SUMMATION PROPERTIES OF THE SPINAL VASOMOTOR REFLEX ARC

R. S. Sonina

UDC 612.833.18

The summation properties of arcs of vasomotor reflexes from spinal afferent fibers of mesenteric nerves were compared in animals with an intact brain and 8 h after anemic blocking of the brain. In spinal animals threshold pressor reflexes developed in response to stimulation at the same frequency (0.25/sec) as in animals with an intact brain. Reflexes in spinal animals, which were reduced on the average to 16 mm Hg, reached a maximum at a lower frequency of stimulation than in animals with an intact brain. Hence, spinal vasomotor neurons are still capable of conducting single impulses. Inhibition, intensified as a result of separation of supraspinal structures, evidently interferes with central summation.

* * *

Numerous experiments [1, 5, 7, 9, 10] have shown after division of the spinal cord a marked decrease in systemic vasomotor reflexes evoked by impulses in spinal afferent fibers takes place. The possible reason for this is a decrease in the ability of excitation to spread along intraspinal pathways in the absence of supraspinal influences.

A previous investigation showed that regional vasomotor reflexes in spinal preparations effected through segments located near to the level of entry of the afferent fibers are decreased to a lesser degree than reflexes effected through more distant segments [3]. It may be postulated that this is due to interference with summation in spinal vasomotor reflex arcs. The object of the present investigation was to verify this hypothesis.

EXPERIMENTAL METHOD

Reflex responses of the arterial pressure to stimulation of the central end of the mesenteric nerves divided immediately distally to the lymph gland by square pulses for 30 sec were recorded in cats anesthetized with urethane (20% solution). The chosen parameters (10 V, 1 msec) are supramaximal for excitation of both A- and C-afferent fibers of mesenteric nerves. The frequency of the pulses varied from 0.25 to 64/sec, its value being doubled with each period of stimulation. Intervals between periods of stimulation were 2-3 min.

The experiments of series I (11 cats) were carried out on animals with an intact brain, and those of series II (10 cats) after anemic blocking of the brain by a method developed previously [4]. Stimulation in the experiments of series II began 8 h after blocking of the brain. Artificial respiration of the spinal preparations was controlled so that the CO_2 concentration in the expired air was about 4%. The CO_2 concentration was measured by a type GUKh-1 instrument. The body temperature was maintained at 36°. The animal was immobilized by intravenous injection of the curariform agent ditilin (10 mg/kg). The arterial pressure was recorded in the carotid artery by a mercury manometer.

EXPERIMENTAL RESULTS

In the experiments of series I (on animals with an intact brain) stimulation of the central end of the divided mesenteric nerve by impulses at more than 2/sec produced only a reflex increase in arterial pressure in all the animals without exception. During stimulation at a lower frequency (0.25-2/sec) some cats with an intact brain developed depressor, and others pressor reflexes. With an increase in pulse frequency from 0.25 to 2/sec, the amplitude of the depressor reflexes increased on the average from 2 to 10 mm Hg.

Laboratory of Biophysics of the Cardiovascular System, Institute of Normal and Pathological Physiology, Academy of Medical Sciences of the USSR, Moscow (Presented by Academician V. N. Chernigovskii).
Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 67, No. 5, pp. 7-10, May, 1969. Original article submitted June 17, 1968.

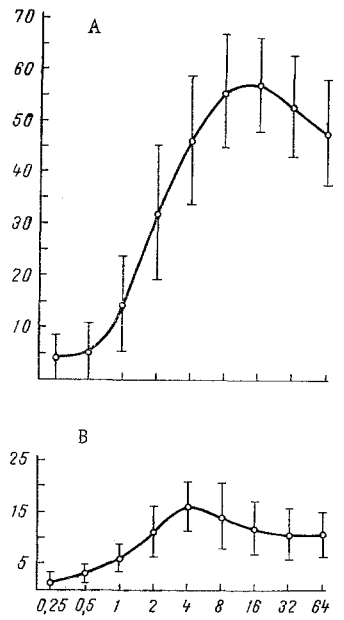

Fig. 1. Mean amplitude of vasomotor reflexes as a function of frequency of stimulation in cats with intact brain (A) and in spinal animals (B). Abscissa, frequency of stimulation (pulses/sec); ordinate, mean amplitude of vasomotor reflexes (in mm Hg). Short vertical lines denote mean errors of mean amplitudes of reflexes in 11 (A) and 10 (B) experiments.

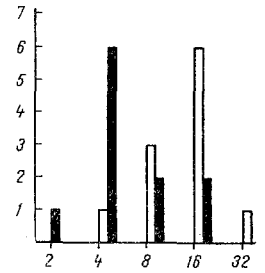

Fig. 2. Distribution of number of experiments in which vasomotor reflexes reached a maximum at a given frequency of stimulation. Abscissa, frequency of stimulation (pulses/sec); ordinate, number of experiments. Unshaded columns represent experiments on animals with intact brain; shaded columns experiments on spinal animals.

