Lesson №9.

Electrocardiography.

Electrocardiography - registration of electrical processes in the heart muscle that occur when it is excited. This method has found widespread use due to its availability and safety. Electrocardiography is one of the main diagnostic methods in the study of heart activity and is used to diagnose disorders of the cardiovascular system and assess the general state of human health.

Einthoven's theory is the cornerstone of electrocardiography. This theory connects the biopotentials of action arising during the contraction of the heart muscle with the potential difference recorded on the surface of the human body. The heart in Einthoven's theory is considered as a current dipole located in a conductive homogeneous medium.

The main characteristic of a current dipole is the dipole moment:

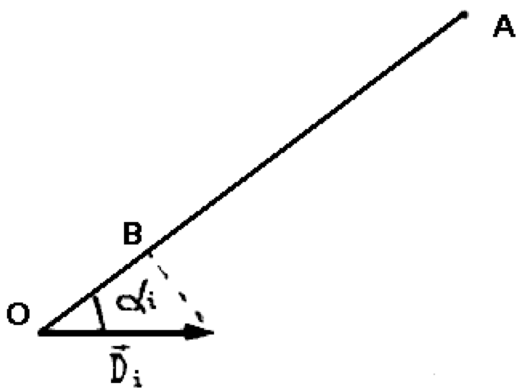
$$\vec{D} = I \cdot \vec{L},$$

where I is the current in the dipole, equal to the current in the external environment; $\vec{L}$ - a vector directed from "-" to "+" (coincides with the direction of the current inside the dipole), equal in magnitude to the distance between the poles.

The potential of a field created by a set of dipoles is equal to the algebraic sum of the potentials of the fields formed by individual dipoles. Then the total potential φ of the electric field at a point located at a distance r from the dipoles is the sum of the potentials of the elementary dipoles Di:

$$\varphi = \frac{\rho}{4\pi r^2} \sum_{i=1}^{n} D_i \cos\alpha_i ,$$

where n is the number of elementary dipoles, ρ - specific resistance of the medium.



Graphical determination of the potential of the electric field created by the current dipole D_i at point A.

The sum of the projections can be considered as the projection of the dipole moment vector $\vec{D}_0$ one current dipole equal to the sum of elementary dipoles $\vec{D}_i$:

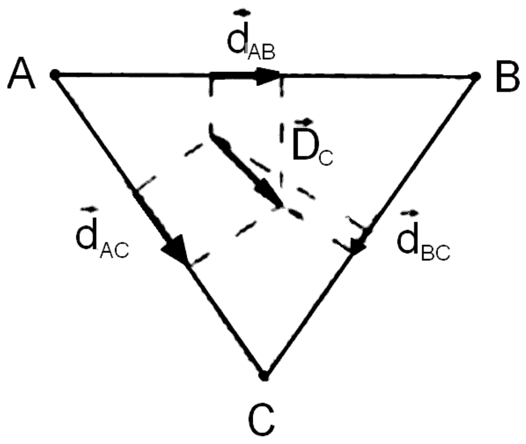
$$\vec{D}_0 = \sum_{i=1}^{n} \vec{D}_i$$

This current dipole is called the equivalent heart dipole. Thus, the potential of an external electric field can be represented as the potential of one equivalent electric dipole $\vec{D}_0$:

$$\varphi_0 = D_0 \cos\alpha_0 \frac{\rho}{4\pi r^2}$$

Where α_0 - angle between $\vec{D}_0$ and direction to the registration point of the potential; D_0 - vector module $\vec{D}_0$...

Let the dipole creating the electric field be in the center of the equilateral triangle ABC:



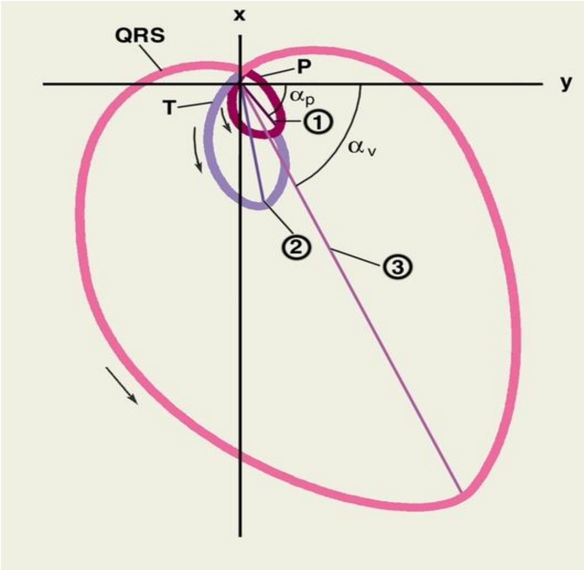
Construction of vector projection $\vec{D}_0$ *on the sides of the equilateral triangle ABC.*

