REFLEX RESPONSES OF MOTOR NUCLEI OF THE LUMBO-SACRAL SEGMENTS OF THE SPINAL CORD IN CATS WITH LOCAL TETANUS

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Reflex excitation of the motor nuclei of the motor nerves is usually brought about by impulses from sensory nerves within a comparatively narrow zone of the corresponding segment of the spinal cord. In these circumstances, stimulation of the sensory nerves of other segments is inhibited.

Since tetanus toxin specifically depresses various forms of synaptic inhibition of motor neurons [9], it appeared interesting to examine the changes in the character of the reflexes during stimulation of the afferent nerves of different segments of the spinal cord in animals subjected to the action of tetanus toxin.

EXPERIMENTAL METHOD

Experiments were conducted on adult spinal and decerebrate cats. Local tetanus of the right hind limb was produced by injection of 500 mouse MLD of tetanus toxin, diluted in physiological saline, into the semitendinosus or gastrocnemius muscle. The animals were used in the experiment on the 3rd-4th day after injection of the toxin. The left hind limb was used as a control. Under Nembutal anesthesia (25-30 mg/kg) the spinal cord was transected at the level of the last thoracic segments. The following nerves were dissected in the hind limbs on both sides: deep peroneal, posterior tibial, filaments running to both heads of the gastrocnemius muscle, sural nerve (cutaneous nerve of the leg), posterior nerve to the biceps, and nerve to semitendinosus. Ether anesthesia was used for anatomical decerebration (by Sherrington's method). The animals were warmed to maintain their rectal temperature at between 38 and 39°. Not less than 2 h elapsed after decerebration before the animals were used in the experiment.

Reflex responses were evoked by stimulation of the dissected nerves with single rectangular stimuli of different strengths and of a duration of 0.3 msec. The nerves lying on the recording and stimulating electrodes were irrigated with warm mineral oil. The action potentials were recorded by means of an "Alvar" amplifier with rheostatic capacitative coupling and a transmission band of 0.5-5000 cps. Photographs were taken of the screen of the cathode-ray oscillograph (type EO-7) during a single sweep of the beam, synchronized with the stimulus. Altogether 20 experiments were conducted: in 10, the toxin was injected into the gastrocnemius muscle and in 10 into the semitendinosus.

EXPERIMENTAL RESULTS

After injection of the toxin into the extensor muscle of the leg (the gastrocnemius) the first signs of tetanus of the hind limb usually appeared at the end of the second day. Well marked rigidity of the muscles of the leg and thigh developed on the 3rd day. If the toxin was injected into the flexor muscle of the leg (the semitendinosus), signs of tetanus were observed on the 3rd-4th day. In both cases, however, the clinical picture of extensor tetanus of the hind limb developed. This interesting discovery led us to investigate the reflex responses of the motor nuclei of the flexor and extensor muscles in animals with local tetanus.

According to the principle of convergence [13], the central endings of different afferent nerves are concentrated

Reflex Responses of the Motor Neurons of Different Segmental Levels to Stimulation of Different Afferent Nerves 3-4 Days after Injection of Tetanus Toxin (in % of Number of Stimuli)

Nerves from which recordings made	Nerves stimulated	On the side of injection of the toxin		On the control side
		m. gasirohem.	m. semitend.	
N. post. biceps+n. semitendinosus	n. peroneus prof	100	100	100
	n. gastrocnem	100	87.5	63.2
	n. tibialis	100	100	82.5
	n. suralis	100	100	77.5
N. gastrocnemius	N. peroneus prof	91	37.5	15
	n. tibialis	90	22.5	16.6
	n. biceps+n. semitendinosus	37	No response	No response
	N. suralis	90	50	17.4
N. peroneus prof.	n. gastrocnem	82	50	6.3
	n. tibialis	91	75	45.1
	n. bicept+n. semitendinosus	46	25	No response
	n. suralis	90	87.5	33.7
N. tibialis post.	n. peroneus prof	100	62	No response
	n. gastrocnem	44.4	No response	" "
	n. biceps+n. semitendinosus	22.2	" "	" "
	n. suralis	55.5	37.5	" "

on the same motor cells and thus, give rise to overlapping of the corresponding reflex fields. For this reason reflex discharges may be caused in motor neurons even from remote sensory nerves. The more distant the segment to which the afferent nerves belong from the investigated group of motor neurons, the more difficult it is for these nerves to produce discharges in the particular motor neurons.

