SPINAL PATHWAYS FOR CORTICAL INFLUENCES ON LUMBAR MOTONEURONS IN RATS

E. S. Bogatyreva

UDC 612.815.2-06:612.83-089.85

Postsynaptic responses evoked from the motor cortex in lumbar motoneurons in rats with partial transection of the spinal cord were investigated by intracellular recording. Intracortical microstimulation did not evoke postsynaptic responses after division of the dorsal columns of white matter at the level T_6-T_8. Corticospinal influences remained intact after division of the ventral columns at the level T_6-T_7; ventral cordotomy in the region T_8-T_9 abolished cortico-motoneuronal EPSPs. It is concluded that pyramidal influences are transmitted along fibers of the dorsal columns, but transmission from pyramidal fibers to lumbar motoneurons takes place through the participation of interneurons, some of which send axons into the ventrolateral columns.

Morphological investigations [2, 4, 6-8] in rodents have shown that corticospinal fibers travel in the dorsal columns of white matter and reach the lumbosacral segments. By intracortical microstimulation [1] synaptic effects transmitted to spinal motoneurons along fibers of the pyramidal tract could be obtained in rats and their polysynaptic character demonstrated.

This paper gives the results of investigations of spinal pathways for cortical influences on lumbar motoneurons in rats. Various partial transections of the spinal cord were performed.

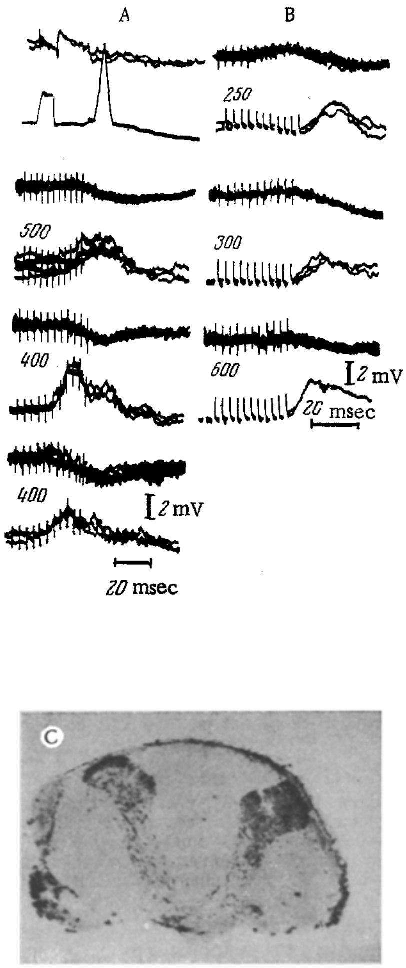
EXPERIMENTAL METHOD

Experiments were carried out on 12 albino rats weighing 280-350 g and anesthetized with pentobarbital (65 mg/kg, intraperitoneally). The animals were immobilized with tubocurarine and artificially ventilated. To stimulate the contralateral motorcortex a coaxial electrode was used (the anode was a silver ring 0.7-1 mm in diameter which touched the cortical surface while the cathode was a glass micropipette filled with Wood's alloy, inserted through the center of the ring to a depth of 0.6-1 mm into the cortex). Stimulation with square pulses (0.2-0.3 msec) was usually applied as a series of 11 pulses at 500/sec.

Intracellular recordings were obtained from motoneurons by means of glass microelectrodes filled with 0.6 M potassium sulfate solution. Parallel recordings were obtained of the dorsal cord potential (DCP). The motoneurons tested were identified by stimulating the ventral roots and nerves of the hind limbs: nerves to the hamstrings (Ham), gastrocnemius (GS), plantaris (PL), flexor digitorum longus (FDL), and extensor digitorum longus (EDL).

The dorsal columns were divided in five rats in various regions of the thoracic portion of the spinal cord and the ventral columns were divided in seven rats. Partial transection of the spinal cord was verified histologically.

Laboratory of Physiology of the Nerve Cell, I. M. Sechenov Institute of Evolutionary Physiology and Biochemistry, Academy of Sciences of the USSR, Leningrad. (Presented by Academician of the Academy of Medical Sciences of the USSR V. V. Zakusov.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 76, No. 12, pp. 3-7, December, 1973. Original article submitted March 26, 1973.



