ROLE OF RELATIVELY HIGH-THRESHOLD AFFERENTS IN FORMATION OF THE DORSAL SURFACE POTENTIAL OF THE SPINAL CORD

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In experiments on spinal cats and cats lightly anesthetized with hexobarbital, the conduction of impulses in thick afferent fibers was blocked by a direct current. The N_2-component of the dorsal surface potential of the spinal cord was shown to reflect the integral postsynaptic potential of segmental interneurons of the dorsal horn activated by relatively high-threshold group $A\gamma\delta$ fibers.

The dorsal surface potential (DSP) of the spinal cord has been investigated in some detail and described [1-8]. Various groups of afferent fibers and central neurons excited by them are known to participate in DSP generation. According to some workers, the origin of the first and largest negative postsynaptic component of the DSP (the N_1-component) is associated with activity of interneurons, mainly nonsegmental, of the dorsal horn [1, 4]. The question of the genesis of later negative components, especially the second (N_2), has not yet been explained.

The role of afferent fibers of various types in the formation of the N_2-component of the DSP is examined below.

EXPERIMENTAL METHOD

The experiments were carried out on spinal cats and cats lightly anesthetized with hexobarbital (50 mg/kg body weight). Laminectomy was performed in the region of the lumbosacral enlargement. The popliteal, common peroneal, superficial peroneal, and sural nerves were dissected. After the operation the animal was fixed securely to a massive metal frame. Potentials from the dorsal surface and ventral roots were amplified and recorded from the screen of a cathode-ray oscilloscope. Square pulses from an electronic generator with radio frequency output were used for stimulation. The animal's body temperature was maintained at the normal level. The brain and nerves were flooded with mineral oil. To obtain an isolated afferent volley in relatively high-threshold fibers, conduction of impulses in thick afferents was blocked by a direct current. This method has advantages over alternative methods because anodic blocking of a nerve is selective, reversible, and easily controlled [9].

EXPERIMENTAL RESULTS AND DISCUSSION

The relationship between the DSP and strength of stimulation was investigated in the first group of experiments. During weak stimulation of mixed nerves (popliteal and common peroneal) an action potential in the afferent fibers appeared first. As the strength of stimulation was increased, an N_1-component and P-wave appeared. At a certain intensity of stimulation (1.3-1.5 thresholds), a later negative N_2-component was formed. A further increase in the strength of stimulation increased the amplitude of the N_1-component and, at the same time, reduced the later negative waves. The results of one experiment are given in Fig. 1. The strength of stimulation was expressed in multiples of the threshold value (T) for the fibers with lowest

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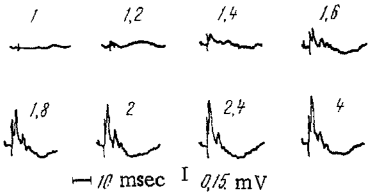

Fig. 1. Changes in DSP in relation to strength of stimulation of popliteal nerve. Numbers show strengths of stimulation in thresholds.

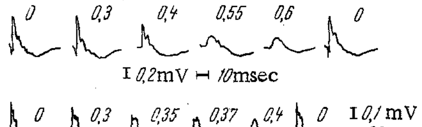

Fig. 2. Changes in DSP in relation to strength of polarizing current blocking conduction in stimulated afferent nerve. Numbers give strengths of polarizing current (in mA); top row – stimulation of popliteal nerve, bottom row – stimulation of superficial peroneal nerve.

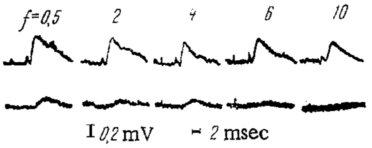

Fig. 3. Dependence of DSP on frequency of stimulation. Top row, DSPs evoked by stimulation of superficial peroneal nerve; bottom row, the same but with polarization of the nerve; numbers show frequency of stimulation.

thresholds contained in the peroneal nerve. As Fig. 1 shows, the N_2-component appeared in response to stimulation with a strength of 1.4 T and reached its maximum in response to stimulation with a strength of 2 T. A further increase in the strength of stimulation led to a reduction in the N_2-component, while the N_1-component increased to its maximum.

