ELECTROMYELOGRAM RECORDING DURING SURGICAL OPERATION ON THE SPINAL CORD IN MAN

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Feasible methods are now being sought for electromyelography, a process currently being developed for recording the total pattern of electrical activity in the human spinal cord. Methodic difficulties, mainly connected with the topographical features of the spinal cord's situation in the vertebral canal, have so far limited recording of spinal cord electrical activity through the bone and muscle teguments in clinical practice.

In our study of the electrographic reactions of the cortex to direct stimulation of the meninges and conductor pathways of the spinal cord [6], we took advantage of a laminectomy operation to derive and record potentials from the exposed human spinal cord.

The Russian literature describes only single experimental investigations of total spinal cord activity in animals, using the puncture method [5] and chronic epidural intraspinal implantation of electrodes [2].

In the picture of total spinal cord electrical activity in dogs and rabbits, these authors were able to distinguish slow waves, 2-6 per sec in frequency and 10-20 μv in amplitude, and faster potentials (15-40 waves per sec) with sharp waves superposed on them.

The first attempt to record the electromyelogram in man was made by Pool [11]. Pool recorded the potentials of the spinal cord without exposing the latter below the level of total traumatic interruption in paraplegic patients.

Here, as in the other two investigations described in the literature, the so-called spontaneous electrical activity of the spinal cord was recorded during spinal puncture [3, 12]. In these investigations, puncture needles (afterwards removed) bearing wire filament electrodes were used to effect subdural contact of the electrodes with segments or roots of the spinal cord. However, since it is impossible to puncture the dura mater at any level of the spinal cord without concomitant clinical indications, this method cannot be used simply to evaluate the functional condition of the spinal cord. Owing to the fact that spinal puncture for diagnostic purposes is usually done at the level of the lumbosacral segments, i.e., at the level of the conus medullaris and the roots of the cauda equina, it is impossible to derive potentials from the higher segments during puncture.

Pool's first work recorded the electrical activity of isolated segments of the human spinal cord; this activity was characterized by the presence of slow waves, a formation which the author ascribed to a summation of after-discharges. He also observed a mass of synchronous discharges – action currents coinciding with the rhythm of muscular twitching (of muscles isolated from the higher levels of the central nervous system).

In an effort to avoid the difficulties involved in the subdural method of recording spinal potentials, M. B. Shtark [8] experimented with multichannel peridural (without puncture of the dura mater) recording of spinal cord activity, using bi- and unipolar leads. According to his data, the electrogram of the spinal cord recorded at levels C_6 and L_3 showed a rhythm of 18 cps with an amplitude of 10-20 μv, peak-like potentials 25 cps in frequency and 100 μv in amplitude and slow waves 4-6 cps in frequency and 50-60 μv in amplitude.

We believed the frequency and amplitude properties of the electromyelogram recorded under clinical conditions by the puncture method should be compared with data obtained by recording potentials from the exposed spinal cord during neurosurgical operations. We therefore recorded the electrical activity of the exposed spinal cord in 10 patients (6 with tumors of the spinal cord and 4 with sequelae of arachnoiditis). In order to compare the electromyelogram in frequency and amplitude with the cortical and cardiac potentials, the electrocardiogram (ECG) and the electrical activity of the cerebral cortex and spinal cord structures were recorded simultaneously.

EXPERIMENTAL METHODS

We used specially prepared electrodes made of supple, easily bent silver wire 500 μ in diameter, 12 and 15 cm long, to lead off the spinal cord potentials. The whole length of each electrode was insulated with plastic. The tips of the electrodes were sterilized. Two pair of these wire electrodes were attached to a special block screwed to an electrode-holder fastened to the edge of the operating table. There was a distance of 10-12 mm between the electrodes. In our investigations, made with the patient lying on his side, the deriving electrodes contacted the dorsal and lateral funiculi of the spinal cord at the thoracic and cervical levels, so that we recorded potentials from the conductor pathways of the spinal cord rather than from the cellular accumulations which make up the grey matter.

EXPERIMENTAL RESULTS

These electromyelograms showed a lower frequency than the cortical potentials recorded simultaneously through the cranium. When the electromyelogram was recorded under conditions of relative rest, i.e., no afferent stimulation, the electrical activity of the spinal cord invariably showed a low frequency rate – 4-8 oscillations per sec (Fig. 1). This rhythm usually appeared on a background of slower waves (1-1.5 cps) which sometimes coincided with the ECG rhythm. The oscillations of the "spontaneous" potentials derived from the conductor pathways of the spinal cord varied between 20 and 70 μv in amplitude.

