SIMULTANEOUS CARDIOTOPOSCOPY AND ELECTROCARDIOGRAPHY USING HIGH-SPEED MOTION PICTURES*

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Our first cardiotoposcopic investigations [1] revealed some aspects of the electric field of the heart, although they did not permit us to record the electrocardiograph at the same time. Furthermore, the dynamics of the QRS complex could not be accurately determined with a motion-picture film moving at the rate of 24 frames per second. In this report, we describe the results of cardiotoposcopy and simultaneous electrocardiography using a high-speed film moving at the rate of 64 frames per second.

Cardiotoposcopy was carried out by means of a 50-channel electroencephaloscope, especially adapted for the purpose [2]. To obtain simultaneous electrocardiography, an electrocardioscope from a 6-channel "Alvar" electrocardiograph was placed at an angle to the screen of the cardiotoposcope. To take simultaneous motion pictures of the cardiotoposcopic changes and the electrocardiogram, a mirror was fixed at an angle to the upper part of the screen of a twin tube. The angle of the mirror was so selected that a motion picture of the electrocardiogram could be taken from the screen of the electrocariotoposcope in the form of a curve from any unipolar lead, and of the cardiotoposcopic picture in the form of 50 scintillating points and 50 scintillating columns.

Because the "Cardiovar" electrocardioscope has a tube with an afterglow, the traced portion of the electrocardiogram could be seen on the frames of the film. The time of taking the film corresponds to the place where the electrocardiogram breaks away from the stronger scintillation of the beam. The pictures were taken with a "Kiev" camera on a 16-mm film. The electrodes for cardiotoposcopy, as in the first investigation, were applied to the whole of the anterior and posterior surfaces of the chest.

The changing pattern of the electrical activity of the heart was studied on a film moving at the rate of 64-69 frames per sec in more than 100 persons. With this speed of film movement, the changes in the QRS complex could be observed over 5-6 frames.

EXPERIMENTAL RESULTS

During cardiotoposcopy with the electrodes situated on the anterior surface of the chest, the dynamics of the electrical activity were observed only in the anterior projection of the heart. The simultaneous recording of the potentials of the heart using 30 electrodes (1st-30th) on the posterior surface, and 20 electrodes (31st-50th) on the anterior surface of the chest, enabled us to observe the beginning of the QRS complex and the subsequent changes in its form.

In the QRS period the electronegativity makes a circular movement around the vertical axis of the human body at an angle to the horizontal plane. The dynamics of the QRS complex can be determined from the angular velocity of the rotating movement of the electronegativity and the angle of the plane of the circular movement to the horizontal plane. By recording the electrocardiogram simultaneously, we were able to interpret the cardiotoposcopic data more accurately (see figure).

The spread of electronegativity from behind and on the left toward the right, into the right arm, takes place

