VASOMOTOR REFLEXES TO EXCITATION OF Aδ AND C AFFERENT FIBERS OF THE INFERIOR CARDIAC NERVE

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The relationship between reflex discharges in the renal nerve and vasomotor reflexes to excitation of afferent fibers of the inferior cardiac nerve was investigated in acute experiments on anesthetized cats. Selective excitation of Aδ afferent fibers, with a threshold of 0.5-1 V, using an electrical stimulus 0.12 msec in duration, evoked single-component reflex sympathetic responses and small depressor or pressor vasomotor reflexes. Excitation of C afferent fibers with a threshold of 4-6 V evoked the appearance of a second component in the sympathetic reflex discharge, and the vasomotor reflexes became purely pressor and of high amplitude. It is postulated that afferent C fibers transmit information concerning nociceptive stimulation of the cardiac reflexogenic zone.

Excitation of afferent fibers of spinal origin, supplying the heart, can evoke pain [13]. Stimulation of the central and of the divided inferior cardiac nerve (ICN) by pulses of current [12] or mechanical stimulation [2] in anesthetized animals gives rise to the motor manifestations of a nociceptive response, components of which are strong pressor reflexes arising in vagotomized cats in response to allogenic stimulation of the epicardium and pericardium by potassium ions and acetylcholine. However, it is impossible, from the results of a study of reflexes affecting the arterial pressure, to determine the type of afferent fibers in ICN transmitted nociceptive information.

Brown [7] considers that only impulses transmitted along Aδ fibers are responsible for nociceptive responses to stimuli affecting the heart. This conclusion appears doubtful, because in response to electrical stimulation of Aδ fibers in Brown's experiments, only weak depressor reflexes appeared. On the other hand, the discovery of nonmedullated afferent fibers of dorsal-root origin (drC fibers, according to Gasser [11]) with a conduction velocity of 0.2-0.6 m/sec in the composition of ICN [5] provides indirect confirmation that impulses transmitted along drC fibers are responsible for pressor reflexes [6].

The object of this investigation was to demonstrate the connection between excitation of Aδ and drC fibers of ICN and the character of the reflex sympathetic discharges in the renal nerve and systemic vasomotor reflexes.

EXPERIMENTAL METHOD

Cats were anesthetized by intravenous injection of a solution of chloralose (80 mg/kg) and urethane (1 g/kg), and in control experiments by injection of nembutal solution (30 mg/kg). Artificial respiration was applied and succinylcholine injected continuously (0.15 mg/kg/min). The first 3 left ribs were removed, the left ICN mobilized extrapleurally, and the nerve divided as close as possible to the heart. The central end of the divided nerve was placed on platinum electrodes and flooded with warm mineral oil. The nerve was stimulated with square pulses (0.12 msec, 0.2-50/sec, 0.1-20 V). The arterial pressure was measured in the carotid artery by an electromanometer and recorded on an ink-writing apparatus.

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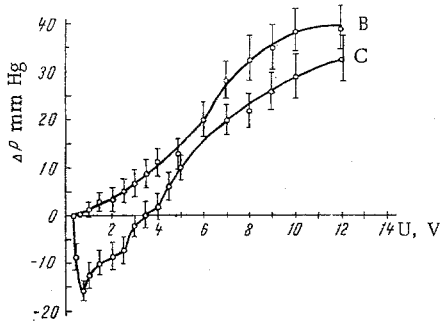

Fig. 1. Reflex changes in arterial pressure versus amplitude of stimulation of central end of inferior cardiac nerve in cats. Duration of stimuli 0.12 msec, frequency 5/sec. At voltages of 0.5-4 V, either small depressor reflexes (9 experiments, curve C) or pressor reflexes (3 experiments, curve B) appeared. At voltages higher than 4 V, only pressor reflexes always appeared. Abscissa, amplitude of stimuli; ordinate, changes in arterial pressure.

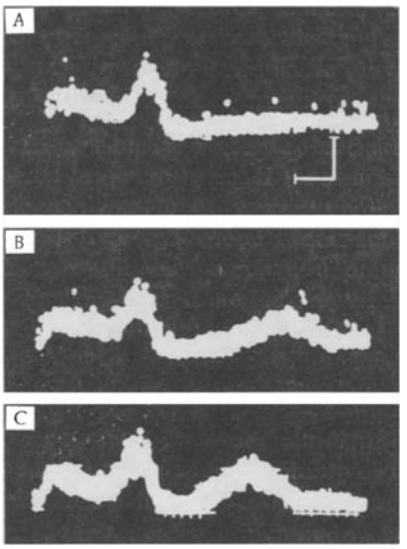

Fig. 2. Reflex responses in renal nerve to electrical stimulation of inferior cardiac nerve. All records are results of averaging a series of 64 responses. Parameters of stimulation: duration 0.12 msec; amplitude: 2 V (A), 5 V (B), 10 V (C). A) single-component response to excitation of Aδ fibers; B and C) two-component responses to excitation of Aδ and drC fibers. Calibration, 50 msec and 20 μV.

Reflex responses in the renal nerve were recorded by platinum electrodes, a type UBP1-02 amplifier, and a special ANOPS-1 computer for analyzing bioelectrical signals. Evoked responses were stored in the computer and averaged. With bipolar recording, the impulse activity was symmetrical relative to the zero line (allowing for a shift of the negative impulses equal to the time of conduction in the interelectrode segment). The mean amplitude of this activity in time is equal to zero whatever the amplitude of the impulses, spontaneous or evoked. For this reason, only positive impulses were stored, yielding an envelope averaged response. In this case, the excitation phase of the sympathetic discharges corresponded to elevation of the curve, and the inhibition phase to lowering of the curve relative to the original level.

