ELECTROMYOGRAPHIC INVESTIGATION OF ORDER OF PARTICIPATION OF TRUNK AND LOWER LIMB MUSCLES OF PATIENTS WITH TOTAL AND PARTIAL TRANSECTION OF THE SPINAL CORD

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Participation of the limb muscles in voluntary activity is shown to be possible in patients with total and partial transection of the spinal cord. The patients are treated by remedial exercises and administration of pyrogenal. In the course of treatment they learn to walk, to go up and down stairs, and to perform other movements. The writers consider that participation of muscles innervated by the distal portion of the spinal cord in activity becomes possible because of the plastic properties acquired by the spinal cord when its connections with the higher levels of the central nervous system are severed, and also because of the increased work done by the muscles.

One of the authors (A.N.T.) has developed a method of restorative treatment of patients with complete or partial transection of the spinal cord [4]. This method is based on the use of intensive and purposive training leading to the formation of new motor reflexes [1] which are necessary for walking, and teaching the patient to reproduce these movements himself.

If pyrogenal (from the N. F. Gamaleya Institute of Epidemiology and Microbiology) is used, the duration of treatment is shortened and its results are improved. This may be due to the fact that pyrogenal activates the pituitary—adrenal system [2], the functions of which are depressed in patients with transection of the spinal cord [5].

Another aspect of the action of pyrogenal may be delay in the formation of a dense scar in the spinal cord at the site of trauma, thus facilitating the passage of nerve fibers through it [3].

The object of the present investigation was to study the order of participation of muscles of the lower limbs in motor activity in patients with complete or partial transection of the spinal cord in the course of their treatment.

EXPERIMENTAL

In 4 (group 1) of the 10 patients investigated, division of the spinal cord at the level of the middle and lower thoracic segments was diagnosed at laminectomy. They had no conduction along their spinal cord. Treatment of these patients by the method described above was commenced at a time when they were seriously ill and bedridden patients.

Group 2 included 6 patients with incomplete transection of the spinal cord at various levels. Treatment of one patient began within a few days of injury, and of the remaining 5 a few months or even years after injury, during which period the patients were confined to bed or able to stand but unable to walk.

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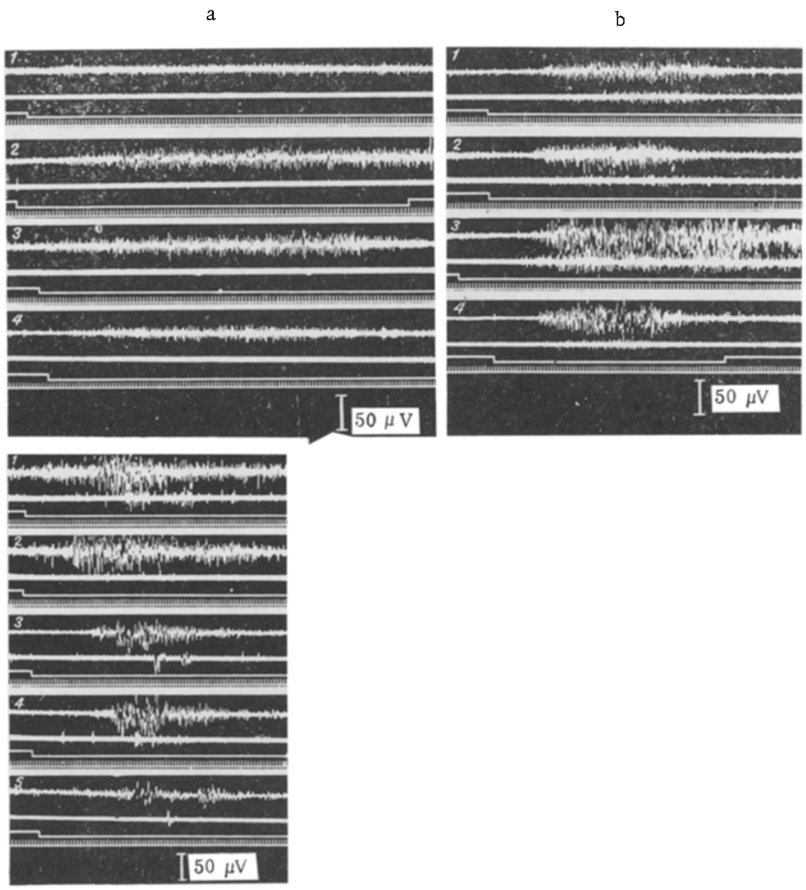

