PHYSIOLOGY

CERTAIN DATA ON THE CHARACTER OF REPRESENTATION OF INTERNAL ORGANS IN THE CEREBRAL CORTEX

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The presence of a connection between the internal organs and the higher levels of the central nervous system has been demonstrated convincingly by the method of conditioned reflexes. However, the question of the character of this connection cannot be considered as finally settled.

There is a view according to which the cerebral end of the internal analysor is unlikely to be represented in the form of "specially delimited, strictly localized areas" [1]. At the same time electrophysiologic investigations have established that stimulation of the internal organs (reflected in the bioelectric activity of the whole cerebral cortex) elicits more intense, qualitatively different changes in definite areas of the cortex, viz. in the premotor region [2, 3, 5, 7, 11]. An important advance in the study of the structure of the visceral analysor is the investigation of primary responses to stimulation of visceral nerves [14, 17]. Foreign workers have established by this method the projection of the splanchnic nerves to the sigmoid and anterior ectosylvian gyri. Representation of the pelvic nerve has been demonstrated in approximately the same region in the laboratory of V. N. Chernigovskii [12]. Earlier, stimulation of the vagus was found to be accompanied by increased oscillations of potential in the orbital region of the frontal lobes [16].

Elucidation of the projection in the cerebral cortex of large collectors of interoceptors gives a definite picture of the structure of the cerebral end of the visceral analysor. An important stage is represented by studies of the distribution of receptive zones in the cerebral cortex as shown by stimulation of separate internal organs [8].

The present work is concerned with the study of the bioelectric activity of the cerebral cortex on stimulation of gastric receptors.

EXPERIMENTAL METHOD

Experiments were carried out on 25 dogs under short-term experimental conditions. The preliminary operation was performed under ether-morphine anesthesia. It consisted of introduction of a rubber balloon into the stomach and trephining of the skull with removal of the dura.

Stimulation was effected by inflation of the balloon introduced into the stomach; air bellows were used and the pressure obtained was equal to 30 mm Hg. Cerebral biopotentials were recorded with a cathode ray oscillograph with a rheostat-capacity amplifier. Amplification was such that a voltage of 100 μv at the amplifier input produced a 4 mm deflection of the oscillograph beam. The image was reduced by half when the record was photographed. The recording electrodes were made of digestive tin.* The indifferent electrode, in the form of a rod with thread cutting, was screwed into the nasal bone. The active electrode was a loop on which was wound a fine wick of cotton moistened with physiologic solution.

The experiments were started 1-1.5 hrs after the preliminary operation. The animal was placed in a darkened, screened and sufficiently sound-proof chamber. The investigations were carried out under deep urethan or ether anesthesia. Urethan was given intravenously in the amount of 1 g per kg of body weight.

* Literally, "alimentary nutritive"; probably tin which can be left in brain and not cause damage. Editor.

EXPERIMENTAL RESULTS

When the gastric mechanoreceptors were stimulated by a single inflation, the cerebral cortex of the anesthetized animal showed a peculiar localized reaction. It was expressed in most cases by a diphasic wave in which the first phase is positive and the second negative. In some of the experiments, especially on deepening the anesthesia, the reaction to such stimulation manifested itself by a monophasic wave, more often positive than negative. The area from which this reaction was recorded corresponded to the posterior part of the sigmoid gyrus, being approximately half way between the anterior and posterior cruciate sulci. The amplitude of the biopotentials varied greatly and fluctuated between 100 and 1000μv, changing both from experiment to experiment and in the same animal. The duration of the electric reaction was from 40 to 100 msec in different experiments.

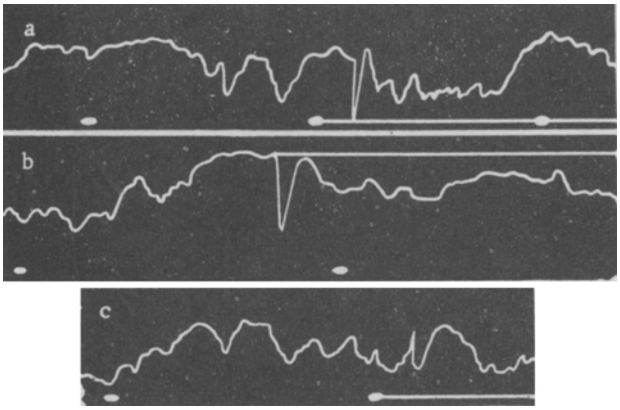

Fig. 1. Electrocorticogram of dog recorded from g. cruciatus posterior dextra under deep ether anesthesia. Experiment 15, October 1956. a) Recording electrode placed on a point of cortex lying approximately midway between the anterior and posterior cruciate sulci; period of stimulation of the stomach (pressure 30 mm Hg) marked by solid line; b) recording electrode placed in the same area of cortex; solid line marks stimulation of the gastric nerve branch (central part) by single induction shock; c) recording electrode moved 1 mm towards the posterior cruciate sulcus, recording reaction to gastric stimulation. Time marker – 1 sec.

Figure 1,a shows the electrocorticogram from the right posterior cruciate gyrus in dog under ether anesthia. Mechanical stimulation of the stomach elicits a diphasic action potential with a positive phase followed by a negative one. The amplitude of the first phase is 400 μv, of the second 150 μv. The duration of this reaction is 80 msec. In a number of its aspects (configuration, amplitude, sequency of phases, localization) such a reaction resembles the primary response observed on stimulation of exteroceptors.

