METHODS

THE IMPORTANCE OF THE INTERELECTRODE RESISTANCE DURING REGISTRATION OF BIOELECTRICAL PROCESSES FROM THE SKIN SURFACE IN MAN

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In a previous paper [1] we reported a method of recording electrocardiograms and electromyograms of industrial workers by means of a comparatively simple apparatus and suitable technique.

In order to secure the required electrical contract between the electrodes and the skin of the subject, at the point where the electrodes are to be applied, the skin is preliminarily treated with alcohol or other substances, because the stratum corneum of the epidermis and the secretion of the sebaceous glands have a high resistance to the electric current. In order to remove part of the stratum corneum of the epidermis for registration of electrocardiograms, the skin is rubbed with an electrode paste containing abrasives, for example finely ground pumice. For the registration of electromyograms and electroencephalograms the skin is simple degreased by being rubbed with alcohol or a mixture of alcohol and ether.

It is considered that after treatment of the skin of the subject with alcohol, when the electrodes used have a diameter, for example, of 10 mm, the interelectrode resistance has a value of the order of 10 kiloohm. Input resistance of the amplifier is greater (1 meg), an interelectrode resistance of this magnitude causes no perceptible distortion of the recorded electrogram.

Experience has shown that these assumptions are not always justified. The measurement of the interelectrode resistance in electrographic practice is performed as the exception, and there is no standard method by which it may be done.

The present paper is devoted to the study of the role of the interelectrode (mainly skin) resistance during registration of the bioelectrical processes from the surface of the skin in man.

Our aims were as follows: to ascertain whether distirtions of amplitude and frequency take place, and in what cases, as a result of a high interelectrode resistance, dependent on the frequency; to find out how this resistance changes with time (in the course of 8 hours); to find an effective method of lowering the interelectrode resistance; to suggest a standard method of measurement of the resistance and to determine criteria of reliability of the skin treatment. Our investigations showed that during treatment of the skin of the forearm with alcohol, and with values of the measuring current below the threshold of sensation, for example 5-10μa, the value of the interelectrode resistance reached 1 meg. If the value of the input resistance of the amplifier was, for example, 1 meg, with an interelectrode resistance of this value, a fall in the amplitude of the electrical activity registered might be expected, on account of the fall of part of the voltage at the interelectrode resistance (amplitude distortions).

The dependence of the magnitude of the interelectrode resistance on the frequency of the measuring current gave grounds for thinking that electrical activity would be recorded with obvious weakening of the slow

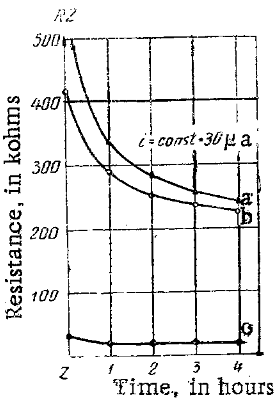

Fig. 1. Relationship between the value of the interelectrode resistance and the time elapsing after application of the electrodes to the subject's skin (electrogram taken with a current of 30 µa). Curves a, b and c were taken with electrodes applied to the forearm: a) and b) after trèatment of the skin with alcohol; a) by the action of a direct current, b) by an alternating current with a frequency of 20 cps, c) by direct current, after combined preparation of the skin.

frequency components (fractions of and unit cps), and that the weakening of the higher frequencies would be less, the higher their frequency (frequency distortions).

These dangers were well-grounded, for the shape of the curves of electrocardiograms is known to be distorted when there is a high interelectrode resistance at the time of recording [7].

An effective lowering of the interelectrode resistance is essential in order to exclude amplitude and frequency distortions, to lower the magnitude of the induction voltage of the alternating current and, as we were able to show, to remove obstacles arising when the subject touched grounded objects (the stands, a grounded instrument and so on.

In order to solve these problems, we were unable to make use of any human electrical activity, for we had no power to change its amplitude and frequency. For this purpose we used a generator of low-frequency electrical sinusoidal oscillations with a measurement current below the threshold of sensation (less than 100 µa). We considered that if the laws of change of interelectrode resistance obtained with this generator were confirmed for any particular case of investigation of the interelectrode resistance by means of human electrical activity, it might then be considered that these laws were applicable in other cases.

We determined the magnitude of the interelectrode resistance to direct and alternating current, ny means of an ammeter-voltmeter scheme.

According to reports in the literature, the magnitude of the interelectrode resistance depends on the site of application of the electrodes on the subject's body [5], on the area of the electrodes, the quality of the skin treatment, the quality of the electrode paste or fluid [6], the temperature of the air around the subject [2], the type of current (direct, alternating, pulsed), the frequency of the current and its strength [3, 4] and the time taken by the current to pass through the interelectrode circuit.

In the first part of the investigation, we used ordinary skin preparation with alcohol.

In order to obtain comparable results during measurement of the interelectrode resistance, we used a standard direct current of 10 µa, and the measurement was carried out quickly (the resistance falls if the current passes for a long time).

