FOCAL SPINAL CORD POTENTIALS IN RATS WITH A PAROXYSMAL SYNDROME FROM ASCENDING TETANUS

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In rats with ascending tetanus in that stage of the toxic syndrome in which generalized paroxysmal activity of the muscles is induced only by stimulation of the receptors or nerves of the hind limb into which the toxin was injected (the "universal departure station" phenomenon) the focal potentials (FPs) were investigated by a microelectrode technique in the lumbar segments of the spinal cord. Stimulation of the nerve on the "tetanus" side was accompanied by the appearance of strong tonic negative FPs in the ventral quadrants of the spinal cord. In response to stimulation of the contralateral nerve phasic FPs of low amplitude were recorded in the same structures. It is postulated that the structures generating tonic paroxysmal activity, irradiating over the spinal cord (the "departure station" of paroxysmal activity), are localized in the ventral quadrants of the spinal cord.

A considerable increase in the amplitude and duration of the positive component (the P-wave) of the dorsal surface potential (DSP) and of the slow negative potential of the dorsal roots of the poisoned segments of the spinal cord is observed [5-7, 9-11] in animals with ascending tetanus at the stage of onset of the "universal departure station" phenomenon [3, 4, 13].

These changes in the P-wave of the DSP are due to an increase in the components whose properties differ from those of the component forming the basis of the P-wave in the healthy rat [5, 9, 10]. The character of distribution of amplitudes of P-waves evoked by stimulation of a nerve on the side of injection of the tetanus toxin over the surface of the spinal cord also differs from the distribution of amplitudes of the P-wave evoked by stimulation of a contralateral nerve or the distribution of amplitudes in the healthy animal [8, 10, 11].

It was decided to study the localization of structures whose increased activity led to changes in the characteristics of the P-wave of the DSP in rats with the "universal departure station" phenomenon because those structures could be generators of the tonic paroxysmal activity irradiating widely over the spinal cord (the "departure station" of paroxysmal activity). For this purpose the focal potentials (FPs) [11] inside the spinal cord were studied, and the results are described below.

EXPERIMENTAL METHOD

Fourteen rats with the "universal departure station" phenomenon, and weighing 300-350 g, were used. The method of poisoning, the operative preparation, and the apparatus used were the same as those described previously [5, 9, 11].

The FPs were recorded by glass micropipets filled with 2.5 M NaCl solution. The resistance of the microelectrodes was 0.5-10 MΩ. During the experiment the microelectrodes were fixed in a holder mounted

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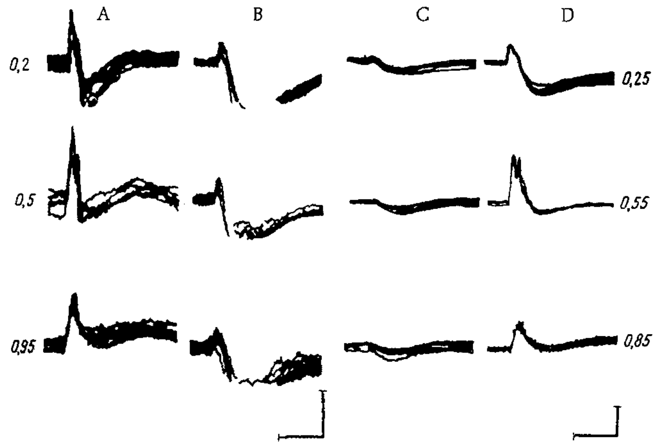

Fig. 1

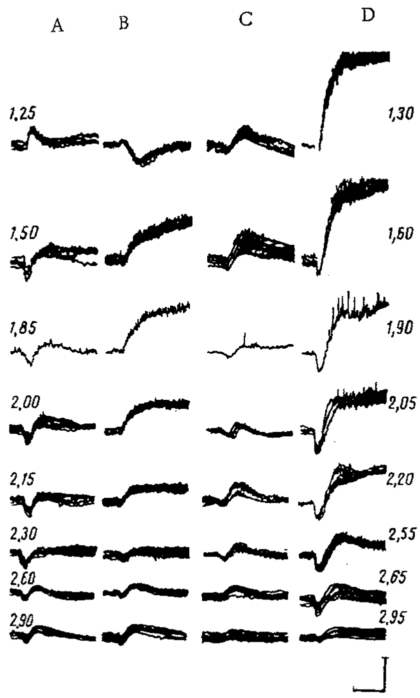

Fig. 2

Fig. 1. FPs in dorsal horns of gray matter of spinal cord of rat with paroxysmal syndrome from ascending tetanus. A and B) FPs in dorsal horn on opposite side to injection of toxin, evoked by stimulation of ipsilateral (A) and contralateral (B) cutaneous nerves at 4 times the threshold strength (4T). C and D) FPs in dorsal horn of gray matter of spinal cord on "tetanus" side evoked by stimulation of ipsilateral (D) and contralateral (C) cutaneous nerves in a strength of 4T. Numbers denote depth (in mm) of insertion of microelectrode counting from surface of spinal cord. Calibration for records A and B, signal 0.5 mV, time 20 msec; for C and D, 1 mV and 20 msec, respectively.

