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DETECTION OF CONDUCTION ALONG EFFERENT SPINAL TRACTS BY LOCAL ELECTROMYOGRAPHY AFTER SPINAL CORD INJURIES IN MAN

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Electrical activity of the gastrocnemius and tibialis anterior muscles during an active effort to extend or flex the ankle was investigated in patients with spinal cord injuries. In some such patients action potentials of motor units (MU) were recorded during voluntary efforts to flex and extend the ankle despite the absence of an interference electromyogram (EMG). Voluntary activation of MU led to the conclusion that efferent conduction along spinal tract which is partially preserved after spinal trauma can be detected by local electromyography.

In some patients after spinal cord trauma, despite the anatomical integrity of that structure, voluntary movement of the lower limbs is absent. This does not mean, however, the complete cessation of conduction of excitation along the spinal tract. The difficulty of assessing efferent conduction along spinal tracts during neurological investigation is made greater by the fact that most such patients develop spasticity of the muscles, which marks their reflex reactions. The method of interference electromyography is insufficiently sensitive to detect the electrical activity of individual motor units that still remain functionally connected with the higher levels of the CNS after spinal cord injury. Nowadays, the method of local electromyography [6] is extensively used in clinical practice for the diagnosis of peripheral nerve injuries [1], muscular diseases [2], and circulatory disturbances in the muscles of the lower limbs [4], and for the detection of disturbances of muscular synaptic transmission of excitation [3].

It was accordingly decided to use the method of local electromyography to assess efferent conduction along the corticospinal tract after traumatic injury to the spinal cord.

EXPERIMENTAL METHOD

Concentric needle electrodes (treated with alcohol) and a two-channel Medicor electromyograph were used. The electrodes were inserted into the belly of the muscle to be tested, perpendicularly to the surface. Potentials of motor units (MU) were recorded from the tibialis anterior and gastrocnemius muscles during passive flexion and extension of the ankle and during voluntary efforts to flex or extend the ankle. To detect

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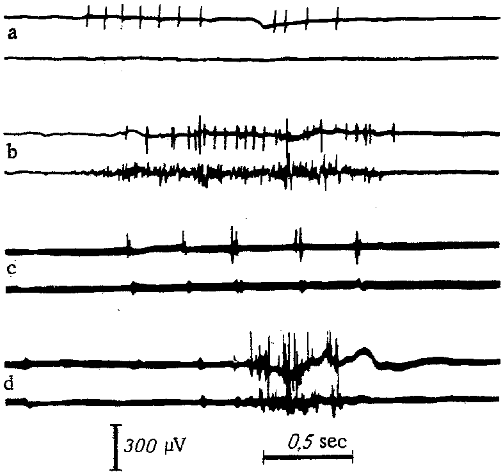

Fig. 1

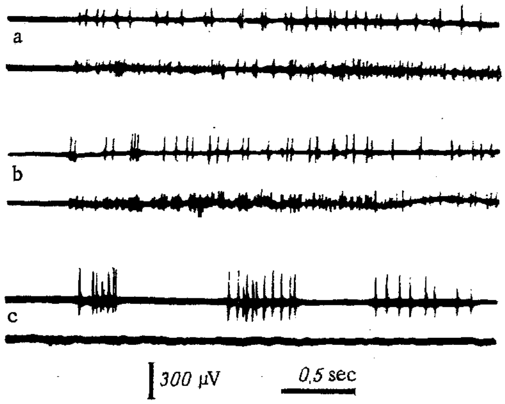

Fig. 2

Fig. 1. Electrical activity of gastrocnemius and tibialis anterior muscles of a patient with spinal cord trauma: a, b) EMG of tibialis anterior muscle, d, e) EMG of gastrocnemius muscle; a, c) EMG during active flexion and extension of ankle, b, d) EMG during passive flexion and extension of ankle. Here and in Figs. 2 and 3, top beam records action potentials of motor unit (MU) derived by concentric needle electrodes; bottom beams record global electrical activity derived by skin electrodes.