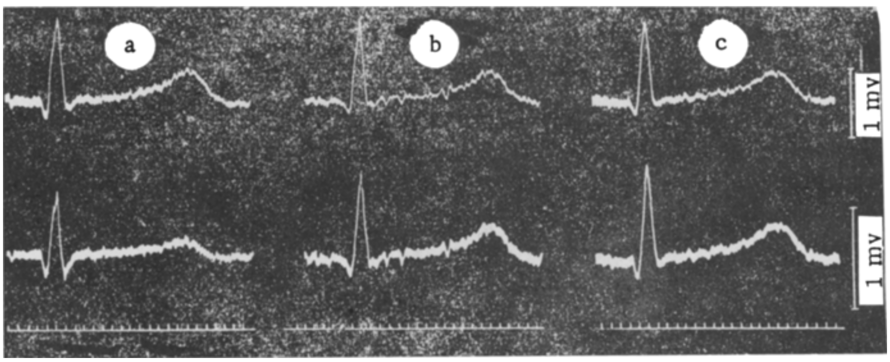

Fig. 2. Amplitude and frequency distortions after preparation of the skin of the subject's forearm with alcohol, and their change with time. For explanation, see text.

A relationship was found between the magnitude of the interelectrode resistance and the time elapsing after application of the electrodes to the subject's skin (in hours). It was shown that the resistance fell appreciably with time. With electrodes applied to the forearm, for example, and a measurement current of 30 μa, the value of the resistance was almost halved in the course of the first hour (Fig. 1, a). It might have been expected that for biocurrents these changes would be even greater, and also that the amplitude and frequency distortions would diminish in time.

We suggested a method of preparation of the skin, referred to as a combined method, which effectively lowered the interelectrode resistance at room temperature to 10-15 kiloohms. The skin beneath the electrode was gently treated with a paste consisting of soft soap and fine pumice (in proportions of 4:1 by weight), after which it was rubbed with ether, and then moistened with a conducting electrode paste whcih was used for recording the bioelectrical processes.

As criterion of the quality of the skin preparation, we used the ratio between the resistances measured by direct currents of 10 and 50 μa, which was equal to or less than 1.2.

With the combined method of skin treatment, neither amplitude nor frequency distortions, nor changes in these with time were shown on the recorded electrogram, since the value of the interelectrode resistance in this case was much smaller than the value of the input resistance of the amplifier.

After combined skin treatment, the value of the resultant interelectrode resistance was low (10-15 kiloohms) and altered insignificantly with time (Fig. 1, c).

The assumptions that amplitude and frequency distortions were present when electrograms were recorded from badly prepared areas of the subject's skin (treatment of the skin with alcohol) and that these decreased in time, thus were confirmed experimentally.

The electrograms were recorded from the subject's forearms. Electrode of the first recording channel were applied to well-prepared areas of the skin of the left and right forearms (interelectrode resistance less than 15 kiloohms). Electrodes coupled to the second recording channel were also applied to areas of skin situated alongside the first, and carefully prepared with alcohol. The electrical activity of the heart and of the abdominal muscles created biological potentials of equal amplitude and identical shape in the forearms if the skin beneath the electrodes were prepared by the combined method.

The second channel electrocardiograms, when recorded after various methods of skin preparation, had smaller values of the P, R and T waves and, as a rule, a larger S wave than the first channel ECG (Fig. 2, a). The shape of the T wave was also often distorted.

The decreased amplitude of the second channel ECG waves showed the presence of amplitude distortions. The unproportional decrease in the second channel ECG waves (the slower the wave, the more it was weakened) confirmed the presence of frequency distortions. The diminution of the second channel waves of the electromogram of the abdominal muscles, with a frequency of the order of 100-200 cps, as might have been expected, was insignificant. The assumed decrease in the distortions of the electrograms in the course of time after application of the electrodes to the skin of the subject was also confirmed experimentally (see Fig. 2).

Such gross distortions of the shape of the recorded electrical activity are inevitable when the forearm or leg is prepared with alcohol and when the value of the input resistance of the amplifier is between 0.5 and 1.0 meg.

From the electrograms recorded by the above method it is also possible to judge the resistance of the interelectrode circuit to the biocurrent. In one particular case, for instance, the value of the interelectrode resistance for oscillations of the type of the R wave of the electrocardiogram was 400 kiloohms, whereas for the T wave it was 1.3 meg.

The interelectrode (skin) resistance is not the same in different areas of the human body. We were able to show that a definite relationship exists between the value of the interelectrode resistance measured with a direct measuring current of the standard value of 10 μa – R_{10}, the ratio between the resistance measured with direct currents of 10 and 50 μa – R_{10}/R_{50} and the gradient of fall of the frequency characteristic of the interelectrode circuit. This relationship enabled the measurement of the interelectrode resistance to a direct current to be confined to a value of 10 μa for the measuring current. If this value was high, it followed that the ratio R_{10}/R_{50} was considerably greater than unity and the relationship between the interelectrode resistance and the frequency of the measuring current was clearly expressed.

The results obtained are of great importance to the electrographic method when applied in various conditions, including clinically.

SUMMARY

The author presents experimental material demonstrating that skin resistance in electrographic investigations plays a much greater role than has been considered hitherto.

It is shown that with the accepted method of preliminary skin treatment with alcohol or with a mixture of alcohol and ether, the recording of electrograms, especially those from the extremities, is subject to amplitudinal and frequency distortions and to the variation of these distortions in time, when prolonged application of the electrodes to the skin of the patient is practiced.

The author suggests a standard method of measuring the interelectrode resistance, another one providing for skin treatment eliminating electrogram distortions and a criterion of the quality of skin treatment.

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*Original Russian pagination. See C. B. Translation.