LOCAL MORPHOPHYSIOLOGICAL ORGANIZATION OF THE BULBAR VASOMOTOR CENTER

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Neurons participating in vasomotor regulation have a metameric organization at the bulbar level. Stimulation of these neurons, depending on the parameters used, more effectively activates preganglionic sympathetic neurons of segments concerned with the innervation of blood vessels of the small intestine in some cases, and those connected with the limb vessels in others. The local character of vasomotor regulation is determined by morphological structural features of the vasomotor center.

Experimental results obtained by studies of the bulbar vasomotor center (BVC) suggest a local organization of this center in which certain zones are responsible for changes in vascular tone principally in a particular region of the vascular system [8, 9, 15]. Some observations along these lines have been published previously [2, 6, 10, 13, 16].

The object of the present investigation was to make a more detailed experimental analysis of the local (metameric) organization of the bulbar BVC.

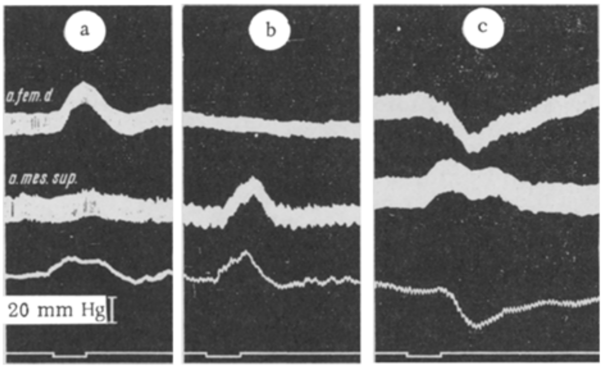

Fig. 1. Regional character of vascular response to stimulation of individual structures of the bulbar BVC. a) Ventral reticular nucleus; b) gigantocellular reticular nucleus; c) nucleus of tractus solitarius. From top to bottom: resistograms of vessels of hind limb and small intestine, arterial pressure, marker of stimulation (10 sec).

EXPERIMENTAL

Experiments were carried out on 80 unanesthetized cats immobilized with diplacin. The preparatory operation was performed under ether anesthesia. Changes in perfusion pressure of blood vessels of the hind limb and small intestine were recorded resistographically [11].

Insulated microelectrodes 30-50 μ in diameter were used for local unipolar stimulation of structures of the rhombencephalon. In most experiments the parameters of stimulation were identical (60/sec, 1 msec, 2V). In some experiments the amplitude or frequency of stimulation was varied. In each case the location of stimulation was determined histologically and identified from an atlas of the cat medulla [3]. The method was described in detail previously [4, 5]. Changes in resistance of the vessels (ΔR) relative to the reserve of resistance and the coefficient of utilization of potential vasoconstrictor ability (K) were calculated from experimental data given in Khayutin's monograph [12].

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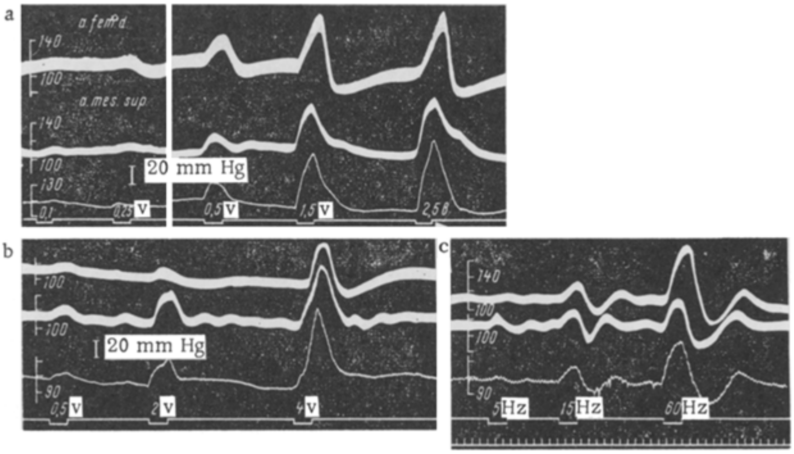

Fig. 2. Potentiation of regional pressor responses during a gradual increase in intensity (a, b) or a change in frequency (c) of stimulation. From top to bottom: resistograms of vessels of hind limb and small intestine, arterial pressure, marker of stimulation (10 sec), time marker (5 sec). Numbers above marker of stimulation give its intensity (a, b) and frequency (c).