Fig. 2. Electrical activity of gastrocnemius muscle before (a, b) and after (c) longitudinal frontal myelotomy of the spinal cord: a, c) EMG during active, b) during passive extension of ankle.

MU activity in response to the instruction to flex or extend the ankle, concentric needle electrodes were inserted twice or three times into the muslce; the electrodes could be placed in two to four positions through a single puncture.

In most investigations the interference electromyogram (EMG) of the same muscles was recorded at the same time. The EMG was derived by skin electrodes with a fixed interelectrode distance of 45 mm between the cup electrodes, 8 mm in diameter. During the investigation the patient was in a screened room lying on his back on a couch. To prevent spastic phenomena from arising during stimulation of the exteroceptors in response to contact between the skin and the couch, Porolon cushions 30-35 cm in diameter were placed beneath the patient's heels. Tests were carried out on 78 patients of both sexes aged from 9 to 60 years between 3 months and 15 years after spinal cord trauma.

EXPERIMENTAL RESULTS AND DISCUSSION

In most patients with traumatic spinal cord injuries and with flaccid and spastic paraplegia, electromyographic investigation revealed no electrical activity in response to the instruction to flex or extend the ankle. Action potentials of MU during voluntary effort to obtain active movement of the ankle were recorded in twelve patients.

Action potentials during voluntary efforts by the patient to flex (Fig. 1a) and extend (Fig. 1c) his ankle can be seen in Fig. 1. Under these circumstances there was no global electrical activity (Fig. 1a, c). The action potentials of MU recorded during voluntary efforts to flex and extend the ankle are evidence of functional connections between the spinal motoneurons and higher levels of the CNS, along efferent pathways still remaining intact after spinal cord injury. During passive flexion and extension of the ankle action potentials of MU were recorded simultaneously with a discharge low-amplitude interference EMG (Fig. 1b, d). Consequently, the absence of an interference EMG during voluntary attempts to flex or extend the ankle was due to the inadequate sensitivity of the method, which cannot reveal activity of single MU which is detectable by local electromyography.

It was much more difficult to detect the presence of a functional connection between cortical motor centers and motoneurons in the anterior horns of the spinal cord in the presence of well marked spasticity. In such patients, the slightest change in the position of the lower limbs or the slightest touch applied to their skin

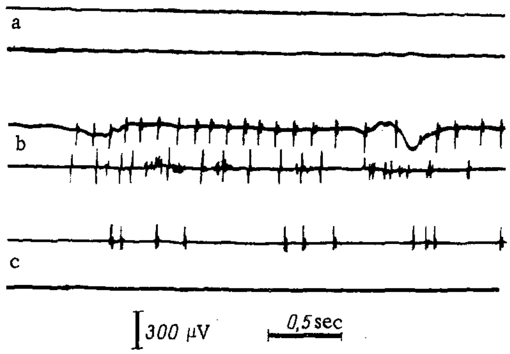

Fig. 3. Electrical activity of gastrocnemius muscle of a patient with spinal cord trauma before (a, b) and after (c) treatment by electrical stimulation: a, c) EMG during active, b) during passive extension of ankle.

surface evoked prolonged and generalized contraction of the muscle, which marked the electrical activity of MU caused by the voluntary effort to make an active movement of the ankle. Accordingly, to detect residual conduction along the efferent tract of these patients, repeated tests were necessary. A record of the electrical activity of the lower limb muscles of such a patient (Fig. 2) shows that during the voluntary effort to extend the ankle action potentials of MU appeared (Fig. 2a). However, their activity was spontaneous in character and it frequently evoked generalized contraction of the muscles, and this also was recorded by the skin electrodes (Fig. 2a). Passive extension of the ankle also evoked spontaneous contraction of the muscles, which was recorded both by concentric and by skin electrodes (Fig. 2b). To abolish the muscular spasm of these patients, myelotomy was performed by Bischof's method [7]. During this operation associative connections at the segmental level were divided in the frontal plane. After the operation the spasticity of the muscle was greatly reduced. The patient's effort to extend the ankle evoked activation of MU which was clearly recorded as volleys of action potentials (Fig. 2c). These observations demonstrate the preservation of conduction along the efferent spinal tracts after such a surgical operation on the spinal cord.