Then, using, we can graphically obtain that the stress ratios on the sides of this triangle are the same as the ratios of the vector projections $\vec{D}_0$ to the corresponding sides of this triangle:

$$U(AB)/U(BC)/U(AC) = D_0\cos\alpha_1 / D_0\cos\alpha_2 / D_0\cos\alpha_3 \ ,$$

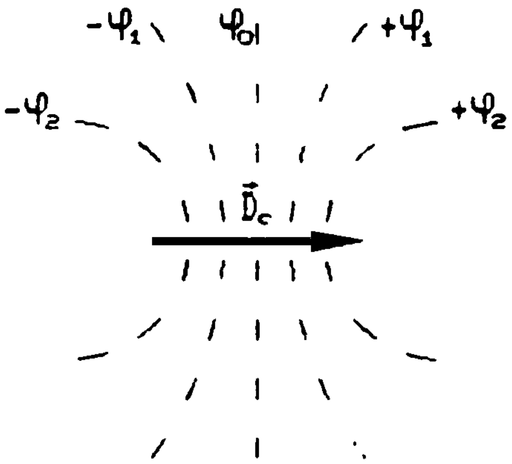
where U is the voltage between the vertices of the triangle; $\alpha_1, \alpha_2, \alpha_3$ - the angles between the vector and the direction to the corresponding points of registration of the potential.

According to Einthoven's theory, the heart is a current dipole with a dipole moment $\vec{D}_0$, which, turning, changes its position during the cardiac cycle, and describes a complex spatial curve, which can approximately be considered lying in the plane of the chest. This curve has three characteristic loops, designated P, QRS and T:



The curve described by the end of the vector of the dipole moment of the heart for the cycle of its work.

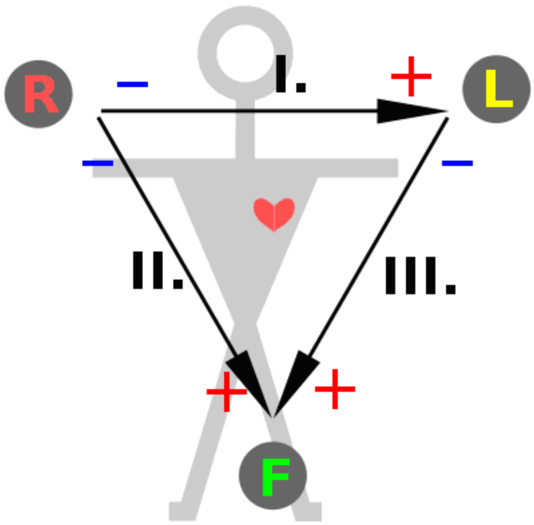
This figure shows the location of the equipotential lines for a current dipole $\vec{D}_0$:



Location of the equipotential surfaces of the heart current dipole.

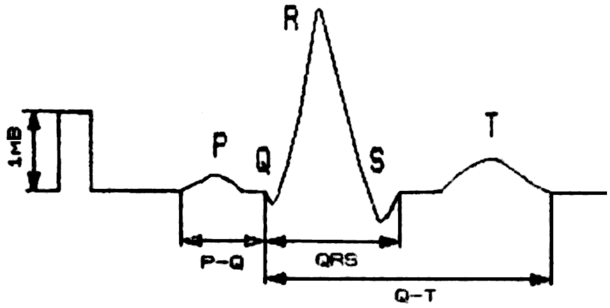
Einthoven proposed to remove the potential difference between the vertices of an equilateral triangle, which are approximately located on the right hand, left arm and left leg.

The potential difference between two points of the body in physiology is called lead. Leads I, II and III are called standard. To obtain them, electrodes are applied to the upper and lower extremities. A ground wire is connected to the right leg. It is also possible to use an additional chest electrode. Leads with this electrode are called chest leads. These leads provide additional diagnostic information.



Scheme of leads according to Einthoven (PR - right hand, LR - left hand, LN - left leg).