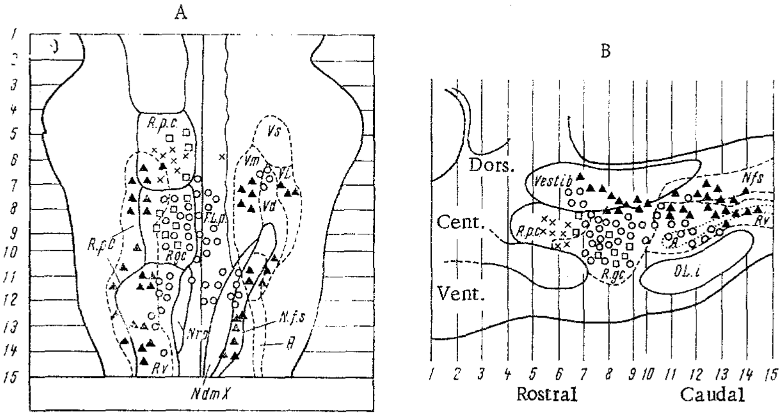

Fig. 3. Topographic distribution of zones of predominant changes in vascular tone of the hind limb or small intestine on the plane of the floor of the fourth ventricle (A) and in a sagittal section through the rhombencephalon (B). Black triangles denote changes predominantly in vessels of hind limb; clear circles—changes mainly in vessels of small intestine; clear squares—an identical change in vascular tone of both regions; X indicates absence of regional changes ("zero" points). Lines 1-15 on the diagrams correspond to sections through the cat rhombencephalon in Gantyn's atlas [2]. R.p.c.) caudal reticular pontine nucleus; Rgc) reticular gigantocellular nucleus; Rv) reticular ventral nucleus; R.pC) reticular parvocellular nucleus; Nvp) reticular paramedian nucleus; Vestib) vestibular nuclei: VS superior, VL lateral, Vm medial, Vd descending; N.f.s.) nucleus of tractus solitarius; NdmX) motor nucleus of vagus nerve; A) nucleus ambiguus; F.L.p) posterior longitudinal bundle; OL. i) inferior olive; Dors., dorsal part; Cent., central part; Vent., ventral part of rhombencephalon.

EXPERIMENTAL RESULTS AND DISCUSSION

The increase in resistance of the hind-limb vessels during stimulation of the ventral reticular nucleus was considerable ($\Delta R = 133$, $K = 20$), but the vascular tone of the small intestine was unchanged (Fig. 1a). Opposite effects are shown in Fig. 1b. During stimulation of the gigantocellular reticular nucleus, a marked pressor response of the intestinal vessels occurred ($\Delta R = 140$, $K = 33$) with no change in vascular tone in the hind limb. In a series of observations when 60 points of the bulbar reticular formation were stimulated, regional responses of this type occurred in one of the recorded vascular zones, with no change in the other zone, in 15 cases.

Under the conditions of local unipolar stimulation used in the experiments the zone of active stimulation (for above-threshold stimuli of 0.5-2 V) did not spread beyond 250 μ. In repeated control experiments, displacement of the electrode by 200-500 μ led to definite changes in the character of the response, and sometimes to its distortion. In the zone of the medial reticular nuclei (gigantocellular, ventral, etc.), where pressor points of the BVC are principally located [5, 15], large and giant-cell neurons with axons forming the reticulospinal tract are grouped together in small clusters of 2-4 cells [7, 20]. The powerful interweaving dendrites of these cells form an extensive honeycomb inside which are situated small cells with processes ramifying between the dendrites. The large number of synapses per unit surface area of these neurons, the presence of long axons, and the resemblance to motoneurons of the spinal cord suggest that these clusters of large reticular neurons are functional units for effector processes. They are specific collectors on the path to preganglionic sympathetic neurons at the segmental level.

During stimulation of the tractus solitarius and central descending tracts (the posterior longitudinal bundle, etc.) changes in vascular tone in opposite directions may be obtained simultaneously (in 21 cases): a decrease in resistance of the hind limb vessels and an increase in resistance of the intestinal vessels (Fig. 1c) or vice versa.

With stronger stimulation of pressor points of the bulbar BVC, the regional character of the vascular response was lost. A pressor response also developed in the other vascular zone. As a rule, the response remained more marked in the zone with the lower threshold of the pressor response (Fig. 2a, b). A change in the frequency of stimulation could give rise to more marked constriction of vessels also in the zone where the response appeared later (Fig. 2c).

Generalization of the vascular response with an increase in the intensity of stimulation was due, on the one hand, to involvement of many neuron groups at the bulbar level, possibly connected with particular spinal segments; on the other hand, it may be due to a higher degree of activation of the propriospinal system of the spinal cord, connecting preganglionic sympathetic neurons in different segments [17].

The relative values of the increase in resistance of the vessels of the hind limb and small intestine in response to stimulation of pressor zones of the BVC are shown in Table 1. From the results of experiments on 30 cats in which 60 points of the medulla were stimulated, responses (26 cases) when the resistance increased more either in blood vessels of the limb (group 1) or in vessels of the small intestine (group 2) with a constant intensity of stimulation (2 V) were selected and grouped together.

