THE RESTING POTENTIAL AND THE SORPTIVE PROPERTIES OF MUSCLE DURING THE MYOTATIC REFLEX, AND AFTER DENERVATION

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Denervation of a muscle by transection of the nerve, by application of cold, or by novocaine block of the nerve leads to a condition of hyperpolarization [3, 7]. The hyperpolarization develops passively as a result of the rapid elimination of the flow of efferent impulses to it. It has been shown [2] that after denervation of a muscle its sorptive power changes during the first few hours.

A study of the polarization potential of the cerebral cortex in mice during anaesthesia has shown [5] that evipan (hexanal) anaesthesia produces hyperpolarization, whereas ether and urethane cause the opposite change—towards depolarization. In this connection it has been found [1] that hyperpolarization of the mouse cerebral cortex produced by evipan anaesthesia is associated with a reduced sorption of dye, whereas ether and urethane anaesthesia which cause depolarization of the cortex enhance sorption. These results of dye sorption in relation to ether and urethane anaesthesia agree completely with previous investigations [4].

We have studied changes in the direct polarization potential (DPP) and of sorption of dye by the gastrocnemius muscle in an intact frog during direct tetanization of the muscle and after it had been denervated. We have also studied the DPP and sorptive properties of a pair of muscle antagonists during the myotatic reflex.

EXPERIMENTAL METHOD

The experiments were carried out on frogs in their first autumn or winter, at a temperature of 18-20°. The DPP of skeletal muscle was studied by the method of Sorokhtin [7], and changes in the sorptive properties were investigated by vital staining [6]. Before the experiment the gastrocnemius muscle to be investigated was separated from the other muscles without loss of blood by means of blunt dissection; the nerves and blood vessels supplying the muscle were not damaged; the muscle was stained for 30 min by immersion in a special tube filled with 3 ml of a 0.05% solution of Neutral Red diluted in sodium-free Ringer. After it had been stained, when the experiment was finished, the muscle was extirpated, washed in distilled water, and placed in a tube containing an accurately measured amount of ethyl alcohol acidified with 2% sulfuric acid to extract the dye. After 24 h the extract was measured in a photo-electric colorimeter model FÉK-M. The figures denoting the amount of dye in the extract E were multiplied by 100, and referred to a thickness of 1 cm. The myotatic reflex was evoked by stretching the divided Achilles tendon of the gastrocnemius muscle (separated from the other muscles) by a load of 35-50 g. Each series of observations was accompanied by control experiments.

EXPERIMENTAL RESULTS

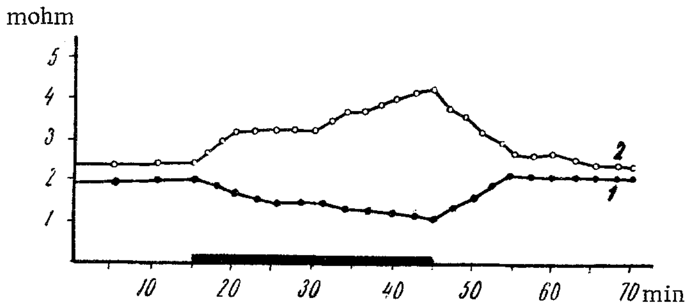
In a series of experiments we studied changes in the sorptive properties of the gastrocnemius muscle immediately after division of the sciatic nerve in the thigh. As can be seen from Table 1 the extent to which the dye was taken up by the muscles was reduced on average by 25% after denervation. This reduction of sorptive activity of the muscle develops during the period of its passive hyperpolarization which occurs after denervation of the muscle.

