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Tachycardia and bradycardia from the point of view of rheology

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Abstract: This article examines the relationship cardiovascular diseases with rheological properties.
Key words: cardiovascular system, arrhythmia, tachycardia, bradycardia, rheological properties of blood, cardiovascular diseases

According to WHO estimates, about 18 million people die from cardiovascular diseases (CVD) every year, which is 31% of all deaths worldwide. This means that about 10,000 people die from them every day. It is noted that with an average global level of 233 deaths from cardiovascular diseases per 100 thousand people per year, Uzbekistan ranks first on this list, with 724 deaths per 100 thousand people. Every year on September 29, the world celebrates World Heart Day.

So what is the cardiovascular system? The cardiovascular system (CVS) (Latin: *systema cardiovasculare*) is a system of organs that includes the heart and blood vessels (arteries, veins and capillaries) that ensures blood circulation throughout the body.

Speaking briefly about the cardiovascular system, the heart is a muscular organ that makes blood move, rhythmically pumping it into blood vessels - hollow tubes of various diameters through which blood circulates. The speed of blood flow in the vascular bed is different and depends on the total sum of the area of the lumens of vessels of this caliber in a given area of the body.

Thanks to her activities oxygen and nutrients are delivered to the organs and tissues of the body, and carbon dioxide, other products metabolism and waste products are removed from organs and tissues and then excreted from the body. The main functions of the cardiovascular system are the transport function (delivery of oxygen and nutrients), thermoregulation (maintaining body temperature by redistributing blood), regulation (participation in the regulation of acid-base balance and metabolism), immune function (protection of the body with the help of blood cells and antibodies), as well as ensuring the rhythmic flow of physiological and biochemical processes in the body.

The heart of a healthy person contracts rhythmically at rest with a frequency of 60-70 beats per minute. The period that includes one contraction and subsequent relaxation is the cardiac cycle. At a heart rate of 70 beats per minute, the full cycle of cardiac activity lasts 0.8-0.86 s. The mechanisms regulating blood circulation are conventionally divided into local (peripheral or regional) and central - neurohumoral. The first mechanisms regulate blood flow in organs and tissues in accordance with their functions and metabolism, the second - systemic hemodynamics during adaptive reactions of the body. All functions of the CVS are strictly coordinated due to neuroreflex regulation, which allows maintaining homeostasis in constantly changing conditions of the external and internal environments.

The above information proves that the activity of this organ is important for our body and any changes in its performance caused by various factors such as: “stress, hormonal changes or pathologies” can lead to irreparable consequences not only in the cardiovascular system but also in other vital organs.

Let's look at some of the cardiovascular diseases, their causes, and preventive measures:

Cardiovascular diseases (CVD) are a group of diseases that affect the heart and blood vessels. They include a wide range of diseases that can occur as a result of both circulatory disorders and structural changes in the heart. Cardiovascular pathology includes, first of all, primary heart diseases: some forms of myocarditis,

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cardiomyopathy, heart tumors. It also includes heart damage in infectious, infectious-allergic, dysmetabolic and systemic diseases and diseases of other organs.

Risk factors (RF) for cardiovascular diseases are the characteristics of the body, external influences and their interactions that increase the probability of disease occurrence, its progression and unfavorable outcome. The main RF are: arterial hypertension, elevated cholesterol and triglyceride levels, smoking, abdominal obesity, fasting hyperglycemia, impaired glucose tolerance, diabetes mellitus, gender and age, adverse heredity, metabolic syndrome. Additional: heart rate, psychosocial stress, alcohol, low physical activity, uric acid. In CVD, the most important clinical values are determination of lipid levels, some electrolytes, uric acid, as well as carbohydrate metabolism indicators, coagulation hemostasis and myocardial necrosis, and renal function assessment.

For the prevention of CVD, in addition to drug treatment (which includes the use of drugs to lower blood pressure, cholesterol levels, and antiplatelet agents to prevent thrombus formation), lifestyle modification methods and non-drug treatment are used: quitting smoking and limiting alcohol, changing diet (maintaining a diet low in saturated fat, salt and sugar, with increased fiber) , physical activity (regular exercise helps maintain normal blood pressure and cholesterol levels) , psychoprophylaxis, and eliminating extracardiac etiological factors.