It follows from Table 1 that vessels of the hind limb utilize their reserve of potential vasoconstrictor ability (K) to a lesser degree than vessels of the small intestine, even in cases when their response is predominant.

In the absence of suprasegmental activation, preganglionic sympathetic neurons of the spinal cord generate discharges at a frequency of 1-9/sec [14]. In the presence of stimulation of suprasegmental structures, the firing rate of sympathetic neurons recorded in the splanchnic nerve is increased [18, 19]. As Khayutin [12] showed, the statistical characteristics of blood vessels of the skeletal muscles and viscera are essentially indistinguishable for frequencies of constrictor impulses exceeding 1-2/sec, so that the differences shown in Table 1 cannot be due to peripheral mechanisms. Hence it follows that descending influences arising in response to stimulation of individual points of the bulbar BVC in some cases activate preganglionic sympathetic neurons of segments connected with the innervation of blood vessels of the small intestine more effectively, and in other cases those connected with the limb vessels.

The topographic distribution of pressor zones of the BVC responsible for changes in vascular tone predominantly in the small intestine or hind limb was analyzed on the basis of stimulation of 240 points in the medulla in experiments on 80 cats. The main results are shown in Fig. 3 and Table 2.

TABLE 1. Increase in Resistance (ΔR) of Vessels (in percent of initial level) and Coefficient of Utilization of Potential Vasoconstrictor Ability (K) during Stimulation of Different Points of Pressor Zone of BVC by Stimuli of Equal Intensity (2 V)

	Group I				Group 2			
	ΔR	$\pm m$	n	K	ΔR	$\pm m$	n	K
Vessels:								
Of hind limb	182,5	7,4	12	51,2	150	10,8	14	31,2
Of small intestine	153,3	7,4	12	42,0	191,6	12,2	14	72,2
Arterial pressure (in mm Hg)	165± ± 10,1	10,1	12		180±9,8		14	

Legend, here and in Table 2: n denotes number of experiments.

TABLE 2. Increase in Resistance (ΔR) of Vessels (in percent of initial level) and Coefficient of Utilization of Potential Vasoconstrictor Ability (K) during Stimulation of Different Medullary Structures

Structure	Vessels of hind limb				Vessels of small intestine				Arterial pressure (in mm Hg)
	ΔR	$\pm m$	n	K	ΔR	$\pm m$	n	K	
Gigantocellular reticular nucleus (sections 7-10)									
Central part	150	12	11	31,2	195	13	11	79,1	179±10
Ventral	131	8	11	19,3	131	7	11	25,8	142±10
Ventral reticular nucleus									
Dorso-caudal part (sections 11-12)	187,5	21,4	6	54,3	158,3	17,8	6	45	175±19,6
Ventral part (sections 11-12)	140	12,1	6	25	164,1	13,6	6	53,3	163±18,1
Parvocellular reticular nucleus (sections 7, 8, 11-14)	162,5	16,0	6	38,7	141,6	16,0	6	31,7	160±21,4
Medial vestibular nucleus (sections 7, 8)	175	10,8	5	47	150	10,8	5	39,6	178±10,8
Descending vestibular nucleus									
Rostral part(sections 7, 8)	108,3	1,4	4	5	118,3	5,7	4	15	120±5,7
Caudal part (sections 10-12	133,3	17,2	3	20,6	125	17,2	3	19,8	136±26,0
Nucleus of tractus solitarius									
Tractus solitarius (sections 11-14)									
Dorsal part	163,3	10,6	7	39,3	135	7,5	7	27,6	170±15,1
Ventral	150	22,8	4	31,2	166,6	22,8	4	55,8	180±31,4
Posterior longitudinal muscle	150	12,5	6	31,2	183,3	17,8	6	69,1	161±25

Note: Serial number of sections of rhombencephalon corresponds to those used in Fig. 3.

During stimulation of the central part of the gigantocellular reticular nucleus, i.e., zones in which large and giant neurons are mainly concentrated, the absolute increase of resistance was greater in vessels of the small intestine. When expressed as the coefficient of utilization of potential vasoconstrictor ability, the greater response of vessels of the small intestine (K = 79.1) compared with the vessels of the hind limb (K = 31.2) becomes still more apparent. In the ventral part of this nucleus, where small reticular neurons are mainly located, the response of the intestinal vessels was still relatively greater but the amplitude of the responses was lower.

Within the ventral reticular nucleus there is a clear division into two zones: dorso-caudal and ventral. During stimulation of the first the increase in resistance was more marked in vessels of the hind limb, and during stimulation of the second, in vessels of the small intestine.