This phenomenon suggests that the N_2-component reflects activity of interneurons excitable by relatively high-threshold fibers with a lower velocity of impulse conduction.

To confirm this hypothesis, in the second group of experiments the thick low-threshold fibers were blocked by dc polarization of the nerve. Experiments on the mixed nerves showed that as the strength of the polarizing current was increased the afferent peak disappeared first, followed by the N_1-component when the strength of the current was 0.4-0.6 mA. The remaining N_2-component was a low-amplitude (100-150 μV) potential and was followed by a positive wave. Its maximum was shifted into the region of longer times (40-50 msec) and its amplitude was reduced on the average by one-third compared with the P-wave of the ordinary DSP. As Fig. 2 (top row) shows, polarization of the popliteal nerve by a current of 0.6 mA led to complete disappearance of the N_1-component. The mean latency of the N_2-component, measured in nerve polarization experiments, was 6.3 msec. Calculations showed that the conduction velocity in fibers responsible for generation of the N_2-component varied between 18 and 38 m/sec, with a mean value of 28.5 m/sec, whereas the conduction velocity in fibers responsible for generation of the N_1-component averaged 53 m/sec. Fibers exciting interneurons generating the N_2-component thus belong to the $A\gamma\delta$ group.

In the next experiments the role of cutaneous fibers in the formation of the N_2-component of the DSP was studied.

Polarization of cutaneous nerves (superficial peroneal and sural) led to changes in the DSP similar to those observed in the experiments with the mixed nerves. Examination of Fig. 2 (bottom row) shows that polarization of the superficial peroneal nerve by a current of 0.35 mA reduced the amplitude of the N_1-component by almost 50% compared with the control. An increase in the current to 0.4 mA led to disappearance of this component while the N_2-component and following positive wave remained intact. Simultaneous recording of the DSP and ventral root potentials showed that at a certain strength of polarizing current stimulation of the afferent nerves caused the appearance only of the N_2-component and of the corresponding polysynaptic action potential in the ventral roots.

In the last group of experiments the effect of repetitive stimulation at different frequencies on the character of changes in the N_2-component of the DSP was studied. Stimuli were applied to the superficial peroneal nerve. Potentials were recorded by superposition of ten sweeps of the beam. As a result of this stimulation the amplitude of the N_2-component was reduced to a certain steady value, and remained stabilized at a lower level than initially. The records shown in Fig. 3 illustrate the substantial difference between the character of changes in the N_1- and N_2-components of the DSPs evoked by repetitive stimulation of the superficial peroneal nerve. At frequencies of 10/sec the amplitude of the stabilized N_1-component was 75% of the initial value, whereas the N_2-component was completely suppressed.

Analysis of these results shows that the N_1- and N_2-components of the DSP reflect the activity of different structures in the spinal cord. The relatively low amplitude of the N_2-component indicates that the interneurons generating it are located in deeper layers of the dorsal horn. This agrees with the observations of Selzer and Spencer [10] that cells generating the N_2-component lie in Rexed's layer V. The correlation now established between changes in the N_2-component and the polysynaptic reflex response confirms the view that the N_2-component reflects the integral excitatory postsynaptic potential of segmental interneurons excited by relatively high-threshold afferents with a lower conduction velocity. The decrease in amplitude of the N_2-component after a certain strength of stimulation is reached can probably be attributed to primary afferent depolarization developing in the terminals of relatively slow-conducting fibers following activation of presynaptic inhibition mechanisms by the preceding volley of impulses in fast-conducting fibers.

The more marked inhibition of the N_2- than of the N_1-component at low frequencies of stimulation is possibly connected with the functional properties of synapses formed by the thinner afferents responsible for generation of this component and also with the deeper homosynaptic depression developing in them.

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