THE BIOELECTRICAL ACTIVITY OF THE CORTEX AND SUBCORTEX OF DOGS DURING ELECTRICALLY INDUCED SLEEP

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The present work is a continuation of previous research on the study of the mechanism of action of an impulse current of low power and low frequency on the cerebral hemispheres [2].

EXPERIMENTAL METHOD

Experiments were carried out on dogs over long periods of time, after insertion of electrodes into the cortex and the optic thalamus. Both unipolar and bipolar tracings of the action currents, in the premotor, motor, temporal and parietal areas of the cortex and in the optic thalamus of the dogs were taken. The distance between the cortical electrodes for the bipolar tracing was 1 cm, and that between the deep electrodes was 2-3 mm. For the unipolar tracing of the bioelectrical activity of the cortex the indifferent electrode was placed in the nasal bones of the animal. The deep electrodes were of platinum wire, 120 μ in diameter, and coated except for the tip with insulating varnish. Two electrodes were inserted into the optic thalamus. For accurate localization of the electrodes in the animals, x-ray films of the head were taken. At the conclusion of the experiments the dogs were killed, the brain photographed and its cell structure examined. Each 5th section of a series of frontal sections (thickness of the section 20 μ) was stained by Nissl's method. Next the localization of the inserted electrodes in the preparations was determined microscopically. The electrograms of the optic thalamus (EOT) were recorded in all the dogs from the medial and ventrolateral groups of nuclei of the optic thalamus. The action currents were recorded on a six-channel ink-recording oscillograph. The dog was strapped in a Pavlov's apparatus. The investigation began with a tracing of the background electrical activity of the cortex (ECG) and of the thalamus. The impulse current was then switched on for 1 minute every 15-20 minutes (to avoid artefacts) and at this time the action currents of the sections of the brain under examination were recorded. The length of the sessions of electrically induced sleep was 2 hours. 20 sessions were carried out with each animal. At the conclusion of the course of electrically induced sleep the action currents of the cortex and thalamus were recorded in these dogs for a further period of 3-4 weeks. The impulse current used was of different frequencies – 6, 10, 12 and 18 impulses/ sec. Current was supplied to both the cortical electrodes and the electrodes inserted into the thalamus. In four animals electrically induced sleep was carried out at first with a current of one frequency, for example at 10 impulses/ sec and a few months later at another frequency, for example 18 impulses/ sec. In all 220 sessions of electrically induced sleep were carried out on 7 dogs.

EXPERIMENTAL RESULTS

One dog (Polkan) fell asleep during the first session of electrically induced sleep. In the dog Pushok drowsiness appeared at the end of the first session, and a profound sleep developed during the second session. Three dogs (Ryzhik, Arabka and Belka) slept under the action of the impulse current after the second and fourth sessions. The dog Druzhok began to sleep only after the fifth session, but the dog Volchok did not sleep at all under the influence of the impulse current, but stayed quietly in the apparatus throughout its whole period of action. Four of