Stimulation of the parvocellular reticular nucleus and medial vestibular nucleus was accompanied by more marked vasoconstriction in the hind limb, while stimulation of the descending vestibular nucleus in its rostral part was accompanied by vasoconstriction of the small intestine.

By the use of particular parameters of stimulation, a metameric organization of the pressor zone of the BVC was thus revealed. This can be seen particularly clearly in Fig. 3, showing a diagram of the floor of the fourth ventricle and a sagittal section through the rhombencephalon. Zones in which changes in vascular tone in the hind limb predominate (black triangles) run dorso-caudally (Fig. 3b), with a preferential distribution in lateral parts of the rhomboid fossa (Fig. 3a). Zones where changes in vascular tone occurred predominantly in the small intestine (clear circles) occupy the ventro-medial portions and are more concentrated in the rostral part of the medulla.

It follows from the results in Table 2 and Fig. 3 that the topographic representation of points of a predominant vasomotor response in the small intestine is fairly extensive. However, it must not be concluded from this that all these zones are in fact concerned with regulation of vascular tone in the small intestine only. Changes in resistance of the vessels in other viscera were not recorded. It is possible that clusters of cells capable of activating preganglionic sympathetic neurons in different segments (at the level of emergence of the splanchnic nerve) and of producing isolated changes of vascular tone in other internal organs, may be represented in the gigantocellular, reticular, ventral, and other nuclei.

All the medullary structures described above cannot, of course, be included in the "pressor zone" of the BVC [1]. Besides changes in vascular tone, many other functional manifestations are found (changes in respiration, changes in tone of the smooth muscle of the urinary bladder and intestine, facilitation and inhibition of segmental somatic reflex reactions, and so on), variously due to activation of functionally different neurons in particular segments of the spinal cord. It must therefore be concluded from these facts that a certain functional-topographic differentiation exists among neurons in the bulbar region. Particular areas of the bulbar reticular formation are evidently connected principally with particular segments of the spinal cord.

The local character of vasomotor regulation is determined by the character of morphological organization of the BVC and it is maintained only within certain limits of intensity of physiological activation. The metameric nature of functional organization of the BVC makes it possible for separate changes of tone to take place in different vessels, during either reflex or suprabulbar activation, and in this way the circulation can be adapted to the different functional requirements of the organism.

LITERATURE CITED

1. A. V. Val'dman (Editor), Current Problems in Pharmacology of the Reticular Formation and Synaptic Transmission [in Russian], Leningrad (1963).
2. A. I. Vyshatina, Fiziol. Zh. SSSR, No. 9, 1133 (1967).
3. A. A. Grantyn', in: Current Problems in Pharmacology of the Reticular Formation and Synaptic Transmission [in Russian], Leningrad (1963), p. 165.
4. A. V. Val'dman (Editor), Investigations into Pharmacology of the Reticular Formation and Synaptic Transmission [in Russian], Leningrad (1961).
5. G. V. Kovalev and M. G. Bondarev, Fiziol. Zh. SSSR, No. 9, 101 (1962).
6. G. V. Kovalev, in: Proceedings of the 10th Congress of the I. P. Pavlov All-Union Physiological Society [in Russian], Vol. 2, No. 1, Moscow–Leningrad (1964), p. 386.
7. N. S. Kosytsyn, Dokl. Akad. Nauk SSSR, 145, 920 (1962).
8. M. E. Marshak, Vestn. Akad. Med. Nauk SSSR, No. 4, 37 (1966).
9. F. V. Ovsyannikov, Selected Works [in Russian], Moscow (1955), p. 57.
10. A. V. Potebnya, Functional Organization of the Vasomotor Center of the Medulla. Author's Abstract of Candidate's Dissertation [in Russian], Aldan (1968).
11. V. M. Khayutin, Fiziol. Zh. SSSR, No. 7, 645 (1958).
12. V. M. Khayutin, Vasomotor Reflexes [in Russian], Moscow (1964).
13. V. L. Tsaturov, Dokl. Akad. Nauk SSSR, 137, 480 (1961).
14. V. A. Tsyrlin, in: Regulation of the Regional Circulation [in Russian], Leningrad (1965), p. 56.
15. R. S. Alexander, J. Neurophysiol., 8, 205 (1946).
16. V. S. Aoki and M. Brody, Circulat. Res., 18, No. 6, Suppl. 1, 73 (1966).
17. S. T. Bok, in: W. Möllendorf (Editor), Handbuch der Mikroskopischen Anatomie des Menschen, Vol. 4/1, Berlin (1928), p. 478.

18. N. Kahn and E. Mills, J. Physiol. (London), 191, 339 (1967).
19. R. F. Pitts and D. W. Bronk, Am. J. Physiol., 135, 504 (1941/42).
20. F. Valverde, J. Comp. Neurol., 11, 71 (1961).