ELECTRICAL ACTIVITY OF THE NEUROGLIAL CLUSTERS IN THE AREA POSTREMA OF THE MEDULLA

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An important role in the neuro-humoral link is played by the chemoreceptor and neurosecretory properties of the tissue. Structures may be identified in the brain in which these functions are associated to a greater or lesser degree with the neuroglia. In the region of the hypothalamus, for instance, neuroglial secreting cells have been found [10]. The secretory function of the glia is manifested very clearly in the ganglia of invertebrates [12]. The evolutionarily more primitive activity—chemical—is carried out by more primitive mechanisms, possibly based on interaction between the less highly differentiated cells (neuroglial), taking place without the participation of the nervous impulse.

The chemoreceptor and neurosecretory functions of the neuroglia are especially well marked in a region of narrow specialization in the medulla—the area postrema. This area passes information to the nervous centers, especially the vomiting center, concerning changes in the chemical composition of the blood [5, 7], and the neuroglial cells evidently are the primary receptor element [9].

The area postrema also influences the hormonal composition of the cerebrospinal fluid, into which it secretes hormones [6]. According to data obtained by Vogt [13], the area postrema is rich in many of the hormones which are also found in the hypothalamus. These include serotonin, P factor, and noradrenalin, the latter, moreover, being synthesized by the cells of the area postrema; heparin is also formed there [6]. Hence, this region plays an active part in neuro-hormonal regulation.

The area postrema of the cat's brain measures 1.5×2 mm^2 and consists of a cluster of neuroglial cells, mainly protoplasmic astrocytes and astroblasts [5, 9]. Their diameter is 5-7 μ. Some of the processes of the neuroglia run towards capillaries, and some form networks, which join together to form bundles and leave this region for the lateral reticular formation. Near some neuroglial cells thin nerve fibrils can be seen, not forming synapses. Many investigators consider that the area postrema consists entirely of neuroglial cells. However, besides cells of typical neuroglial form, in the depth of the area postrema there are cells with a diameter of 12 μ, with short branches possessing no endings. By their morphological signs these cells have been classed as neurons by several investigators [6, 9].

The concentration of neuroglia on the surface of the area postrema provides suitable conditions for the study of the electrical phenomena in a group of neuroglial cells in intravital conditions. According to Hild and Tasaki [11], an electrical potential is present on the membrane of the neuroglial cell in tissue culture, and it changes slowly in response to strong stimulation, recovering after 5 sec. However, the conditions of tissue culture are different from those appertaining in life and they provide no information about the interaction between the cells.

The object of the present study was to discover the character of the electrical phenomena—the electrogram and the very slow rhythms [1, 3]—in the group of neuroglial cells on the surface of the area postrema of the medulla in the rabbit.

METHOD

Experiments were carried out on 11 rabbits, immobilized with diplacin and maintained on artificial respiration. Some experiments were conducted under urethane anesthesia (0.5 g/kg). Bipolar nichrome needle electrodes, 100 μ

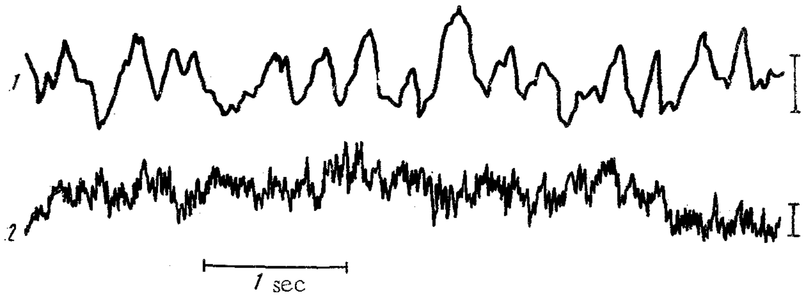

Fig. 1. Electrogram of area postrema (1) and cerebral cortex (2). Bipolar recording. Vertical marker represents 100 μV.

in diameter [2], or a monopolar electrode in the form of an elastic silver plate, 0.6 mm in diameter, were used for recording, and the indifferent electrode, 4 mm in diameter, was placed on a part of the hemisphere that had previously been coagulated. The electrogram was recorded by means of an ac amplifier with an ink-writing system; the very slow waves were recorded by means of a dc amplifier. The cardiac rhythm was also recorded. Electrical stimulation of the area postrema was applied by means of bipolar electrodes with rectangular pulses with a duration of 10 μsec, an amplitude of 4 V, and a frequency of 50 cps; stimulation lasted for 10-20 sec.

RESULTS

Unlike the electrocorticogram, the electrogram of the area postrema consists mainly of low-frequency components (Fig. 1). Regular waves with a frequency of 3-6 cps were most characteristic, but sometimes the frequency was doubled to 6-12 cps. In a series of tracings waves of these two frequencies were combined: waves of 3 cps and an amplitude of 25-30 μV. The waves were remarkable for the regularity and consistency of the rhythm. In neighboring areas of the medulla waves with a frequency of 14 cps were recorded. Control recordings of the cardiac rhythm showed that the phases of the pulse waves did not coincide with those of the electrogram.

Electrical stimulation of low power and short duration increased the frequency of the regular waves. Conversely, stronger stimulation (not, however, causing respiratory arrest, despite the close proximity between the point of application and the respiratory center) depressed the electrical activity of the area postrema; recovery of the activity began 20-30 min after stimulation ceased, the waves with a frequency of 3 cps beginning to recover sooner than those with a frequency of 6 cps.