It follows from the results given in the table that on the 3rd-4th day after injection of tetanus toxin responses could be recorded from those nerves from which it was difficult to obtain action potentials on the control side (a very strong stimulus was required and the response itself was very small). On the side of injection of the toxin responses were, as a rule, recorded easily and in a high proportion of cases.

It may be seen from Fig. 1 that on the control side during stimulation of the deep profundus, posterior tibial, and sural nerves weak discharges were recorded, while during stimulation of the nerves to the biceps, semitendinosus and the nerve to the gastrocnemius no response generally appeared. On the side of injection of the toxin a marked increase in the strength of the responses was observed (the areas of the discharges in planimetric units are shown in Fig. 1) and it became possible to record responses from the posterior nerve to biceps and the nerve to semitendinosus, which could never be done on the control side. Particularly marked reflex responses were recorded from the posterior tibial nerve (see table). On the control side there were generally no responses to stimulation of the sensory and muscular nerves. The discharges did not reach the posterior tibial nerve: they were inhibited. On the side of injection of the toxin responses were recorded fairly constantly during stimulation of which on the control side produced no result. Hence, in local tetanus the processes of inhibition in the spinal cord were considerably disturbed, as revealed by the possibility of obtaining reflex responses which were not recorded on the control side.

It is interesting to note that after injection of the toxin into the semitendinosus muscle, besides the later development of the clinical manifestations of local tetanus, the chances of the appearance of spinal reflexes were much less than after injection of the toxin into the gastrocnemius muscle. It follows from the results given in the table that in the animals receiving injection of toxin into the semitendinosus muscle, in some cases it was generally impossible to obtain responses, whereas after injection of the toxin into the gastrocnemius muscle they were consistently recorded.

The widening of the "zones of appearance" of spinal reflexes during local tetanus was accordingly used as an

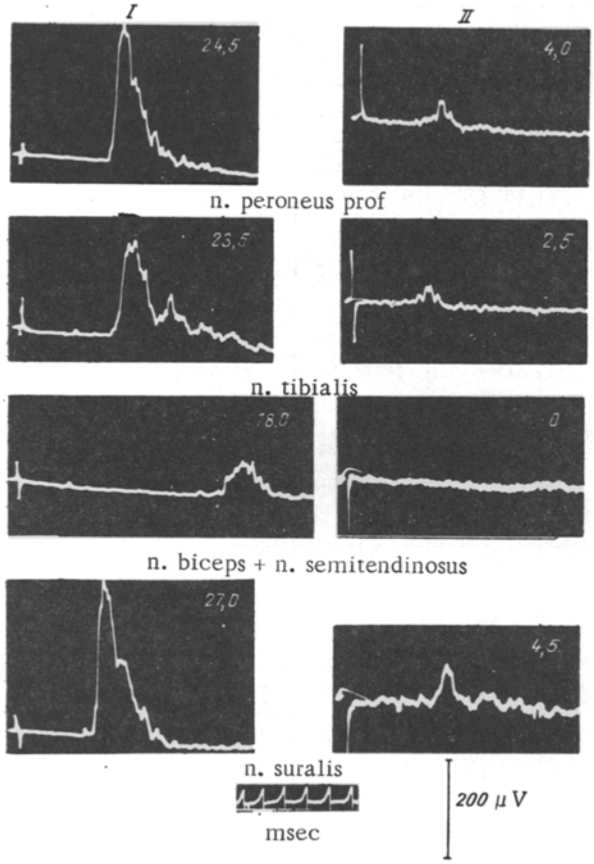

Fig. 1. Maximal reflex discharges recorded in the fibers of the gastrocnemius nerve during stimulation of various sensory nerves (on 3rd day after injection of toxin into the gastrocnemius muscle). The numbers indicate the area of the discharges in planimetric units. I) On the side of injection of toxin; II) on the control side.

