VASOMOTOR CONTROL MECHANISMS

COMMUNICATION I. CORRELATION OF SYSTEMIC AND REGIONAL VASOMOTOR REFLEXES DURING STIMULATION OF CERTAIN INTEROCEPTIVE ZONES

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The changes in the arterial pressure which arise during stimulation of numerous interoceptive zones are due, as we know, to a reflex alteration in the lumen of the blood vessels under the control of vasomotor fibers. These reflexes may be called systemic, since they affect the circulatory system as a whole. The systemic reflexes are an integral reaction caused by aggregation of regional vasomotor reflexes taking place in several different vascular regions.

A number of results obtained in previous investigations [4-6] led us to the view that behind the outwardly standard character of the systemic reflexes there are hidden various complexes of regional vasomotor reflexes whose specific features are determined by the appearance locally of afferent signals. During prolonged stimulation of an interoceptive zone the afferent impulses gradually lose their effectiveness in consequence of the appearance of inhibition in the central link in the reflex arc; this inhibition is, however, localized to this particular arc and does not prevent the appearance of systemic reflexes from other zones. This phenomenon permits speculation on the presence of definite "projections" of the interoceptive zones in the vasomotor regulatory centers and suggests that there are differences in the efferent structure of the systemic reflexes arising from different zones.

This is demonstrated by the results of a number of investigations. According to Bernthal and Swind [9], stimulation of the carotid and aortic chemoreceptors diminishes the blood flow in the brachial artery of dogs significantly more than in the vessels of the small intestine. T. S. Lagutina showed that stimulation of the mechanoreceptors of the urinary bladder causes a change in the pattern of impulses in the efferent fibers of the mesenteric and renal nerves and of the subcutaneous, hypogastric and cervical sympathetic nerves, and moreover the intensity and direction of the changes in the efferent impulses are regularly determined by the strength of stimulation of the mechanoreceptors. A. M. Blinova, G. N. Aronova and K. E. Serebrianik [1] discovered a somewhat differnt change in the resistance in the vascular channels of the mesenteric, femoral and renal arteries during what outwardly appeared to be a homogeneous systemic reaction – an increase in the general arterial pressure in response to stimulation of the hypothalamus or compression of the carotid arteries. A systematic study of the reflex connections between the interoceptive zones and the vessels in different organs would, in our view, aid in our understanding of the mechanisms of vasomotor control.

EXPERIMENTAL METHOD

A quantitative estimation of regional vasomotor activity is usually made with the aid of measurement of the blood flow in the vascular region under investigation. However in a simultaneous investigation of the changes in the arterial pressure (systemic reflex) and in the lumen of the vessels in individual organs (regional reflexes), registration of the rate of the blood flow leads to indeterminate results, demanding further interpretation of the values of hemodynamic and vasomotor factors in the blood supply of the organ.

Considerations such as these led us to the necessity of using a method which would enable the quantitative estimation of the regional vasomotor activity from the resistance shown by the vessels to the flow of blood [7]. The principle of this method, which we called the method of "resistography,"* consists of stabilization of the rate of the blood flow in the organ under study by means of a special perfusion pump [8].