According to Khayutin [4], the reflex fall of arterial pressure during electrical stimulation of somatic nerves takes place only under conditions of general anesthesia or decerebration, when the normal relationships are disturbed between effects evoked by impulses in the different groups of afferent fibers. The same causes may be responsible for development of depressor reflexes in response to stimulation of visceral nerves also. In fact, in a similar series of experiments carried out on unanesthetized cats immobilized with ditilin, stimulation of the mesenteric nerves evoked only pressor reflexes whatever the frequency of stimulation.

When the curve of reflex amplitude as a function of stimulation frequency was plotted (Fig. 1A), only pressor reflexes were considered. In three experiments, threshold pressor reflexes appeared in response to stimulation of the mesenteric nerves at 0.25/sec. The mean amplitude of the reflexes reached a maximum at a frequency of 16/ sec. With higher frequencies the amplitude of the reflexes diminished.

In the experiments of series II (on spinal preparations) only pressor reflexes developed in response to stimulation of the central end of the mesenteric nerves whatever the pulse frequency (Fig. 1B). Comparison of curves of mean amplitudes of the reflexes as a function of stimulation frequency in the two series of experiments shows that after blocking of the suprasinal structures the vasomotor reflexes were reduced in amplitude. Nevertheless, even in spinal animals a threshold vasomotor reflex can appear in response to stimulation at 0.25/sec. Pressor reflexes were observed with this frequency in 4 of 10 experiments. As the frequency of stimulation increased, the amplitude of the reflexes became higher, to reach a maximum (mean 16 mm Hg) in response to stimulation at 4/sec. In two experiments the maximal reflexes were 34 and 37 mm Hg. When stimulating the central end of the splanchnic nerve 30 min after division of the spinal cord, Langley [11] observed a maximal pressor reflex of 33 mm Hg. When the frequency of stimulation exceeded 4/sec, the mean amplitude of the reflexes diminished.

In anesthetized animals with an intact brain, maximal simultaneous stimulation of A- and C-fibers of the mesentreric nerves is accompanied by facilitation in the central link of the arcs only if the frequency of stimulation exceeds 2/sec [8]. The development of vasomotor reflexes in response to higher frequencies of stimulation is thus determined by summation of excitation in the effector link, which is possible because of inertia of the blood vessels.

These experiments showed that threshold vasomotor reflexes in animals with an intact brain and in spinal animals arise in response to stimulation at the same frequency: 0.25/sec. This means that after dissociation of spinal vasomotor neurons from supraspinal structures these neurons can still respond to sti-

mulation by single pulses. Meanwhile, the decrease in amplitude of vasomotor reflexes in response to stimulation of any freqeuncy is evidence of a reduction in the number of excited neurons or in the frequency of their discharges. In other words, excitability of a certain proportion of internuncial or preganglionic neurons is lowered to such a degree that afferent volleys become subthreshold for them.

In most experiments on spinal animals, pressor reflexes reach a maximum when the frequency of stimulation was 4/sec. Meanwhile, in animals with an intact brain, maximal reflexes developed in response to stimulation at 8-16/sec (Fig. 2). This result agrees with those obtained by Lebedeva [2], in whose experiments maximal reflexes to stimulation of the mesenteric nerve in cats anesthetized with urethane developed during stimulation at 10-20/sec.

It can be postulated that the maximum of the curve for the spinal animals is displaced because of strengthening of inhibition, interfering with central summation. The presence of inhibition in spinal sympathetic arcs was demonstrated by Perl and co-workers [10]. In their experiments, single stimulation of the splanchnic nerve in spinal animals produced as an after-effect a lowering of excitability of preganglionic neurons lasting for 200 msec. Hence it follows that vasomotor reflexes in spinal animals may reach their maximum in response to stimulation of a frequency of about 5/sec. In fact, the number of preganglionic sympathetic neurons in spinal cats excited by stimulation of A-fibers of somatic nerves is reduced if the frequency of stimulation exceeds 4-10/sec [5].

Changes in vasomotor reflexes in spinal animals are thus probably determined by increasing inhibition in spinal arcs. Consequently, one of the important functions of supraspinal structures must be to depress spinal inhibition.

LITERATURE CITED

1. G. A. Kovaleva, Byull. Éksperim. Biol. i Med., No. 1, 14 (1952).
2. V. A. Lebedeva, Mechanisms of Chemoreception [in Russian], Moscow-Leningrad (1965).
3. R. S. Sonina, Proceedings of the 11th Conference of Junior Research Workers of the Institute of Normal and Pathological Physiology, AMN SSSR [in Russian], Moscow (1965), p. 69.
4. V. M. Khayutin, Vasomotor Reflexes [in Russian], Moscow (1964).
5. C. M. Brooks, Am. J. Physiol., 106, 251 (1933).
6. W. S. Beacham and E. R. Perl, J. Physiol. (Lond.), 173, 431 (1964).
7. C. B. B. Downman and B. A. McSwiney, J. Physiol. (London), 105, 80 (1946).
8. L. Fedina, A. Ja. Katunski, V. M. Khayutin, et al., Acta Physiol. Acad. Sci. Hung., 29, 157 (1966).
9. A. Fernandez de Molina and E. R. Perl, J. Physiol. (London), 181, 82 (1965).
10. D. N. Franz, M. H. Evans, and E. R. Perl, Am. J. Physiol., 211, 1292 (1966).
11. J. N. Langley, J. Physiol. (London), 59, 233 (1924).