CHANGE IN FUNCTIONAL STATE OF NEUROMUSCULAR PERIPHERY ON FORMATION OF SPINAL CORD DOMINANT

PART II. EFFECT OF SPINAL CORD DOMINANT ON MOTOR NERVE ACCOMMODATION

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Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 50, No. 12,
pp. 20-27, December, 1960
Original article submitted Decmeber 31, 1959

It was shown in a previous communication [21] that when a dominant focus was formed in the flexor center of the spinal cord the excitation parameters (rheobase, chronaxie, threshold quantity of electricity and threshold energy) of the motor nerve and the muscle of the corresponding limb innervated by it were reduced and their values for the opposite limb were simultaneously increased.' In the present work we investigated the effect of a spinal cord dominant on the accommodation of the motor nerve. As far as we know, no investigations along this line have been carried out, though the accommodation parameter is a sensitive index of the functional state of tissue [8, 9, 12, 19] and reflects the state of its metabolism and surface polarization [6, 7, 20].

METHOD

We removed the cerebral hemispheres from the frog Rana ridibunda and prepared the semitendinous muscles, the peroneal and ulnar nerves (the peripheral ends of which were transected), and the motor branch of the sciatic nerve (its hind inferior branch) innervating the semitendinous muscle.* A graphic record was made of the contractions of the two semitendinous muscles. The dominant was created by subjecting the sensory peroneal nerve of the frog to the action of rhythmic subthreshold stimulations by an induction current of frequency 50 cps and strength 2 cm below the threshold). In the intervals between the action of the subthreshold stimulations we recorded the reflex contractions of the semitendinous muscles, and against this background we applied test stimulations of the ulnar of opposite peroneal nerves. The dominant was manifested in the development of a summation effect and in the distortion of the reciprocal relations between the centers of the antagonistic muscles. This was expressed in the enhancement of the contractions of the semitendinous muscles on test stimulations of the nerves.

The nerve accommodation was studied by means of exponentially increasing currents by D. I. Solandt's method [15]. The accommodation curves were plotted from the results of measurements of the stimulation thresholds with rise constants RC equal to 5, 10, 25, and 50 msec. To avoid excessive traumatization of the preparation (which affects the nature of its reflex activity) we did not employ exponential currents with a rise constant of more than 50 msec. The obtained stimulation threshold values, referred to the value of the rheobase v_0, were plotted on the y-axis and the rise constants of the stimulating current were plotted on the x-axis. The rate of

*The method was fully described in a previous paper [21].