Fig. 1. Electrical activity in trunk muscles during raising of the straight lower limb at the beginning (a), and 2 months (b) and 7 months (c) after the beginning of treatment. From top to bottom: in a, b: 1) m. lat. dorsi, upper part; m. lat. dorsi, lower part; 2) m. long. dorsi, upper part; m. long. dorsi, lower part; 3) m. obl. abd. ext., upper part; m. obl. abd. ext., lower part; 4) m. rect. abd., upper part; m. rect. abd., lower part; for c: 1) m. long. dorsi, upper part; m. rect. femoris; 2) m. long. dorsi, upper part; m. gastrocnemius; 3) m. obl. abd. ext., upper part, m. glut. med.; 4) m. obl. abd. ext., upper part; m. sartorius; 5) m. rect. abd., upper part; m. biceps femoris. Third line is marker of signal to begin movement; fourth line is time marker (20 msec).

The technique of the remedial exercises consisted of the repeated application of passive movements of the lower limbs and massage, together with repetition of movements of the upper part of the trunk and attempts to involve in these movements muscles innervated by the distal portion of the spinal cord. Treatment was divided into two stages: in the first stage (4-6 months), exercises were given with the patient in the horizontal position, and in the second stage (6-12 months), with the patient in the vertical position.

Muscular activity was studied while lifting the straight lower limb by displacing the pelvis, i.e., during a movement which is the basic element of stepping forward during teaching to walk, during attempts to flex and extend the lower limb at the knee, and also during walking.

The electromyogram was recorded in the upper and lower segments of the long muscles of the trunk, and in the muscles of the buttocks, thigh, and leg. The muscle potentials were recorded by means of bipolar electrodes, 8 mm in diameter, which were fixed to the skin with adhesive plaster. The muscle potentials were fed into a type UBP-1-01 amplifier and recorded on a type N-102 loop oscillograph.

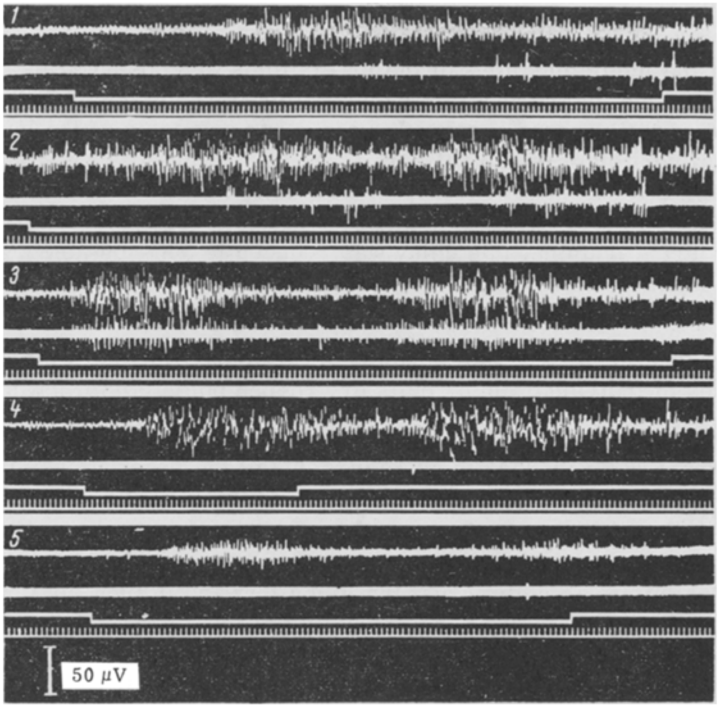

Fig. 2. Electrical activity in muscles of the trunk and lower limb of a patient of group 1 during walking. From top to bottom: 1) m. lat. dorsi, upper part; m. rect. femoris; 2) m. long. dorsi, upper part; m. vast. lat.; 3) m. obl. abd. ext. upper part; m. glut. med.; 4) m. obl. abd. ext., upper part; m. sartorius; 5) m. rect. abd., upper part; m. biceps femoris. Remainder of legend as in Fig. 1.

