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EXTERNAL ELECTRIC FIELD RECORDED AROUND ANIMALS, MAN

By

U. S. Velyeyev, O. S. Osyenniy, et al.

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EXTERNAL ELECTRIC FIELD RECORDED AROUND ANIMALS, MAN

[Article by U. S. Velyeyev, O. S. Osyenniy, Yu. V. Tornuyev, D. F. Rakytyans'kiy; Institute of Physiology, Siberian Branch of the USSR Academy of Sciences, Novosibirsk; Kiev, Fiziolohichnyy Zhurnal Akademiyi Nauk Ukrayins'koyi RSR, Ukrainian, Vol 19, No 1, 1973, pp 99-104]

The attention of many researchers has been attracted recently by electromagnetic fields that originate in and around excited systems. Information regarding the presence of an electric field around an excited isolated nerve appeared first in 1949 [5]. The existence of a magnetic field around a nerve [6] and of electric and magnetic fields around the heart became known later [2, 4]. Experimental results regarding the electric field around man and animals [1] showed that characteristics of the recorded electric field around the human heart at a distance of 1 m cannot be explained within the framework of our understanding of the heart as an electric field generator.

The aim of this work was to study the characteristics of the electric field which can be recorded around biological subjects and to explain its nature.

Methods

The method of recording the external electric field of biological subjects was developed on the assumption that the source of this field is the hypothetical electric dipole located in the volumetric conductor and which produces a difference in potentials that is equal to the QRS wave amplitude on an electrocardiogram.

In order to record the electric field of biological subjects, it is necessary to have very sensitive apparatus (10^{-3} to 10^{-4} V). In our experiments we used the electrometric amplifier UI-2 with the input base of $R_{input} = 10^{11}$ ohm which was necessary to satisfy the field source impedance and the recording device. The maximal sensitivity of the

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device between 0.5 Hz and 1 kHz was 10^{-3} V. In several instances, standard band filters were used at the input of the indicating device.

A comparatively high external interference produced by the earth's electric field, other functioning equipment, and the feed network required very strict screening of the subject under study. The screening chamber was in the shape of a cube, with 3-meter sides. Designing a chamber that considerably exceeded the size of the subject under study was very important, because only in this case would it be possible to observe alternations in the recorded external electric field which originate due to the volumetric asymmetry of the subject with respect to the walls of the screening chamber. For the same reason, all subjects were placed approximately in the center of the chamber in a horizontal position.

Three remote electrometer units of three amplifiers were suspended with special stretchers /roztyazhka/ from the chamber ceiling at different distances from the heart of the subject investigated. This made it possible to record the electric field at three points simultaneously. In addition, it was made possible to record the EKG synchronously with the recording of the electric field. All measuring devices were placed outside the chamber, with the exception of the remote units of the amplifiers and the electric field sensors. Leads for the contact EKG were shielded and the shields were grounded.

Metal discs 25 mm in diameter served as field sensors, and they were attached to input terminals /shtyr'/ of the electrometer units. Each disc was surrounded by a protective ring which was connected through a resistance with the case of the remote unit. The time constant of this ring was equal to the time constant of the input of the electrometer with the electric field sensor. The disc side facing the subject was considered to be the working surface.

The humidity of the surrounding air was recorded simultaneously with the electric field.

The amplifying line was calibrated by placing the field sensor between two plane-parallel plates to which was applied the calibrating pulse, the shape of which resembled that of the field signal.

Frogs, cats, and people were the subjects of study. The electric field was recorded when the subject was grounded, and when there was no contact between the subject and the surrounding leads or the ground. In the second case the EKG was not taken. Figure 1 shows a schematic diagram of the recording unit.

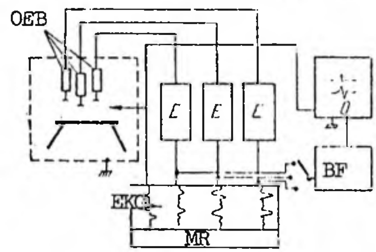

Figure 1. Schematic Diagram of the Recording Unit

OEB - remote electrometer units
MR - multichannel recorder
O - oscillograph
BF - band filter
E - electrometer

<u>Experimental Results</u>

It was established that the electric field recorded around an individual changes synchronously with the heart function and is present at any point of the human body. Figure 2 shows a comparative recording of the field signal and the EKG. It is evident that the peak of the electric field corresponds to the T wave peak in the EKG.

Figure 2. A Comparative Recording of the Field Signal (a) and the EKG (b)

The difference in field potentials even at a distance of 15 cm from the man's chest considerably exceeds the amplitude of the ventricle complex of the EKG obtained in contact studies (Figure 2).

It should be noted, however, that the configurations and amplitudes of the external electric field recorded over different body points are not similar. Figure 3 shows differences in the amplitude of the electric field in longitudinal and transverse directions.

