INFLUENCE OF POLARIZATION OF THE SPINAL CORD ON VISCERO MOTOR REFLEXES

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Many authors have pointed out [2, 3, 6, 7, 11] that stimulation of the chemo- and mechanoceptors of the digestive tract, or stimulation of the afferent visceral nerves may exert either a stimulating or a depressive influence on the skeletal musculature. Many investigators [6, 11-13] divide the interoceptive influence on a skeletal muscle into release and correcting mechanisms, although they do not consider them to be fundamentally different [11].

Taking as our starting point the existing views on the role of electrotonic phenomena in the mechanism of nervous activity [4, 8, 14, 15] we have undertaken a study with a view to determining the significance of electrotonic changes in various structures of the spinal cord during the development of release and of corrective interoceptor influences on skeletal muscle.

EXPERIMENTAL METHODS

The work was carried out in a series of acute experiments on 18 cats. Under urethane anaesthesia (1 g/kg) the spinal cord was exposed in the region of the lumbosacral enlargement. Electrical potentials were picked up by means of needle platinum or tantalum electrodes and were displayed on a cathode ray tube after amplification by an amplifier having a symmetrical input. The reflex responses of the tibialis muscle were evoked by stimulation of the central end of the peroneal nerve with single shocks from an induction coil.

The electrotonic changes developed in various parts of the spinal center of the peroneal muscle (segments L_5-L_6) by cathodic or anodic polarization. The polarization was produced by means of a unipolar micro-electrode insulated by glass, and having a diameter at the tip of 30 μ. Surface polarization of the cord was produced by a nonpolarizing Ag−AgCl electrode having a thread in Ringer-Locke solution. In all experiments the indifferent electrode (silver plate measuring 4 × 4 cm) was placed on the muscles of the back rostral to the active electrode.

After exposure of the dura mater we made a small incision in the arachnoid mater, by means of a stereotaxic instrument we implanted the micro-electrode at different depths in the grey matter of the spinal cord, including the motor nucleus of the tibialis muscle. The position of the tip of the micro-electrode was determined from histological sections of the cord 10-20 μ thick, which were stained in hematoxylin-eosin. To reduce the superficial branching of the current, and to protect the spinal cord from drying up, the surface was covered with paraffin oil at a temperature of 38°. The interoceptors were stimulated by dilatation of a rubber balloon placed in the ampulla of the rectum, and inflated to a pressure of 40-120 mm Hg, the pressure being indicated on a manometer. The body temperature was maintained constant at around 38° by means of an ultra thermostat.

EXPERIMENTAL RESULTS

The background electrical activity of the tibialis muscle shows peak potentials of amplitude 2050 μV, rising up to 1 mV and having frequencies of 3-5 per second; sometimes frequencies up to 60 per second were observed. As the anaesthesia deepened the electrical activity of the muscles was depressed, and when the anaesthesia was deeper still it was completely suppressed, indicating a central influence.

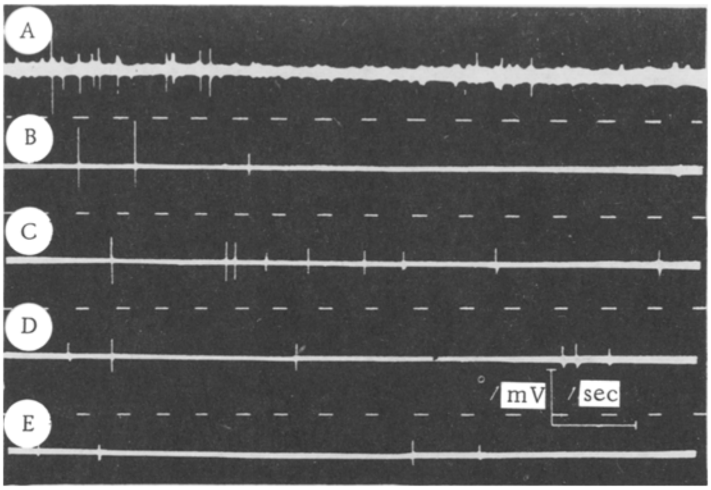

Fig. 1. Change in the background of electrical activity of the tibialis muscle during interoceptor stimulation and polarization of the dorsal surface of the spinal cord. A) Background activity of the tibialis muscle; B) during stimulation of rectal mechanoceptors (pressure 80 mm Hg); C) as in B, during polarization of the spinal cord by a descending direct current; D) as in B, 1 min after switching on the current; E) as in B, during polarization of the spinal cord by an ascending direct current. The dotted lines indicate interoceptor stimulation.