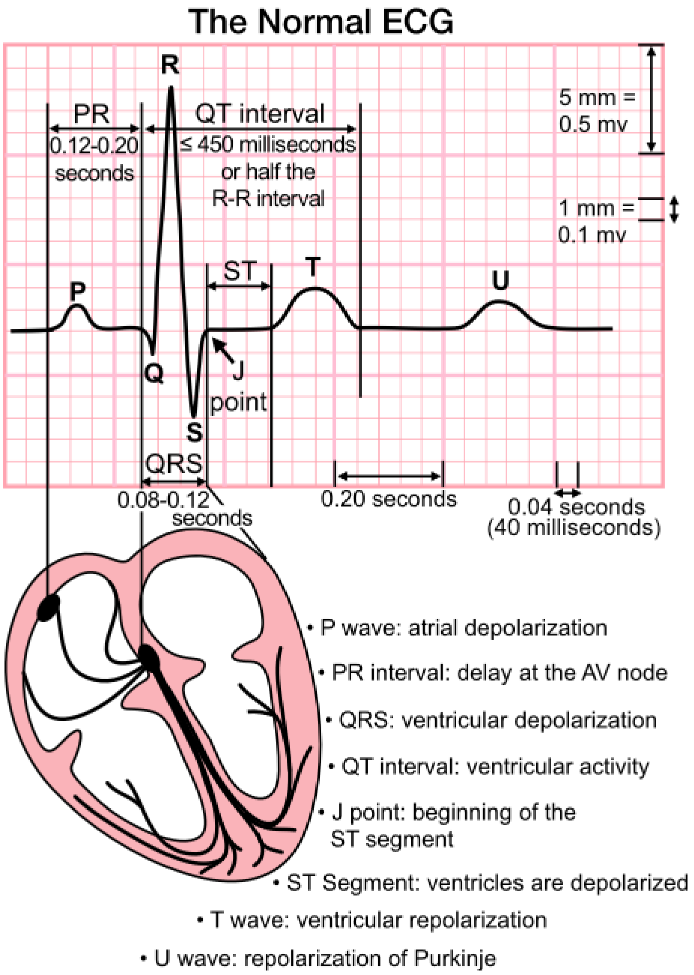
The main leads correspond to the sides of the triangle ABC and the potential differences between the vertices of this triangle. The dynamics of changes in the potential difference at each lead has a characteristic form, shown in Fig. 7 and is called an electrocardiogram.



Electrocardiogram.

On the electrocardiogram, there are three positive (upward) waves of P, R, T, and two negative (downward) waves of Q and S. These teeth characterize the magnitude of the EMF of the heart in different periods of its work. In addition, time intervals are measured on the electrocardiogram, which characterizes the duration of various phases of the cardiac cycle.

The ECG begins with a positive P wave. It is followed by a horizontal or nearly horizontal line that ends in an irregular, usually very small Q wave. The P-Q interval is measured from the beginning of the P wave to the beginning of the Q wave. The ascending part of the Q wave passes directly into the positive R wave. the descending part of the R wave passes into a negative variable S wave. The S wave (or R) is followed by a horizontal line - the ST interval. Sometimes the S wave immediately turns gently into a positive T wave. The T wave is sometimes followed by a U wave. Then there is a horizontal (isoelectric line) corresponding to the period of diastole.



Connection of the QRS loop, described by the end of the vector of the dipole moment of the heart $\vec{D}_0$ *and the QRS complex on the electrocardiogram.*

The ECG distinguishes between atrial and ventricular complexes. The P wave appears when atrial excitation begins. The initial part of it corresponds to the excitation of the right atrium, the middle - to the excitation of the left atrium. The shape, direction and size of the P wave in the norm for different leads vary within wide limits.

The P-Q interval corresponds to the period from the onset of atrial excitation to the onset of ventricular excitation. The QRS complex reflects the process of gradual oxatation of excitation of both ventricles. The R wave is usually the largest and corresponds to the period of ventricular systole. The size and shape of the R wave varies in different leads and depends on the position of the heart in the chest. The T wave corresponds to the period of falling ventricular excitation.

The main characteristics of the ECG are the shape and height of the teeth and the duration of the intervals. With pathological changes in the heart, these characteristics change, which makes it possible to use electrocardiograms to diagnose heart diseases. Knowing the height of the ECG teeth, it is possible to determine the angles formed by the vector of the dipole moment of the heart with the lead lines.

At the time when the dipole moment of the heart takes the maximum value (R wave on the ECG), the direction of the dipole moment (the electric axis of the heart) coincides with its anatomical axis. Based on this, using an electrocardiogram, it is possible to determine the position of the anatomical axis of the heart.

Control questions

1. What is called electrocardiography?
2. What is Einthoven's theory?
3. What is a dipole? What is the characteristic of the dipole field?
4. What is called an electrocardiogram?