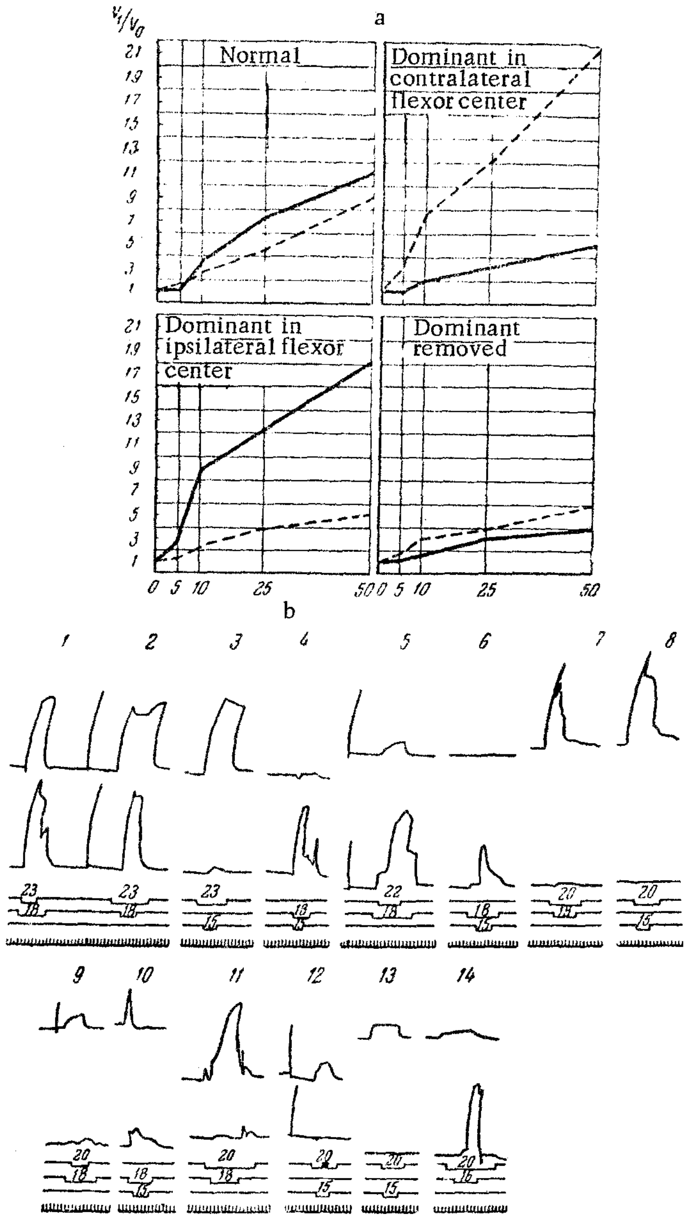

Fig. 1. Change in accomodation curves of motor nerve on formation of dominant in flexor centers of spinal cord (Expt No.78, August 8, 1957). a) Accommodation curve of ipsilateral motor nerve (hind inferior branch of sciatic nerve; solid line). On the y-axis) v/v_0; on the x-axis) rise constants (in msec); b) kymogram of same experiment: frames 1, 2, 3, 4) reflex contractions of semitendinous muscle at start of experiment, before formation of dominant; frames 5, 6, 7, 8) the same on formation of dominant in contralateral flexor center by subthreshold stimulations of contralateral peroneal nerve (frequency 50 cps, strength 2 cm below stimulation threshold); frames 9, 10) the same after disappearance of dominant; frames 1, 2, 3) the same after formation of dominant in ipsilateral flexor center by stimulation of ipsilateral peroneal nerve by subthreshold current; frame 14) the same after disappearance of dominant. Meaning of curves (from top to bottom): myogram of reflex contractions of ipsilateral semitendinous muscle; the same for contralateral semitendinous muscle; stimulation marks for ipsilateral peroneal nerve; the same for contralateral peroneal nerve; the same for ulnar nerve; time marks (1 sec). Numbers above stimulation marks—distance between coils (in cm).

accommodation, corresponding to the initial slope of the accommodation curve, was calculated from A. V. Gill's formula [5]: $1/\lambda = \frac{v - v_0}{v_0 \cdot a}$ for the rise constants of 5, 10, and 25 msec.

A total of 97 experiments were carried out—13 on an isolated nerve-muscle preparation and 84 on the intact animal. In some experiments we determined the rheobase and chronaxie simultaneously with the measurements of the motor nerve accommodation and with the same electrodes. For the measurements we used a combined chronaximeter and adaptometer. We employed chlorided silver electrodes; the distance between them was 0.8-10 mm. The current direction was descending. The accommodation of the motor nerves of the two limbs was measured before formation of the dominant, during formation of the dominant, and after its disappearance.

RESULTS

The investigations showed that when a dominant was formed in the flexor centers of the spinal cord there was a marked increase in the rate of accommodation of the motor nerve of the limb in the centers of which the dominant had been elaborated. The rate of accommodation of the motor nerve of the opposite limb was reduced.

From a comparison of the accommodation curves for the motor nerve before and during formation of the dominant (Fig. 1a) we see that the slope of the accommodation curves for the motor nerve of the corresponding side increases both in the region of low rise constants (5 and 10 msec) and particularly in the region of larger values (25 and 50 msec). At the same time the accommodation curves for the motor nerve of the opposite limb have a more gentle slope than the initial curves before formation of the dominant. The kymogram of this experiment (Fig. 1b) shows that at first, before the application of the subthreshold stimulations, a reciprocal relationship existed between the antagonistic muscles—weakening of the contractions of the ipsilateral muscle on stimulation of the contralateral nerve and conversely (see Fig. 1b, 1, 2, 3, 4). The accommodation curves of the two motor nerves for this period of the experiment are shown in Fig. 1a (top left). After a ten-minute subthreshold stimulation of the contralateral peroneal nerve (in the interval between 4 and 5) a flexor dominant was elaborated in the centers of this limb. As the kymogram shows (see Fig. 1b, 5, 6), stimulation of the ipsilateral peroneal and ulnar nerves caused enhanced contraction of the contralateral muscle instead of inhibition. During the formation of the dominant the accommodation curve for the contralateral nerve became much steeper while that of the ipsilateral, on the other hand, decreased in slope, which led to a characteristic "scissors-like" position of the curves (see Fig. 1a, top right).

