SUPRASEGMENTARY CONTROL OF THE INTRASPINAL PATHWAYS OF VISCEROMOTOR REFLEXES

N. N. Preobrazhenskii and Z. A. Tamarova

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The results of the study of the pathways carrying visceral afferent impulses into the spinal cord [3-5] and of the character of the synaptic reactions in the motor neurons during visceral stimulation in cats with an intact central nervous system and in spinal animals [1, 2] have led to the suggestion that a supraspinal mechanism of regulation of the visceromotor reflexes may exist. Meanwhile, the supraspinal structures may also play a direct part in the visceromotor reflexes themselves.

Division of the spinal cord in the cervical portion causes facilitation of the transmission of visceral influences to the motor neurons and causes their increased irradiation along the spinal cord [4, 5]. Consequently, we can speak of the inhibitory effect of the suprasegmentary structures on the visceromotor reflexes.

The mechanism of this supraspinal control is very interesting. To explain it, a study was made of the character and order of excitation of the various neuronal structures of the lumbar portion of the spinal cord in response to visceral influences in spinal animals. The results of the investigation were compared with analogous results obtained in animals with an intact nervous system.

EXPERIMENTAL METHOD

Investigations were carried out on cats anesthetized with chloralose and Nembutal (45 and 15 mg/kg body weight). The method of dissection of the somatic and the greater splanchnic nerves and the details of their stimulation have been described earlier [3]. The spinal cord was divided at the level of the second cervical vertebra, and the animal was transferred to artificial respiration and paralyzed with tubarine (D-tubocuraine chloride) in a dose of 1-2 mg/kg body weight intravenously.

The focal potentials were detected by means of glass microelectrodes with a point 5-10 μ in diameter and a resistance of 0.5-1 mΩ at the level of the 5th lumbar segment of the spinal cord. The technique and order of recording the focal potentials were described earlier [3].

The reactions recorded were used to draw up a scheme of distribution of amplitudes of the focal potentials and the density of the currents throughout the cross section of the spinal cord at various time intervals after stimulation of the ipsilateral splanchnic nerve. From the results of several experiments, a scheme of the order of activation of the neuronal structures of the 5th lumbar segment of the spinal cord during stimulation of the splanchnic nerve was also plotted.

EXPERIMENTAL RESULTS

A previous investigation [3] conducted on cats with an intact central nervous system showed that during stimulation of the ipsilateral splanchnic nerve the earliest electrical activity, with a latent period of 12-13 msec, appeared in the dorsal columns of the spinal cord. Later, after 16-17 msec, focal potentials appeared in the region of the lateral columns of the spinal cord, while after 19-20 msec, potentials appeared in the medial part of the ventral horn and the adjacent white matter. In the region of the motor nuclei of the ventral horn, negativity was recorded after 17-18 msec in the zone of localization of the flexor motor neurons, and after 18-19 msec, a powerful focus of positivity developed in the zone of the extensor motor neurons.

After division of the spinal cord at the level of the second cervical vertebra, the pattern of the time sequence and the character of the focal potentials changed considerably.

Laboratory of General Physiology, A. A. Bogomolets Institute of Physiology, Academy of Sciences of the UkrSSR, Kiev (Presented by Active Member of the Academy of Medical Sciences of the USSR V. V. Parin). Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 62, No. 10, pp. 3-7, October, 1966. Original article submitted April 15, 1965.