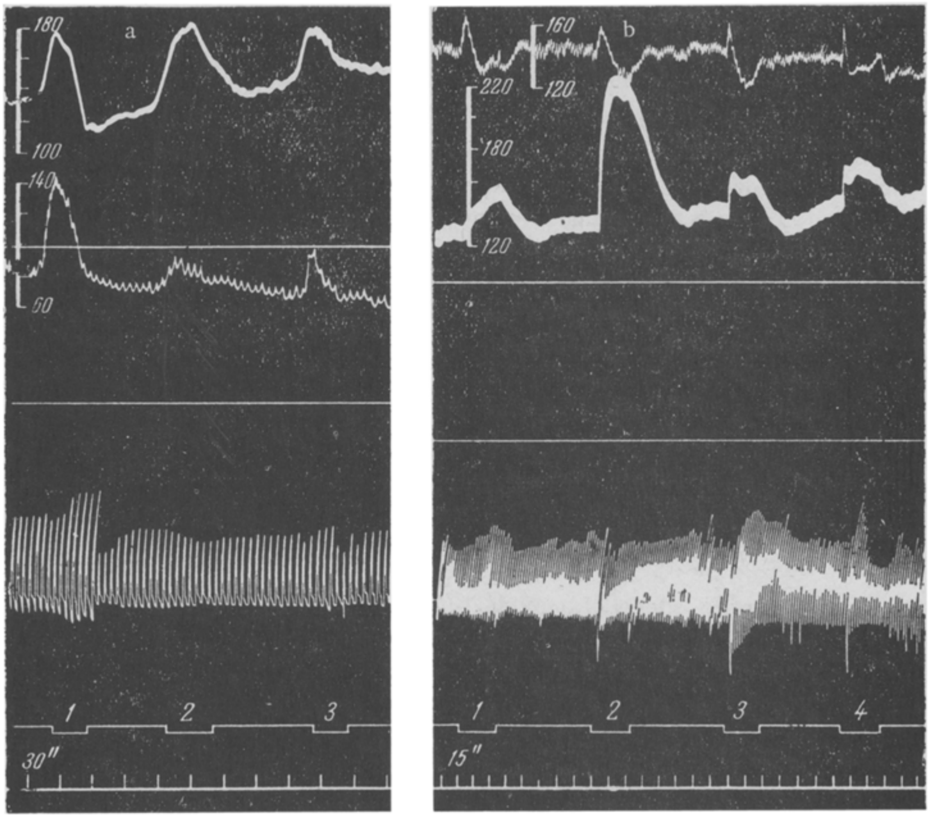

Fig. 1. Systemic and regional reflexes (a – on the walls of the branches of the superior mesenteric artery, b – on the renal vessels) during stimulation of mechanoreceptors: 1) of the carotid sinus; 2) of the large intestine (distension with air at a pressure of 100 mm mercury); 3) of the tibial nerve (intensity: a = 6v; b = 4v); 4) of the mechanoreceptors of the urinary bladder (pressure 60 mm mercury). Significance of the curves (from above downwards): a) perfusion pressure; its zero line, general arterial pressure (mercury manometer), its zero line, respiration, stimulation marker, time marker (30 seconds); b) general arterial pressure, perfusion pressure, zero lines (remainder as in tracing a), time marker (15 seconds).

By drawing blood from the proximal end of the artery supplying the organ and injecting it into the distal end of the artery, i.e. by carrying out autoperfusion, the pump maintains the minute volume of blood flow at a constant level. The perfusion pressure, recorded by a mercury manometer in the outlet of the pump, is in this case a function of the resistance of the vascular system of the organ, which is mainly determined by the size of the lumen of the arterioles, and consequently by the degree of vasomotor activity. Thanks to the constancy of the blood flow, a diminution in the lumen of the arterioles (increase in the resistance of the vessels) leads to a rise in the perfusion pressure, and dilatation of the arterioles (diminution of resistance) is accompanied by a fall in the perfusion pressure.

*We propose this term by analogy with the terms "plethysmography" and "rheography."

Experiments were carried out on cats under general anesthesia (urethane – 0.5 g/kg and chloralose – 0.03 g/kg). The arterial pressure (in the carotid artery) and the respiration were recorded in the usual way. In the first series of experiments using the method of resistography the resistance of the vessels in a loop of small intestine was measured. In order to exclude any collateral circulation the loop of small intestine was isolated from neighboring areas and the anastomosing branches of the superior mesenteric artery were ligated. In the second series of experiments measurements were made of the resistance of the vessels of the left or right kidney by autoperfusion of the vascular system of the organ through the renal artery. Heparin was used as an anticoagulant (given intravenously in a dose of 7.5 – 12.5 mg/kg).

In both series of experiments the mechanoreceptors of the large intestine and the urinary bladder were stimulated by distension of the organs with air, and the receptor zone of the carotid sinus (by compression of the carotid artery). The central end of the tibial nerve was stimulated by an alternating current with a frequency of 50 cps, the tension at the electrodes being controlled by a voltmeter. In the first series of experiments the mechanoreceptors of a loop of small intestine, proximal to the perfused area, was also stimulated. The stimulation of all these zones and nerve was repeated 3-4 times in the experiment, after which the vagus nerves on both sides were divided in the neck, and further stimulation applied. The duration of these last stimuli was usually 30 or 60 seconds. A strength of stimulation was selected which, as a rule, was adequate for producing perceptible reflexes affecting the arterial pressure.

