CHANGES IN ELECTROMYOGRAM OF SKELETAL MUSCLES OF SENSITIZED ANIMALS UNDER THE INFLUENCE OF ANTIGEN TO MUSCLE AND SPINAL CORD

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The reacting injection of an antigen or its local application to smooth muscle is accompanied by prolonged contraction of the smooth muscle—anaphylactic contracture (the Schultz—Dale phenomenon) [13,14]. Many investigations have been made of allergic reactions of smooth-muscle structures, and some aspects of the mechanism of development of anaphylactic contracture of smooth muscles are now understood.

Only isolated accounts have been given of allergic reactions of skeletal muscles [1, 3, 8, 9, 11]. In sensitized animals these workers did not observe a contractile reaction of skeletal muscle after contact with specific antigen. A reaction of anaphylactic contracture type developed only after preliminary denervation of the muscle, which in these conditions reverted,as it were,to a lower level of evolutionary development and acquired tonic properties similar to those of smooth muscle [1, 9, 11].

According to the authors' observations [5], intramuscular injection of serum protein into a sensitized animal in several experiments facilitated the development of fibrillary contractions of skeletal muscle, which had the character neither of contracture nor of tetany.

Because of these results it was decided to make a special investigation to determine the cause of appearance of spontaneous contractions in skeletal muscles in response to a reacting injection of antigen. To detect finer deviations of the functional state of a muscle, electrophysiological recording of the muscle contraction was used*.

EXPERIMENTAL METHOD

Experiments were carried out on control and sensitized guinea pigs. Sensitization was carried out by subcutaneous injection of normal horse serum in two doses, each of 0.5 ml, at an interval of 48 h. The animals were used in the experiment on the 15th-20th day after the final injection of serum. Under urethane anesthesia (100 mg/100 g body weight, intraperitoneally) the sciatic nerves were dissected, after which the guinea pig was fixed to a special frame by the knee and ankle joints and by the sacral vertebrae. Needle electrodes, 8 mm apart, were inserted into the belly of the gastrocnemius muscle. For visual observation and recording of the summated muscle potentials,a type EMG-4-01 electromyograph with a transmission band of 10-3000 cps was used. The electromyograms (EMG) were recorded on photographic paper moving at a speed of 100 mm/sec.

EXPERIMENTAL RESULTS

The experiments of series I were carried out on 8 sensitized and 4 control guinea pigs. At the beginning of each experiment the initial EMG of both gastrocnemius muscles was recorded. In most experiments spontaneous electrical activity of the resting muscles was absent. In 5 cases action potentials with a frequency of 1-3 impulses/sec were recorded. Injection of 0.4 ml physiological saline into the muscle did not change the functional state of the gastrocnemius muscles. Sometimes a brief flow of impulses could be seen at the moment of insertion of the injection needle into the muscle.

After the control injection of physiological saline into the opposite gastrocnemius muscle, 0.4 ml horse serum was injected. This manipulation was accompanied by no visible changes in electrical activity of the muscles of the unsensitized animals.

*The student G. V. Poryadin assisted with this work.

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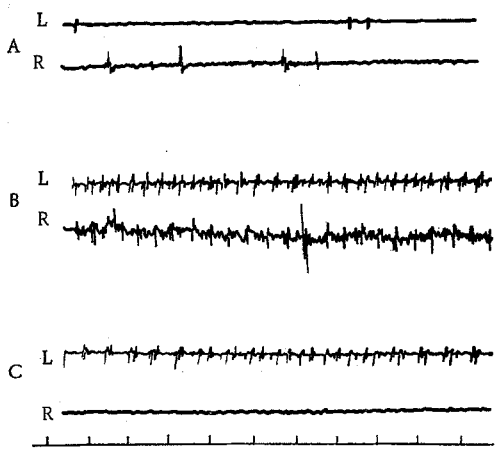

Fig. 1. Electromyograms of gastrocnemius muscles of a sensitized guinea pig after intramuscular injection of antigen. A—original EMG; B—EMG 3 min after injection of 0.4 ml horse serum into the right muscle; C—EMG after division of right sciatic nerve. Time marker 0.1 sec.

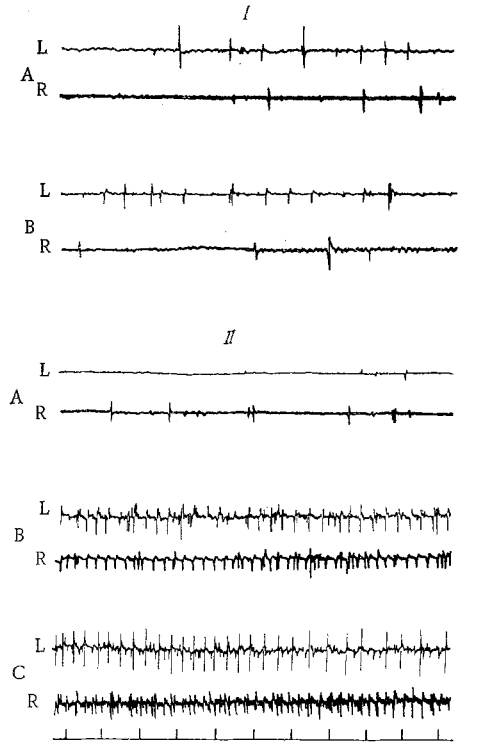

Fig. 2. Electromyograms of gastrocnemius muscles of control (I) and sensitized (II) guinea pigs 24 h after division of spinal cord. A—Original EMG; B—EMG 3 min after application of horse serum in a dilution of 1:30 to spinal cord; C—the same 15 min after application. Time marker 0.1 sec.

