ARE THERE SPECIALIZED COLD RECEPTORS IN THE SKIN?

A. V. Zeveke and V. L. Shaposhnikov

UDC 612.794.014.43

The relative number of unmyelinated fibers of a cutaneous nerve conducting impulses of excitation from mechanoreceptors during contraction of pilomotors without cooling and during cooling of the skin by 10°C at the rate of 1 deg/sec was determined by an integrative colliding impulses method. During deformation of the skin by pilomotors the same mechanoreceptors are excited as are excited during cooling of the skin.

KEY WORDS: unmyelinated fibers; mechanoreceptors; temperature receptors; skin; pilomotors; collagen.

The cat skin is known to possess combined mechanical and cold receptors, innervated by unmyelinated C fibers [4-6]. It has been shown that these bimodal receptors connected with C fibers account for up to 75% of receptors in the cat skin [5]. At the same time, it has been shown experimentally that up to 95% of these fibers are excited by mechanical deformation of the skin. The same number of C fibers also can be excited during contraction of pilomotors [2]. Consequently, too few unmyelinated fibers (under 5%) are left for the specialized temperature receptors.

The object of this investigation was the quantitative determination of specialized cold fibers on the basis of the ratio between the numbers of active fibers during mechanical deformation and during cold stimulation of the skin.

EXPERIMENTAL METHOD

Experiments were carried out on 18 cats anesthetized with hexobarbital. An area of skin in the region of the anterior surface of the leg, innervated by the genicular branch of the saphenous nerve was separated by dissection from the underlying tissues and placed in a thermode. The proximal and distal edges were secured in forceps connected to a strain gauge. The dimensions of the dissected piece of skin were the same as its dimensions before dissection. The blood supply and nerve supply to the skin were preserved. The temperature in the thermode was kept constant at 38°C. At the time of application of temperature stimulation, its temperature was reduced by 10°C at the rate of 1 deg/sec. The cutaneous nerve (saphenous nerve) in the region of the inguinal fold was placed on stimulating electrodes. The nerve was stimulated by square pulses of current with above-maximal amplitude for excitation of all unmyelinated nerve fibers. This amplitude of the stimulating pulse caused excitation of C efferents and contraction of the pilomotors of the skin flap. The nerve was stimulated with a frequency of 1.5 to 15 Hz. Activity in unmyelinated fibers from the receptors of the skin flap was determined by the colliding impulses method [5]. For this purpose, recording electrodes connected to an amplifier were placed on the cutaneous branch of the nerve. The amplitude of evoked C action potentials (C-AP), the force of deformation of the skin, and the change of temperature were recorded by means of a photooptical recorder.

EXPERIMENTAL RESULTS

In seven experiments no contractions of the pilomotors were recorded to stimulation of the nerve at all frequencies. However, cooling the skin in these experiments caused deformation of the skin and the appearance of afferent activity. The afferent impulses under these circumstances collided with antidromic impulses and the amplitude of C-AP was reduced on average to 60%.

The absence of contraction of pilomotors in these experiments can be explained by the fact that in some experimental animals there were either very few of these structures or none whatsoever in the area of skin

Institute of Applied Mathematics and Cybernetics, N. I. Lobachevskii Gor'kii University. (Presented by Academician V. N. Chernigovskii.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 88, No. 9, pp. 270-272, September, 1979. Original article submitted October 31, 1978.

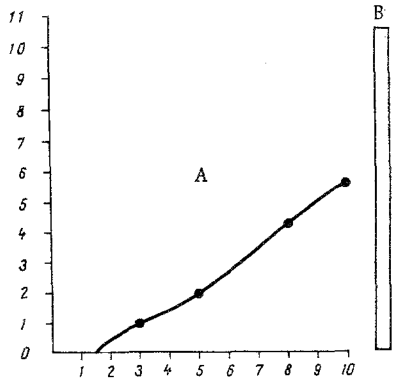

Fig. 1. Force of deformation of skin resulting from contraction of pilomotors as a function of frequency of stimulation of cutaneous nerve (A) and of contraction of collagen bundles of the skin during cooling by 10°C (B). Abscissa, frequency of nerve stimulation; ordinate, force of skin contraction (in g).

