CIRCULATORY RESPONSES TO SELECTIVE ACTIVATION OF MYELINATED AND UNMYELINATED FIBERS OF THE AORTIC NERVE

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In experiments on thoracotomized cats the arterial blood pressure (BP), cardiac frequency, force of contraction of a fragment of the left ventricle, and the resistance of the blood vessels of the hind limb were recorded. Myelinated and unmyelinated fibers (A and C fibers) of the left aortic nerve were stimulated selectively. Lowering of BP in response to stimulation of A fibers was observed to take place mainly through a decrease in the peripheral vascular resistance, whereas during excitation of C fibers the cardiac component of the reflex — a reduction in the frequency and force of cardiac contractions — was most marked.

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

Reflex responses of the circulation to stimulation of afferent nerves from the arch of the aorta and carotid sinuses have been studied in fair detail [6, 7]. However, nearly all such investigations have failed to take account of the fact that the aortic and sinus nerves contain both myelinated and unmyelinated fibers (A and C fibers) [2, 8, 9], the functional role of which in the regulation of the circulation may differ. This possibility was mentioned over 20 years ago by Douglas et al. [4, 5]. They pointed out that during stimulation of the left aortic nerve in rabbits with pulses of different duration and amplitude, depressor biphasic responses were observed: Once a certain intensity of stimulation was reached the magnitude of the response increased suddenly and stepwise. These workers suggested that the reason for the biphasic nature of the responses of the arterial blood pressure (BP) was excitation of two groups of mechanoreceptor fibers (A and C fibers), responses to excitation of C fibers being of higher amplitude. The present writers have shown that the electrophysiological characteristics of aortic baroreceptors with A and C fibers are different: The threshold pressure for excitation of receptors with C fibers is higher, and their range of function is wider, than for receptors with A fibers [1]. These data also indicate that the functional role of vascular mechanoreceptors with A and C fibers in the regulation of the circulation may be different.

The object of the present investigation was to study reflex responses of BP, the frequency and force of the cardiac contractions and the resistance of the blood vessels of skeletal muscles to selective stimulation of A and C fibers of the left aortic nerve in cats.

METHODS

Experiments were carried out on cats anesthetized with chloralose (40 mg/kg) and urethane (0.5 g/kg body weight) intravenously after thoracotomy and during artificial ventilation of the lungs. BP was recorded by an electromanometer in the right common carotid artery. The force of contraction of a fragment of the left ventricle was determined by means of a special transducer sutured to the surface of the myocardium. The transducer consisted of a spring arch, to the inner and outer surfaces of which were glued strain resistor elements, connected to a strain-gauge amplifier (from Narco, USA). The hind limb was perfused by means of a constant-flow roller pump (from LKB, Sweden). Heparin was injected beforehand into the animal's blood stream. The response of the limb vessels was judged from the change in perfusion pressure measured by an electromanometer. The cardiac frequency was measured by a KM-1 cardiomonitor and led in analog form to a recorder.

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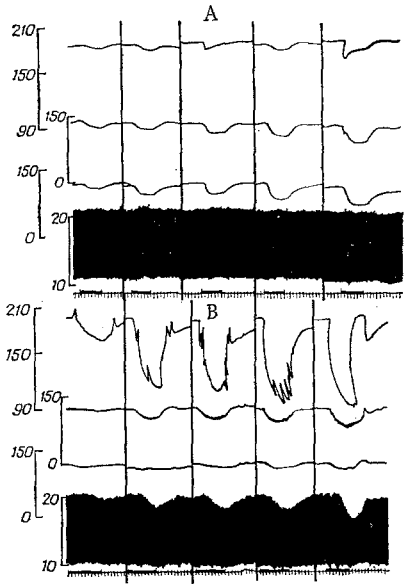

Fig. 1. Circulatory response to stimulation of depressor nerve. Tracings from top to bottom: force of contraction of fragment of left ventricle (in g); perfusion pressure (in mm Hg); mean BP (in mm Hg); frequency of cardiac contractions per minute. A) Parameters of stimulating pulses: duration 0.1 msec, amplitude 1 V. Frequency of stimulation, from left to right: 20, 40, 60, 80, and 100 Hz. B) Parameters of pulses: duration 1 msec, amplitude 7 V. Frequency of stimulation from left to right: 4, 8, 12, 16, and 20 Hz. Periods of stimulation indicated by continuous line. Time marker 5 sec.

The left aortic nerve was located in the neck by its characteristic volley activity, observed on the monitor of a 1500 electromyograph (from Disa, Denmark). In about half of all cases it was a separate branch, and in the rest it could sometimes be separated from the vagus or sympathetic nerve. From the type of activity it could be determined whether the aortic nerve consisted of mechanoreceptor fibers only. The nerve was divided and its central end stimulated by bipolar platinum electrodes. The right aortic nerve and the left sinus nerve were divided. In some experiments, a second pair of electrodes was applied proximally to the stimulating electrodes to produce an anodal block. Previously [1] the writers showed that a steady current of 8-30 μA selectively blocks conduction in A fibers of the aortic nerve. The presence of a block to conduction in A fibers was revealed by disappearance of reflex responses to their excitation.