Different results were obtained in experiments with sensitized animals. A burst of impulses was recorded 3-5 min after injection of serum into the gastrocnemius muscle both on the same and on the opposite sides (Fig. 1). In 4 experiments the impulses appeared sooner in the muscle on the opposite side and later in the muscle into which the antigen was injected. Impulses persisted in the muscles for 2-3 sec and reappeared after 2.5-3 min. Spontaneous discharges of impulses could be seen for 15-25 min after injection of serum. The amplitude and frequency of the action potentials varied in different experiments.

Because of these results it had to be determined whether the spontaneous impulses in the resting muscle were the result of an allergic reaction evoked by the action of the antigen on muscle tissue. The appearance of impulses in the muscle on the opposite side could be explained by assuming that antigen entering the general blood stream reached the opposite muscle where an allergic reaction also took place.

At the same time, there are grounds for another suggested explanation. The appearance of impulses in the muscle may be connected with the action of antigen on muscle receptors, excitation of which may provoke reflex responses of the muscle. Grounds for this hypothesis are given by results obtained by several authors showing that during sensitization the excitability of the vascular and tissue receptors is increased [2]. In particular, an increase in frequency of potentials in the sinus nerve have been described following injection of antigen into the perfused carotid sinus [6], and an increase in the frequency of impulses in the sensory nerve of a muscle has been reported after injection of specific serum into the muscle [4].

To determine whether excitation of the muscle arises reflexly following the primary action of antigen on muscle receptors or whether the appearance of potentials in the muscle is associated with the direct action of antigen on the muscle tissue, in the course of the experiment the sciatic nerve was divided. If the injected antigen led to the appearance of spontaneous discharges in the skeletal muscle as the result of its action on muscle tissue, after denervation of the muscle the impulses in it should still persist. This did not take place in these experiments. In all experiments division of the sciatic nerve led to cessation of impulses in the muscle evoked by injection of antigen into it (Fig. 1). The impulses in the opposite muscle persisted. If serum was injected into the muscle after division of the nerve, impulses did not develop in this muscle but only in the opposite muscle.

It may be concluded from these results that the bursts of impulses recorded in the gastrocnemius muscles are not associated with the action of antigen on muscle tissue, i. e., are not due to an allergic reaction of the skeletal muscle. The results of experiments in which the nerve was divided rule out the possibility of reflex excitation of the muscle as a result of the action of serum on muscle receptors, for division of the nerve on the side of antigen injection did not abolish impulses in the opposite muscle, although the reflex pathway was interrupted. It could be considered that the appearance of spontaneous impulses in the muscle was due to initial excitation of the spinal cord by action of the antigen on it. According to data in the literature the spinal cord exhibits increased pathological activity after a reacting injection of antigen [10, 12].

In investigate this fact, the experiments of series II were carried out, in which serum was applied to the spinal cords of 6 control and 18 sensitized guinea pigs. The guinea pigs were anesthetized, the sciatic nerves were dissected, and the spinal canal was opened between the 5th lumbar and 1st sacral vertebrae, after which the dura was divided. The initial EMG from both gastrocnemius mucles was recorded, followed by the EMG after application of serum to the spinal cord and the EMG after division of the sciatic nerves.

In experiments on the control animals a concentration of serum (1:30) was selected which, when applied to the spinal cord, produced no changes in the original EMG of the muscles, i.e., which was indifferent toward the spinal cord. Horse serum was diluted in physiological saline, pH 7.4-7.6, close to the pH of the cerebrospinal fluid.

Application of indifferent doses of serum (0.5 ml in dilutions of 1:30 or 1:50) to the spinal cord of the sensitized animals led to a considerable increase in electrical activity of the investigated muscles, or was accompanied by the appearance of impulses where previously none had been found. Impulses appeared much sooner (40-80 sec) than when the antigen was injected intramuscularly. Spontaneous discharges of impulses persisted for 2-3 sec and were repeated several times.

Division of the sciatic nerve, carrying motor fibers to the gastrocnemius muscle, interrupted the burst of impulses in this muscle, whereas impulses to the opposite muscle continued to appear, evidently as a result of integrity of the communication between the muscle and the spinal cord. As soon as this connection was broken by division of the nerve, impulses in the muscle disappeared.

Since all the experiments described above were carried out on intact animals, activation of the muscle potentials in conditions of anaphylaxis could have been due to the action of the antigen both on the spinal cord and on the cortex or subjacent structures of the brain. There is information in the literature that a reacting injection of antigen is accompanied by an increase in electrical activity of the cerebral cortex [7].

To obtain a more distinct picture in the next variant of the experiments, 9 sensitized guinea pigs were used in which the spinal cord was first divided at the level of the 2nd-3rd thoracic vertebra. Experiments were carried out 4-5 h after division of the spinal cord or next day. In 6 of 9 experiments no impulses were present the muscles initially. After application of horse serum in dilutions of 1:30 and 1:50 to the spinal cord, considerable discharges of impulses were recorded periodically from the gastrocnemius muscles for 20-30 min (Fig. 2). Each burst of impulses continued for longer (up to 10 sec) than in the previous experiments. Hence, when the spinal cord was separated from the brain, more marked activation of the muscle potentials was observed after application of antigen to the spinal cord than in intact animals.

It may be concluded from these results as a whole that the action potentials arising in skeletal muscles after a reacting injection of antigen are not the result of an allergic reaction of the skeletal muscle, but are associated with action of the antigen on the spinal cord of the sensitized animals. A change in the functional state of the spinal cord under the influence of antigen is accompanied by spontaneous bursts of impulses in the skeletal muscles.

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