Later, on stimulation of the ipsilateral peroneal nerve in the same experiment a dominant was elaborated in the flexor centers of the ipsilateral limb (see Fig. 1b, 11, 12), and the relationship between the accommodation curves for the ipsi- and contralateral nerves was reversed (see Fig. 1a, bottom left). After disappearance of the dominant the two curves again became parallel and their angle with the x-axis was reduced (see Fig. 1a, bottom right).

In the majority of experiments we did not determine the whole accommodation curve but the rate of accommodation for two or three rise constants (5, 10, and 25 msec). Figure 2 shows the results of one of these experiments. After the fourth subthreshold stimulation of the ipsilateral peroneal nerve a dominant was formed in the flexor centers of the corresponding limb, (Fig. 2b, 5, 6) and, as the graph for this experiment shows (see Fig. 2a), the rate of accommodation of the ipsilateral motor nerve was greatly increased, especially for a rise constant of 5 msec (ten times; see Fig. 2a, 1). The rate of accommodation of the motor nerve of the opposite limb at this time for a 5 msec rise constant was halved (see Fig. 2a, 3). In the case of formation of a dominant in the contralateral flexor center the rate of accommodation of the contralateral motor nerve was greatly increased (13 times), as Fig. 3b, 3 shows. The rate of accommodation of the motor nerve of the opposite limb was halved (see Fig. 3b, 1).

In some experiments even repeated subthreshold stimulation of the sensory nerves (sometimes up to 15 times) did not lead to the formation of a spinal cord dominant; in this case we observed no appreciable changes in the rate of accommodation of the motor nerve. On the other hand, when the dominant was induced by previous chilling of the animal (without subthreshold tetanization), the rate of accommodation of the motor nerve was increased, just as in the case of the dominant elaborated by subthreshold stimulation of the sensory nerve. In both cases the increase in the rate of accommodation was greater, the stronger the manifestation of the dominant. In ten experiments with the dominant present we simultaneously measured the excitation parameters and rates of