RESULTS

It was shown previously [1] that pulses 0.1 msec in duration and 1 V in amplitude excite only myelinated fibers of the aortic nerve. The results of an experiment in which the left aortic nerve was stimulated are illustrated in Fig. 1A. Clearly excitation of A fibers caused reflex lowering of BP and of the vascular resistance of the hind limb. An increase in the frequency of stimulation potentiated these responses. The maximal response was achieved at a frequency of 80-100/sec. The frequency and force of cardiac contractions remained practically unchanged. On the other hand, during simultaneous excitation of A and C fibers (Fig. 1B), at low frequencies of stimulation the fall in BP was accompanied by a marked decrease in the frequency and force of the cardiac contractions. These reflex responses reached a maximum when the frequency of stimulation was 16-20/sec. It can tentatively

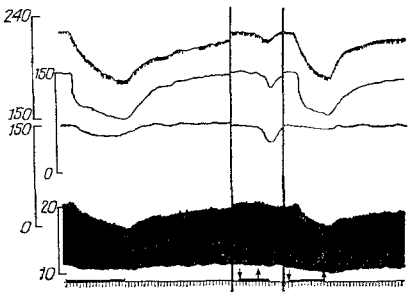

Fig. 2. Comparison of reflex responses to stimulation of (A + C) fibers and of C fibers alone of depressor nerve. Parameters of stimulating pulses: left and right fragments, duration 1 msec, amplitude 7 V, frequency 20 Hz; middle fragment, duration 0.1 msec, amplitude 1 V, frequency of stimulation 40/sec. Arrows indicate anodal block on and off. Strength of current through blocking electrodes 20 μA. Remainder of legend as in Fig. 1.

be suggested that these responses were to excitation of C fibers, for selective stimulation of A fibers with a frequency of 20 Hz evoked only very small changes in BP (compare the first fragment in Fig. 1A with the last in Fig. 1B). To test this hypothesis six experiments were carried out in which conduction along A fibers was selectively blocked by the anodal block [1]. In these experiments, a gradual increase in the strength of the current through the blocking electrodes led to disappearance of the reflex responses to excitation of A fibers. The results of these experiments were similar, and one of them is illustrated in Fig. 2. The anodal block clearly abolished conduction along A fibers (middle fragment). The amplitudes of responses of frequency and force of cardiac contractions to stimulation of (A + C) fibers and selectively of C fibers only were virtually identical (fragments 1 and 3 in Fig. 2). Reflex changes in cardiac activity in response to stimulation of the aortic nerve were thus evoked by excitation of C fibers.

On the other hand, a change in the resistance of the hind-limb vessels took place in response to excitation of A fibers of the aortic nerve. For instance, stimulation of A fibers alone (Fig. 1A) with a frequency of 20 Hz evoked the same decrease in perfusion pressure as stimulation of (A + C) fibers with the same frequency (Fig. 1B). Blocking conduction along the A fibers prevented a change in perfusion pressure (Fig. 2). Aars et al. [3] obtained data to confirm these conclusions. They showed that when the left aortic nerve was intact, the right nerve divided, and influences from the carotid sinuses abolished, a moderate increase in BP led to considerable inhibition of vasoconstrictor activity of the renal vessels. This response was completely abolished by blocking conduction along A fibers of the aortic nerve. A considerable increase in BP under these conditions nevertheless reduced the flow of impulses somewhat in the renal nerve, which could be explained by excitation of mechanoreceptors of the heart (division of the aortic nerve very slightly modified this response in the vasoconstrictor fibers).

However, it might be suggested that the difference between the reflex responses to stimulation of the aortic nerve by pulses of different intensity was the result of the unequal inhibitory action of the general anesthesia on the sympathetic and vagus divisions of the cardiovascular center. In that case, if the vagus division were inhibited by a greater degree, excitation of a larger number of aortic nerve fibers would be required to activate it. The group of C fibers of the aortic and sinus nerves is known to be more numerous. To test this hypothesis seven experiments were carried out on rabbits under local anesthesia (0.25% procaine solution). BP and the cardiac frequency were recorded. It was found that during excitation of A fibers of the aortic nerve the cardiac frequency did not change very significantly (on average by 8%), whereas stimulation of C fibers reduced it considerably (on average by 32%).

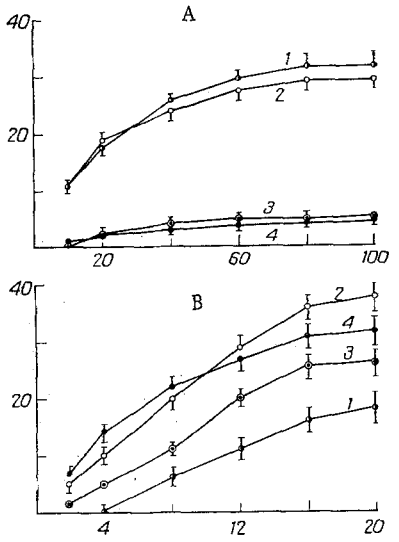

Fig. 3. Amplitudes of reflex responses as a function of frequency of stimulation. 1) Vascular resistance of hind limb; 2) BP; 3) force of contraction of myocardium; 4) frequency of cardiac contractions. Ordinate, reduction in value of parameters (% of initial); abscissa, frequency of stimulation, Hz. Parameters of stimulating pulses: A) duration 0.1 msec, amplitude 0.5-1 V; B) duration 1-1.4 msec, amplitude 5-8 V. Values of M ± m shown (n = 15).

The mean results of 15 experiments are illustrated in Fig. 3. It can be concluded from the results that during excitation of vascular mechanoreceptors with A fibers the decrease in BP takes place chiefly through a decrease in the peripheral vascular resistance. Mechanoreceptors with C fibers, with higher thresholds [1, 3], have a reflex influence on BP, acting mainly on the cardiac component of the reflex, i.e., changing the frequency and force of the cardiac contractions.

In our view, the results must be taken into account when the method of stimulation of baroreceptor nerves is used in clinical practice in order to abolish hypertensive crises and attacks of angina pectoris.

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