THE RELATION BETWEEN REFLEX CHANGES OF THE SYSTEMIC AND LOCAL CIRCULATION

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The problem of the relationships between local and systemic changes in circulation can properly be considered one of the central problems in the physiology and pathology of the cardiovascular system.

Present-day physiology has collected an enormous amount of information concerning the characteristics of the reflex mechanisms that ensure adjustment of the cardiovascular system to the constantly changing conditions of the organism's activity. But it often has not been taken into account that the systemic hemodynamic indices are the net result of extremely diverse local circulatory changes. This state of affairs has been discussed repeatedly by clinicians.

It is therefore not difficult to understand the interest aroused by the problem of the relationship between the systemic and the regional circulation.

The existence of various interrelations between the systemic and local changes in circulation has already been considered in the work of V. N. Chernigovskii [15], M. E. Marshak [3, 4], V. M Khayutin [11, 12, 13], T. S. Lagutina[1,2], V.L. Tsaturov[14,] and N.K. Saradzhev[5].

V. N. Chernigovskii and V. M. Khayutin developed the conception that individual vascular regions are represented in the vasomotor center. It is their view that the preferential excitation or inhibition of individual groups of neurons connected with one vascular bed or another may arise as a result of activity of part of the vasomotor center.

In elucidating the mechanisms of the systemic and local circulation it is essential, in our opinion, to make a simultaneous comparison of the reactions of several regional vasculatures with the changes in systemic blood pressure, and under a variety of conditions of stimulation of various receptor zones. There is no need for special proof that relationships between the systemic and local circulation can be established by studying the vascular reactions of organs with different functional significance.

METHODS

The experiments were performed on cats and rabbits under urethan (cats) and chloral hydrate (rabbits) anesthesia. Changes in systemic blood pressure and respiration were recorded simultaneously, as well as the activity of the ear vessels and those of the kidney and hindlimb. The systemic blood pressure was recorded from the carotid artery with mercury and spring-type manometers, and respiration with a tracheotomy tube connected to a Marey tambour. The activity of the vessels of the ear, kidney, and hindlimb was studied by the method of perfusion with Ringer-Locke solution to which N. G. Belen'kii's therapeutic serum was added in a 4 : 1 dilution to reduce edema formation.

The perfusion fluid entered the vessels of the organ under constant pressure (80 cm of water) and at constant temperature through a cannula inserted into the corresponding artery (the large auricular, renal, and femoral arteries, respectively), and left through a cannula from the corresponding vein.

The reaction of the vessels was given by the number of drops leaving by way of the vein; as they fell, the drops closed the contacts of a circuit containing a storage battery, a polarizing relay, and an electrical marker.

We studied the changes in the systemic and local circulation accompanying stimulation of receptors of the carotid sinus and the upper respiratory tracts and the tibial and aortic nerves, and also those accompanying transient asphyxia.

RESULTS

The data obtained testify to the extreme diversity of the relationships in the changes of local and systemic vascular tone under reflex influences on the cardiovascular system. To put it differently, one type of change in the systemic blood pressure may result at different times from entirely different distributions of local vascular reactions. But one general rule emerges in the whole diversity of regional changes: there is coordination between the reactions of different vascular beds, directed toward the restoration of the original level of systemic blood pressure.

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* Deceased

Application of stimuli of different intensities and durations to receptor fields and nerves allows us to demonstrate certain stages in the relationships between local and systemic hemodynamic changes.

In a number of experiments, stimulation of the tibial or depressor nerves with a current of subthreshold intensity did not result in changes in the systemic blood pressure, but the tone of individual vascular beds did change.

Even more diverse relationships were found between local reactions accompanying marked changes in the systemic blood pressure. We sometimes observed simultaneous constriction and dilatation of the vessels of different regions, while in other experiments the changes were just the opposite. So, for example, on stimulation of the depressor nerve the reduction in systemic arterial pressure was sometimes accompanied by constriction of the ear vessels and dilatation of the vessels of the hindlimb. On the other hand, some vascular beds (the renal vessels) did not react to stimulation of the depressor nerve.