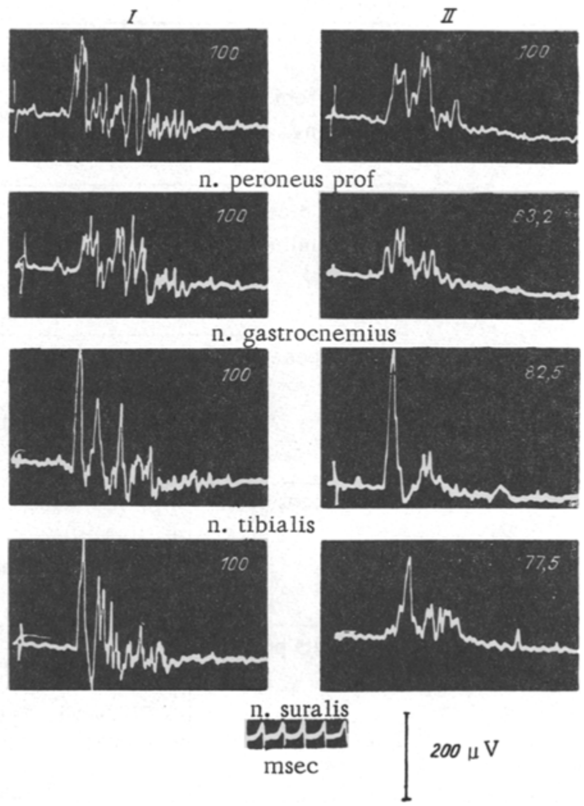

Fig. 2. Maximal reflex discharges recorded in the fibers of the nerves (on 3rd day after injection of toxin into the gastrocnemius muscle). The numbers denote the percentage of cases in which responses could be recorded. Remainder of legend as in Fig. 1.

indicator to judge whether a particular group of motor neurons was injured by tetanus toxin. Two groups of motor neurons were investigated: one belonging to the flexor muscles of the leg, innervated by the deep branch of the peroneal nerve and the nerves to the biceps and semitendinosus, and the other belonging to the extensor muscles innervated by the posterior tibial nerve and the nerve to gastrocnemius. It was found that the nuclei of the flexor and extensor muscles (even those moving the same joint) are localized differently in the spinal cord: the nucleus of the flexor is situated slightly more orally than the extensor nucleus [2, 7]. Since tetanus toxin enters the spinal cord along the motor nerves [1, 3, 4, 6, 14, 15], the possibility of a selective injury to particular groups of motor neurons arises. For instance, after injection of toxin into the gastrocnemius muscle the motor neurons of this muscle were primarily affected, and after injection of toxin into the semitendinosus muscle, the motor neurons of this muscle were similarly the principal target. It is clear from Fig. 2 that although recordings were made from the nerves of the flexor muscles and toxin was injected into the extensor muscle, certain signs demonstrate that the motor neurons of the semitendinosus and biceps femoris muscles were injured by the toxin.

Hence, when the extensor nucleus is injured by tetanus toxin, the characteristic changes of tetanus also appear in the flexor nucleus, and this may be indirect evidence of the movement of the toxin along the spinal cord. Our findings confirm this hypothesis, which is also supported by the results of many experimental investigations [1, 3, 5, 8-12, 14].

SUMMARY

An electrophysiological method of examination demonstrated that manifestations of the flexor and extensor reflexes occur in cats with local tetanus of the posterior extremity. These reflexes were not seen in control limbs. The manifestations are much stronger following injection of the toxin into the gastrocnemius than into the semitendinosus muscle.

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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.