Recordings made from the area postrema sometimes showed electrical processes of another type—very slow, rhythmic waves (Fig. 2). The range of variation of the very slow rhythms characteristically found in the area postrema was much wider than in the cortex. Minute rhythms—1-3 waves per min with an amplitude of 0.8-1.5 mV, second rhythms—5-12 waves per min with an amplitude of 0.4-0.7 mV, and faster rhythms—15, 18, and 24 waves per min, with low amplitude (0.1-0.4 mV) were recorded. The very slow waves were evidently very localized, arising in a very narrow part of the area postrema, for shifting the electrode through a distance of 1.5 mm into the neighboring region usually led to disappearance of the very slow rhythms (Fig. 2). In some experiments, however, very slow rhythms were also recorded in neighboring regions.

Direct electrical stimulation lasting 15-30 sec increased the frequency of the very slow waves, as was seen most clearly a few minutes after stimulation. The tracings in Fig. 2 show that after stimulation a rhythm of 5 waves per min was replaced by one of 10 waves per min. Depending on the strength of stimulation, in some cases it caused depression of the very slow waves.

Hence, the electrogram of a nonneural structure (as defined by Borison and Brizzee [5]) contains frequencies of 3-4 and 6-8 cps, which may also be found in the electrogram of neural tissue.

That the presence of bodies of neurons in a system is not essential for the development of electrical waves is also demonstrated by the fact that in the axo-dendritic zone of the cerebral cortex, with all its neural connections interrupted, electrical waves with a frequency of 6-7 cps may appear after stimulation [4].

Although, generally speaking, the development of wave activity is not absolutely dependent on the presence of conduction of impulses, in a concrete system it is certainly associated with the appearance of a pulse form of activity. This may take place in the axo-dendritic zone, where both pulsed and gradual forms of excitation at first appeared disconnectedly, and the working of the elements then became synchronized.

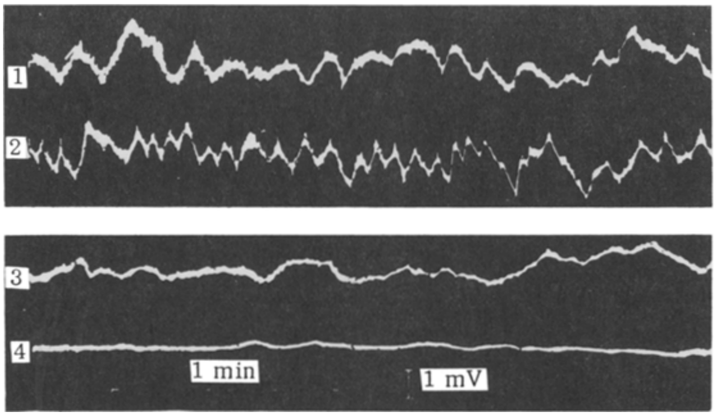

Fig. 2. Very slow rhythmic waves of potential in the area postrema. 1) Rhythm of 5 waves per min; 2) 2 min after electrical stimulation (rhythm 10 waves per min); 3) rhythm of 2-3 waves per min; 4) absence of waves in the region 1.5 mm from 3. Bipolar recordings.

The individual elements in the cluster of neuroglial cells produced mainly a gradual activity of an evolutionarily more primitive pattern, spreading with a decrement. Primitive properties such as these may be found, not only in the neuroglial cells and their processes, but also in short-axon neurons [8].

In such a system the changes taking place in one element are evidently necessary and sufficient to influence the activity of another element, although the physical mechanism of the link between the elements is unexplained. A directly confirmatory experiment was described by Watanabe and Bullock [14], who showed by means of experiments on the ganglia of the lobster's heart that a slow change in the membrane potential of one of the large cells affects the frequency of the discharge from the small cells situated a few millimeters away. This effect is achieved without the participation of nervous impulses. These authors postulate the existence of a thin bridge of protoplasm, formed by the cell with a low membrane resistance, creating a positive feedback between the active elements.

Hence, the electrical waves in a cluster of neuroglial cells may arise on account of the involvement of the cells in a general rhythm of activity, brought about by means of communication but without conduction of impulses. The frequency characteristic of these communications is such that they transmit slow changes of potential. This mechanism of synchronization can also be conceived in the case of very slow activity.

It is important to stress the presence of very slow rhythms of higher frequencies (12-24 waves per min) in the area postrema. Very slow rhythms of similar frequency are also characteristic of hypothalamic structures, notably the neurosecretory nuclei [2]; they have been demonstrated, for example, in investigations of the cerebral ganglion of the cricket [3].

The increase in the frequency of the very slow waves in the area postrema after its electrical stimulation, like that after stimulation of the hypothalamic region and the ganglia of invertebrates, suggests that this increase may be linked with hormonal activity.

The presence of very slow potentials in the area postrema indicates the existence of a general principle, according to which the formation of very slow waves is an inherent property of chemically sensitive systems [3].

Hence, two factors are evidently concerned in the maintenance of the electrical activity characteristically found in a cluster of neuroglial cells: firstly, chemical factors, and secondly, communications along which signals may spread, not in the form of an impulse, but as slow changes of potential.

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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.**