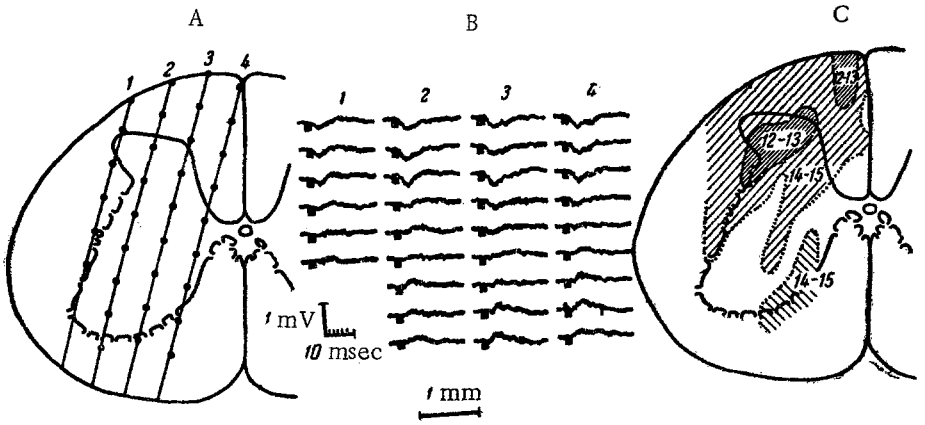

Fig. 1. Distribution of electrical reactions evoked by stimulation of the ipsilateral splanchnic nerve over the cross section of the spinal cord in spinal cats. A) Scheme of cross section of the 5th lumbar segment of the spinal cord. The lines denote the channels along which the microelectrode passed (1, 2, 3, 4), and the dots the depths at which the focal potentials indicated in B were recorded (an upward deflection of the beam corresponds to negativity beneath the point of the microelectrode and a downward deflection to positivity). C) Time sequence of activation of different neuronal structures of the 5th lumbar segment of the spinal cord during visceromotor reflexes in spinal animals. Mean values of latent periods (in msec) from results of several experiments.

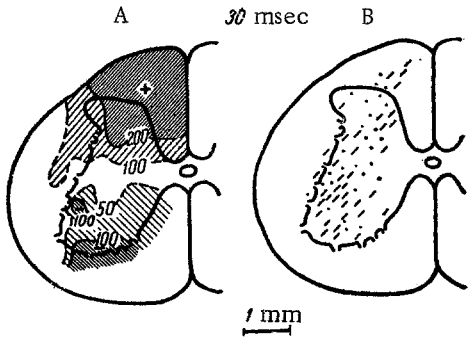

Fig. 2. Schemes of distribution of amplitudes (in μV) of focal potentials (A) and density of sources and discharges of currents (B) over the cross section of the spinal cord 30 msec after stimulation of the ipsilateral splanchnic nerve. The regions in which the currents were directed into the cells are shown by strokes, and the regions where the currents are leaving the cells – by dots.

Examples of the focal potentials arising in the 5th lumbar segment of the spinal cord during stimulation of the ipsilateral splanchnic nerve in spinal animals are given in Fig. 1B. A scheme of the cross section of this segment is shown in Fig. 1A, and on it are superposed the channels along which the microelectrode passed into the spinal cord and the points from which the corresponding electrical reactions were obtained.

Analysis of these reactions shows that the latent period and duration of the potentials arising in different parts of the 5th lumbar segment of the spinal cord during stimulation of the splanchnic nerve were shorter than those in animals with an intact nervous system.

The latent periods of the electrical reactions recorded in different parts of the spinal cord were unequal. The distribution of the latent periods of the reactions over the cross section of the 5th lumbar segment of the spinal cord is shown in Fig. 1C. The earliest positive electrical reactions as in the animals with the intact nervous system, appeared in the medial part of the dorsal column. Their latent period was 12-13 msec. However, besides these reactions, considerable focal potentials also appeared rapidly in the region of the substantia gelatinosa and in the adjacent areas of the dorsal horn. In animals with an intact central nervous system analogous activity in this region was observed much later – after 16 msec and more.

When 14-15 msec had elapsed after stimulation, electropositivity covered the whole dorsal horn and column and also spread to the lateral column and to the region of the intermediate nucleus of the gray matter of the spinal cord. Meanwhile, in the medial part of the ventral horn negativity had developed and spread towards the motor nuclei of the spinal cord. The latent period of the appearance of the focal potentials in the region of the motor neurons of the ventral horn was 15-17 msec.

To make a more detailed analysis of the processes in the various parts of the conducting tracts of the visceromotor reflexes, schemes of the distribution of the amplitude of the focal potentials and the density of the incom-

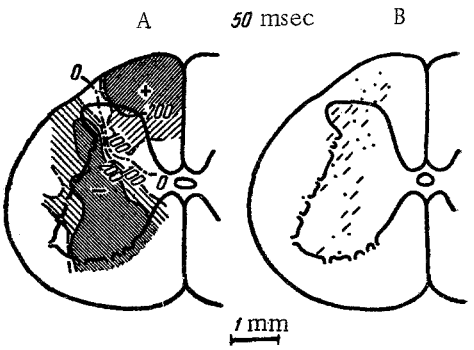

Fig. 3. Distribution of amplitudes of focal potentials (A) and density of sources and discharges of currents (B) over the cross section of the spinal cord 50 msec after stimulation of the ipsilateral splanchnic nerve. Legend as in Fig. 2.

ing and outgoing currents in the 5th lumbar segment of the spinal cord were compiled at various time intervals (30 and 50 msec) after stimulation of the ipsilateral splanchnic nerve.