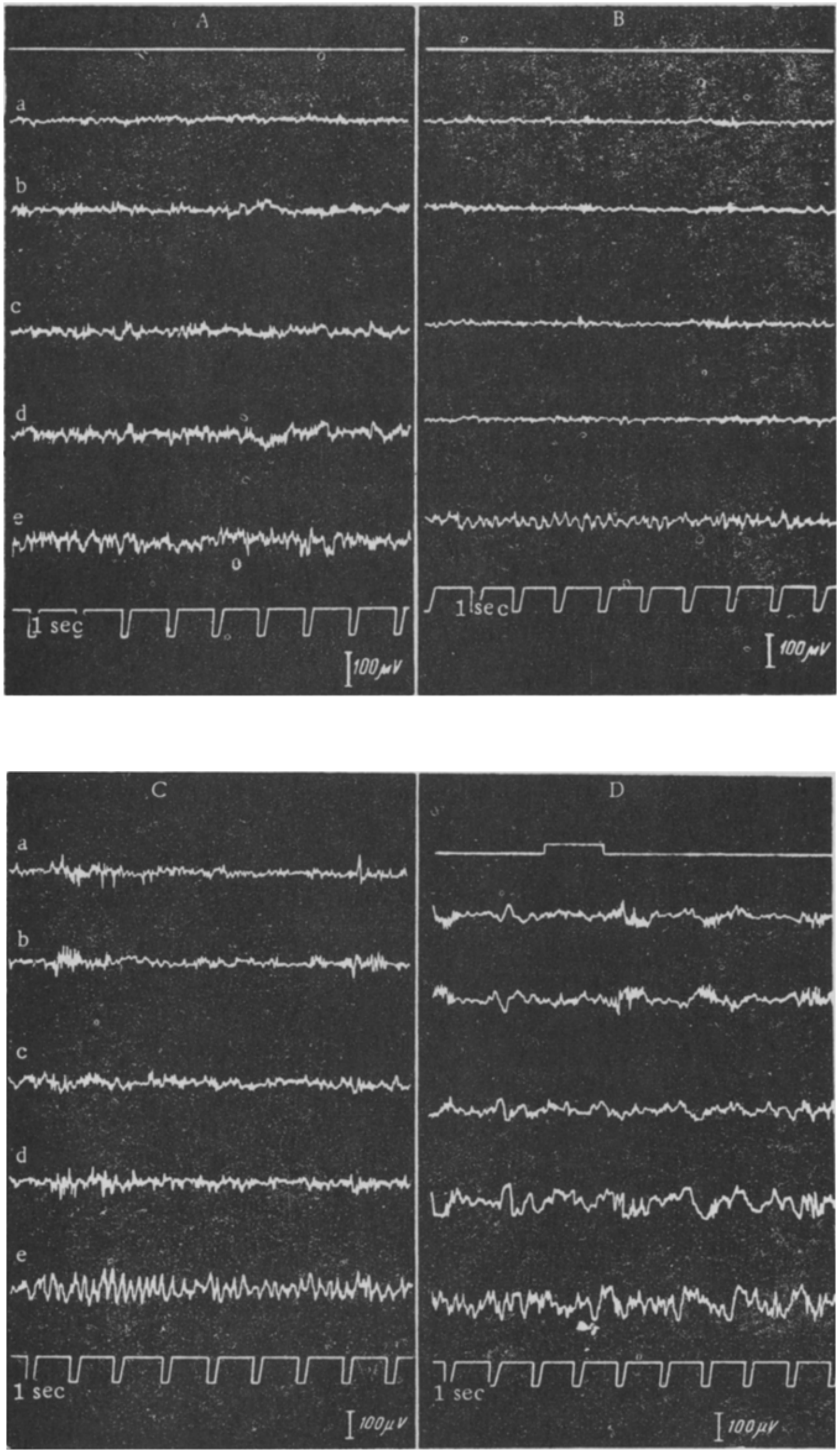

Fig. 1. Electrocorticogram of the dog Polkan recorded during the first session of electrically induced sleep. Bipolar tracing.
a, b, c, d) Electrocorticograms of the motor, sensory, temporal and parietal areas of the cortex; e) EOT; A) initial background electrical activity; B, C, D) tracings made 15, 30 minutes and 1 hour after the current was switched on.

these animals, subjected after 2-3 months to a second course of action of the impulse current at a different frequency, showed almost the same behavior at the sessions of electrically induced sleep. Polkan and Belka fell asleep at the second session, Druzhok at the third and fourth sessions simply dozed and actually slept only at the fifth session, and Volchok did not sleep at all, although he was somewhat drowsy.

