EFFECT OF TEMPERATURE ON FREQUENCY SPECTRUM IN MEDULLATED A_δ AFFERENT FIBERS DURING STIMULATION OF SKIN MECHANORECEPTORS

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UDC 591.176+591.484/488+612.883

Lowering the temperature affected the frequency spectrum of afferent impulses in A_δ fibers from mechanoreceptors of the skin during its stretching. The spike frequency (measured by the colliding impulse method) was reduced at 10-16° to 20-30 pulses/sec compared with 50-60 pulses/sec at 32-36°. An increase in the skin temperature above normal also shifted the frequency spectrum towards lower values.

Studies of the properties of single mechanoreceptors have shown that their response is clearly dependent on the external environmental temperature [6, 8-10]. Lowering the skin temperature from 40 to 10° caused changes in the spike frequency in a single afferent fiber conveying impulses from the mechanoreceptor.

This paper described the results of a study of the effect of temperature changes on the frequency of afferent impulses traveling along group A_δ fibers from mechanoreceptors during stretching of the skin. The integral afferent flow of impulses in these fibers was studied in the whole nerve trunk, using the method of colliding impulses.

EXPERIMENTAL METHOD

Cats were anesthetized with urethane. The hair over the knee joint and anterior surface of the leg was carefully shaved. An area of skin supplied by the medial cutaneous branch of the saphenous nerve was detached, leaving its blood and nerve supply intact. The temperature of the dissected piece of skin could be varied from 40 to 10°C by placing it on a hollow metal container inside which water circulated. The container was connected to a thermostat to keep the temperature at the assigned level. The skin temperature was measured by an electrothermometer.

The mechanoreceptors of the skin were stimulated by stretching the skin by a measured amount by means of a special device. The saphenous nerve, supplying the skin on the medial aspect of the leg, was divided where it branches from the femoral nerve and stimulated with volleys of square pulses (0.02-0.05 msec, 3-5 V), which were stronger than the minimum required to excite all group A fibers. Evoked potentials were recorded on the medial cutaneous branch by bipolar electrodes and amplified by a type UBP1-01 amplifier, and then recorded on loop and cathode-ray oscillographs. Both parts of the nerve, with the stimulating and recording electrodes, were flooded with mineral oil and kept at body temperature. The distance between the stimulating and recording electrodes varied in different experiments from 60 to 80 mm. The mean conduction velocity for group A_δ fibers was determined from the time taken by the pulse to cover the distance between the two pairs of electrodes.

The frequency of afferent impulses was measured by one modification of the colliding impulses method [1, 2].

Department of Biocybernetics, Institute of Applied Mathematics and Cybernetics, N. I. Lobachevskii Gor'kii University. (Presented by Academician V. V. Parin.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 69, No. 6, pp. 12-14, June, 1970. Original article submitted August 25, 1969.

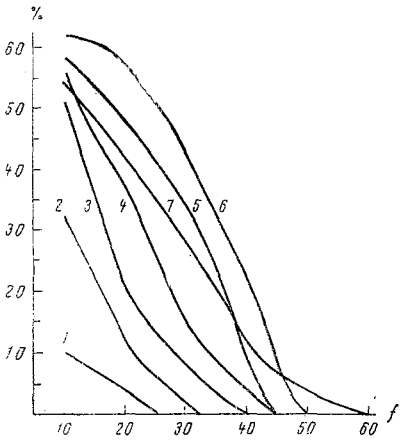

Fig. 1

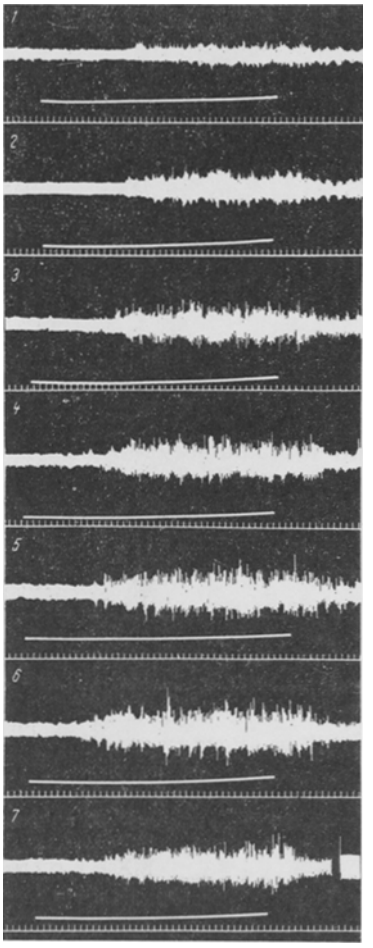

Fig. 2

Fig. 1. Changes in amplitude of A_δ potential during stretching skin by 1 mm at a speed of 2.5 mm/sec at skin temperatures of 10° (1), 16° (2), 20° (3), 24° (4), 28° (5), 32° (6), and 36° (7). Abscissa, spike frequency per second; ordinate, ratio between amplitude of potential during stretching and its amplitude before stretching the skin (in %).