TABLE 1. Effect of Denervation and Indirect Tetanic Stimulation on the Uptake of Dye by the Gastrocnemius Muscle

I series of expts.		II series of expts.	
Control	After denervation	Control	During stimulation
E×1000			
1 200	760	660	930
760	730	730	1 030
730	400	660	1 100
660	500	600	860
730	600	660	830
830	600	1 200	1 300
630	530	730	900
600	460	760	930
500	430	730	930
600	400	1 200	1 230
760	460	630	830
560	530	800	1 200
560	600	1 000	1 300
600	430	630	930
430	400	830	1 200
430	600	600	1 100
900	400	660	900
1 100	730	800	1 300
1 200	700	630	830
1 200	1 030	600	790
1 230	760		
960	930		
$M \pm m$			
780±55,7	592±37,8	755,5±41	1 020±20,5

TABLE 2. Sorption of the Dye During the Myotatic Reflex (Extension of the Left Gastrocnemius; Antagonist—Left Tibialis Anticus Longus)

Gastrocnemius		Tibialis anticus longus	
Control expts.	Expts. with stretching	Control	Time of stretching gastrocnemius
E×1000			
800	930	1 030	930
670	900	730	700
700	1 130	1 030	700
670	930	770	600
570	730	660	560
630	970	760	700
610	800	730	660
630	900	760	660
600	730	700	600
570	800	700	660
630	700	630	600
560	660	630	560
560	630	630	560
500	630	630	560
530	630	760	600
500	830	660	560
600	860	800	660
600	700	860	560
600	800	660	600
530	600	660	500
$M \pm m$			
603±16,6	793±32,4	738±27,7	625±21,1



Reciprocal relationship in the DPP in muscles during the myotatic reflex. 1) DPP of the stretched left gastrocnemius; 2) DPP of its antagonist, tibialis anticus longus of the same side. The thick black line indicates the time for which the muscle was stretched with a load of 35 g.

In the II set of experiments the muscle was stained during a 30 min period of optimal indirect stimulation on the gastrocnemius muscle by a tetanizing current. In order to eliminate the development of the pessimum of the myoneural junction, the tetanization was carried out periodically, 1 min rest being given at the end of the 30 sec period of stimulation. It can be seen from the results in Table 1 that the sorptive properties of the muscle were increased by 35.2% after optimal tetanization of the nerve.

In the III series of experiments we studied changes in the DPP and in the sorptive properties of the left gastrocnemius muscle during the myotatic reflex; the mucle was stretched by a load, and the antagonist was the left tibialis anticus longus. It was found that in the extended gastrocnemius muscle a condition of depolarization developed which changed over to repolarization after the stretching load was removed. At this time the antagonist muscle reacted by an increased positive polarization, and not until the load had been removed from the gastrocnemius muscle did its DPP return to the original value (see figure).

In the muscle antagonist which was protected by reciprocal inhibition emanating from the spinal centers and reaching the muscle by impulses passing along the efferent pathways, during the myotatic reflex a passive hyperpolarization developed resembling the hyperpolarization developing in a denervated muscle [7].

It was found to be statistically significant (Table 2) that the uptake of dye by the extended left gastrocnemius muscle during the myotatic reflex increased by 62% over the amount of dye taken up by a control muscle of the same side. At the same time in the antagonist muscle the sorptive power was reduced by 25% compared with the sorptive power of the control muscle of the same side (tibialis anticus longus).

Thus studies of the myotatic reflex in frogs has established reverse relationships of the DPP, and corresponding changes in the sorptive properties of the muscles. The stretched muscle which responds reflexly to the extension is depolarized, and its uptake of the dye is increased. At the same time the antagonist which is protected from central inhibitory impulses is hyperpolarized, and the uptake of dye is reduced.

To generalize from these results we may conclude that there is a definite relationship between the level of the DPP and the sorptive properties of muscle. Denervation of skeletal muscle leads to the development of hyperpolarization and to a reduction in its sorptive properties, whereas the active condition of the muscle existing during excitation is associated with depolarization and leads to an enhanced uptake of the dye. Like denervation, central inhibition leads to a deficit of excitation, and elicits a passive hyperpolarization with reduction of sorptive properties.

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