One of the common diseases that occurs in the cardiovascular system is a disease associated with a disturbance in the heart rhythm, arrhythmia.

Arrhythmia is a pathological condition in which the heart rate, rhythm and contraction sequence are disrupted, which can occur in the atria, ventricles or at the level of the cardiac conduction system. This is a general name for pathology, it is characterized by any deviation from the normal state of the heart . Symptoms of arrhythmia include uneven, very frequent or slow heartbeat, dizziness, a state close to fainting, chest pain, regular sensations of heart pain, limb tremor syndrome, insomnia, frequent panic, anxiety, shortness of breath. In some cases, the patient may not feel any signs of heart rhythm disturbance . The causes of arrhythmia can be vegetative-vascular dystonia; the presence of sinus node pathologies; abnormalities in the thyroid gland; excess weight; genetic factor; hormonal changes in the body; heavy physical exertion; alcohol abuse; smoking; damage and pathologies of the cardiac system; abnormalities in the functioning of the nervous system; congenital defects; consumption of fatty foods; lack of sleep; heart failure; uncontrolled use of certain medications; the presence of diabetes.

Types of arrhythmia:

Depending on the place of origin:

- Sinus
- Ventricular
- Atrial

Depending on heart rate:

- Tachycardia
- Bradycardia
- Paroxysmal disorders
- Extrasystole
- Atrial fibrillation of the heart

Diagnosis of arrhythmia:

Arrhythmia diagnostics allows us to study the patient's condition in detail, determine the type of arrhythmia and prescribe the most effective treatment methods.

1. **An electrocardiogram (ECG)** is the main diagnostic method that allows recording the electrical activity of the heart and identifying rhythm disturbances.
2. **ECG monitoring** - using Holter monitoring to record heart activity over 24-48 hours to help identify rare or paroxysmal arrhythmias.
3. **Echocardiography** - used to evaluate the structure of the heart, valve function, and the presence of changes in the myocardium that may contribute to arrhythmias.
4. **Electrophysiological study** is a special procedure to determine the exact location of arrhythmia and assess cardiac conduction.

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Sometimes the causes of arrhythmia are hidden in something completely different. An ECG may show good results, but problems are still present. In this case, additional methods of arrhythmia diagnostics are prescribed to establish a diagnosis, if there are no contraindications to their use. These include: biochemical blood and urine tests ; hormonal analysis; ultrasound of the kidneys; radiography; MRI of the brain; echocardiography. Since tachycardia and bradycardia are the main types of arrhythmia, let us consider these diseases in more detail.

Tachycardia

Tachycardia is a heart rhythm disorder in which the heart rate exceeds 100 beats per minute (at rest). Normally, a person's heart at rest contracts at a rate of about 60-80 beats per minute, and any acceleration above this norm is considered tachycardia. It can manifest itself as a rapid heartbeat, shortness of breath, dizziness, loss of consciousness, or chest pain. In severe cases, it can lead to a heart attack or ventricular fibrillation.

Types of tachycardia:

- Sinus tachycardia is an increase in the frequency of normal sinus contractions over 90 per minute. Sinus tachycardia is based on increased automatism of the sinus node due to an increase in the tone of the sympathetic nervous system, a decrease in the tone of the parasympathetic nervous system, or as a result of the direct effect of various substances on the cells of the sinus node. This can be caused by both physiological reasons (physical and emotional stress), and some pathological conditions (acute heart failure and chronic heart failure, respiratory failure, thyrotoxicosis, pheochromocytoma, anemia, fever), as well as a number of toxins and medications (caffeine, cocaine, alcohol, nicotine, β-adrenergic agonists, anticholinergics, theophylline).

Reciprocal SA tachycardia is a relatively rare rhythm disorder, occurring in 1–3% of cases among patients with paroxysmal SVT. The rhythm disorder is accompanied by a moderate increase in heart rate (90–160 beats per minute) and is often asymptomatic. It is characterized by sudden onset and cessation. During an attack, the ECG reveals P waves preceding the QRS complex and practically indistinguishable in morphology from sinus P waves.

