BLOCKING THE RECEPTORS OF THE SKIN AND VEINS BY COLD

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Several investigations have been made of the effect of cooling on vascular [2-5] and skin [1, 3, 5-7] receptors.

The object of the present investigation was to determine the temperature of blocking of the receptors of the skin and subcutaneous veins by cold.

EXPERIMENTAL METHOD

Experiments were carried out on rabbits, cats and isolated preparations. During cooling of the tested area of skin or subcutaneous vein at the rate of 0.16 and 0.03 deg/sec, the impulses in the peripheral end of the nerve supplied by the test object were recorded on a cathode-ray oscillograph. Cooling was continued until complete blocking of the receptors took place. The object was then warmed until the electrical activity was restored. For determining the cold block of the skin receptors 30 experiments were carried out on animals and 37 on isolated preparations. In animals anesthetized with chloral hydrate, a small twig of a cutaneous nerve was dissected in the thigh or leg and the area of skin supplied by this nerve was cooled with a thermode filled with a mixture of ice and salt. The functional state of the mechanoceptors of the skin was judged by their pulsed activity evoked by graded rhythmic contact with a pin. The temperature of the cooling surface of the vessel was measured by a thermocouple. In the experiments with the isolated preparation, the skin was cooled by means of a type TOS-1 thermocooling table. The cooling action was dosed by an automatic thermoregulator and controlled by a thermocouple.

To determine the temperature of the cold block of the venous receptors 10 experiments were carried out on rabbits and 12 on an isolated vein-nerve preparation. The lateral thoracic vein of a rabbit, humorally isolated by division of all its side branches, was perfused with cold Ringer-Locke solution. The impulses were recorded in the lateral cutaneous branch of the intercostal nerve supplying the skin and the subcutaneous vessels. Cooling of the vein began after denervation of the skin, when the integrity of the impulses arriving from the venous receptors had been verified.

In the series of experiments with the isolated preparation, the veing was excised together with the nerve twig supplying it and placed in a bath of Ringer-Locke solution (18-20°), and the vein was perfused with solutions of different temperatures under a pressure of 1-3 mm Hg at the outlet of the supplying cannula. The functional state of the receptors was judged from their pulsed activity recorded throughout the experiments. The temperature of the outflowing solution was measured directly in the outlet cannula by means of a thermocouple.

EXPERIMENTAL RESULTS

Before cooling the area of skin, the original pulsed activity of the mechanoceptors evoked by a standard stimulus was recorded. Since many receptors were stimulated, volleys of impulses of different amplitudes were recorded on the oscillograph. With a fall of temperature the number of impulses in response to stimulation diminished, but their amplitude increased. With a further decrease in temperature, the amplitude of all the impulses fell, the number of impulses in the volley progressively diminished, and the block first appeared in the low-voltage impulses. The remaining receptors became blocked with more intense cooling acting for a longer time.

When determining the temperature blocking the mechanoceptors of the skin in the animal, the rate of cooling had no significant effect. During cooling at the rate of 0.16 deg/sec the cold block of the mechanoceptors appeared when the thermode temperature was between −3 and −5.3° (average −4.3°), while in the series of experiments when the rate of cooling was 0.03 deg/sec, the cold block of the receptors took place at between −3 and −7.5° (average −4.4°). Similar results were obtained in man by Morton and Provins [5], who observed a total loss

