EFFECT ON THE HEART RATE OF TREATING MUSCLES WITH HYPO-, ISO-, AND HYPERTONIC SOLUTIONS

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Reflex visceral and skeletal muscle changes may be induced by perfusing [1, 7, 13], injecting [3, 14], or applying various chemical substances to the surface of the muscles of limbs which retain only a nervous connection with the rest of the body. Chemical stimulation of proprioceptors must therefore take place, and this view is confirmed by recording potentials from the sensory nerve supply to the muscle while the latter is treated with salts and other substances [4, 16].

We have studied the effect on muscle of distilled water, isotonic saline (0.65 % NaCl), and hypertonic saline (1.3 and 1.95 % NaCl); Ringer's solution was used for the control. Reflex changes in the activity of the heart and skeletal muscle were used as indicators of proprioceptor stimulation.

METHOD

The experiments were carried out on 20 Spring and 20 Autumn male frogs (Rana temporaria).

Before the experiment, a cut was made through the skull bone to divide the brain between the medulla and the optic lobes. The heart was exposed and so were the muscles of the anteromedial surface of both thighs, or all the muscles of both hindlimbs.

The experiment was begun 45-60 min after dividing the brain, after recovery from spinal shock. The heart contractions were recorded on a kymograph. Every 2-4 min one of the solutions was applied on a piece of filter paper 6 · 8 mm to the m.cruralis, or, less frequently, to the gastrocnemius muscle. The period of stimulation was varied from a few seconds to 1 ½-3 min. The electrocardiogram was recorded both during the application of the stimulus and for a few minutes after it had been washed out with Ringer's solution.

RESULTS

As was to be expected, the application of Ringer's solution to muscle had no effect on the heart rate.

Sodium, potassium, and calcium ions must be present in a certain proportion for normal functioning of the neuromuscular apparatus to take place. It would therefore be expected that stimulating the muscle with different concentrations of NaCl would bring about proprioceptor changes.

Physiological saline (0.65 % NaCl) caused no change in the heartbeat or in the functioning of the other organs, the probable reason being that the diffusion of salt, which may change the ionic composition and properties of muscle, takes place quite slowly.

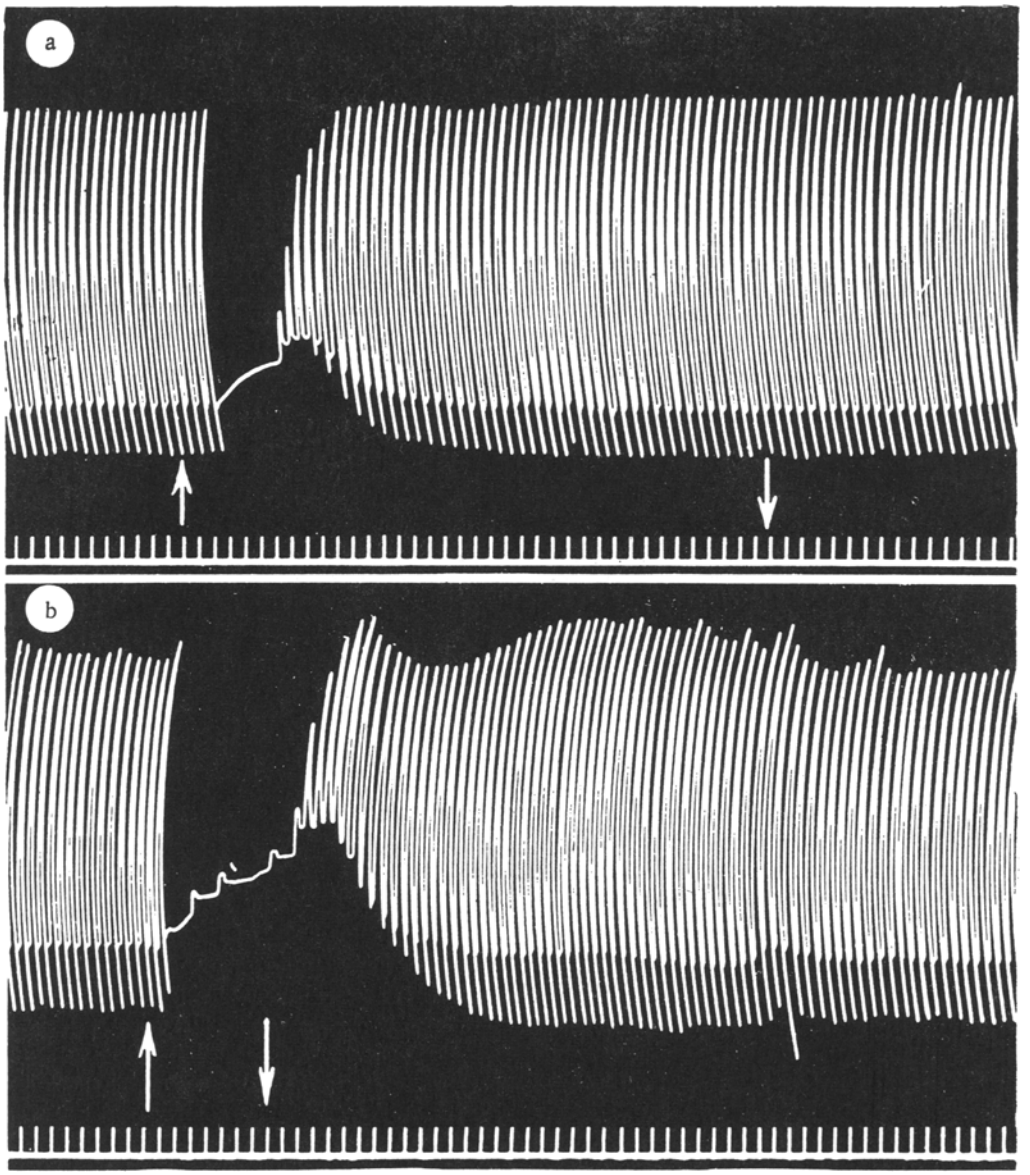
When the muscles were stimulated by a 1.3 % sodium chloride solution, in seven out of the 14 tests, the heartbeat was affected.