- Atrial tachycardia is a tachycardia originating in the atria. It is characterized by a faster and more regular heart rhythm. Causes may include atrial overload (eg, in heart failure) or electrical activity that originates in a different part of the atria than the sinus node. Short bouts of unsustained atrial tachycardia are detected in 2–6% of healthy individuals during Holter monitoring. In mitral valve prolapse, bouts of atrial tachycardia are detected in 20% of patients, and in the acute phase of myocardial infarction, in 4–19% of patients. The prevalence of sustained atrial tachycardia is 10–15% of all cases of supraventricular tachycardia. It often occurs in the context of coronary heart disease, valvular heart disease, and cardiomyopathy. In addition, atrial tachycardia often occurs in patients with digitalis intoxication. In this case, the development of atrioventricular block 2:1 is typical. Reciprocal atrial tachycardia often occurs after surgical treatment of congenital heart defects (postincisional arrhythmia).
- Ventricular tachycardia is a more dangerous type of tachycardia in which the impulses originate in the ventricles of the heart. It can be caused by serious heart conditions such as a heart attack or cardiomyopathy. Ventricular tachycardia can quickly progress to ventricular fibrillation and cardiac arrest if not treated immediately.
- Paroxysmal tachycardia is an attack of rapid heartbeat that begins and ends suddenly. Such tachycardia can be either atrial or ventricular, and often occurs when the conduction of cardiac impulses is impaired.

Bradycardia

Bradycardia is a slowing of the heart rate, when the heart rate drops below 60 beats per minute at rest. This may be a normal condition in athletes and people who are physically trained, but in other cases, bradycardia may indicate various pathological processes in the heart. A constant, rare heartbeat at 40 bpm for several days requires a medical examination. A decrease in heart rate within 40-35 bpm is a threat, the brain begins to feel a lack of oxygen. A decrease in heart rate to 30 beats per minute requires immediate medical attention. Bradycardia can cause dizziness, fatigue, fainting, and insufficient blood supply to organs, which leads to hypoxia (lack of oxygen).

Types of bradycardia:

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- Neurogenic : caused by extracardiac (non-cardiac) diseases;
- Systolic : develops when the heart's contractions are disrupted;
- Respiratory : often asymptomatic, less often manifested by a slowing of the pulse on exhalation, sometimes by its stopping and acceleration on exhalation.

Types of bradycardia:

- Sinoatrial bradycardia is a type of bradycardia in which the sinus node, which controls the heart's rhythm, beats at a slow rate. This can occur due to damage to the sinus node, aging, or certain medical conditions (such as coronary artery disease). This type of bradycardia can be functional (in trained people) or pathological.
- Atrioventricular (AV) block is a disruption in the conduction of electrical impulses between the atria and ventricles. This can lead to a slow heart rate. AV block is divided into several degrees:

1st degree - the impulse passes through the blocked part, but with slowdown.
2nd degree - some of the impulses do not pass to the ventricles, and they do not contract.
Grade 3 - complete block, when impulses do not pass, and the ventricles contract independently of the atria (installation of a pacemaker may be required).

- **Sick sinus syndrome** is a condition in which the sinus node fails to maintain a normal heart rhythm, resulting in bradycardia. This may be due to age-related changes, heart disease, or drug toxicity.

Causes of bradycardia:
Damage or disease of the sinus node (eg, coronary artery disease).
Electrolyte disturbances (eg, elevated blood potassium levels).
Effects of drugs such as beta blockers or cardiac glycosides.
Head injuries or traumatic brain diseases that affect the heart rhythm control center.
Congenital anomalies of the cardiac conduction system.

Let us consider the above-mentioned diseases from the point of view of rheology.

Rheological properties

Blood rheological properties are an important aspect of physiology and pathophysiology, as they determine the behavior of blood in the vascular bed and its ability to maintain normal blood circulation. These properties significantly affect blood flow, the distribution of oxygen and nutrients, as well as various mechanisms associated with thrombus formation and pathological processes in the cardiovascular system.