Fig. 2. FPs in intermediate zone and ventral horn of gray matter of spinal cord of a rat with paroxysmal syndrome from ascending tetanus. The same experiment as in Fig. 1. Legend the same. Calibration: signal 0.5 mV, time 20 msec.

on a micromanipulator. Electrical contact between the microelectrode and the holder was secured with silver wire, one end of which was soldered to the holder while the other (chlorided) was immersed in the electrolyte in the wide part of the microelectrode. The reference electrode was inserted into the spinal muscles.

The FPs were led into a cathode follower supplied with the UBP1-02 amplifier. The resistance of the microelectrodes was measured in the usual way [2]. The state of the spinal cord was judged from the characteristics of the DSP recorded simultaneously with the FP. Only those animals in which no significant disturbance of the blood flow was observed in the vessels of the spinal cord were used in the experiments.

The pia mater was removed above the site of insertion of the microelectrode (an area of the spinal cord medially to the entrance of the L_6 dorsal roots) by means of two electrolytically sharpened steel needles. The microelectrode was inserted into the spinal cord through the area denuded of the membrane. FPs evoked by stimulation of the ipsilateral and contralateral cutaneous (sural) nerves with a strength of 4 thresholds (4T) were recorded on insertion of the recording microelectrode on the side of injection of the toxin and on the opposite side. The recordings were obtained from equidistant points (100-150 μ apart).

At the end of the experiment the portion of spinal cord containing the microelectrode was removed and fixed in 10% formalin solution for 2-3 days. The direction of the track was determined from the orientation of the microelectrode tip in the cord section. The position of the recording points was calculated from the readings of the micromanipulator.

The results of the various experiments for each recording point were added algebraically and the mean amplitude of the FPs for the given point calculated. Amplitudes of the FPs were calculated for two moments

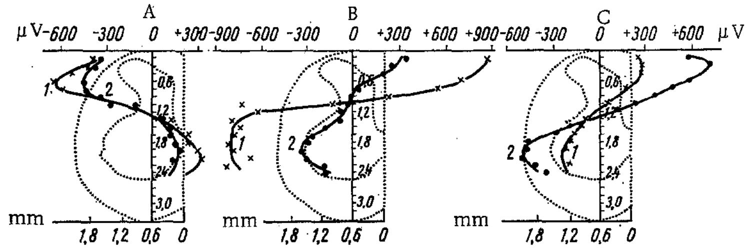

Fig. 3. Changes in amplitudes of spinal FPs of rats with a paroxysmal syndrome from ascending tetanus during insertion of recording microelectrode into spinal cord on "tetanus" (1) and opposite (2) sides: A) for time corresponding to N_1-wave of DSP reaching its maximum (4 msec); graphs plotted from results of ten experiments (for each side). B) For time corresponding to P-wave of DSP reaching its maximum (20 msec); graphs plotted from mean results of nine experiments for "tetanus" and 10 experiments for side opposite to injection of toxin. FPs, changes in which are shown in graphs A and B, were evoked by stimulation of ipsilateral nerves of "tetanus" side and side opposite to injection of toxin with a strength of 4T. C) The same as B but FPs on "tetanus" side and side of spinal cord opposite to injection of toxin were evoked by stimulation of contralateral nerves; graphs plotted from results of eight experiments for "tetanus" side and seven experiments for opposite side. Abscissa: above – amplitude of FPs (in μV), below – scale of size of spinal cord (in mm); ordinate – depth of insertion of microelectrode (in mm).

of time: the time at which the N_1-wave of the DSP reaches a maximum (4 msec) and the time at which the P-wave of the DSP becomes maximal (20 msec). These mean values of the amplitudes of the FPs were used to plot general graphs of the change in FP amplitude during insertion of the microelectrode into the spinal cord.

EXPERIMENTAL RESULTS

On insertion of the microelectrode into the spinal cord changes occured in the shape, size, and sign of the FPs corresponding in time to individual components of the DSP. The N_1-wave ipsilateral to stimulation, both on the side of injection of the tetanus toxin and on the opposite side, initially increased to reach a maximum at a depth of 0.5-0.7 mm, after which it decreased (Fig. 1A, D and Fig. 3). Deeper than 1.3 mm the N_1-wave was recorded as positive (Fig. 2A, D and Fig. 3A).