The reactions of local vascular beds did not always remain constant, even in response to stimulation of the same receptor field. Thus, following stimulation of the tibial nerve we were able to observe constriction of the renal vessels and dilatation of the vessels of the ear or hindlimb; but in other experiments we found the opposite effect. In a large fraction of the experiments, particularly following the application of intense stimuli, we observed a uniform type of change in vascular tone. These experiments confirm the conclusion, drawn by V. M. Khayutin, that there are different connections between different receptor fields and vascular beds. Comparison of the reactions of the vessels of different beds shows that following stimulation of the upper respiratory tracts (inhaling ammonia vapors) and the tibial nerve (induction current), the vessels of the ear and hindlimb are particularly reactive (Fig. 1). In response to stimulation of the carotid sinus receptors (clamping the carotid artery) the greatest changes occur in the renal vessels, and the tone of the ear vessels and those of the hindlimb remains almost unchanged.

The reactions of individual vascular beds display specific differences. Thus, the reaction of the vessels of the hindlimb to stimulation of various receptor fields is marked by a distinct diphasic character. It is well known that stimulation of the tibial nerve is followed by a pressor reaction. But at the beginning of stimulation the hindlimb vessels dilate, as shown by a brief increase in the outflow rate, and then a pronounced vasoconstriction ensues.

This sort of diphasic behavior was not observed in the ear vessels, but here the latent period of the reac-

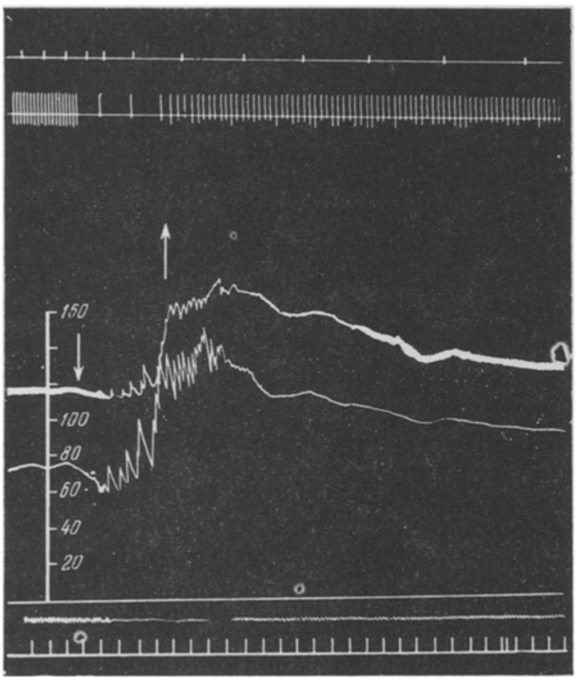

Fig. 1. Changes in systemic blood pressure and tone of vessels of hindlimb and ear in rabbit upon stimulation of upper respiratory tracts with ammonia fumes. Meaning of curves (from top): outflow from vessels of hindlimb and ear, in drops; recording of arterial pressure with membrane manometer and with mercury manometer; zero line for mercury manometer; pneumogram; time marker (5 sec). Arrows point to beginning and end of stimulation.

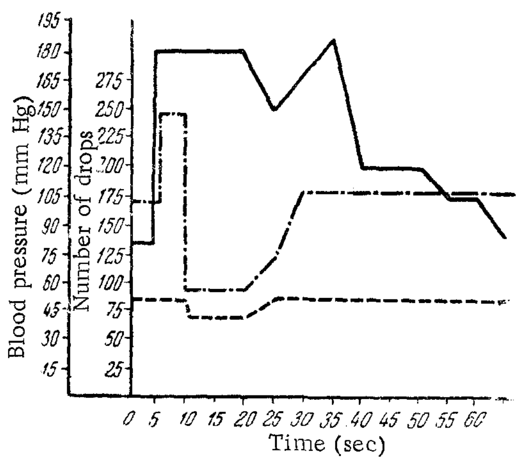

Fig. 2. Changes in systemic arterial pressure and tone of vessels of hindlimb and ear in the rabbit, following stimulation of the tibial nerve. Explanation: abscissa is time (in seconds); ordinate is magnitude of systemic blood pressure (in mm Hg) and number of drops; solid line-changes in systemic arterial pressure; dots and dashes-number of drops flowing out of hindlimb; dotted line-number of drops flowing out of ear vessels.