Basic rheological properties of blood and their relationship with heart disease:

- **Blood viscosity** : Blood viscosity is determined by its resistance to flow, which depends on a number of factors, including the concentration of blood cells (red blood cells, white blood cells, platelets), the level of plasma proteins such as fibrinogen, albumin and globulins, and the hydrodynamic conditions of the circulation. Factors that increase viscosity include: increased red blood cell concentration (hematocrit), inflammation (increased fibrinogen levels), hyperlipidemia and hyperglycemia. It can be increased by various conditions, such as hyperglycemia, inflammation, atherosclerosis or dehydration. Increased viscosity makes the blood "thicker", which leads to increased peripheral vascular resistance and increased workload on the heart. The higher the viscosity, the more difficult it is for the heart to pump blood through the vessels, which increases the risk of cardiovascular diseases such as hypertension, coronary heart disease and stroke. In response, the heart may attempt to compensate for the higher resistance by increasing its heart rate, resulting in tachycardia.
- **Erythrocyte aggregation** : Aggregation is the process by which red blood cells stick together to form larger aggregates, which increases viscosity and reduces blood fluidity. This process is regulated by fibrinogen concentrations and other plasma proteins. such as atherosclerosis, diabetes, and inflammatory diseases. Increased red blood cell aggregation can impair microcirculation, especially in small vessels, which promotes thrombus formation. Diabetes, hypertension, and inflammation increase aggregation, which increases the risk of thrombus formation and impairs microcirculation, leading to vascular damage. If the rheological properties of the blood are impaired due to red blood cell aggregation (when blood cells "stick together"), this can impair blood flow in the microcirculatory bed. Under these conditions, the heart compensates for the slowdown in blood flow by increasing the heart rate (tachycardia), trying to improve the supply to tissues.

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- **Red blood cell deformability** : Red blood cells have the ability to change their shape when moving through capillaries, allowing them to pass through narrow vessels. Disruptions in this ability lead to deterioration of microcirculation, which is observed in diseases such as sickle cell anemia. In this case, red blood cells lose their deformability, which interferes with normal blood circulation and causes blockages in blood vessels, disrupting tissue nutrition.
- **Plasma rheology** : Plasma proteins such as fibrinogen play an important role in regulating the rheological properties of blood. Excessive amounts of fibrinogen can lead to increased blood viscosity, which reduces its fluidity. This can cause deterioration of microcirculation, especially in inflammatory processes and conditions associated with increased levels of this protein in the blood.

The influence of rheological properties on tachycardia and bradycardia:

- **Tachycardia** : Tachycardia, i.e. increased heart rate, may be a compensatory response to increased blood viscosity. When viscosity increases, the heart is forced to work harder to provide sufficient blood supply to tissues and organs. This leads to an increase in heart rate to overcome vascular resistance. In some cases, tachycardia develops as a response to deterioration of microcirculation caused by increased cell aggregation and blood viscosity, which is typical for diseases such as hypertension, atherosclerosis and diabetes. The development of these diseases leads to increased resistance in the vessels (especially in small ones). This makes the heart work harder to maintain the required blood flow, which can lead to tachycardia as a compensatory reaction. With tachycardia, especially long-term, microcirculation can be impaired due to insufficient time for adequate metabolism in the capillaries. This occurs due to accelerated blood flow, which reduces the time required for optimal exchange of oxygen and nutrients. In turn, this can cause blood stagnation and deterioration of rheological properties, such as increased aggregation of erythrocytes and increased viscosity . Also during this disease, the blood flow velocity increases, which can cause aggregation of erythrocytes and platelets, lead to increased deformation of erythrocytes, to a decrease in the time the blood stays in the capillaries, where the exchange of oxygen and nutrients occurs. This can aggravate the condition if the blood has high viscosity, since the accelerated flow does not allow time for normal metabolism in the tissues. In this case, the heart is forced to work at an increased rate to compensate for the lack of oxygen, which only increases tachycardia. Accelerated blood flow can, which in turn worsens blood fluidity and increases its viscosity. Violation of the rheological properties of the blood due to cell aggregation leads to an increase in vascular resistance, which increases the load on the heart and can lead to even more pronounced tachycardia as a compensatory reaction. With tachycardia, hypercoagulation can also develop, that is, an increased tendency to thrombus formation. Acceleration of blood flow with insufficient blood rheology leads to thrombus formation, which further worsens blood fluidity and increases the risk of thrombus formation. This can also lead to disruption of microvascular circulation and the occurrence of more serious cardiovascular problems.
- **Bradycardia** : Slowing of the heart rate, may occur when blood viscosity is normalized , for example, when fluids or plasma substitutes are administered, when the blood becomes less viscous and does not require rapid pumping , or in situations where the microcirculation does not require increased cardiac activity to maintain blood supply. For example, when blood viscosity is low, the heart can reduce its contraction rate, since blood easily passes through the vascular bed. Bradycardia can also result from hypoxic conditions or hypotension, when blood circulation becomes slow, which does not require high heart rates. In some cases, a decrease in blood viscosity, for example, in anemia or overhydration, can reduce the load on the heart. This leads to a decrease in peripheral resistance and an improvement in blood circulation, which can also lead to a decrease in heart rate, since the cardiac system does not experience high vascular resistance. In this case, the heart can compensate for the reduced resistance by slowing the rhythm, which can manifest as bradycardia. When the rheological properties of the blood deteriorate (e.g., with hyperfibrinogenemia or red blood cell deficiency), normal blood flow in the capillaries may be hampered, which leads to a decrease in oxygen supply to the tissues. In such cases, compensatory mechanisms may be activated, including a slowing of the heart rate to reduce the need for oxygen, which also contributes to the development of bradycardia. Also, in some cases, hypervolemia (blood moistening, for example, excessive fluid administration) can reduce blood viscosity, which can also lead to a compensatory slowing of the heart rate, especially if the heart feels