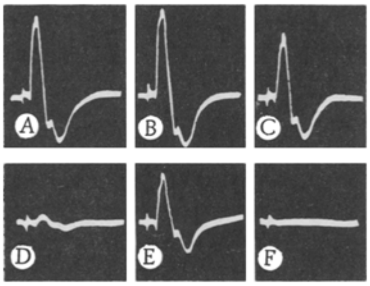

Fig. 2. Potentials from the tibialis muscle in response to stimulation of the ipsilateral popliteal nerve during polarization of the spinal cord; micro-electrode implanted to a depth of 0.1 mm from the dorsal surface of the spinal cord; stimulation of rectal mechanoceptors. A) Muscle potentials in response to stimulation of the popliteal nerve; B) muscle potentials superimposed on background of the polarization of the spinal cord by a direct current produced 15 sec previously (micro-electrode inserted to a depth of 0.1 mm); C) during polarization of the spinal cord by an ascending current; D) as in A, combined with effects of stimulation of the rectal mechanoceptors for 30 sec previously (pressure 80 mm Hg); E and F) as in D, during polarization of the spinal cord by a descending (E) and an ascending (F) direct current.

On stimulation of the interoceptors of the rectum (at pressure of 80-120 mm Hg) a marked suppression of the background activity of the tibialis muscle was observed, and it usually occurred immediately after the interoceptor action. Inhibition became more marked as time passed, and was maintained for 10-20 min (according to the duration of the interoceptor stimulation).

During the suppression of electrical activity of the tibialis muscle, which occurred during stimulation of the rectal mechanoceptors we started an ascending and a descending direct current of subthreshold strength. Polarization of the dorsal surface of the spinal cord by descending direct current led to some reduction in the suppression of electrical activity of a muscle induced by interoceptor stimulation. This result can be seen in the oscillograms of the experiment shown in Fig. 1.

Polarization exerts a different influence when the electrode is placed in the motor nucleus of the tibialis muscle (2-25 mm below the dorsal surface of the spinal cord). Here the suppression of electrical activity in the tibialis muscle caused by interoceptor stimulation is enhanced by a descending direct current and somewhat reduced by an ascending current.

In the next set of experiments we studied the influence of interoceptor stimulation on the reflex responses of the tibialis muscle evoked by stimulation of the ipsilateral popliteal nerve. Also we studied the influence of local reflex response, and also on a reflex response modified by preceding interoceptor stimulation.

The results showed that when the electrode was implanted in the spinal cord to a depth of 0.1-0.3 mm from the dorsal surface, at the region where the dorsal roots entered (1 mm lateral to the midline), polarization by a subthreshold descending direct current usually increased (Fig. 2, B) or (less frequently) had no effect on the reflex response of the tibialis muscle, whereas polarization with an ascending current depressed it to some extent (Fig. 2, C).

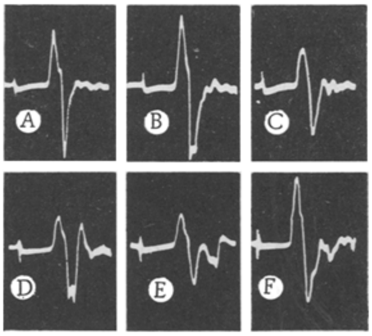

Fig. 3. Potentials from the tibialis muscle in response to stimulation of the popliteal nerve (micro-electrodes at a depth of 2 mm from the dorsal surface of the spinal cord). Indications as in Fig. 2.

Stimulation of mechanoceptors of the rectum led in most cases to a considerable suppression of the reflex response of the muscle (Fig. 2, D); the suppression began 3-5 sec after the onset of interoceptor stimulation, and then became deeper, reaching a maximum intensity after 30-50 sec.

Cathodic polarization (by introduction of the micro-electrode to a depth of 0.1-0.3 mm) reduced the depression of the reflex response evoked by interoceptor stimulation (Fig. 2, E), while anodic polarization produced the reverse effect, and enhanced the reflex (Fig. 2, F).