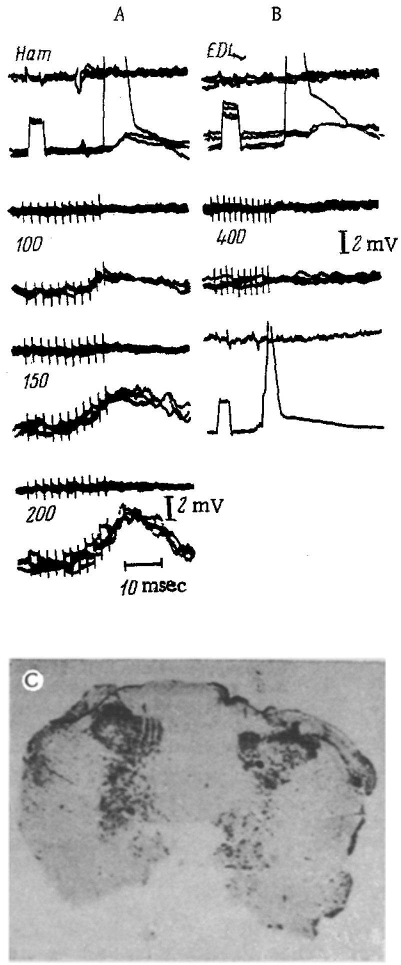


Fig. 1 Fig. 2

Fig. 1. Effect of division of ventral columns of spinal cord on corticospinal effects: A) EPSPs evoked by intracortical stimulation before cordotomy; B) after ventral transection at level T_6. Top beam records DCP, bottom beam intracellular potentials. Numbers signify intensity of stimulation (in A). Calibration pulse for spike 5 mV, 1 msec; C) section through spinal cord.

Fig. 2. Changes in effects of intracortical microstimulation following division of ventral columns. Above: identification of motoneurons by responses to stimulation of muscular nerves. Top beam records DCP, bottom beam records intracellular potentials. Calibration pulse 5 mV, 1 msec. A) EPSPs evoked by stimulation of motor cortex; B) absence of responses to intracortical stimulation after division of ventral columns in region T_8. Numbers denote strength of stimulation (in A). Calibration pulse for spike 20 mV, 1 msec; C) degree of destruction of ventral columns of spinal cord.

EXPERIMENTAL RESULTS AND DISCUSSION

Intracortical stimulation of the motor area for the hind limb evoked polysynaptic effects chiefly of an excitatory character in the lumbar motoneurons [1]. The minimal intensity of stimulation was 5-10 μA

Corticospinal influences on lumbar motoneurons after division of the ventral columns of the spinal cord were investigated in seven rats. Altogether 27 motoneurons were recorded, and in 20 of them division of the ventral columns in the region T_8-T_9 completely abolished cortico-motoneuronal EPSPs (five rats), whereas division in the region T_6-T_7 did not change the corticospinal effects.

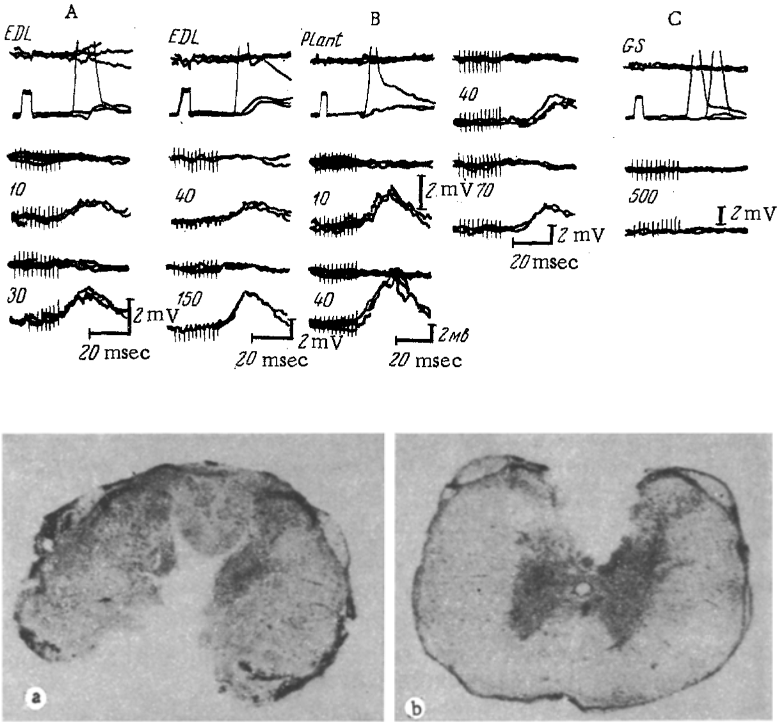


Fig. 3. Corticospinal effects after division of ventral (B) and dorsal (C) columns of the spinal cord. Top beam records DCP, bottom beam records intracellular potentials. Above: identification of test motoneurons. Calibration pulse 5 mV, 1 msec. A) EPSPs evoked by intracortical microstimulation. Numbers denote intensity of stimulation (in μA); B) EPSPs recorded in two motoneurons in response to stimulation of motor cortex after ventral transection of spinal cord at level T_7; C) absence of responses after division of dorsal columns in region T_8; a) histological control of destruction of ventral columns; b) of dorsal columns.