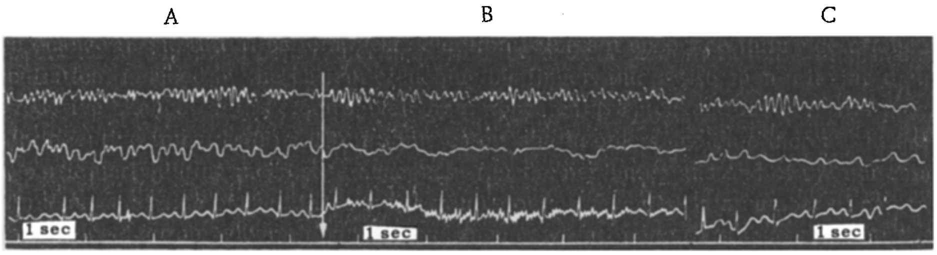

Fig. 1. Simultaneously recorded EEG (through cranium) and electromyelogram from exposed spinal cord (level D_6-D_8) of patient S. with spinal arachnoiditis. A) Before; B) after proprioceptive stimulation electromyelogram shows decrease in amplitude of 6-7 per sec wave rhythm; C) change in electromyelogram in zone of arachnoiditis – wave rhythm of 6-7 per sec absent. Curves (from top to bottom) are: EEG (left occipitoparietal region); electromyelogram; ECG.

Our data show that electromyelograms of patients with organic disease of the spinal cord did not contain fast potentials (over 15 waves per sec) or the axon-like impulses which Pool observed in an ink recording of the electromyelogram from "isolated" segments of the spinal cord. In a region of arachnoidal adhesions and cyst formation, the electromyelogram could appear almost level with the zero line, and a reduced vascular rhythm, coinciding with the heart rate, was apparent on this background (Fig. 1C).

Comparison of electromyelograms recorded at the level of thoracic (see Fig. 1A), cervical (Fig. 2) and supralumbar (Fig. 3) segments showed similar frequency and amplitude characteristics. Slow waves ranging from 4 to 8 per sec with an amplitude of 20-70 μv predominated in all three recordings.

Potentials slowed to 1-2 waves per sec were apparent in the electromyelogram recorded 1-2 cm from the site of an extramedullary tumor (Fig. 3). The pattern of spinal cord electrical activity showed a retarded rhythm in the location zone of the extramedullary tumor in all the patients investigated. The fundamental rhythm of local excitation in the conductor pathways of the spinal cord evidently becomes retarded under the influence of a gradually increasing pathologic focus.

Not wishing to confine ourselves to electrography under conditions of relative rest, we investigated the reactive changes in spinal cord potentials to such afferent stimulation as the conditions of the operation allowed. The data obtained showed change in the initial pattern of the electromyelogram under the influence of one example of proprioceptive impulsation, induced by the patient clenching his fingers into a fist, then relaxing them. Under these conditions, the reactive changes in the electromyelogram appeared as a blockade of the initial potentials under the influence of proprioceptive impulses (Fig. 1B) in some cases, and in others, as some increase in the amplitude of the slow waves, particularly during the first few seconds after the beginning and end of the muscular contraction (Fig. 2). Simultaneous recording of the EEG and electromyelogram revealed in a number of cases coincidence in the times at which the slow electromyelogram potentials changed and fast potentials appeared in the parietal and posteroparietal regions of the cerebral cortex. An example of this is given in Fig. 2, which shows an increase of slow waves in the electromyelogram recorded from the cervical level of the spinal cord and the appearance of fast EEG waves in response to proprioceptive impulsation. Further research in this direction could furnish new data on the different forms of functional association in the human central nervous system.

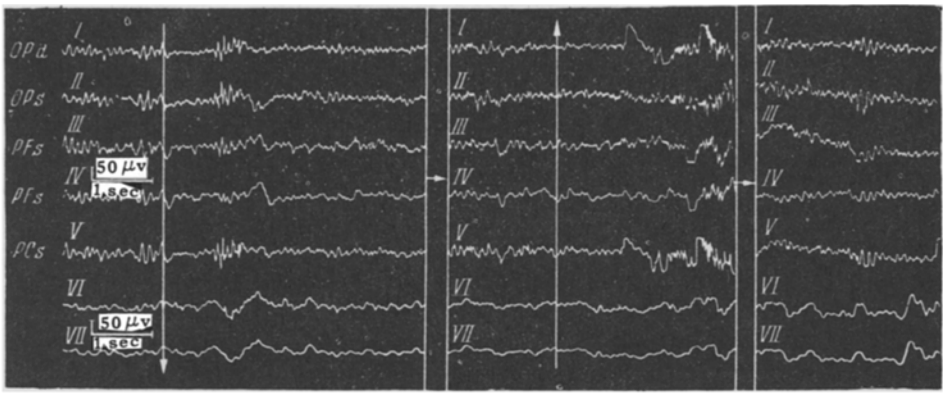

Fig. 2. Simultaneously recorded EEG and electromyelogram (level C_5-C_6) of patient F. with spinal arachnoiditis. Increased amplitude of slow waves in electromyelogram and appearance of fast EEG potentials in response to proprioceptive stimulation: I-V) EEG; VI and VII) same electromyelogram recorded on different filters; OPd and OPs) right and left occipitoparietal regions; PFd and PFs) right and left parietofrontal regions; PCs) left parietocentral region. First arrow shows start of fingers clenching into fist; second shows end of muscular contraction induced by proprioceptive impulsation.