We must note that reduction of interoceptor inhibition during polarization of the spinal cord by descending direct current was observed even in cases when polarization itself (without interoceptor stimulation) was without influence on the extent of the reflex action potential of the muscle.

Different results were obtained when the polarizing micro-electrode was pushed deeper into the grey matter of the spinal cord. Where it reached a depth of 1.8-2.5 mm from the dorsal surface, then just as in the case when it lay on the surface,the reflex response of the tibialis muscle was enhanced (Fig. 3, B), whereas anodic polarization caused a depression (Fig. 3, C).

Interoceptor stimulation by itself at a pressure of 60-120 mm Hg in most cases caused negligible depression of the reflex action potential of the muscle (Fig. 3, D). Polarization by descending direct current enhanced the reflex response of the tibialis muscle evoked by stimulation of rectal mechanoceptors (Fig. 3, E), while on the other hand polarization with an ascending current had the reverse effect (Fig. 3, F).

Sometimes interoceptor stimulation somewhat enhanced the reflex response of the muscle, but under these circumstances polarization of the spinal cord by descending current (when the micro-electrode was submerged to a depth of 2-2.5 mm) led to an interoceptor inhibition, although the reflex response itself (without interoceptor action) was enhanced.

The results of the experiments show that cathodic depolarization of afferent structures in the spinal cord reduces or eliminates suppression of "spontaneous" or reflex electrical activity of the tibialis muscle resulting from interoceptor stimulation. Hyperpolarization by an anode causes the reverse influence, and increases interoceptor inhibition.

Also polarization of the region of the motor nucleus of the tibialis muscle produced opposite changes in interoceptor inhibition; depolarization by a cathode enhanced interoceptor inhibition, whereas hyperpolarization by an anode somewhat reduced it. This result indicates that an increase in the influx of afferent impluses from the interoceptors appears to evoke in the afferent structures of the spinal cord changes characteristic of anelectrotonus, because the cathode reduces and the anode enhances interoceptor inhibition. However in the region of the internuncial and motor neurones of the spinal cord interoceptor stimulation causes changes of a catelectronic type, because polarization by the cathode enhances inhibition, whereas polarization by an anode reduces it.

These results are in agreement of those found by E. F. Bogovarova [1], who observed an increase of excitability and a reduction of lability in the motor nucleus of the tibialis muscle, while on the other hand in the premotor zone of the spinal cord she found a reduction of excitability and an enhanced lability during stimulation of rectal mechanoceptors.

The following fact is evidence that the interoceptive stimulae produced changes characteristic of catelectrotonus in the region of the internuncial and motor neurones. When the background potentials were lead off from neurones of the spinal cord by means of a focal micro-electrode (when it was immersed to a depth of 2.5-3 mm), as the interoceptor stimulation increased,at first an enhancement of rhythmic activity of the neurones was observed, and not until the 5-10th second did it start to change to an increasingly profound suppression of this activity. This result indicates that interoceptor inhibition of activity of the internuncial and motor neurones of the spinal cord is a secondary effect.

It is known [4, 8, 10] that the cathode of a direct current supply of small strength and short duration causes an enhanced excitability of a peripheral nerve and of the spinal cord centers. However, if the strength and duration of the cathodic action are sufficient the initial increase of excitability is replaced by a depression (cathodic depression). The increase which we observed in the interoceptor inhibition of the reflex response of the tibialis muscle by a cathodic current introduced in the region of the motor nucleus, may here be explained on the basis of functional changes which develop during cathodic action on excitable tissues.

Apparently interoceptor stimulation creates a catelectrotonic condition among the internuncial and motor neurones which then changes over into a cathodic depression under the influences arriving as a result of somatic afferent nerve stimulation; alternatively (during release influences) this condition may arise as a result of summation of interoceptor impulses with local excitation of central neurones, a result which leads to the development of interoceptor inhibition. According to the degree of these functional changes in the central regions of a reflex arc either an enhancement or inhibition of spinal reflexes may be observed, as has been found also by many authors.

Nevertheless, as judged by electrophysiological indications, release influences from interoceptors directed towards skeletal muscles usually develop among a background of already existing potentials in the neurones of the spinal cord and in skeletal muscle, i. e., they are essentially corrective in nature. In this connection the differences between release and corrective influences originating in interoceptors and influencing skeletal muscle must be considered as entirely relative.

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