Usually definite changes in the bioelectrical activity of the brain are observed in the dog even in the first session of electrically induced sleep. They are shown by the appearance of rhythmic electrical oscillations in the thalamus, by an increase in the amplitude and synchrony of the rapid oscillations on the ECG and a subsequent fall in the amplitude of the action potentials of the cortex to 10-15 μv (Fig. 1, B). With continued action of the impulse current the amplitude of the rhythmic waves in the thalamus increases from 50-60 to 100-120 μv. Bursts of rhythmic waves with a frequency of about 14 per second (α-like waves) appear on the ECG, and these settle down into slow waves with a frequency of 5-7 per second (Fig. 1, c). Later on there is a slowing of the low-frequency processes in the cortex and an increase in their amplitude. The rhythmic oscillations in the thalamus are replaced by large, slow waves with a frequency of about 1 per second and an amplitude reaching 130 μv (Fig. 1, d). The animal goes to sleep strapped up. However any external stimulation – a sound, a flick of the thumb, a slight touch, the entry of the experimenter into the chamber – immediately causes it to awaken, with disappearance from the electrocorticogram (ECG) of the above-mentioned bursts of waves with a frequency of 14 per second and with restoration to the electrogram of the optic thalamus (EOT) of its rhythmic oscillations with a frequency of 4 per second. With deepening of the sleep the amplitude of the slow waves in the cortex grows considerably to reach 100 μv, but their frequency falls to 1-1.5 oscillations per second. Slow waves with an amplitude of 120--130 μv dominate the EOT. With sleep of this depth a sound does not always cause awakening of the animal. In some cases even electrical stimulation of the skin causes awakening of the animal, disappearance of the slow waves from the ECG and appearance of the characteristic rhythmic activity (4-5 per second) on the EOT only after repeated application (slightly over the threshold value). Only 2-3 minutes afterwards slow waves reappear in the cortex, followed by the thalamus. The sleep usually continues after the current is switched off. Its duration varies – from 20 minutes to 1 hour. In the cortex at this period there is seen a gradual fall in the amplitude of the slow waves and the appearance of α-like waves, whereas in the thalamus waves appear with a rhythm of 4-5 per second.

It must be pointed out that in all the dogs except Volchok and Belka, in some cases after 10-14 sessions it was possible to discern a conditioned reflex sleep, which appeared on the ECG in the form of changes identical with those during electrically induced sleep. Conditioned reflex sleep developed when the animal was placed in the apparatus and the electrodes connected up without the current being switched on. It lasted for different lengths of time – from a few minutes to 30-40 minutes.

In those cases where the animal did not go to sleep in the sessions of electrically induced sleep (for example the dog Volchok), the ECG showed a considerable fall in the amplitude of the waves, particularly in the anterior divisions of the cortex, with the appearance of bursts of α-like waves with an amplitude of 60-70 μv. On the EOT at this time were observed synchronous rhythmic waves with a frequency of 4-5 per second.

It shoul be mentioned that the rhythm of 4-5 waves per second which appears at the end of the first or during the second session is maintained in the thalamus for a longer time. Usually at the third or fourth session it is the dominant process, overshadowing the background EOT. At the conclusion of 20 sessions of electrically induced sleep, the rhythm of 4-5 waves per second continues to be recorded in the thalamus of the dog for 2-3 weeks, and the electrical activity of the brain returns only gradually to its initial background level.

Rhythmic oscillations with a frequency of 4-5 per second appear in the thalamus of the dog in all cases in which electrically induced sleep is carried out, irrespective of the frequency of the impulse current used. Consequently, irrespective of the frequency of the external stimulus, the brain tissue reacts to it at its own optimal rhythm of excitation.

The slowing of the frequency of the dominant rhythm of the cortical structures in the course of development of electrically induced sleep demonstrates a fall in the lability of the cortex. In spite of the fact that the subcortical formations are in the zone of greatest intensity of action of the current (as pointed out by N. M. Liventsev et al. [1]), the development and deepening of the state of inhibition (slowing of the frequency of the dominant rhythm) is observed primarily in the cerebral cortex. In the conditions of the present investigations, when the impulse current was supplied directly to the electrodes inserted into the brain tissue, the role of tactile receptors was eliminated. Consequently the changes in the bioelectrical activity of the brain were due to the direct action of the impulse current on the nerve cells of the cerebral hemispheres.

SUMMARY

Impulse current of low intensity and frequency has a weak parabiotic effect on cerebral hemispheres. The functional changes appearing under the effect of impulse current are retained in the central nervous system after cessation of its action. The longer was the action of the current the more prolonged the retention of the functional changes in the central nervous system. The majority of animals fall asleep due to the action of impulse current. The depth of sleep varies in animals depending on the individual peculiarities of the function of the central nervous system.

LITERATURE CITED

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