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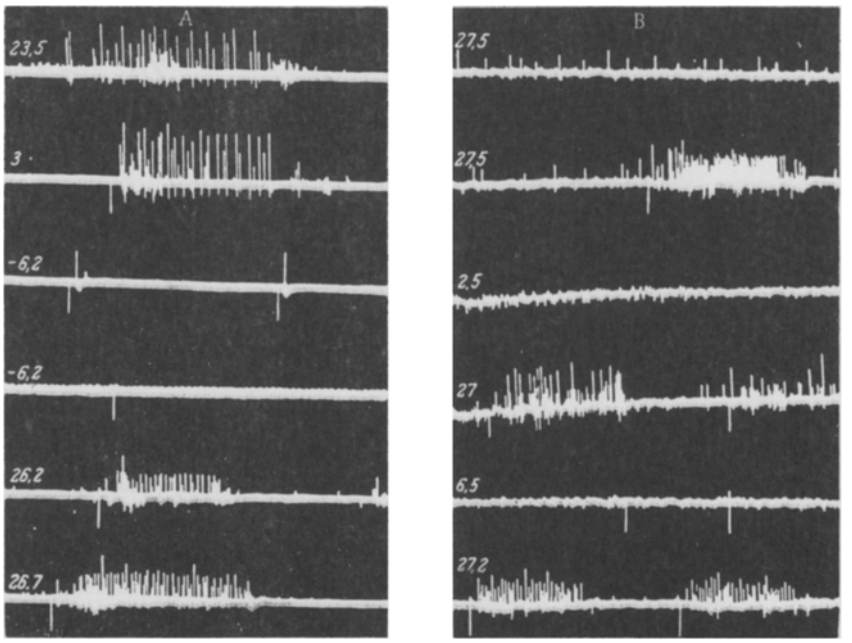

Fig. 1. Development of cold block of skin receptors in an animal (A) and an isolated skin flap (B). Numbers on the left—temperature of thermode. Artefact deflected downward—moment of application of stimulus.

of tactile sensation when the skin temperature was between −2.5 and −5°. Although the temperature at which the block began in the two series of experiments described above was the same, the time of action of the low temperature necessary for obtaining the cold block differed. With a lower rate of cooling the block developed after 8-36 min (average 12.07 min), whereas at the higher rate of cooling the block of the mechanoceptors developed after 1.5-6 min (average 4.09 min). This difference may be explained by the relationship between the temperature of the cooled skin surface and the temperature of the inflowing arterial blood. During slow cooling of the thermode the arterial blood flowing into the skin slowed the fall in its temperature in the cooled area. As a result of the repeated determination of the cold block of receptors in the same area of skin, no change was found in the temperature at which the cold block appeared.

During heating of the skin the activity of the mechanoceptors was restored, but at a higher temperature than the initial level. The order of restoration of the impulses corresponded to the pattern of the decrease in their excitability: the higher impulses were restored first and the low-voltage impulses last. The character of the depression and restoration of the activity of the mechanoceptors was independent of the rate of cooling.

In the experiments with an isolated skin flap, blocking of the receptors developed at a higher temperature than in the experiments on the animal, and the rate of cooling had a considerable influence. In the case of rapid cooling of the skin (0.16 deg/sec), blocking of the receptors began at 6.5-0° (average 3°), whereas at the slower rate of cooling (0.03 deg/sec) it appeared at 15-5° (average 11.9°).

When the cold block of the same skin flap was determined a second time, its limit was shifted toward the higher temperatures (Fig. 1). The order of development of the block in the various receptors and the order of restoration of their pulsed activity were the same as in the experiments on the animal. Blocking of the receptors giving high impulses developed later and their activity was restored sooner than the activity of the remaining receptors.

The differences in the temperature at which the blocking of the receptors of the isolated and nonisolated areas of skin appeared, with the same rate of cooling, must evidently be explained by the fact that when the temperature of the cooling surface of the thermode was the same, the total intensity of cooling of the whole thickness of skin was lower when the blood supply to the part was normal than when the skin flap was isolated, in which case the temperature of the surrounding solution was constant at the level of 18-20°.

