ELECTROPHYSIOLOGICAL CHARACTERISTICS OF AORTIC BARORECEPTORS

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UDC 612.815.2:612.17

Myelinated and unmyelinated fibers with conduction velocities of 12-30 and 0.9-1.2 m/sec respectively were identified in the left aortic nerve in rabbits. In experiments on an isolated preparation of the aortic arch the electrophysiological characteristics of the aortic baroreceptors with myelinated and unmyelinated fibers were studied by selectively blocking conduction in these fibers. Baroreceptors with unmyelinated fibers were shown to have a higher threshold pressure and a wider range of function.

KEY WORDS: vascular baroreceptors; myelinated and unmyelinated fibers; nervous regulation of the circulation.

Electrophysiological characteristics of mechanoreceptors located in the walls of blood vessels and the chambers of the heart have frequently been investigated. Data have been obtained on the thresholds of excitation, sensitivity, and range of function of the mechanoreceptors and correlation between these parameters and the extensibility of the regions where these receptors are situated under normal and pathological conditions [1, 2, 4, 6]. However, most of these investigations have been undertaken without regard to the fact that the cardiovascular mechanoreceptors are not a homogeneous group of nerve endings. They differ not only in localization, but also in the type of nerve fibers proceeding from them. For instance, the atrial mechanoreceptors, and also some receptors of the ventricles, send impulses along myelinated fibers whereas most receptors of the ventricles and blood vessels have unmyelinated nerve fibers [3, 7, 9, 10]. There is reason to suppose that the functional role of the cardiovascular mechanoreceptors with different types of nerve fibers in the regulation of the circulation may differ [3, 5, 8].

The object of this investigation was to make a separate study of the electrophysiological characteristics of aortic baroreceptors with myelinated and unmyelinated nerve fibers by selectively blocking conduction in these fibers.

EXPERIMENTAL METHOD

Experiments were carried out on rabbits under urethane anesthesia (1-1.5 g/kg body weight, intravenously). In the experiments of series I thresholds of excitation and velocities of conduction were determined for different groups of fibers in the aortic nerve. For this purpose the left aortic nerve was exposed in the neck over as long a distance as possible and three pairs of bipolar platinum electrodes were placed on it. Stimulating pulses from an SI-10 stimulator (Narco, USA), with radiofrequency output, were applied to the distal electrodes. The evoked potential was recorded from the proximal electrodes (at a distance of 2.5-3.5 cm from the stimulating electrodes), connected to the amplifier of an electromyograph (Disa1500, Denmark). The sweep of the myograph monitor was triggered by the stimulating pulse. Each sweep of the beam was memorized and led to a recorder (frequency band 0-30 kHz). Electrodes for anodal block were placed between the stimulating and recording electrodes. The current generator, assembled on a PMTsG-315 battery, had an output resistance of 3-50 MΩ and provided for a change in the current through the blocking electrodes from 0 to 100 μA.

In the experiments of series II on the isolated "arch of the aorta–aortic nerve" preparation the dependence of activity of baroreceptors with different types of fibers on the intraaortic pressure was determined. The method of isolation of the arch of the aorta was described previously [1]. Three pairs of electrodes were placed just as in the experiments of series I. The intraaortic pressure, recorded by an electromanometer,

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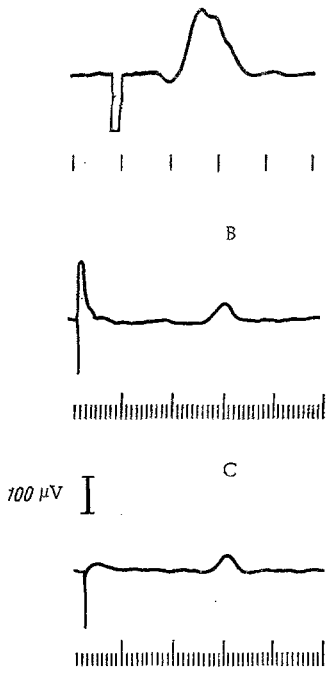