The results of an experiment in which division of the ventral columns was carried out at the level of T_6 are given in Fig. 1. In response to stimulation of three different points of the motor cortex an EPSP appeared in the motoneuron with a latent period of about 20 msec (A). After ventral transection of the spinal cord stimulation of the motor cortex evoked EPSPs with a latent period of 35 msec (B). The amplitude of the response was unchanged. The histological section (Fig. 1) shows that the ventral part of the spinal cord was completely destroyed.

In response to stimulation of the motor cortex (100-200 μV) EPSPs were produced in the Ham motoneuron with a latent period which varied from 10 to 15 msec (Fig. 2A). Division of the ventral columns in the region of segment T_8 completely abolished the cortico-motoneuronal EPSPs (Fig. 2B). Stimulation of the motor cortex with a current of 400 μA did not evoke postsynaptic effects in the EDL motoneuron. In response to stimulation of the ventral root an action potential with amplitude of more than 60 mV was generated in the cell.

After division of the dorsal columns of the spinal cord corticospinal effects were studied in five rats. Altogether 34 motoneurons were recorded. After division of the dorsal columns at the level T_6-T_8 stimulation of the motor cortex did not evoke EPSPs in the lumbar motoneurons; EPSPs with an amplitude of between 0.5 and 2 mV were recorded in only five cells if the strength of stimulation was increased to 500 μA.

In one experiment combined division of the dorsal and ventral columns of the spinal cord was carried out at different levels. Stimulation of the motor cortex by a current of 30 μA evoked polysynaptic EPSPs in the EDL motoneuron (Fig. 3A). The minimal strength of current for evoking a response was 10 μA. The latent period of the EPSPs was 20 msec. After division of the ventral columns in region T_7 cortical stimulation, as before, evoked EPSPs in EDL and PL motoneurons (Fig. 3B). The threshold intensity of the current for evoking a postsynaptic response was 40 and 10 μA, respectively. The latent period of the EPSPs varied from 20 to 35 msec. The histological section through the spinal cord demonstrated complete destruction of the ventral columns.

Dorsal division of the spinal cord in the region T_8 abolished cortico-motoneuronal EPSPs (Fig. 3C). Stimulation of the motor cortex by a stronger current (500 μA) did not evoke EPSPs in the GS motoneuron.

The results show that corticospinal effects in rats are transmitted through the dorsal columns of the spinal cord. This conclusion is confirmed by morphological evidence [3, 6, 7, 9, 10] of the localization of the pyramidal fibers in the dorsal funiculus of white matter of the spinal cord. The existence of another (lateral) crossed bundle in the corticospinal tract has also been described [5, 11]. This may evidently explain the EPSPs of small amplitude recorded in four motoneurons after division of the dorsal columns.

Ventral division of the spinal cord in the region T_8-T_9 abolished the cortico-motoneuronal EPSPs. The histological control to verify completeness of transection demonstrated complete destruction of the ventral columns and also partial damage to the gray matter of the spinal cord. As a result of spinal transection, activation of the interneurons transmitting pyramidal influences to lumbar motoneurons may have been disturbed. After ventral transection at the level T_6-T_7 the cortico-spinal EPSPs remained. The latent period of the EPSPs after transection increased to 20-35 msec (10-22 msec in the control). This suggests that the corresponding interneurons were localized caudally to the 7th thoracic segment.

LITERATURE CITED

1. E. S. Bogatyreva and A. I. Shapovalov, Neirofiziologiya, No. 2, 177 (1973).
2. L. T. J. Brown, Exp. Brain Res., 13, 432 (1971).
3. D. C. Goodman, Anat. Rec., 133, 383 (1959).
4. F. Goldby and G. N. Kacker, J. Anat. (London), 97, 517 (1963).
5. D. C. Goodman, L. E. Yarrand, and J. F. Nelson, Anat. Rec., 154, 462 (1966).
6. J. L. King, Anat. Rec., 4, 245 (1910).
7. A. M. Lassek and G. L. Rasmassen, J. Comp. Neurol., 72, 417 (1940).
8. R. W. Ranson, Am. J. Anat., 14, 411 (1913).
9. A. Torvik, J. Comp. Neurol., 106, 51 (1956).
10. F. Valverde, Z. Zellforsch., 71, 297 (1966).
11. W. Zeman and J. R. M. Innes, in: Craigie's Neuroanatomy of the Rat, New York (1963).