tion was longer; thus, during the dilatation of the hindlimb vessels the ear vessels did not react (Fig. 2). In mild reactions of the systemic arterial pressure, one can see the variations in the tone of vessels in individual organs.

It is common knowledge that when the application of a stimulus is prolonged the reflexes to the cardiovascular system become weakened-this is known as adaptation of reflex reactions (V. N. Chernigovskii and V. M. Khayutin [16], V. M. Khayutin [10], and V. V. Frol'kis [6, 8, 9]). Study of the changes in local vascular reactions in the course of adaptation enables us to approach one of the components of the mechanism of adaptation.

Adaptation of reflexes proceeds differently for different vascular beds.

Moreover, the vascular reactions of individual organs frequently return to normal before the arterial blood pressure returns to its original level. Restoration

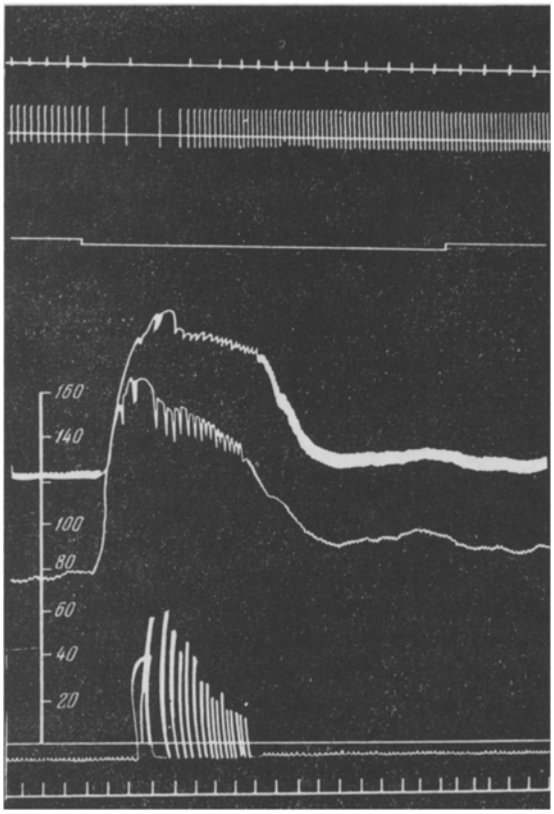

Fig. 3. Changes in systemic arterial pressure and tone of hindlimb and ear vessels in the rabbit during prolonged stimulation of tibial nerve. Meaning of curves (from top); number of drops leaving hindlimb vessels; number leaving ear vessels; stimulus marker; systemic arterial pressure recorded with membrane manometer; same, recorded with mercury manometer; zero line for mercury manometer; pneumogram; time marker (5 sec).

of the original level of arterial blood pressure during adaptation of reflexes may occur as a result of compensatory reactions of individual vascular beds. In Fig. 3 an experiment is presented in which "adaptation" of a reflex was observed during prolonged stimulation of the tibial nerve. In response to stimulation, the vessels of the ear and hindlimb constricted, but while the background of systemic hypertension continued we observed a marked dilatation of the ear vessels: the number of drops leaving the ear per unit time increased sharply. This dilatation occurred at a time when the vessels of the hindlimb were still constricted.

Comparison of the reactions of the systemic and local circulation discloses the extreme diversity and complexity of the changes in the tone of different vascular beds during displacements of the same type in the magnitude of the systemic blood pressure. While the level of arterial pressure remains constant we may observe variations in vessel diameters in only one vascular bed, or opposing shifts-constriction and dilatation-in the reactions of several vascular beds; and we may see numerous variations on the change in regional blood flow while systemic blood pressure rises or falls. The complex relationships of the reactions of individual vascular beds are an important compensatory mechanism directed toward the maintenance of a constant level of hemodynamics.