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that it does not need such a strain to cope with the blood flow. Such an effect can be observed during therapy using fluid preparations, such as plasma substitutes. It is observed that, with bradycardia, the heart contracts slowly, which slows down the overall blood flow. This can lead to stagnation of blood in large and small vessels, worsening microcirculation, which can lead to hypoxia, since under conditions of low blood flow rate, the cells do not receive the required amount of oxygen. This can worsen the rheological properties of blood, as hypoxia causes deformation of cells, especially red blood cells, which reduces their ability to deform in narrow capillaries. This also contributes to an increase in blood viscosity and a decrease in its fluidity.

Treatment of arrhythmias:

- **Drug therapy** : anti-rhythmic drugs such as beta blockers, calcium channel blockers, anticoagulants, antiarrhythmics to control the heart rate and rhythm.
- **Electrical cardioversion** : The use of electrical shocks to restore normal rhythm in certain types of arrhythmias (such as atrial fibrillation).
- **Radiofrequency ablation** : A surgical procedure that aims to destroy areas of the heart that are causing arrhythmia.
- **Permanent pacemaker or defibrillator** : Placement of a device to control the heart's rhythm in chronic or life-threatening arrhythmias.

Alternative treatment:

- Tinctures of hawthorn, valerian, motherwort;
- Tincture of indifference;
- Aristolochia manchurianum;
- Peony evading;
- Calendula tincture;
- Sesame oil;
- Infusion of Leuzea carthamoides;
- Chicory.

Some herbs are used to create pharmacological preparations. They exhibit sedative properties, are able to relieve stress, nervous tension, and eliminate pain. But herbal medicine can only be used under the supervision of an experienced specialist. The reason for this is the large number of contraindications for such plants.

In the absence of timely treatment of a dangerous disease, consequences such as the development of a state of anxiety and stress; thromboembolism; cardiogenic shock; development of fainting spells, suffering of the body from blood pressure; pain in all organs; development of cardiac arcs (such as cardiac ischemia), risk of stroke, as well as sudden cardiac arrest, eventually leading to death.

In conclusion, it can be said that changes in the rheological properties of blood, such as increased or decreased viscosity, aggregation of blood cells and disruption of their deformation, directly affect the functioning of the heart, therefore, a disturbance in the heart rhythm (tachycardia or bradycardia) can change vascular resistance and blood flow, which, in turn, affects the rheology of the blood, changing its fluidity, viscosity and ability to circulate normally through the microcirculatory bed.

Thus, tachycardia and bradycardia can directly affect blood rheology, which contributes to the development or worsening of cardiovascular diseases.

Taking into account the combination of the above-mentioned factors, special attention should be paid to the rheological properties of the blood, in particular its viscosity, and appropriate measures should be taken to maintain this parameter within normal limits.

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