DORSAL SURFACE POTENTIALS OF THE SPINAL CORD IN RATS WITH CONVULSIONS DUE TO ASCENDING TETANUS

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Amplitudes of the N_1-wave of the dorsal surface potential of the spinal cord evoked by stimulation of the sural nerve of both hind limbs were essentially indistinguishable in rats with convulsions (with the "universal departure station" phenomenon), in rats with local tetanus, and in healthy animals. The N_2-wave recorded in animals with the "station" phenomenon in response to stimulation of the nerve on the tetanus side was greater in amplitude than the N_2-wave evoked by stimulation of the nerve on the contralateral side. The distribution of amplitudes of N_1-wave over the surface of the spinal cord is similar in rats with the "station" phenomenon and in healthy rats. Amplitudes of the P-wave evoked by stimulation of the nerve on the tetanus side in rats with the "station" phenomenon were greater over the whole area of the lumbosacral enlargement than the amplitudes of the P-wave evoked by stimulation of the nerve on the contralateral side or amplitudes of the P-waves at corresponding points of the spinal cord in healthy rats.

In previous investigations [1] to study the phenomenon of facilitated irradiation of excitation from segments affected by toxin in rats with ascending tetanus (the "universal departure station" phenomenon) it was shown that stimulation of cutaneous nerves of the limb into which the toxin was injected causes the appearance of slow negative potentials of increased amplitude and duration in the dorsal roots and of corresponding positive potentials on the dorsal surface of the spinal cord (P-waves of the DSP), and these potentials differed from those in healthy animals in several respects [2-4].

This paper gives information on negative dorsal surface potentials (N-waves of the DSP) in rats with the "station" phenomenon and compares the distribution of negative and positive potentials along the length of the spinal cord.

EXPERIMENTAL METHOD

The investigation was carried out on 58 albino rats weighing 300-500 g. Local tetanus was produced by injection of tetanus toxin into the gastrocnemius muscle in a dose of 0.05 MLD, and ascending tetanus by injecting toxin in a dose of 4-6 MLD. In the latter case, to block the spread of toxin from the blood, antitetanus serum was injected intravenously in a dose of 0.025 a.u. Details of the method of dissection, stimulation of the nerves, and recording the dorsal surface potentials were given in the previous paper [3]. In a separate series of experiments (on 4 animals with the "station" phenomenon and on 4 healthy rats) the distribution of amplitudes of the DSPs along the length of the spinal cord was investigated. The active electrode was moved along the midline of the spinal cord by means of a micromanipulator, and at each point DSPs evoked by stimulation of the sural nerve on each side were recorded.

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TABLE 1. Amplitudes of N_1-Waves of DSP in Healthy Rats and Rats with Tetanus

Animals investigated	Side of stimulation	Amplitude (in μV)					
		4 T			40 T		
		n	*M*±*m*	*P*	*n*	*M*±*m*	*P*
Healthy	Left	12	327±13	>0,05	12	334±44	>0,05
	Right	12	320±44		12	333±42	
With local tetanus	Tetanus	16	352±34	>0,05	16	369±38	>0,05
	Contralateral	15	355±30		15	363±27	
With "station" phenomenon	Tetanus	22	425±52	>0,05	22	428±43	>0,05
	Contralateral	17	403±47		17	443±59	

Legend: 4T and 40T represent strengths of stimulation equal to 4 and 40 times the threshold values, respectively, for the corresponding nerves.

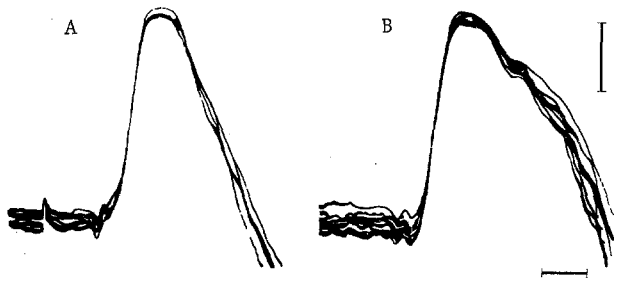

Fig. 1. Negative dorsal surface potentials of the spinal cord in rats with the "station" phenomenon: A) potentials evoked by stimulation of nerves contralateral to injection of toxin; B) potentials evoked by stimulation of nerves on side of tetanus. Strength of stimulation 40 threshold values for corresponding nerves. Calibration: amplification 150 μV, time 2 msec.