Changes in the N_2-wave were not parallel to changes in the N_1-wave. It is clear from Fig. 1A that on the side opposite to the injection of toxin the N_1-wave was reduced in amplitude at a depth of 0.95 mm and showed evidence of reversal, while the N_2-wave was changed only slightly from its appearance in the previous record. Similarly the FP corresponding to the N_2-wave changed as the microelectrode was inserted on the "tetanus" side (see Fig. 1C and D, records for depths of insertion 0.55 and 0.85 mm).

Comparison of the curves in Fig. 3A shows that the character of the change in amplitude of FPs corresponding to the time of the N_1-wave was similar during immersion of the recording microelectrode on the "tetanus" side and on the side opposite to injection of the toxin. The maximal values of the negative FPs were recorded in both cases in the dorsal, and maximal values of the positive FPs in the ventral horn of the gray matter at approximately the same depths. The values of the points at which the sign changed also coincided.

Differences in the characteristics of the FPs on the "tetanus" side and the side opposite to the injection were obtained for FPs corresponding in time to the P-wave of the DSP. Stimulation of the nerve on the "tetanus" side evoked negative FPs in the intermediate zone and in the ventral horn of the gray matter of the spinal cord, which were much greater in amplitude and duration than FPs evoked by stimulation of the ipsilateral nerve in symmetrical areas of the spinal cord on the opposite side (see Fig. 2A, D and Fig. 3B).

At the peak of the slow negative FPs evoked by stimulation of the ipsilateral nerve on the "tetanus" side prolonged spike activity was recorded (Fig. 2D, records of potentials at depth of 1.6 and 1.9 mm). Ipsilateral stimulation evoked strong positive FPs in the dorsal horn on the "tetanus" side (see Fig. 1D and Fig. 3B).

A similar pattern as regards the characteristics of the FPs evoked by stimulation of nerves on the two sides and corresponding to the P-wave was observed when FPs were recorded on the contralateral side (see Fig. 2B, C and Fig. 3C). It will be clear from Fig. 2 that at a depth of 1.5-2 mm FPs evoked by stimulation of the nerve on the "tetanus" side in the gray matter of the opposite side of the cord (Fig. 2B) are greater in amplitude and duration than FPs evoked by stimulation of the contralateral nerve on the "tetanus" side (see Fig. 2C). Moreover, on the opposite side of the cord FPs evoked by stimulation of the nerve on the "tetanus" side (see Fig. 2B) were greater in amplitude and duration than FPs evoked at the same points by stimulation of the ipsilateral nerve (Fig. 2A).

Correlation between the duration of the slow FPs and the length of the period when spike activity could be recorded simultaneously is interesting. On the "tetanus" side of the cord at a depth of 1.9 mm, stimulation of the ipsilateral nerve evoked a tonic discharge of spikes, whereas stimulation of the contralateral side evoked only a single spike. On the opposite side of the cord stimulation of the nerve on the "tetanus" side also evoked a prolonged FP, at the crest of which prolonged spike activity could be seen (see Fig. 2B, depth of insertion of microelectrode 1.85 mm).

DISCUSSION

The study of changes in the negative DSPs during insertion of the microelectrode into the spinal cord of a rat with the "universal departure station" phenomenon showed that negative FPs, corresponding to N_1- and N_2-waves of the DSP, are recorded in the dorsal horn; the maximal negative FP corresponding to the N_1-wave, moreover, is recorded more dorsally than the maximal FP corresponding to the N_2-wave, in agreement with data for the localization of the structures generating these components in the cat spinal cord [12].

In the healthy animal the maximal FP corresponding to the P-wave evoked by stimulation of cutaneous nerves is generated by structures of the dorsal horn [13]. Conversely, the facts described above are evidence that changes in the characteristics of the P-wave in animals with the "universal departure station" phenomenon took place on account of an increase in the activity of structures in the ventral half of the spinal cord.

Data on differences in the location of structures generating the main component of the P-wave in the healthy animal and the component responsible for changes in the characteristics of the P-wave in rats with the "universal departure station" phenomenon are in good agreement with the writers' earlier observations of differences in the functional properties of these two components [6, 10, 11].

Since slow negative FPs with temporal characteristics of tonic paroxysmal activity are evoked only by the arrival of the afferent volley in the "tetanus" half of the spinal cord and are recorded only in the ventral part of it, it can be concluded that neurons generating the tonic paroxysmal activity irradiating over the spinal cord (neurons of the "departure station") are located in the ventral half of the cord on the "tetanus" side.

This hypothesis is confirmed by the results of experiments to study the effects of selective poisoning of spinal cord structures. These showed that the typical picture of the "universal departure station" phenomenon and changes in the characteristics of the P-wave of the DSP characteristic of animals with this phenomenon can be obtained if only the ventral quadrant of one half of the cord is poisoned [1, 11].

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