EXPERIMENTAL RESULTS AND DISCUSSION

Graphs showing reflex changes in arterial pressure as a function of stimulus amplitude for a frequency of stimulation of 5/sec are given in Fig. 1. Within the range 0.5-4 V, in 9 experiments small (up to 20 mm Hg) depressor reflexes appeared (curve A), while in 3 experiments weak (up to 15 mm Hg) pressor reflexes were evoked (curve B).

Reflex responses appeared in the renal nerve with a latent period of about 100 msec and duration 50 msec (Fig. 2A). These were followed by a phase of inhibition of spontaneous discharges lasting about 200 msec. The character of the reflexes depended on the ratio between the mean levels of activity in the vasomotor nerves before and during stimulation. In most experiments (original arterial pressure between 120 and 140 mm Hg), at low frequencies of stimulation (under 5/sec), when the small reflex discharge was followed by prolonged inhibition, the mean level of activity fell and a depressor reflex appeared [1, 3], (Fig. 1, curve A). When, on the other hand, the original arterial pressure was low (80-100 mm Hg), the flow of impulses in the renal nerve was increased, and during electrical stimulation the wave of inhibition was shortened. The level of integral activity rose, leading to the appearance of small pressor reflexes (Fig. 1, curve B). The depressor reflexes were also converted into pressor when the frequency of stimulation was increased, because this also shortens the phase of inhibition [3].

If the amplitude of the stimuli exceeded 4 V, a second component of the reflex response appeared (Fig. 2B, C). Its latent period was 150-200 msec and its duration 100-150 msec. With an increase in amplitude of stimuli, the duration and amplitude of the second component also increased, thus filling the phase of inhibition of the first component. At the same voltages, starting with 4 V, pressor reflexes appear and increase sharply in strength with an increase in stimulus amplitude (Fig. 1).

The first component of the reflex discharges in the renal nerve was due to excitation of Aδ fibers; the range 0.5-4 V in fact corresponds to excitation of Aδ fibers of ICN [5]. The second component of the

reflex response in the renal nerve was evoked by impulses in C afferent fibers [1, 8-10]. As a previous investigation [5] showed, the threshold of excitation of drC fibers in ICN is 4-6 V. Filling the inhibitory phase of the component by the second component as a result of a reflex from drC fibers of ICN leads to an increase in activity in the sympathetic nerves. Its level is considerably higher than that of the background activity, and it therefore causes the appearance of strong pressor reflexes.

According to Sherrington [14], pressor reflexes are one component of the nociceptive response. Meanwhile, in experiments similar to those now described, but using nembutal anesthesia, Brown [7] recorded only depressor reflexes in response to excitation of Aδ fibers in ICN. He considered that they are nociceptive, although this contradicts Sherrington's definition.

In the three control experiments conducted under nembutal anesthesia, the changes in arterial pressure in response to stimulation of ICN with pulses of between 0.5 and 20 V either did not go beyond the limits of spontaneous variations or they were purely depressor. Under these conditions the second component of the reflex volleys in the renal nerves was absent. It can thus be considered that the absence of pressor reflexes in Brown's experiments (and of the second component of the reflex volleys in the present control experiments) was due to inhibition by nembutal of the central structures transmitting impulses from the drC fibers to the preganglionic vasomotor neurons.

The thresholds of excitation of drC fibers and of the second component of the reflex response in vasomotor nerves coincide with the threshold of appearance of strong depressor reflexes. It can accordingly be concluded that "nociceptive" influences on the heart excite impulse activity in the free afferent fibers, and thus evoke pseudoaffective responses.

LITERATURE CITED

1. L. Fedina, A. J. Katunsky, V. M. Khayutin, et al., Acta Physiol. Acad. Sci. Hung., 29, 157 (1966).
2. V. I. Skok, Fiziol. Zh. SSSR, No. 5, 610 (1959).
3. V. M. Khayutin, Vasomotor Reflexes [in Russian], Moscow (1964).
4. V. M. Khayutin and Yu. E. Malyarenko, Krovoobrashchenie, 1, 21 (1968).
5. V. M. Khayutin, V. L. Shur, and E. V. Lukoshkova, Transactions of the Institute of Normal and Pathological Physiology, Academy of Medical Sciences of the USSR [in Russian], Vol. 13, Moscow (1970), p. 88.
6. V. L. Shur, Transactions of the Institute of Normal and Pathological Physiology, Academy of Medical Sciences of the USSR [in Russian], Vol. 13, Moscow (1970), p. 140.
7. A. M. Brown, J. Physiol. (London), 190, 35 (1967).
8. R. Collin, A. Kaufman, and K. Koizumi, J. Physiol. (London), 201, 49P (1969).
9. J. H. Coote and J. E. Perez-Gonzalez, J. Physiol. (London), 197, 25P (1968).
10. J. Fussey, C. Kidd, and J. G. Whitwam, J. Physiol. (London), 200, 77P (1959).
11. H. S. Gasser, J. Gen. Physiol., 33, 651 (1950).
12. J. N. Langley, Lancet, 207, 955 (1924).
13. A. Malliani, P. J. Schwartz, and A. Zanchetti, Am. J. Physiol., 217, 703 (1969).
14. C. S. Sherrington, The Integrative Action of the Nervous System, New York (1906).