The positive electrical reactions in the region of the dorsal horn, and the dorsal and lateral columns reached their maximal values (up to 400 μV) 30 msec after application of the stimulus (Fig. 2A). The region of negativity covered nearly the whole ventral horn and the adjacent white matter, evidently indicating the development of excitatory postsynaptic potentials in the majority of the motor neurons and the ventral horn. A map of the densities of the ingoing and outgoing currents in the spinal cord 30 msec after stimulation of the splanchnic nerve (Fig. 2B) shows that in this period the region of the motor nuclei of the ventral horn is a region of mainly incoming current.

The essential difference between the electrical reactions of the region of the motor nuclei in the spinal animals was the absence of the characteristic positive focal potentials in the region of the extensor motor neurons, usually observed in response to visceral influences in animals with an intact nervous system.

A distribution of electrical fields over the cross section of the spinal cord typical for depolarization of the central terminals of the afferent endings was observed 50 msec after stimulation of the splanchnic nerve (Fig. 3A, B) in the spinal animals [6-8]. (Positivity in the region of the dorsal column, which corresponds to negativity in the dorsal horn – A.) The region of the dorsal horn is a region of mainly incoming currents, and the dorsal column of outgoing (B).

The negativity preserved at this period in the zone of the motor nuclei of the ventral horn was evidently a residue of the postsynaptic processes in the motor neurons.

DISCUSSION OF RESULTS

From a comparison of the spatial and temporal sequence of excitation of the neuronal structures in the 5th lumbar segment of the spinal cord in spinal cats and animals with an intact central nervous system, some definite conclusions may be drawn regarding the localization of the supraspinal inhibitory influences of intraspinal transmission of visceromotor impulses.

The fact that during stimulation of the splanchnic nerve, both in animals with an intact central nervous system and in spinal cats, the earliest activity with a latent period of 12-13 msec appeared in the medial part of the dorsal columns shows that the pathway of rapid conduction of visceral impulses passes through this region. Since the latent periods of the electrical reactions in the region of the dorsal column in spinal animals and animals with an intact central nervous system are identical, it may be concluded that the supraspinal centers have no influence on these rapidly conducting pathways.

In contrast to the posterior columns, the activity in the region of the apex of the dorsal horn and the adjacent part of the lateral column in the spinal animals appeared much earlier and was more intensive than in the animals with an intact nervous system. Evidently the propriospinal system, transmitting visceral influences, which is under the tonic inhibitory control of the supraspinal centers, passes through these regions. When the connections between the spinal cord and the suprasegmentary structures are disturbed, there is considerable facilitation of the irradiation of visceromotor influences along the spinal cord through this system [4, 5].

The shortening of the latent periods of the electrical reactions in the region of the commissural and motor nuclei of the spinal cord in the spinal animals indicates that this facilitation of transmission of visceral influences to the intermediate and motor neurons takes place not only in the thoracic (5) but also in the lumbar portion of the spinal cord [2].

Removal of the supraspinal influences thus leads not only to de-inhibition of the pathways of intraspinal transmission of visceral influences. In these conditions the absence of positive electrical reactions in the region of the extensor motor neurons indicates that the inhibitory processes in the extensor motor neurons in response to visceromotor influences are not a purely spinal phenomenon but are a component of the complex reaction taking place

with the participation of structures in the brain stem. This conclusion concerning the nature of the electrical reactions in the region of the nuclei of the motor neurons in spinal cats during visceral influences agrees with the results of intracellular recordings of synaptic processes in the motor neurons of the spinal cord in analogous conditions [1, 2].

SUMMARY

Experiments on spinal cats under chloraeose-nembutal anesthesia (45 mg and 15 mg per kg of body weight) were carried out to study the time and spatial sequence of activation of different neuron structures of the 5th lumbar segment of the spinal cord in stimulation of the ipsilateral splanchnic nerve.

The descending fast pathways of visceral impulses passing in the medial part of the dorsal columns of the spinal cord are outside of the sphere of control by the supraspinal centers. Analogous pathways passing in the region of the substantia gelatinosa and part of the lateral columns of the spinal cord adjoining the gray matter are under the tonic inhibitory influence of the supraspinal centers.

Breaking off connections of the spinal cord with the suprasegmentary structures considerably facilitates the transmission of visceral impulses to the segmentary neurons. This disconnection also eliminates the transmission of introceptive inhibitory influences to extensor motoneurons.

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