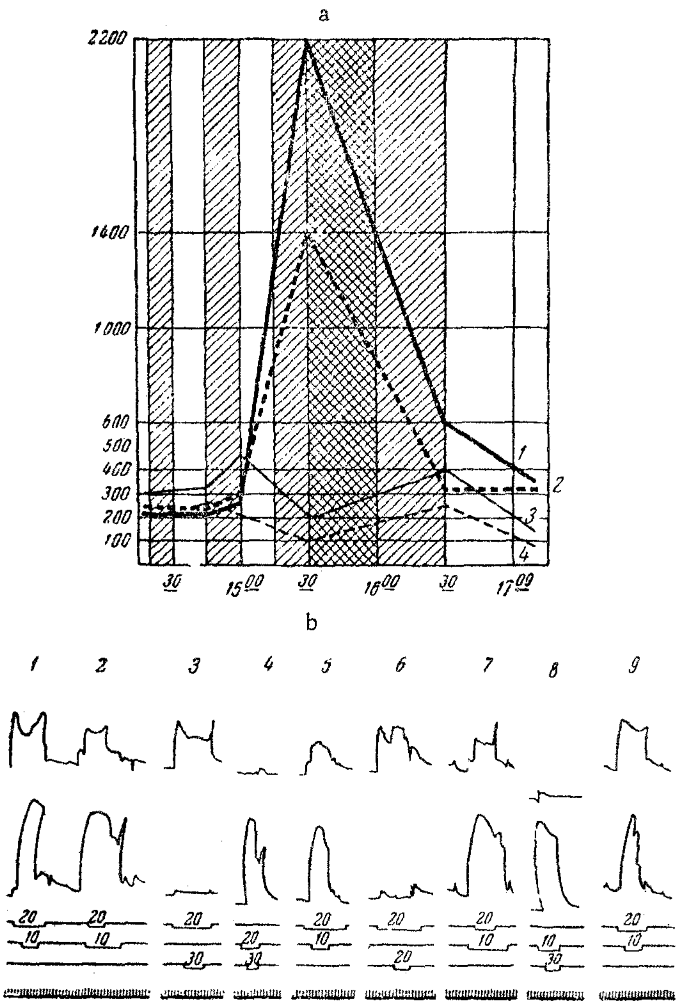

Fig. 2. Change in rate of accommodation of motor nerve on formation of dominant in ipsilateral flexor center (Expt No.32, December 26, 1958). a) Increase in rate of accommodation of ipsilateral motor nerve of semitendinous muscle. The ipsilateral peroneal nerve was again subjected for 10 min to subthreshold tetanization (hatched column) which resulted in formation of dominant (cross-hatched column); 1) rate of accommodation of ipsilateral motor nerve for rise constant 5 msec; 2) the same for rise constant 10 msec; 3) rate of accommodation of contralateral motor nerve for rise constant 5 msec; 4) the same for rise constant 10 msec; b) kymogram of same experiment; frames 1, 2, 3, 4) reflex contractions of semitendinous muscle before formation of dominant; frames 5, 6, 7) the same after formation of dominant in ipsilateral flexor center by stimulation of ipsilateral peroneal nerve (frequency 50 cps, strength 2 cm below stimulation threshold); frames 8, 9) the same after disappearance of dominant. Meaning of curves as in Fig. 1b.

accommodation of the motor nerves. Figure 3 shows the results of such an experiment. When the dominant arose in the contralateral flexor center (see Fig. 3c, 5, 6, 7, 8) the rate of accommodation of the contralateral motor nerve increased by a factor of 13 (see Fig. 3b, 3), the rheobase was reduced by a factor 2.5 and the chronaxie was

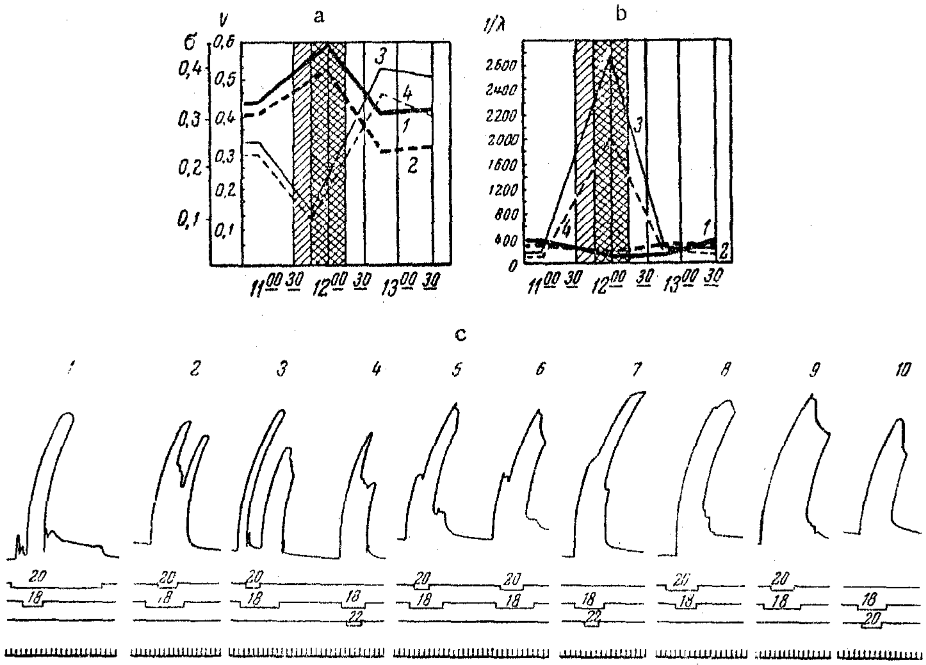

Fig. 3. Change in rate of accommodation and excitability of motor nerves on formation of spinal cord dominant in contralateral flexor center (Expt No. 72, June 20, 1958). a) Change in excitability of motor nerve in presence of dominant; 1) rheobase of ipsilateral motor nerve; 2) chronaxie of ipsilateral motor nerve; 3) rheobase of contralateral motor nerve; 4) chronaxie of contralateral motor nerve; b) change in rate of accommodation of motor nerve in presence of dominant. Meaning of curves as in Fig. 2a; c) myogram of same experiment; frames 1, 2, 3, 4) reflex contractions of semitendinous muscle before formation of dominant; frames 5, 6, 7, 8) the same after formation of dominant in contralateral flexor center due to subthreshold tetanization of contralateral peroneal nerve (same conditions of experiment); frames 9, 10) reflex contractions after disappearance of dominant. Meaning of curves as in Fig. 1b.

halved (Fig. 3a). We observed similar relations in other experiments. As a rule the rate of accommodation was a more sensitive index of the change in the functional state of the nerve on formation of the dominant than the rheobase and chronaxie. Changes in the rate of accommodation usually preceded changes in nerve excitability, were more pronounced and were observed even in cases where the rheobase and chronaxie had still not changed significantly.

