood pressure;
- blood viscosity.

Normal hemodynamic processes ensure the delivery of oxygen and nutrients to body tissues. When cardiac function weakens or vessels narrow, circulatory disturbances occur.

4. ANALYSIS AND DISCUSSION

The analysis shows that the biophysical parameters of blood reflect the overall functional condition of the body. Increased viscosity raises the risk of thrombosis, hypertension, and heart failure.

Impaired rheological properties worsen capillary circulation, leading to tissue oxygen deficiency. Changes in osmotic and oncotic pressure may result in dehydration or edema-related pathological conditions.

Laboratory monitoring of blood biophysical parameters allows early detection of many diseases. These indicators are especially important in cardiovascular disorders, diabetes, and hematological syndromes.

Therefore, the study of blood biophysics has great scientific and practical importance in preventive medicine, intensive care, and the development of individualized treatment strategies.

5. CONCLUSION

The biophysical structure of blood is a complex multicomponent system whose composition and physicochemical properties ensure the stability of vital functions in the organism. Viscosity, osmotic and oncotic pressure, rheological properties, and hemodynamic processes determine the normal functional state of blood.

Changes in these parameters may lead to various pathological conditions. Therefore, a deep understanding of blood biophysics is of significant scientific and practical importance for early diagnosis, development of individualized treatment strategies, and improvement of modern medical practice.

In the future, the application of artificial intelligence, digital monitoring, and biomarker analysis in blood biophysics may open a new stage in the advancement of medicine.

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