Fig. 2. Effect of temperature on level of natural activity in saphenous nerve during stretching of an isolated area of skin by 1 mm at a speed of 2.5 mm/sec (calibration voltage 20 μV, time marker 100 Hz). 1) Skin temperature 10°; 2) 16°; 3) 20°; 4) 24°; 5) 28°; 6) 32°; 7) 36°.

EXPERIMENTAL RESULTS

Changes in amplitude of the A_δ potential at the time of stretching the skin during stimulation of the nerve with volleys of impulses of different frequencies, at different skin temperatures, are shown in Fig. 1.

At a temperature of 32°, stimulation of the nerve by a volley of pulses at 10/sec (Fig. 1, 6) caused the greatest change in amplitude of the A_δ potential. In this case it was 62% of the amplitude of this potential before stretching the skin. This indicates that in 62% of A_δ fibers collisions took place in the part of the nerve between the electrodes. With an increase in the frequency of nerve stimulation the amplitude of the potential increased by a smaller amount. The amplitude thus reached a maximum in response to stimulation of the nerve at 55-60/sec. This maximal amplitude also determined the maximal frequency in the fibers during stimulation of the mechanoreceptors. Lowering the skin temperature affected the number of active fibers. At a temperature of 28° and with the same parameters of nerve stimulation and skin stretching, the maximal change in the A_δ potential was 57%, compared with 51% at 20°, 35% at 16°, and 10% at 10°. This decrease in the percentage of fibers in which impulses collide in the

the zone between the electrodes is due to a decrease in the number of A_δ fibers conducting impulses at high frequencies. Whereas at 32° the maximal spike frequency during stretching of the skin was 50/sec, at 28° this was reduced to 35/sec, at 20° to 40/sec, at 16° to 35/sec. and at 10° to 25/sec. Raising the skin temperature to 40-44° reduced the spike frequency to 35-40/sec. The normal skin temperature, measured in the unanesthetized animal, was 33-34°. Tracings of natural activity made at different temperatures at the time of stretching of the skin are given in Fig. 2. Stretching of the skin at the same speed at a temperature of 10-16° caused a much smaller flow of impulses than at a skin temperatures of 28-32°.

The ability of the cutaneous mechanoreceptors to become excited by lowering of the temperature has often been described [5, 6-8]. However, changes in discharge frequency in response to mechanical stimulation at different skin temperatures have never been investigated, although the subject has been mentioned [7, 8].

During cooling of the skin, changes in the properties not only of the mechanoreceptors, but also of the afferent fibers themselves are evidently possible, and this could lead to blocking of some of these fibers. However, it is known [3] that fibers of the A_δ type (with a conduction velocity of 8-18 m/sec) can conduct impulses with frequencies of the order of 40-50/sec if the temperature is lowered to 10°, and with frequencies of 75-80/sec at 12°.

The shift of the frequency spectrum toward lower values is evidently due to changes in the elastic properties of the skin taking place at different temperatures.

LITERATURE CITED

1. B. I. Balanter, A. V. Zeveke, and V. M. Khayutin, in: Current Problems in the Physiology and Pathology of the Nervous Systems [in Russian], Moscow (1965), p. 199.
2. A. V. Zeveke and V. M. Khayutin, Fiziol. Zh. SSSR, No. 3, 258 (1966).
3. D. N. Franz and A. Iggok J. Physiol. (London), 199, 319 (1968).
4. K. Hellman, J. Physiol. (London), 169, 621 (1963).
5. H. Hensel and Y. Zotterman, J. Physiol. (London), 115, 16 (1951).
6. C. C. Hunt and A. K. McIntyre, J. Physiol. (London), 153, 88 (1960).
7. A. Iggo, in: Touch, Heat, and Pain, London (1966), p. 237.
8. I. Witt and H. Hensel, Pflug. Arch. Ges. Physiol., 268, 258 (1959).