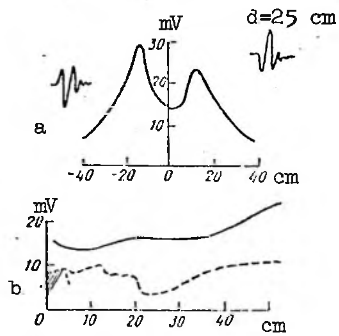

Figure 3. Electric Field Amplitudes With Respect to a Horizontal Line in Longitudinal (a) and Transverse (b) Directions.

The left and right graphs in the upper figure represent the left and right sides of the human chest, respectively.

Motion of the chest cage during respiration considerably affected the recordings between 0.5 - 1.5 kHz. Figure 4 presents the synchronous recording of the total field potential between 0.5 - 1.5 kHz, and of the signal at 20 Hz $\pm$ 1.5 kHz, as well as the electrocardiogram. The use of a filter (f_n = 20 Hz) at the input of the recording unit changed the amplitude, as well as the signal shape, although the signal characteristics were closer to those of the EKG. Therefore, we decided not to use the band filters but to stop the respiration instead during the recording of the electric field. This limited the continuous recording to 0.5 - 1 minute.

Figure 4. Synchronous Recording of the Total Field Potential between 0.5 - 1.5 kHz (a) and of the Signal at 20 Hz $\pm$ 1.5 kHz (b), and the Electrocardiogram (c).

Figure 5 shows the electric field recordings at three points at distances of 15, 36, and 60 cm from the human chest. The decrease in the field potential with the increase in distance from the chest is almost linear. Figure 6 presents the difference in potential of the external electric field as a function of the distance from the subject (the field sensor was located over the heart region).

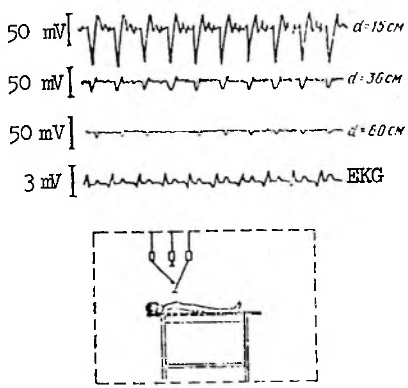

Figure 5. The Electric Field Recordings at Three Points at Different distances From the Human Chest.

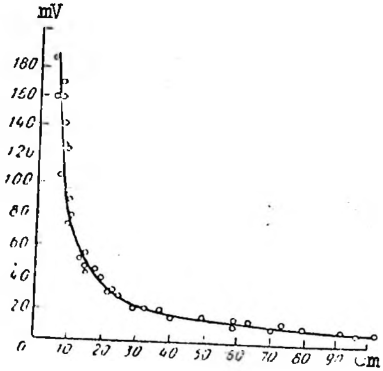

Figure 6. Graphical Representation of the Difference in Potential of the External Electric Field in Relation to the Distance of the Recording Device from the Subject.

These experimental results were obtained during all seasons of the year at room temperature (20-25°C) and a relative humidity of 17-35 percent.

Experiments carried out under conditions of artificially changed air humidity showed a close relation between the amplitude of the electric field and the concentration of water vapor. When the relative humidity reached 50-85 percent, the electric field around a human body at a distance of 5 cm disappeared in almost all instances (Figure 7). When the air humidity was returned to normal, the electric field appeared again.

Figure 7. Electric Field Changes as Function of Air Humidity. The humidity changed from 25 percent (left arrow) to 85 percent (right arrow).

However, when the human body was rubbed with a cloth or with a bare hand, the field amplitude increased considerably even in the presence of high laboratory humidity (45 percent). The value of the field potential in this case practically did not depend on the presence or absence of grounding; only the shape of the signal changed (Figure 8).

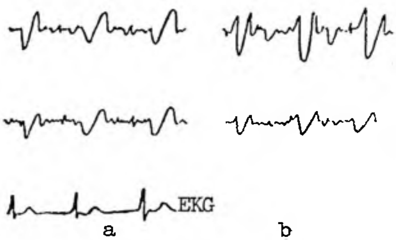

Figure 8. Signals Recorded at Two Distances From the Human Body. a. with grounding; b. without grounding.

Measurement of the electric field around an animal with a fur coat (cat) showed that the electric field changes synchronously with respiration and heart rhythm, but did not differ from that around the human body. However, the amplitude of the signal that corresponds to respiration considerably exceeded the total heart rhythm. Figure 9 presents a recording of the electric field around a cat.