EXPERIMENTAL RESULTS

The negative DSP in healthy rats, like the negative DSP evoked by stimulation of the nerve on the side opposite to that of injection of the toxin in animals with the "station" phenomenon, consists of a wave of simple shape (Fig. 1A), the ascending phase of which is complicated by a small spike potential (afferent spike). Sometimes a small additional negative wave was present on the ascending phase. These negative DSPs correspond to waves first described by Bernhard [6] in cats as N_1 and N_2-waves.

The amplitudes of the N_1-wave in the animals with the "station" phenomenon, with local tetanus, and in healthy rats are compared in Table 1. Unlike the definite asymmetry in amplitudes of the polysynaptic reflexes found at the stage of local tetanus and of P-waves in animals with the "station phenomenon, [3, 4], the N_1-waves evoked by stimulation of the nerves on both sides were essentially indistinguishable in animals of all three investigated groups.

The N_2-wave in healthy animals and in rats with local tetanus was observed in comparatively rare cases, and in these experiments the N_2-waves evoked by stimulation of the nerves on both sides were approximately equal in value. In rats with the "station" phenomenon a large N_2-wave, in the form of an additional wave on the descending phase of the N_1-wave (Fig. 1b), was observed in half of the tracings of the negative potential evoked by stimulation of the nerve on the side of tetanus. Stimulation of the contralateral nerve in the same preparations did not always evoke an N_2-wave (Fig. 1A). In cases when an N_2-wave did appear in response to stimulation of the contralateral nerve, it was smaller than that evoked by stimulation of the nerve on the side of tetanus.

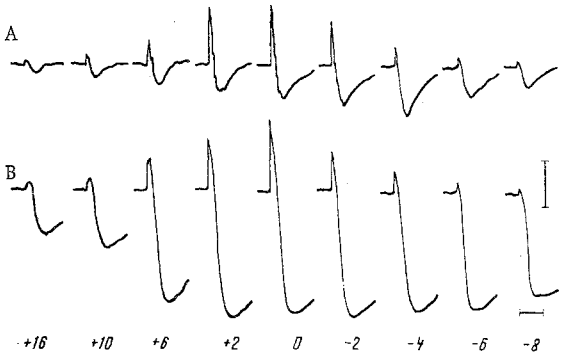

Fig. 2. Dorsal surface potentials (DSPs) at various points of the lumbar enlargement in rats with the "station" phenomenon: A) DSPs evoked by stimulation of the nerve contralateral to the side of injection of toxin; B) DSPs recorded at the same points, but during stimulation of the nerve on the tetanus side. Strength of stimulation 4 threshold values of the corresponding nerves. Numbers below curves denote distance (in mm) in cranial (+) and caudal (−) directions from point with maximal values of negative potentials, taken as 0. Calibration: amplification 500 μV, time 50 msec.

DSPs recorded at different points along the midline of the lumber enlargement on the spinal cord in rats with the "station" phenomenon are shown in Fig. 2. N_1-waves evoked by stimulation of nerves on both sides showed identical changes as the active electrode was moved along the spinal cord, but the P-waves changed differently. The P-wave evoked by stimulation of the contralateral nerve was maximal at the point −4. In the cranial and caudal directions from this point, the potentials decreased steadily. The region of maximal values of the P-wave evoked by stimulation of the nerve on the side of tetanus was definitely wider: amplitudes of the P-waves were about equal for a distance of 8 mm (at the points +2, 0, −2, −4, and −6). A similar tendency toward widening of the region with maximal values of P-waves evoked by stimulation of nerves on the side of tetanus was also observed in the remaining three experiments to study the character of distribution of DSP amplitudes in rats with the "station" phenomenon (collective curves shown in Fig. 3A).

It is clear from Fig. 3 that the character of distribution along the length of the spinal cord of DSPs evoked in rats with the "station" phenomenon by stimulation of the nerve on the side contralateral to that of injection of the toxin and in healthy animals is similar as regards both the N_1- and P-waves. The only significant difference between the corresponding curves in Figs. 3A and 3B is that the character of distribution along the length of the spinal cord of the P-wave evoked in rats with the "station" phenomenon by stimulation of the nerve on the side of tetanus is different from normal. The absolute amplitudes of P-waves evoked by stimulation of the nerve on the side of tetanus were greater than in healthy animals throughout the length of the lumbosacral enlargement, while the region of maximal amplitudes was slightly wider.