Several hypotheses can be offered as to the nature of the "spontaneous" slow waves recorded from the conductor pathways of the spinal cord.

One possible hypothesis is that the normal level of local excitation in the nerve fibers, which is probably maintained by the after-potentials that attend each afferent impulsation, is typically low in amplitude. Pool's theory that the fundamentally slow activity of the spinal cord is due to a summation of after-discharges is plausible from this point of view.

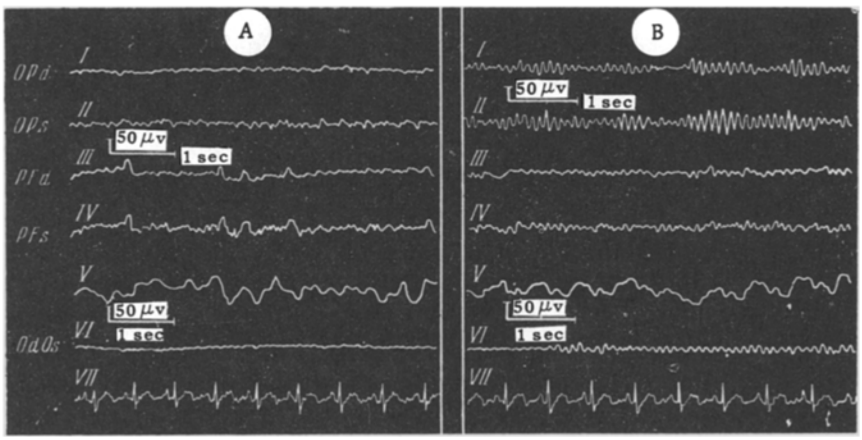

Fig. 3. Simultaneously recorded EEG and electromyelogram (level L_1) of patient S. with a tumor of the spinal cord at the level of the epiconus. A) Electromyelogram recorded at time of cortical rhythm desynchronization; B) same electromyelogram recorded at time of cortical rhythm synchronization. Predominance of slow waves (1-2 per sec) in electromyelogram recorded from tumor location zone (1-2 cm from tumor), I-IV, VI) EEG; V) electromyelogram; VII) ECG. EEG leads the same as in Fig. 2; OdOs) bipolar lead from occipital regions of cerebral cortex.

The second interpretation of the slow waves of the spinal cord potentials is based on the assumption that electrotonic influence from the cellular accumulations of the spinal cord and the bulbar sections of the brain stem provides a constant level of local excitation in the conductor pathways of the spinal cord.

The investigations of Barron and Matthews [9, 10] have offered particularly convincing arguments for the presence of electrotonic phenomena in the region of the spinal cord. After analyzing oscillographic recordings of rhythmic excitation impulses, these authors concluded that each afferent stimulation en route to a motoneuron first exerts a certain electrotonic influence on its synapses and that no rhythmic excitation discharge reaches the motoneuron until it has assumed the specific amplitude of the slow potentials.

N. P. Rezvyakov [7], P. K. Anokhin and V. E. Maiorchik [1] studied perielectrotonic influences during spinal cord activity (first described by N. E. Vvedenskii [4] on a nerve-muscle preparation). These investigations demonstrated related changes in excitability depending on the type of perielectrotonus in the nerve fibers and the functional condition of the spinal centers. Therefore, there is reason to believe that electrotonic and perielectrotonic phenomena may be a significant factor in the over-all electrical activity recorded from the spinal cord as potentials with a consistent rhythm ranging from 4-8 waves per sec in frequency.

Despite the present paucity of relevant data, it is evident that a gradually increasing pathologic focus affecting the conductor pathways of the spinal cord causes the rhythm of fundamental spinal cord electrical activity to slow to 1-2 waves per sec. This may indicate that the electrogram of the spinal cord conductor pathways can reflect changes in their functional condition caused by the action of a local pathologic process.

SUMMARY

Electric activity of the conduction paths of the spinal cord (electromyelogram – at the level of the cervical, thoracic and superior lumbar segments) was recorded during laminectomy in 10 patients with diseases of the spinal cord.

In leading the potentials of the conduction paths (lateral and posterior stems) of exposed spinal cord a constantly observed rhythm of the background electric activity was present at a rate of 4-8 oscillations per sec , and an amplitude of 20-70 microvolt. Reactive changes of the main rhythm of the electromyelogram noted were the most pronounced at the beginning and at the moment of suspension of proprioceptive stimulation. These changes were associated in a number of observations with the appearance of frequent potentials in the EEG of the parietal and posteroparietal cerebral areas. In the zone directly adjacent to the extramedullary tumor was an attenuation of the main electromyelogram rhythm to 1-2 oscillations per sec. The data obtained should be taken into consideration in developing various methods of preoperative electromyelography for objective determination of the level of the spinal cord effection in man.

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