Additional support for the probability of such a suggestion was afforded by investigations in which the gastric nerves were subjected to electric stimulation. In response to stimulation by single induction shocks the electric reaction appeared at the same cortical points as those from which the bioelectric effect was recorded after stimulation of the stomach (Fig. 1, b; 2,b). Both reactions showed certain similarities with respect to the form of the biopotentials. The main difference between the bioelectric effects obtained on stimulation of the nerves and receptors of the stomach is the difference in the duration of the latent period, which is shorter when the nerve is stimulated. Our method does not allow precise determination of the true extent of the latent period following stimulation of the stomach, since in these experiments only the beginning of inflation of the balloon was recorded and not its complete inflation.

The extent of the cortical area from which localized bioelectric response to stimulation of the stomach can be obtained is about 3 mm. When the electrode is moved from the main points toward the periphery there is a change in the character and amplitude of the biopotentials (Fig. 1,c). At more distant cortical areas the stimulation only elicits a change in the basic rhythm of electrical activity.

Our experiments have shown that a localized cortical response may arise not only at the beginning of gastric stimulation but also after its cessation. Direct proof of this was obtained in the electrophysiologic investigations of V. E. Delov and his collaborators [6] who found impulses in the gastric nerves both during distention and collapse of the gastric wall.

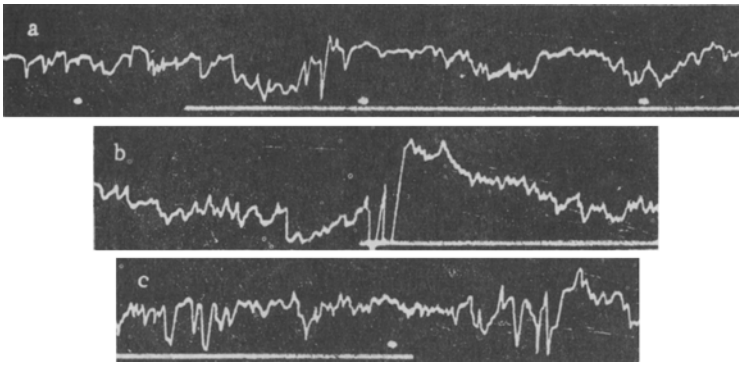

Fig. 2. Electrocorticogram of dog recorded from g. curciatus posterior dextra. Experiment June 30, 1956. a) On stimulation of the stomach under deep ether anesthesia; b) on stimulation of the gastric nerve branch by induction current; c) on stimulation of the stomach and after its cessation under lighter anesthesia. Time marker – 1 sec. Horizontal line on traces – stimulus marker.

When excitability is increased as, for example, in lighter anesthesia, stimulation of the stomach may elicit a series of electric complexes in the projection area of the cerebral cortex which follow each other in a train both at the moment of stimulation and for some time after cessation of stimulation (Fig. 2,c). This phenomenon has been described by a number of authors in connection with stimulation of exteroceptors [10, 13, 15] or visceral nerves [14] and is interpreted as an expression of excitation of thalamocortical systems by impulses arriving from the periphery [4]. On this basis, the repetitive discharges in our experiments can be explained by the arrival of impulses in the brain from gastric receptors. However, this question requires special elucidation. When analyzing the bioelectric reaction it is important to solve the problem, in principle, concerning the origin of this reaction: could it be a primary response or is it a secondary cortical response ? It is known that the main differences between the primary and secondary responses lie in the difference of the duration of the latent period (which is markedly longer in the case of secondary responses) and in the spatial extent of the reaction in the cortex – secondary responses can be recorded from almost the whole of the cerebral cortex whereas primary responses are observed only at strictly localized cortical areas.

Since experiments with stimulation of the gastric nerve branches gave records of bioelectric phenomena similar to those found on stimulation of the stomach but with considerably shorter latent periods, it is possible to regard the reaction as a primary response. The main basis, however, for such a conclusion is the clearly localized nature of the reaction both to stimulation of the stomach and of the gastric nerves.

The somewhat more prolonged character of the reaction in our experiments as compared with the data of other authors must be explained by the special features of the experiments. Mechanical stimulation of the stomach is unlikely to be associated with a synchronous volley of impulses at the cerebral cortex. A series of impulses proceeding from a mass of mechanoreceptors in the stomach can elicit a more prolonged cortical bioelectric effect. There are references in the literature to prolongation of the primary effect on stimulation of exteroceptors [10].

A clear primary response is obtained on stimulation of the stomach under deep anesthesia (in our experiments with urethan or ether) when the level of "spontaneous" electrical activity of the brain is significantly lowered but the excitability of the cortical cells with respect to interoceptor impulses does not disappear.

Beyond the limits of the area from which the primary response is recorded, upon stimulation of the stomach a so-called generalized reaction develops which manifests itself in changes in the character of the basic electrical activity. Our data obtained by electrophysiologic methods serve as yet another proof of I. P. Pavlov's hypothesis [9] that "stimulation arising in receptors impinges upon certain definite points of the cerebral cortex."

SUMMARY

Short-term experiments were performed on dogs under ether or urethan anesthesia. It was established that a localized bioelectric reaction appeared in the area of g. cruciatum posterior as a result of stimulation of the stomach mechanoreceptors or of electric stimulation of the gastric nerve branches. This reaction may be considered as a primary response. Data on the primary response following stimulation of the stomach may be used for determination of the projection of the stomach receptor fields in the cerebral cortex.

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