EXPERIMENTAL RESULTS

As can be seen in Fig. 1, a, stimulation of the receptors of the carotid sinus and large intestine and of the afferent fibers of the tibial nerve causes both systemic and regional vasomotor reflexes which are registered in the superior mesenteric artery. It is characteristic, however, that the more powerful systemic reflexes from the carotid sinus and the tibial nerve (64 and 32 mm mercury) are accompanied by less pronounced regional reflexes (43 and 35 mm mercury). Meanwhile during stimulation of the mechanoreceptors of the large intestine, causing the smallest systemic reflex (22 mm of mercury), the largest regional reflex is produced (60 mm mercury).

Thus the degree of the reflex effects of individual interoceptive zones on the vessels of that particular region is not the same. Can this be connected with differences in the strength of stimulation ? Direct comparison of the physical force of stimulation of different receptor zones, caused by different methods (distension of the walls of hollow organs, compression of the carotid artery, electrical stimulation of afferent fibers) is impossible; at the same time the effective strength of the stimulus may be estimated by the magnitude of the systemic reflex on the arterial pressure.

Magnitude of the Regional Reflexes in % of the Value of the Systemic Reflexes, Taken as 100% (mean results of all experiments)

Receptor zone	Vessels			
	of the kidney		of the superior mesenteric	
	%	number of observations	%	number of observations
Carotid sinus	49	16	53	18
Tibial nerve	51	14	66	24
Urinary bladder	121	17	130	9
Large intestine	272	6	178	25
Small intestine	–	–	350	13

Taking the magnitude of each systemic reflex as 100%, the magnitude of the corresponding regional reflex can be related to it (measured under conditions of resistography, in millimeters of mercury). In this case the regional reflex from the carotid sinus is found to be 67% of the magnitude of the systemic reflex appearing at the same time, and the regional reflex from the tibial nerve is 109% of the magnitude of the corresponding systemic reflex. The magnitude of the regional reflex from the receptors of the large intestine reaches a value of 252% of its corresponding systemic reflex.

The accuracy of this method is confirmed by Fig. 1,b, in which are shown tracings of the systemic and regional reflexes on the vessels of the kidney. In this experiment the differences in the power of the effects of the different interoceptive zones are shown particularly clearly, since in this particular animal the systemic reflexes from all four zones were almost equal. The maximum effect on the renal vessels arises from the receptors of the large intestine, reaching 100 mm mercury, and is 500% of the magnitude of the pressor phase of the systemic reflex. Corresponding values for other zones are as follows: carotid sinus – 15%, tibial nerve – 150% and urinary bladder – 123%.

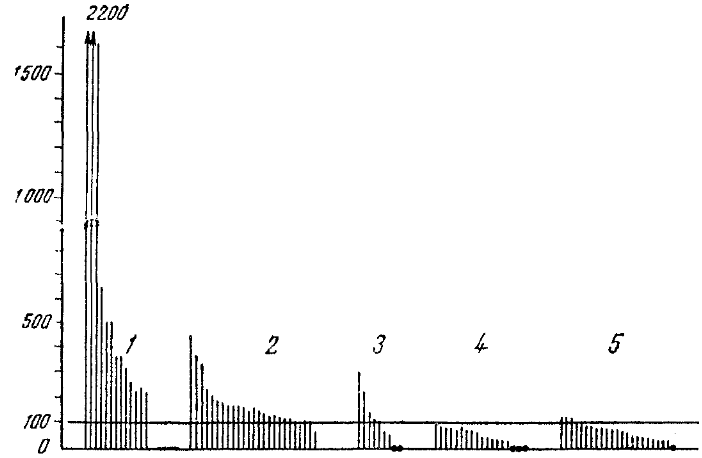

Fig. 2. The percentage relationship between the values of the systemic and regional reflexes on the vessels of the area supplied by the superior mesenteric artery (along the ordinate axis). The magnitude of the systemic reflex in each individual observation is taken as 100%. Along the axis of the abscissae – groups of reflexes resulting from stimulation of: 1) an area of the small intestine, 2) of large intestine, 3) urinary bladder, 4) carotid sinus, 5) tibial nerve. Results are from different experiments. Points along the axis of the abscissae – regional reflex absent.

The perfect regularity of the relationships between the systemic and regional reflexes for each interoceptive zone is shown convincingly by the curves which summarize the results of all the experiments of both series (Figs. 2 and 3) and the mean results which are shown in the Table.