Fig. 1

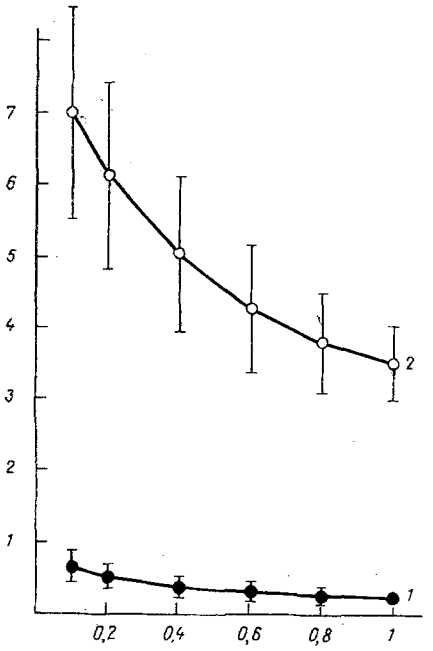

Fig. 2

Fig. 1. Potential arising in aortic nerve in response to stimulation. A, B) Anodal block absent, C) current through blocking electrodes 15 μA. Time marker 1 msec; calibration of sensitivity 100 μV; duration of stimulating pulse 0.15 msec; distance between stimulating and recording electrodes 3 cm.

Fig. 2. Threshold of excitation (M ± m) as a function of duration of stimulating pulse for groups of fibers of aortic nerve with fast (1) and slow (2) conduction velocities (results of six experiments). Abscissa, duration of stimulating pulses (in msec); ordinate, amplitude of stimulating pulses (in V).

and activity of the aortic nerve, amplified by the amplifier of the 1500 myograph, were recorded on frequency-modulated channels of the 14F60 tape recorder (Disa). The necessary cuts of the record of activity were processed by an IÉ-1 integrator and recorded together with the pressure on the myograph recorder. At the beginning of each experiment, before isolation of the arch of the aorta, the current through the blocking electrodes at which high-amplitude activity in the aortic nerve disappeared, i.e., when conduction was blocked in the myelinated fibers, was determined (Fig. 3A).

EXPERIMÉNTAL RESULTS

The conduction velocities along the different groups of fibers were determined by dividing the time between the artefact of the stimulating pulse and the corresponding wave of the compound potential by the distance between the stimulating and recording electrodes. Typical records obtained in an experiment of series I are given in Fig. 1. Clearly the first and fastest wave of the compound potential appeared 1.8 msec after stimulation (Fig. 1A). The second wave of potential (Fig. 1B) appeared much later (after 30 msec). The conduction velocity along the group 1 fibers was within the range 12-30 m/sec and along the group 2 fibers 0.9-1.2 m/sec (results of six experiments), and on that basis the group 1 fibers can be regarded as myelinated and the group 2 fibers as unmyelinated.

A gradual increase in the strength of the current passing through the blocking electrodes led to disappearance of the fast wave of the compound potential (Fig. 1C). The strength of the current blocking conduction in the myelinated fibers varied in different experiments from 8 to 30 μA, probably because of differences in the thickness of the aortic nerve. A current of over 40-50 μA was required to block conduction along unmyelinated fibers.

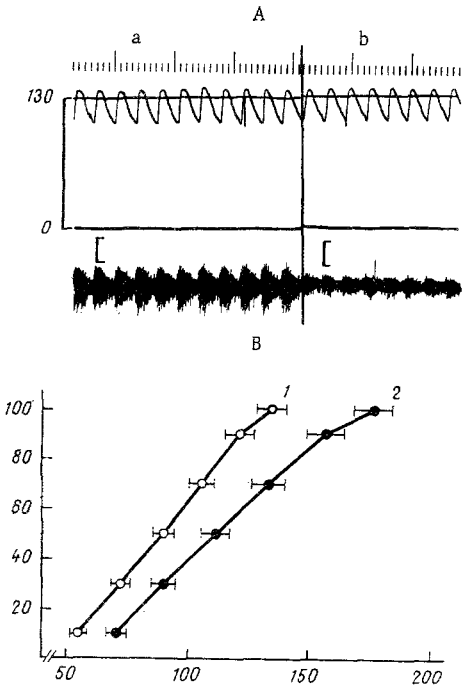

Fig. 3. Results of experiments on "aortic arch–aortic nerve" preparation. A) Choice of strength of current blocking conduction in myelinated fibers (see: "Experimental Method"), a) anodal block absent, b) current through blocking electrodes 20 μA. Top curve indicates intra-aortic pressure (in mm Hg), bottom curve indicates activity in aortic nerve. Calibration of sensitivity: a) 100 μV, b) 50 μV. Time marker 0.1 sec; B) dependence of activity in myelinated (1) and unmyelinated (2) fibers of aortic nerve on intra-aortic pressure. Abscissa, intra-aortic pressure (in mm Hg); ordinate, activity of aortic nerve (% of maximal). Values of M ± m given (results of nine experiments).