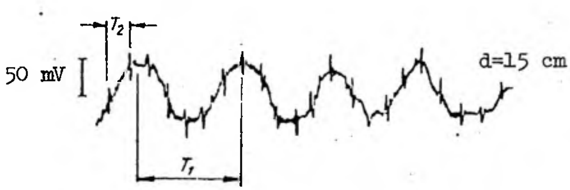

Figure 9. Electric Field Around a Cat.

T_1 - during respiration;

T_2 - during contraction of the heart muscle.

No electric field was recorded around a frog even at a distance of 0.5 cm when the chest cavity was closed. The same thing was observed when the chest cage was opened and the recording was made directly at the heart. However, when the heart was removed from the chest cavity the field signal was recorded in the vicinity of the functioning heart (Figure 10).

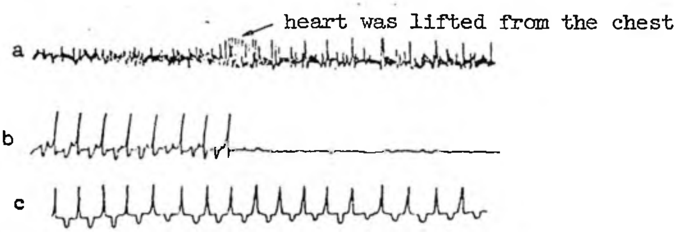

Figure 10. Electrogram of the Synchronous Recording of an EKG directly From the Heart Ventricle (c); EKG Recorded During the First Standard Recording (b); Electric Field Signal Recorded at a distance of 1.5 cm From the Heart (a).

Discussion of the Experimental Results

According to the contemporary understanding regarding the dipole properties of the heart, the potentials produced at the surface of the body are expressed by

$$V \approx \frac{l \cdot \cos \alpha}{r^3}.$$

where l is the dipole moment; r is the distance from the observation point to the dipole center; a is the angle describing the body position with respect to the dipole axis.

Since the maximal amplitude of the large EKG wave on the body surface does not exceed 2 mV, the postulated indexes of the difference in the electric field potentials from the same source in air should be of the order of 1 mV at the body surface, and a decrease in this field with distance should obey the cubic law in air.

The characteristics of the observed electric field around man and animals cannot be explained by the electric dipole of the heart located in a conductive medium.

A gradual decrease in the field with distance from the body and high values of this field that exceed those expected can be explained on the assumption that the observed fields were fields of the source located at the boundary between the organism and the external medium and that its dimensions were equal to the size of the body around which the electric field is recorded /1/. The independence of this field with respect to the presence or absence of grounding in the case of man and animals indicates that electric charges are distributed on the body surface and form an electric dipole in the simplest case. The field of such a dipole is smaller than its size at a distance and decreases according to the square law, but the difference in potentials decreases according to the linear law.

The functioning heart represents a sort of mechanical vibrator which forces the human or animal body to perform some oscillatory motions. The motion of a charged body in a space creates a changing electric field in the air, which we recorded.

The amplitude of this field depends on the extent of mechanical motion of the body surface of man or animal. In this case, evidently, the maximum of the field signal corresponds to the systolic state of the ventricles.

When the humidity of the surrounding air increases, conditions are more favorable for the draining of the static charge from the body surface. This was verified by measurements of the field at a distance of 5 or more centimeters in the presence of high air humidity (55-58 percent).

Conditions for the existence of a static charge on the body surface of animals covered with hair (fur) are more favorable than on man. This explains the high electric field around animals and its relation to the hair cover.

Frogs do not possess the electric charge because their bodies are covered with a moist slimy layer. This was proved by our experiments. The expected electric field produced directly by the electric dipole of the heart was very small in all cases investigated by us, and it did not appear on the background of the field around the electrically charged biological subject.

As was mentioned before, the use of band filters greatly alters the field signal, by decreasing its amplitude and making it resemble the EKG. The amplitude of the electric field recorded in the presence of high air humidity was also low.

The electroaurogram obtained by P. I. Gulyayev /2/ was taken under the conditions of Leningrad, i.e., in the presence of high air humidity. The author used filters with a frequency of 10 Hz, which considerably changed the space-time characteristics of the electric field signals. The comparatively low levels of these signals made it possible for P. I. Gulyayev to identify the electroaurogram only with the observed components of the contact EKG.

The fact that the external electric field was recorded best when the electric field sensors were located over the human head (hair cover) indicated that electrostatic charges on the body surface play an important part in the formation of the electroaurogram. This was evident in our experiments and in P. I. Gulyayev's /2, 3/. This proves once more the correctness of the hypothesis we suggested /1/ regarding the origin of the external electric field around animals and man.

Conclusions

1. There is an electric field around man and animals which depends on the heart muscle contractions and on respiration.

2. We recorded the electric field in our experiments at a distance of 100 cm from biological subjects.

3. The recorded electric field is the result of the mechanical functions of life processes in man and animals and is not related, evidently, to electrical processes occurring in the animal organism.

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