The characteristic relationships between the systemic and regional reflexes for particular interoceptive zones are preserved also after bilateral division of the vagus nerves in the neck.*

It has to be pointed out that the regional reflexes recorded in the superior mesenteric artery arise as a result of constriction of the vessels of the small intestine and the portal vessels of the liver. In 2 experiments we measured the resistance of the vessels of the intestinal loop alone, by connecting a suitable branch of the mesenteric vein with a chlorovinyl tube to the external jugular vein. This naturally affected the absolute value of the regional reflexes, and correspondingly, their relationship to the systemic reflexes. However these relationships for each individual reflexogenic zone maintained the same order which corresponds to the mean results given in the Table.

Thus stimulation of different interoceptive zones, because of their dissimilar connections with the vessels of different organs, must lead to the appearance of unequal complexes of regional reflexes. The more or less

*This operation was carried out in order to minimize the possibility of an effect by the cardiac component on the magnitude of the systemic reflex. Simultaneous exclusion of the influence of the aortic reflexogenic zone slightly altered the absolute values of the systemic and regional reflexes, but did not noticeably affect the relationship between these values.

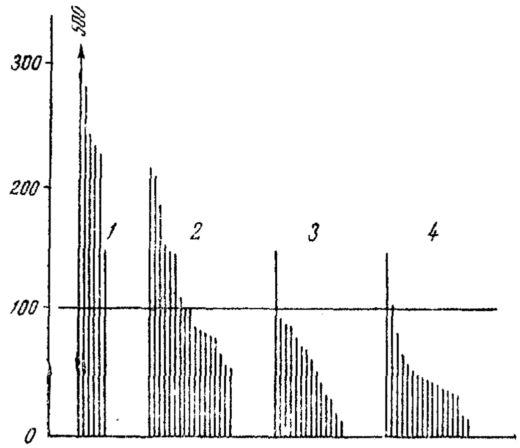

Fig. 3. Percentage relationship between the values of the systemic and regional reflexes on the vessels of the kidney (along the ordinate axis). The magnitude of the systemic reflex in each individual observation is taken as 100%. Along the axis of the abscissae – groups of reflexes resulting from stimulation of: 1) large intestine 2) urinary bladder, 3) tibial nerve, 4) cartoid sinus.

constant ratio between the values of the systemic and regional reflexes in different animals demonstrates the considerable degree of constancy of the complex generated by afferent signals from a particular zone.

It is known that stimulation of afferent fibers of different nerves in the limb excites a different number of motor neurones from the sum total making up the motor nucleus of the particular skeletal muscle (the principle of fractionation [3]). The facts described suggest that this principle is applicable to the vasomotor reflex, thereby indicating the existence of specific nuclei responsible for reflex control of the vessels of the various organs. At the present time it is not possible to state definitely whether these nuclei correspond to spinal preganglionic neurones or whether they are found in the bulbar vasomotor center. However it is clear that fractionation of vasomotor reflexes, with a different degree of connection between the interoceptive zones and the vessels of the individual organs, suggests some limitation on the spread of excitation, characteristic for each interoceptive zone, in the centers of these reflexes.

To counter the spatial conception of Cannon of the unrestricted irradiation of excitation in the sympathetic nervous system, Schweitzer [10] and Hellhorn [2] put forward the hypothesis of a more selective spread of excitation in its central divisions, suggesting that this was associated with differences in "synaptic resistance." The results of previous investigations [4-6] and also a number of new findings which we shall report in later articles, show that limitation of irradiation of excitation is determined by the simultaneous appearance of processes of inhibition and that limitation of irradiation of the reflexes has both a morphological and a functional basis.

SUMMARY

The author investigated the relationship of reflexes on arterial pressure (systemic) and regional reflexes on the blood vessels of kidneys and a portion of small intestine caused by stimulation of mechanoceptors of the urinary bladder, large and small intestine, carotid sinus and the tibial nerve. The regional reflexes were registered by the method of resistography (autoperfusion with stabilized minute blood volume). A definite relationship exists between the values of systemic and regional reflexes elicited from each receptor zone. These data show the existence of definite complexes of regional vasomotor reflexes caused by stimulation of the given interoceptive zone and point out the fractionation of reflexes in the centers of vasomotor regulation.

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