Thresholds of excitation of the different groups of fibers were determined as the minimal amplitude of the stimulating pulse required to produce the corresponding wave of the compound potential. With all durations of the stimulating pulse the threshold of excitation of the myelinated fibers was considerably lower than of the unmyelinated; the shorter the stimulating pulse, the greater this difference (Fig. 2). Myelinated fibers of the aortic nerve could thus be selectively activated by electrical stimulation. Similar results regarding the thresholds of excitation and velocities of conduction along myelinated and unmyelinated fibers of the cardiac mechanoreceptors in cats were obtained by Öberg and Thoren [7].

The results of the experiments on the "aortic arch–aortic nerve" preparation are illustrated in Fig. 3. The frequency and amplitude of the impulses in the myelinated fibers were much higher than in the unmyelinated fibers; when combined activity in the aortic nerve was recorded in the absence of a block, activity in the myelinated fibers only was thus in fact determined. When conduction was blocked in the myelinated fibers, the threshold and saturation of activity in the unmyelinated fibers could be determined with a fair degree of accuracy by increasing the sensitivity of the amplifier and integrator. The curve of dependence of activity in the unmyelinated fibers on the intraaortic pressure is located further to the right, i.e., in the region of higher intra-aortic pressures, than the corresponding curve for myelinated fibers (Fig. 3B). It also has a less steep slope relative to the pressure axis, i.e., the range of function of mechanoreceptors with unmyelinated fibers is wider. The threshold pressure and the pressure at which activity becomes maximal were 55 and 71 mm Hg ($P < 0.005$) and 132 and 177 mm Hg ($P < 0.001$) for the groups of myelinated and unmyelinated fibers respectively.

The aortic baroreceptor zone thus contains two groups of mechanoreceptors which differ not only in the type of their nerve fibers, but also in the range of their function. These results are evidence that the functional role of vascular mechanoreceptors with myelinated and unmyelinated fibers in the regulation of the circulation may differ.

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RELATIVE RESISTANCE OF CENTRAL MECHANISMS DETERMINING THE DEPTH AND FREQUENCY OF RESPIRATION

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UDC 612.28

Hypercapnia in vagotomized cats can induce not only an increase in the depth of respiration, but also an increase in the frequency of inspiratory volleys. With deepening of anesthesia, the increase in depth of the inspiratory volleys continues, whereas the increase in the respiration rate disappears. These observations point to differences in the central mechanisms controlling the frequency and depth of respiration, of which the former is more susceptible to suprabulbar influences.

KEY WORDS: control of respiration; frequency and depth of respiration; hypercapnia; vagus nerve.

It is generally accepted that under normal conditions CO_2 increases the depth and frequency of respiration. However, the results of the action of hypercapnia in vagotomized animals are surprisingly contradictory. According to some workers [1, 5, 14] vagotomy prevents the increase in the respiration rate induced by hypercapnia, whereas according to others [2, 4, 11, 12] it has no such action.

Yet this is a very important problem. If vagotomy prevents the increase in respiration rate induced by CO_2, the respiration rate is determined by a vagal mechanism whereas the depth of respiration is determined by central mechanisms. If the increase in the respiration rate is not prevented, it follows that not only the depth, but also the rate of respiration are determined by central mechanisms.

During the analysis of this problem the writers' attention was drawn to the following circumstance. Some workers [7, 9, 11, 12] have found that after vagotomy hypercapnia induces an increase in the respiration rate in unanesthetized animals. Others [4], on the other hand, claim that after vagotomy an increase in the respiration rate takes place only in anesthetized animals and not in waking animals.

EXPERIMENTAL METHOD

Experiments were carried out on 18 cats anesthetized with pentobarbital (30-35 mg/kg) intraperitoneally. Subsequent doses of pentobarbital were injected intravenously (5-7 mg/kg). The vagus nerves were divided in

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(Presented by Academician of Medical Sciences of the USSR A. M. Chernukh.) Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 85, No. 1, pp. 6-8, January, 1978. Original article submitted April 15, 1977.

0007-4888/78/8501-0004$07.50