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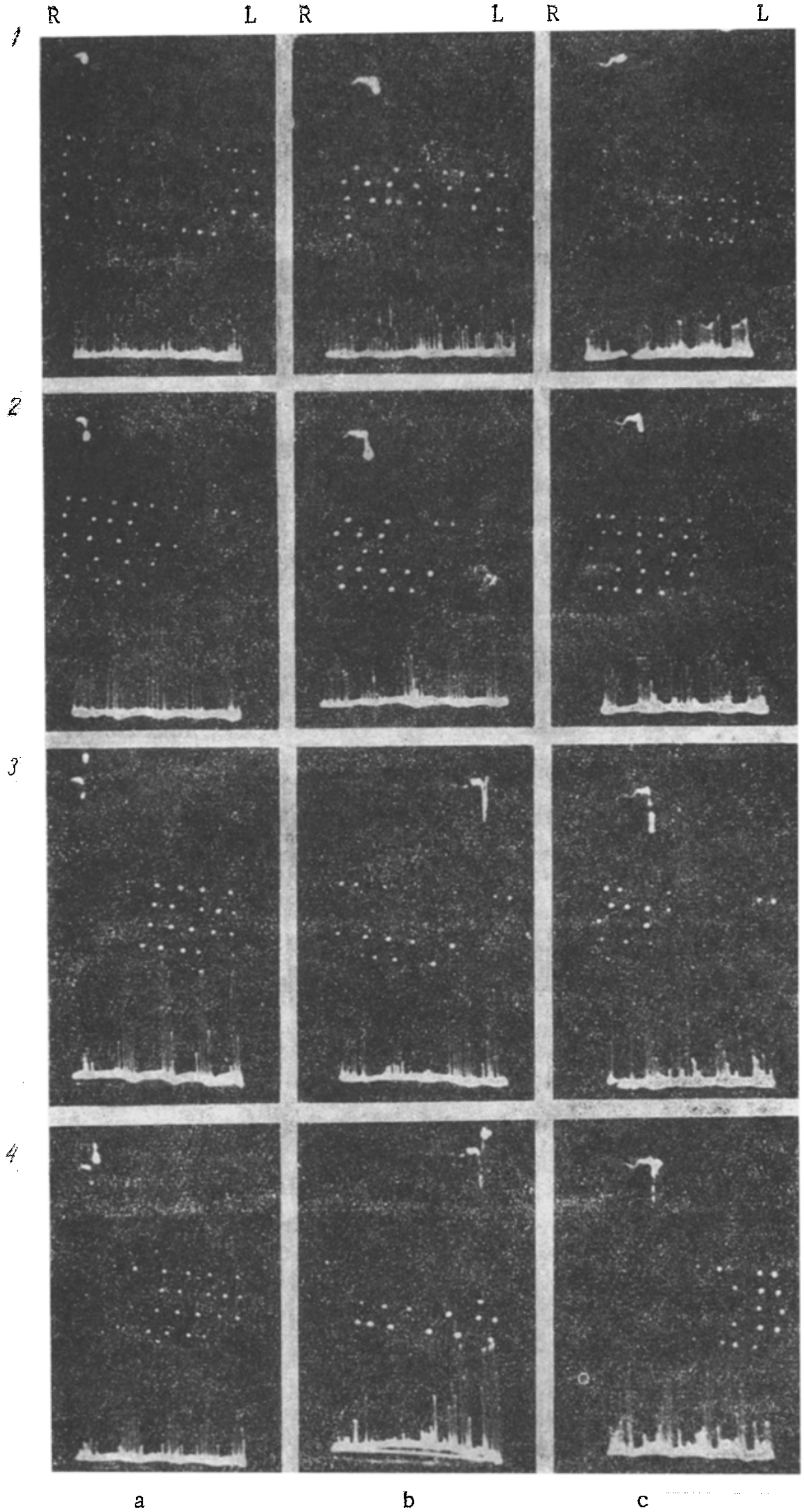

Dynamics of the electric field of the heart of a healthy person using high-speed motion pictures (investigation No. 116). ECG) Lead from right arm. a) All electrodes situated on anterior surface of chest; b) 30 electrodes situated on posterior and 20 electrodes on anterior surface of chest; c) all 50 electrodes situated on posterior surface of chest. R) Right side; L) left side. Dynamics of electric field of heart in the QRS period extend over 4 frames of film. First (horizontal) row – appearance of electropositivity anteriorly and electronegativity posteriorly. Second row – increase of potential differences and transfer of electronegativity to right side with "overflow" onto anterior surface of chest. Third row – further movement of electronegativity over anterior surface of chest with development of electropositivity posteriorly. Fourth row – final stage of movement of electronegativity anteriorly and to the left, and partly to posterior surface.

simultaneously with movement in the ECG (lead 2) from Q to the apex of the R wave. The apex of the R wave corresponds to the maximum of electronegativity in both the anterior and posterior surfaces of the right side of the chest.

As soon as movement from R to S begins to take place on the ECG, a decrease in electronegativity is seen on the cardiotoposcope on the right to the posterior surface of the chest, and an increase in electronegativity anteriorly, spreading to the left. The movement of electronegativity anteriorly over the surface of the chest ends in the lower left part of the chest.

As a result of the circular movement of the electric zones of the heart, the presence of an upper and a lower pole of rotation with a zero or minimal potential is established. The projection of these poles changes significantly, depending on the position of the heart. Recordings of the vectorcardiogram showed that the direction of movement of the loop of the QRS complex coincided with the direction of movement of the electric zones of the heart.