In some patients recovery of functional connections between the cortical motor center of the brain and anterior horn motoneurons of the spinal cord after electrical stimulation treatment was revealed by local electromyography. Before treatment, during an active effort to extend the ankle, electrical activity of MU and global electrical activity of the muscles was absent (Fig. 3a). During passive flexion electrical activity of MU and the interference EMG were recorded (Fig. 3b). After several courses of electrical-stimulation treatment of the spinal cord of this patient action potentials of MU were recorded during voluntary effort to flex the ankle (Fig. 3c). After the instruction to flex the ankle, this patient needed a certain length of time for the proper organization of the movement, as shown by the fact that he found it necessary to concentrate on the motor act.

The method of local electromyography thus enabled efferent conduction along spinal tract to be detected after spinal cord trauma in the event of preservation of a small proportion of functioning axons, not sufficient to give rise to limb movement, but sufficient to activate individual motor units. Resotration of the functional connections between the locomotor centers of the brain and spinal cord in patients with spinal cord trauma after treatment by electrical stimulation is evidence of the resumption of conduction along the residual pathways or of the formation of new axons performing the function of efferent conduction in the region of trauma [5, 8].

By local electromyography it is thus possible to make an objective judgement regarding preservation or restoration of conduction along efferent pathways after traumatic injury to the spinal cord.

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REACTION OF INTRACRANIAL AND EXTRACRANIAL VESSELS TO NORADRENALIN IN EXPERIMENTAL CARDIOGENIC SHOCK

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Weakening of the constrictor response of the intracranial and extracranial vessels to noradrenalin in animals with cardiogenic shock was established by resistography and rheoencephalography in acute experiments on anesthetized cats. Under these conditions elevation of the systemic arterial pressure by noradrenalin leads to passive dilatation of the brain vessels and to an increase in the volume of blood in them.

KEY WORDS: noradrenalin; cerebral circulation; cardiogenic shock.

Pressor substances used in clinical practice to restore the systemic arterial pressure to normal in cardiogenic shock can at the same time potentiate the already well marked constriction of the regional vessels [5, 7, 8]. According to some investigators [3] the response of the cerebral vessels to injection of noradrenalin (NA) in these patients depends on the severity of the cardiogenic shock. It was shown previously [1, 4, 6] that NA in intact animals as a rule evokes a constrictor response of both intracranial and extracranial vessels.

It was appropriate to study the response of the cranial vessels to noradrenalin in experimental cardiogenic shock.

EXPERIMENTAL METHOD

Acute experiments were carried out on 47 cats weighing 2.5-3.5 kg under urethane anesthesia (1 g/kg). A two-channel resistograph was connected to the common carotid arteries for parallel recording of the tone of the intracranial and extracranial vessels. To disconnect the intracranial circulation from the extracranial, the corresponding vessels were ligated [1]. After the resistograph had been connected the vertebral arteries were tied, so that the effect of the systemic arterial pressure on cerebral vascular tone could be excluded. The arterial pressure was recorded by a mercury manometer in the central end of the carotid artery. To prevent the blood from clotting heparin was given. In some experiments the method of rheoencephalography was used. The 4RG-1A attachment was connected to an Élkar four-channel electrocardiograph. The electrodes were arranged for orbital-occipital and orbital-lingual derivations, to characterize the tone and the blood volume of the intracranial and extracranial vessels [2]. Parallel with the rheoencephalogram (REG), the ECG was recorded in standard lead I. The experiments were carried out under controlled respiration. Cardiogenic shock was induced by chemical necrosis of the myocardium, by injecting 0.25 ml of a 25% solution of sulfuric acid into the wall of the left ventricle (under ECG control without thoracotomy). NA was injected intravenously in doses of 5 and 10 μg/kg and into the carotid artery in a dose of 0.5-1 μg/kg 30-45 min after the beginning of myocardial necrosis. In the course of this time interval the systemic arterial pressure in most cases fell by more than 30%.

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