In contrast to the mechanoceptors of the skin, reacting to an applied stimulus, the receptors of the subcutaneous veins are characterized by spontaneous rhythmic activity [5], very stable at a given temperature. The characteristic reaction of the venous receptors to moderate cooling was an increase in the frequency and amplitude of the

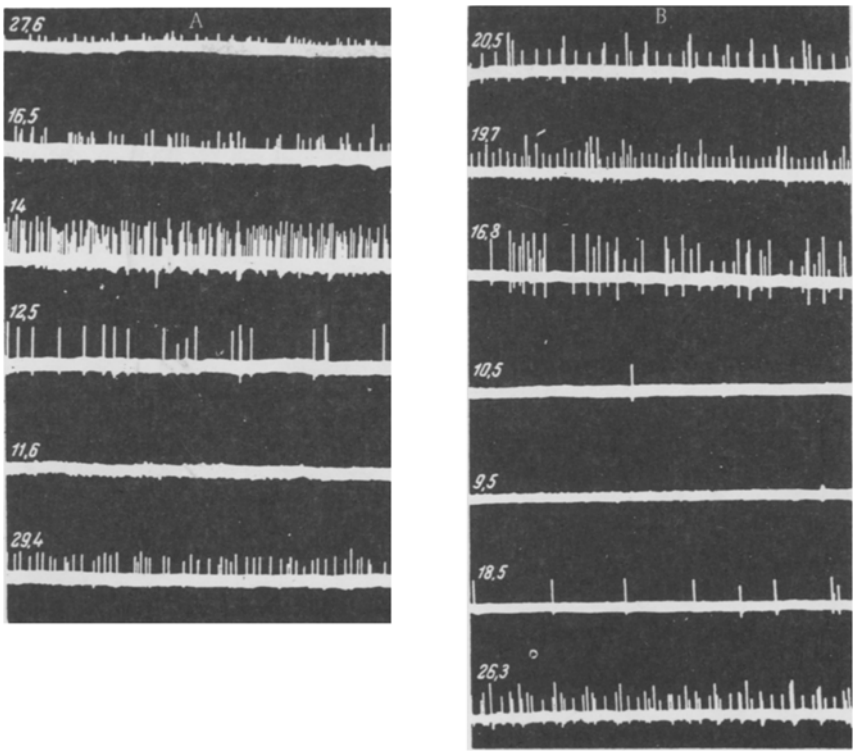

Fig. 2. Development of cold block of the receptors of the lateral thoracic vein of a rabbit (A) and an isolated preparation of the lateral thoracic vein of a rabbit (B). Numbers on the left—temperature of the outflowing solution.

impulses, observed when the temperature fell to 20-14°, followed by a decrease in the frequency and amplitude of the impulses on further cooling (Fig. 2).

In these experiments the cold block of the venous receptors appeared at 6.8-14.2°, and in the vein-nerve preparation at 6.5 - 12°. No significant difference in the temperature of the block was observed in these series. Production of a block of the venous receptors of the isolated preparation required a shorter period of action of the low temperature, because the preparation was in stable conditions unlike the vein lying on the rabbit's body, the temperature of which affected the rate of its cooling. To obtain a block of the receptors of the isolated vein, the duration of cooling in most experiments was 3-8 min, and only in three experiments was it as long as 13-15 min. The time of action of the low temperature on the receptors of the nonisolated vein in most experiments was 18-85 min, falling to 5 min in only 4 experiments. During heating rhythmic impulses again appeared, but at a higher temperature than initially. If the vein was heated to 31° or more, the frequency of the impulses fell.

The increase in the amplitude of the impulses in the initial phase of cooling observed in these experiments and also by other authors [3, 9] may be explained both by the increase in the action potential of the investigated afferent fibers and by the possible involvement of new receptors in the reaction because of an increase in their excitability [2, 4].

SUMMARY

The purpose of investigations was a study of the blocking of mechanoceptors of the skin and receptors of the external thoracic vein in a whole animal and isolated preparations. The blocking of skin mechanoceptors in a whole animal occurred at a thermodic temperature of from 3 to 7.5°C below zero. The blocking of an isolated skin flap with cold depended on the speed of cooling and occurred at a thermoid temperature of from 0 to 15°C.

Blocking with cold of receptors of the external thoracic vein in isolated preparation in a whole animal occurred at temperatures of 6.5 to 14.2°C.

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