When a 1.95 % solution of NaCl was applied to the surface or used to irrigate the muscle, the heartbeat changed in 42 % and 84 % of the cases respectively.

When the thigh muscles were irrigated with 1.95 % NaCl, the solution might reach the inner skin surface and so stimulate cutaneous receptors. For this reason, experiments were carried out in which the skin of one limb and the muscles of the opposite limb from which all skin had been removed were irrigated alternately. Under these conditions, cutaneous stimulation brought about the same cardiac changes and the same motor responses as when the thigh muscles were irrigated. However, the latent period of the response induced by irrigating the muscles had an average value which did not exceed 13 sec whereas when the skin was irrigated the latent period had an average value of 90 sec.

When a "hypotonic solution" consisting of twice-distilled water was used, cardiac and skeletal-muscle changes occurred which resembled those induced by hypertonic solutions (see Figure).

Cardiac changes occurred in 127 of the 166 tests with water. In 118 cases, the amplitude of the contractions was reduced and then returned to the original value either immediately, or after a temporary increase or fluctuation in amplitude. Whether the water was applied on filter paper or by irrigation, the amplitude change was about 26-36%; the change lasted for 81-100 sec. In 89 out of the 166 tests the heart rate was slowed on average by 30 % for 45-46 sec. In 47 of the tests, the heart stopped for an average time of 7 sec.



Change in frog heart rate on stimulating thigh muscles. a) Twice-distilled water applied to the muscles; b) muscles irrigated with twice-distilled water. Arrows indicate onset (↑) and end (↓) of stimulation.

Proprioceptor stimulation with hyper- and hypotonic solutions, therefore, usually causes marked changes in the amplitude of the cardiac contraction or in the heart rate. Similar results [2] were obtained by stretching the muscles.

It can be seen, therefore, that muscular stimulation by either hyper- or hypotonic solutions will cause different degrees of irradiation according to the strength.

The heart rate is affected only when proprioceptor stimulation is intense. The threshold was higher for this response than for the alteration in the amplitude of the contractions.

The threshold for the motor response was higher still. In our experiments, the response took different forms: there might be a fibrillation of the muscle at the point to which the stimulus was applied, or a movement of the digits or of the whole limb, or possibly a generalized motor response. The latent period for this reaction was as a rule longer than that for the cardiac response.

The characteristic stepwise relationship between the cardiac and skeletal-muscle responses to proprioceptor stimulation should be noted. A. A. Ukhtomskii's principle of stepped theresholds applies to interoceptors as well as proprioceptors [8].

The principle of the effect of hypertonic sodium chloride solutions and of distilled water on propioceptors is as follows.

Disturbance to the vital function of an organ or tissue may be brought about either by a change of salt content or of the osmotic pressure of the solution. However, it has been shown [12], that the osmotic factor acts first. Only after a longer time interval is the effect due

to diffusion of salts reduced [10]. In our experiments the time of action of the solutions was limited to 1 ½-3 min , and it is probable , therefore, that proprioceptor impulses were induced by increase or decrease in osmotic pressure.

When the muscles were irrigated with twice-distilled water for periods up to 3 min , the initial cardiac change was not maintained for the whole period. Evidently, the considerable reduction in osmotic pressure first stimulates and then depresses the proprioceptors. It is known [4] that distilled water causes some loss of both motor and receptor muscle-fiber function.

In our method, repetition of the irrigation with distilled water after an interval of 5-10 min again caused an irradiation of the response affecting heart and skeletal muscle. Evidently, the suppressor effect of osmotic pressure changes on muscle receptors is rapidly removed by the mechanism for regulating the osmotic pressure.

The cardiac and skeletal muscle changes induced by the action of hyper- and hypotonic solutions on muscles takes the form of a motor visceral reflex. The latent period has an average value of 12-16 sec. The latent period depends on the rate of diffusion of the water. The reflex nature of the changes is shown by the fact that in 50 tests, the reaction occurred 2-7 sec after applying the sodium chloride solution or water to the muscle.

Proprioceptors are therefore sensitive to osmotic pressure changes so that reflexes involving responses of viscera or skeletal muscles may be produced not only mechanically but also by physicochemical stimuli.

SUMMARY

Experiments were performed on bulbar frogs. Ringer's solution, 0.65 % physiological saline, 1.3 and 1.95 % sodium chloride solutions, and distilled water were applied to the femoral muscles for periods ranging from several seconds to three minutes. The solutions were applied on filter paper, or else were used to irrigate the muscles. It appeared that the induced change of proprioceptor osmotic pressure constituted a physicochemical stimulus which provoked a reflex cardiac change. In most cases the heart beat slowed or stopped, and the amplitude of contractions diminished.

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