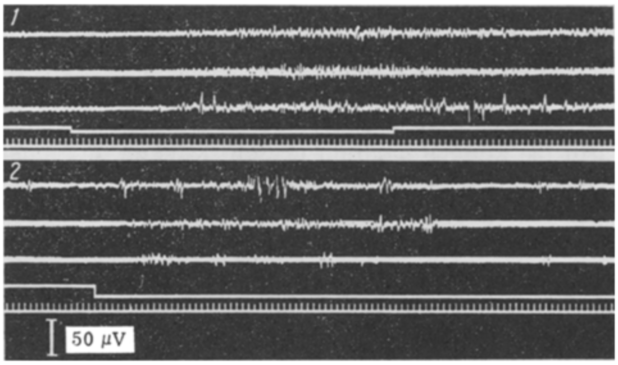

Fig. 3. Electrical activity in muscles of trunk and lower limb during flexion of limb at the knee in a patient of group 1. From top to bottom: 1) m. obl. abd. ext., upper part; m. obl. abd. ext., lower part, m. glut. med.; 2) m. glut. med., m. rect. femoris, m. gastrocnemius.

Pyrogenal was injected in increasing doses, starting from 50 m.p.d. and increasing to 250-500 m.p.d.; as a rule it was given on alternate days, but in some cases daily. The course of treatment lasted 1-2 months and it was repeated after an interval of 1 month.

EXPERIMENTAL RESULTS

Partial recovery of the motor functions of the lower limbs was observed in all patients. In the first stage of treatment of the patients in group 1, 1-2 months after it began, during attempts to raise the extended lower limb, a high degree of activity was observed in the upper segments of the long muscles of the trunk, innervated by the proximal portion of the spinal cord (Fig. 1a). In the lower segments of these muscles, activity appeared only after 2-3 months of exercises (Fig. 1b). The amplitude of the potentials in these muscles was smaller, and the potentials appeared after a delay of 1-1.2 sec compared with potentials in the upper parts. Gradually, during training, this delay was reduced to 300-400 msec, and in the second stage of treatment to 30-70 msec, in some cases actually falling below 20 msec. Under these circumstances the amplitude of the potentials was increased.

After 6-8 months of treatment, the limb muscles began to participate in motor activity. At first this activity consisted of spikes of individual motor units or grouped potentials of low amplitude (Fig. 1c).

During training the character of the activity changed. For instance, during walking by the patient, an interference electromyogram was recorded in some muscles of the lower limbs, and grouped potentials in other muscles (Fig. 2). In the course of treatment the patient's method of walking improved. At the beginning, when the patient was placed in the vertical position, forward movement was achieved by raising the lower limb upward by means of the trunk muscles and by displacing the limbs passively. At the end of the 2nd stage of treatment, the patient actively thrust the limbs forward in turn, by flexing them at the hips. The degree of recovery of motor functions in the patients of group 1 depended on the level of injury, the character of the trauma, and the patient's state of health. In patients of group 2, the time required for restorative treatment, and the order of participation of muscles controlling individual joints in the activity varied from one to another depending on the level and degree of the lesion.

The electromyographic investigation showed that in most cases activity appeared comparatively rapidly (within 1-3 months) in the muscles of the thigh, and then of the leg, or in the case of a lesion at the level of the cervical segments, in the muscles of the upper limbs. Later, during treatment, characteristic features of the patients of the particular groups appeared: firm weight bearing on the lower limbs was recovered because of the development of tone of the antigravity muscles, and voluntary movements of the ankle joints also appeared. In most cases, in patients with partial transection of the spinal cord, even in the cervical division, motor activity was restored comparatively completely.

A surprising feature during treatment was the possibility of participation of muscles innervated by the distal portion of the spinal cord in voluntary motor activity even after complete disturbance of conduction. Under these circumstances the muscle and skin receptors evidently play the principal role, impulses from them acting as the triggers for muscular contraction. For instance, repeated passive flexion of the lower limb at the knee, or extension of the limb caused activation of the receptors of the quadriceps muscle, or in the second case, of the gluteus medium muscle, causing the muscle to contract. These responses, produced in this way, appeared even during slight stretching of the muscle (case 1) or displacement of the skin over it (case 2). This last effect could be produced by a particular movement of the trunk. Successive activation of muscles in individual parts of the body and controlling joints of the limb took place, starting with the proximal muscles.

The electromyogram of different muscles during flexion of the lower limb at the knee in a patient in a late stage of treatment, when this movement was clearly defined, is shown in Fig. 3. It is clear that the external oblique muscle responded the first, initially in its upper part and later, after a short delay, in its lower part. The gluteus medius muscle reacted slightly later, followed by the quadriceps. The gastrocnemius muscle reacted the last.

Hence, despite the absence of conduction of excitation along the spinal cord, partial recovery of motor functions can take place even after its complete transection.

A leading role in the development of compensatory reactions is played by the ability to modify functions, based principally on the possibility of involving new neuronal elements in motor reflexes, and on the prolonged preservation of excitation, and also by the maintenance of the neuronal apparatus of the spinal cord in a normal condition by means of training.

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