Simultaneous cardiotoposcopy and electrocardiography showed that the ST interval corresponds to a definite distribution of the zones of electrical activity, which correspond, in turn, to the previously established period T_A. It should be pointed out that the period T_A arises immediately after the end of the QRS complex, and with a film moving at a speed of 64 frames per sec, no electrically inactive interval is observed between QRS and T. An increase in the potential of the T wave corresponds cardiotoposcopically to an increase in potential difference and to a slight displacement of the zones of electronegativity and electropositivity.

After the T wave on the ECG has started to fall, in the cardiotoposcopic picture the zone of the preceding positive potential acquires a negative charge, and the zone of electronegativity becomes electropositive. The period arising after T_A we call T_B. If the phonocardiogram is recorded at the same time, the second sound follows 3-4 frames of the film after the end of the period T_A (0.04-0.05 sec). Another feature of the T wave is that the period T_B is more positive than the descending part of the T wave, and coincides in time with the U wave.

By the use of the method of cardiotoposcopy, new data can be obtained regarding the genesis of the ECG in all its leads. Since the process of excitation performs a circular movement, during unipolar registration of the ECG in any lead the apex of the S wave corresponds to the moment of passage of excitation. The period from the R wave to the S wave reflects the drawing near of the excitation to that zone of the heart which lies closest to the position of the lead.

In order to test the diagnostic possibilities of cardiotoposcopy and to study the genesis of the electrocardiographic changes, we investigated patients with various heart diseases: chronic coronary insufficiency (without infarction or after infarction), aneurysm of the ventricle, mitral stenosis, and pericarditis, and also with congenital defects (dextrocardia with patent ductus arteriosus, Fallot's tetralogy, coarctation of the aorta, etc.).

The results revealed significant changes in the pattern of movement of the excitation process. The electronegativity moved in the opposite direction in the patient with dextrocardia. Indentations in the R waves found in the electrocardiograms of some patients corresponded to a change in the path of movement of the excitation at this time. This was observed, in particular, in patients with scarring of the myocardium after infarction. One of the variants of the disturbances of the dynamics of excitation was a sharp limitation of its path of movement. It seemed to be concentrated in the region of the myocardial lesion.

The zone of the myocardial lesion is defined initially during excitation by the zone of electronegativity and, subsequently, for the extent of the periods T_A and T_B it becomes demarcated as a zone of electropositivity, adequately marked out at its periphery by points having a negative potential.

In hypertrophy of the right ventricle with slowing of the spread of excitation through the ventricle (as shown by the ECG), by means of cardiotoposcopy we observed how the electronegativity, when it crossed to the anterior surface of the chest, moved across the upper part of the chest from right to left, and after passing over the left side, moved to the lower part of the chest. As a result of this path of movement, the zone of maximal electropositivity shifted to the right side of the chest. Because the electronegativity in its movement apparently avoided the right side of the chest, the duration of the R wave was correspondingly lengthened.

In left ventricular hypertrophy we observed the movement of electronegativity across the right side of the upper surface of the chest. In this case, the electronegativity avoided the left side of the chest, and in the left chest leads an increase in the positive potential in time and amplitude was therefore recorded.

During the investigation of patients with bundle branch block, we observed changes both in the path and in the velocity of movement of the electronegativity.

SUMMARY

An inquiry was made into the dynamics of the electric field of the heart with the aid of 50-channel electroencephalograph of the M. N. Livanov and V. M. Ananiev's design, adjusted for this purpose. Electric activity of the heart was recorded from 50 chest leads, located along the whole anterior and posterior surfaces of the chest. All the 50 leads were projected on one screen in the form of bright spots, the brightness of which depended on the value of the cardiac biopotentials. For simultaneous filming (64 frams per sec) an ECG from any chest lead was projected from the electrocardioscope to the same screen with the aid of a mirror. In healthy persons the electric field excitation is divided into a zone of electronegativity and contralocated zone of electropositivity. At the QRS period these zones make a circular movement around the vertical axis counterclockwise. The travel of these zones may vary considerably in different patients, both in the direction and velocity of the movement.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.