The reflex changes described above in the blood flow in individual vascular beds confirm the thesis of V. N. Chernigovskii [15] and V. M. Khayutin [12] concerning fractional activity of the vasomotor center. The power of the central mechanisms that regulate the circulation becomes even more evident when we consider the connection of the vascular reactions with changes in the activity of the heart.

At the present time there is reason to consider the whole complex system of central regulation of the circulation as a unit. From this standpoint, a useful view is the view developed by one of us [7] of the hemodynamic center as the complex aggregate of neurons involved in the central regulation of the heart and vessels.

Its activity ensures the diverse changes in the regional circulation, as well as the complete regulation of the cardiovascular system. The concept of the complex dynamics of nervous processes in the hemodynamic center explains the unity of systemic and local changes in blood flow, and shows their connection with changes in cardiac activity.

We can interpret the adaptation of cardiovascular reflexes from the same standpoint. The observed differences in recovery of the tone of various vascular beds, and the development of reactions of opposite character, both confirm the conclusion that inhibition of various degrees and depths develops in the individual parts of the hemodynamic center during adaptation of reflexes. The adaptation of cardiovascular reflexes may be brought about in some cases predominantly through widespread irradiation of inhibition in the hemodynamic center, and in others, through deepening of inhibition in various groups of central neurons.

SUMMARY

The authors studied the changes in the systemic blood pressure and the tone of blood vessels of the ear, kidney, and hindlimb in rabbits and cats. It was shown that a given type of change in the systemic blood pressure may be caused by different interrelationships between the vascular reactions of the organs. During adaptation of cardiovascular reflexes, the tone of different vascular beds varied differently.

LITERATURE CITED

1. T. S. Lagutina, Byull. Éksp. Biol. Med., 7, 3 (1957).†
2. T. S. Lagutina, Byull. Éksp. Biol. Med., 1, 3 (1959).†
3. M. E. Marshak, Abstracts of Conference on the Circulation [in Russian] (Kiev, 1959).
4. M. E. Marshak, Vestnik Akad. Med. Nauk SSSR, 9, 36 (1959).
5. N. K. Saradzhev, Byull. Éksp. Biol. Med., 2, 49 (1958).†
6. V. V. Frol'kis, in: Higher Nervous Acticity and Corticovisceral Interrelations [in Russian](AN USSR, 1955).
7. V. V. Frol'kis, Reflex Regulation of the Activity of the Cardiovascular System [in Russian] (Kiev, 1959).
8. V. V. Frol'kis and A. V. Frol'kis, Fiziol. Zhur. 42, No. 10 (1956).
9. V. V. Frol'kis and A. V. Frol'kis, in: Processes of Fatigue and Recovery of the Organism's Activity [in Russian] (Kiev, 1958).
10. V. M. Khayutin, Materials on the Mechanism of Adaptation of Unconditioned Interoceptive Reflexes [in Russian] (Leningrad, 1952).
11. V. M. Khayutin, Byull. Éksp. Biol. Med., 10, 18 (1958).†
12. V. M. Khayutin, Transactions of the Ninth All-Union Congress of Physiologists [in Russian] (Minsk, 1959).
13. V. M. Khayutin and V. L. Tsaturov, Byull. Éksp. Biol. Med., 2, 17 (1959). †
14. V. L. Tsaturov, Byull. Éksp. Biol. Med., 9, 3 (1959). †
15. V. N. Chernigovskii, Abstracts of Conference on the Circulation [in Russian] (Kiev, 1959).
16. V. N. Chernigovskii and V. M. Khayutin, in: Nervous Regulation of the Circulation and Respiration [in Russian] (Moscow, 1952) pp. 8-22.

† Original Russian pagination. See C. B. translation.