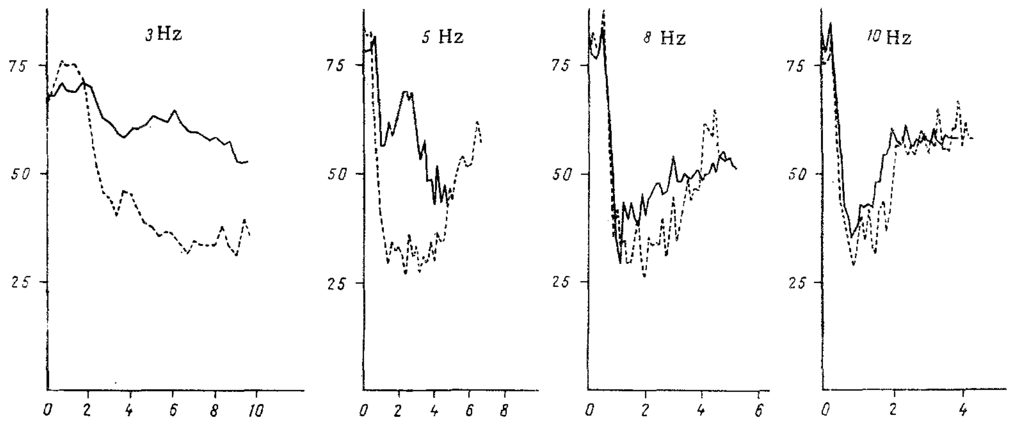

Fig. 2. Changes in amplitude of evoked potential of unmyelinated fibers due to contraction of pilomotors before (continuous line) and during (broken line) cooling of tissue. Abscissa, time (in sec); ordinate, amplitude of C-AP (in μV).

studied. This suggestion is perfectly reasonable, because the thickness of the skin, the density of the hair cover, and the diameter and length of the hair on the cat's leg are very variable.

Deformation of the skin caused by contraction of the pilomotors was recorded in the other 11 experiments. It depended on the frequency of cutaneous nerve stimulation (Fig. 1). The amount of contraction of the skin increased with an increase in the frequency of nerve stimulation. During deformation of the skin by the pilomotors, excitation of the mechanoreceptors developed. Afferent impulses collided with antidromic and the amplitude of the C-AP recorded was reduced. The decrease in amplitude of the potential corresponded to the degree of deformation of the skin within the range of frequencies of nerve stimulation from 3 to 8 Hz (Figs. 1 and 2).

If cold stimulation was applied to the skin during excitation of C fibers caused by contraction of the pilomotors, the activity of the C fibers ought evidently to have been increased because of excitation of the specific cold receptors. In that case the amplitude of C-AP should have been reduced by a greater amount because of an increase in the number of active C fibers. The difference between the decrease in amplitude of C-AP ought to correspond to the percentage of fibers connected with the specific cold receptors. In fact, in those experiments in which the decrease in amplitude of C-AP resulting from pilomotor contraction was under 50%, a very small increase was observed in the number of active fibers during skin cooling. This fact could be explained from the position of the theory of specificity, if it were quite certain that during a single contraction of the pilomotors all mechanoreceptors are involved in excitation, including the combined mechanical and cold receptors, and that during cooling of the skin no additional deformation takes place. Whereas the first condition, concerning complete excitation of all mechanoreceptors, can be satisfied by choosing animals with well-developed pilomotors, the second condition is impossible to satisfy. During cooling of the skin it is known to undergo deformation through shortening of collagen fibrils [1, 2], and under these circumstances the force of contraction of the skin is much greater than during its deformation by pilomotors (Fig. 1). It is therefore impossible to explain the increase in the number of active fibers during cooling of the skin purely by excitation of the so-called specific nerve terminals sensitive to cold. During cooling and during contraction of the pilomotors the same mechanoreceptors are evidently excited. This is clear from the experiment illustrated in Fig. 2. Cooling the skin by 10°C at the rate of 1 deg/sec caused powerful contraction of the collagen. This deformation of the skin led to excitation of mechanoreceptors, which was transmitted along 70% of the unmyelinated fibers. However, these same fibers also were excited by pilomotor contraction, when the nerve was stimulated by electric pulses at a frequency of 8-10 Hz. The remaining 30% of C fibers are evidently efferent fibers of pilomotors [7] and afferent fibers, whose receptors were cut off during dissection of the skin flap.

Hence it follows that there are no specific temperature receptors in the cat's skin with a special mechanism of excitation. This conclusion, in the writers' view, is not unexpected. A complete review of research on excitation of mechanoreceptors during temperature stimulation is given in Minut-Sorokhtina's monograph [3]. Here investigations showed that the smooth muscles of blood vessels are the temperature-sensitive elements. The present experiments supplement the conclusion regarding the mechanical character of temperature reception with the fact that when the temperature falls collagen, a fibrillary protein, shortens. When these proteins are joined into long threads, the temperature deformation may be quite sufficient to cause excitation of low-threshold slowly-adapted mechanoreceptors.

LITERATURE CITED

1. A. V. Zeveke, Fiziol. Zh. SSSR, No. 11, 1740 (1974).
2. A. V. Zeveke, Fiziol. Zh. SSSR, No. 1, 91 (1976).
3. O. P. Minut-Sorokhtina, The Physiology of Temperature Reception [in Russian], Moscow (1972).
4. W. W. Douglas and J. M. Ritchie, J. Physiol. (London), 138, 19 (1957).
5. W. W. Douglas and J. M. Ritchie, in: Pain and Itch. Nervous Mechanisms, London (1959), p. 26.
6. H. Hensel, A. Iggo, and J. Witt, J. Physiol. (London), 153, 113 (1960).
7. S. W. Ranson and H. K. Davenport, Am. J. Anat., 48, 331 (1931).