The table gives the results relating to the change in accommodation of the motor centers on formation of a dominant in the flexor center of one of the limbs. In 48 cases out of 54 the rate of accommodation of the corresponding motor nerve increased 200 to 400 % on the average (in some experiments by a factor of ten or more) when the dominant appeared. In three cases out of the 54 we found no changes and in three cases we noted an insignificant reduction in the rate of accommodation. In 29 cases out of 42 the rate of accommodation of the motor nerve of the opposite limb was reduced, in nine cases it was unaltered, and in four cases it increased slightly.

When the dominant disappeared the rate of accommodation of the motor nerve was usually restored to its initial value. It should be noted that at the moment the dominant disappeared the rate of accommodation of the ipsilateral nerve was still below the initial level and only gradually attained it.

The changes observed in our experiments on the rate of accommodation of the motor nerve on induction of a spinal cord dominant were very similar in their nature and rapid reversibility to those usually observed in the development of electrotonus in the nerve [6, 7]. As we know, in the region of catelectrotonus the rate of accommodation increases markedly when the direct current is made and, when the current is broken, the rate of

Nature of Change in Rate of Accommodation of Motor Nerve on Formation of Dominant

On side of dominant				On opposite side			
total no. of observations	no. of observations with increased rate of accommodation		increase in rate of accommodation	total no. of observations	no. of observations with reduced rate of accommodation		reduction in rate of accommodation
	total	no. with indicated increase			total	no. with indicated reduction	
54	48	2	20:1	42	29	1	1:60
		4	15:1			1	1:15
		4	10:1			1	1:7
		4	8:1			1	1:4
		3	6:1			3	1:3
		3	5:1			7	1:2
		6	4:1			7	1:1,5
		6	3:1			8	1:1–1,5
		5	2:1				
		6	1,5—1				
		5	1—1,5:1				
	no. of observations with reduced rate of accommodation		reduction in rate of accommodation		no. of observations with increased rate of accommodation		increase in rate of accommodation
	total	no. with indicated reduction			total	no. with indicated increase	
	3	1	1:3		4	1	3:1
		2	1:1,5			1	2:1
						2	1,5:1
	total no. of observations with no change in rate of accommodation						
	3	—	—		9	—	—

accommodation at first falls below its initial value and is then restored to its initial level [6]. Similarly in our experiments, as we indicated above, the appearance of the dominant was accompanied by an increase in the rate of accommodation of the corresponding motor nerve, and the disappearance of the dominant was accompanied by a reduction in the rate of accommodation to values below the initial level.

From these results we can postulate that the changes in the rate of nerve accommodation in the presence of a spinal cord dominant are also of an electrotonic nature; this fits in well with the ideas of the electronic nature of subordination effects [1, 2, 9, 11, 13, 14, 16, 17]. On the basis of the results of our experiments we can postulate that the spinal cord centers in the dominant state have catelectrotonic effects on the periphery, and the centers in a state of conjugate inhibition have anelectrotonic effects on the periphery. However, our earlier results [21] on the nature of the changes in motor nerve excitability on formation of a spinal cord dominant do not all fit in with this theory; as distinct from the case of catelectronus, the chronaxie is not increased, but reduced.

The reduction of the chronaxie of the motor nerve, according to published information [3, 4, 18], is associated with the subordination effect of the sympathetic nervous system. It is possible that this effect is also present on the formation of a spinal cord dominant. This hypothesis, however, requires further investigations.

SUMMARY

This work deals with a study of motor nerve accommodation following formation of a spinal cord dominant. The dominant was formed in one of the flexor centres of the posterior limb by acting upon the frog's sensory nerves with rhythmic subliminal stimuli. The presence of the subthreshold dominant was manifested in the reversal of the reciprocal relations between the antagonistic centers. As shown by experiments, the formation of a dominant in the spinal cord centres leads to an increased rate of motor nerve accommodation in the corresponding limb and its reduction in the contralateral limb. In their character and rapid reversibility these changes are very similar to those developing in the nerve in the area of catelectrotonus and anelectrotonus.

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