It is interesting to note that strychnine has a similar effect on DSPs [8]. Injection of strychnine into a cat had no effect on either the amplitude or character of distribution of the N_1-wave along the surface of the spinal cord, whereas the amplitude of the P-wave was increased at the same recording points. Together with deepening of the P-wave, the appearance of an N_2-wave was observed after injection of strychnine [8].

The absence of changes in the N_1-wave, reflecting monosynaptic excitation of tract neurons [6], in rats with the "station" phenomenon can be regarded as further evidence that tetanus toxin has no direct excitatory action on neurons. This has been shown previously on the example of monosynaptic reflexes in motoneurons [9].

The N_2-wave is generated by structures of the posterior horn [11], and according to some workers [5] it is an integral EPSP of the segmental interneurons. In that case, the increase in amplitude of the N_2-

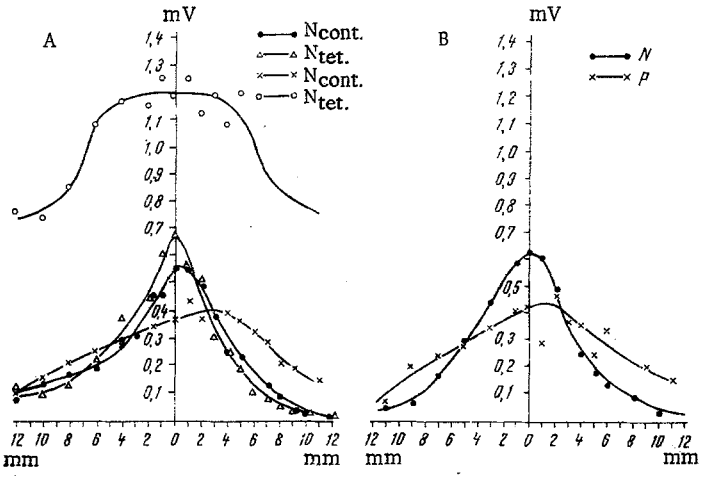

Fig. 3. Comparison of character of distribution of DSP amplitudes along length of spinal cord in rats with the "station" phenomenon: A) distribution along spinal cord of amplitudes of negative (N_1-waves) and positive DSPs evoked by stimulation of nerve on side of tetanus and contralateral side in rats with "station" phenomenon; B) distribution along spinal cord of amplitudes of negative (N_1-wave) and positive DSPs in healthy rats. Data for DSPs evoked by stimulation of nerves on both sides are aggregated (8 observations altogether). Legends to curves given separately on figure.

wave in rats with the "station" phenomenon is evidence of increasing activity of interneurons on the side of injection of tetanus toxin. So far the increase in activity of interneurons in tetanus has been estimated indirectly, on the basis of an increase in amplitude of polysynaptic reflexes of motoneurons [9].

The facts relating to changes in the P-wave are of considerable interest from the standpoint of study of the "station" phenomenon. Bernhard [8] showed that in preparations in which no P-wave is evoked, transmission of excitation between segments of the spinal cord is also absent. In the present experiments on rats with the "station" phenomenon, stimulation of the nerve on the "tetanus" side led both to wide irradiation of excitation over the spinal cord and also to generation of a P-wave of greater amplitude and duration than the P-wave in the healthy animal [3, 4].

The P-wave in rats with the "station" phenomenon consists of two components, and changes in the parameters of the P-wave are due to changes in that part of it which is intimately connected with generation of the efferent paroxysmal discharge [3]. The tendency for widening of the region of the spinal cord where maximal values of the P-wave are recorded can be considered to be due to an increase in the population of neurons generating the "paroxysmal" component.

The paroxysmal component of the P-wave observed in the present experiments on rats with the "station" phenomenon is probably analogous to the component of the P-wave evoked by stimulation of afferent fibers of the flexor reflex carried in muscular and cutaneous nerves [10], which differs from the component evoked by stimulation of low-threshold cutaneous afferent fibers in its wider distribution along the length of the spinal cord.

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