ANALYSIS OF FLUCTUATIONS IN BLOOD VOLUME OF AN ORGAN AND OF PULSE CHANGES IN ITS VOLUME DURING INVESTIGATION OF THE ORIENTING REFLEX

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Investigations of the vascular component of the orienting reaction in man have shown that during a definite change in the total volume of an organ, differences may appear in the character of changes in the pulse waves (the rheogram), and variations in the shape and amplitude of the rheogram waves frequently do not exhibit that characteristic complex which, according to the interpretation widely current in rheography, expresses particular changes in arterial tone. The volume of blood in an organ cannot be estimated from the rheogram, and the functional importance of the shape of the rheographic waves still remains unknown.

According to the propositions of "morphologic plethysmography," widely discussed in the rheographic literature, pulse changes in blood volume reflect primarily fluctuations in the volume of the arterial vessels and the degree of their tonic contraction [1-8]. It is interesting to compare changes in the shape and amplitude of the pulse waves with changes in the total blood volume of an organ. It is usually accepted in rheography [1-3, 5] that an increase in arterial tone is expressed as a decrease in the gradient of the ascending part of the wave, a decrease in its amplitude, the appearance of a plateau at its apex, and upward displacement and decrease in size of the dicrotic wave, while lowering of the arterial tone is characterized by an increase in the amplitude and steepness of the ascending part of the wave, a more pointed shape of the systolic wave, and downward displacement and deepening of the dicrotic wave.

It was justifiably expected that a correlation must exist between changes in the total volume of an organ and pulse changes in its volume, at least during reactions which are considered to be effected through changes in tone of the arterial muscles. An attempt was made to verify this hypothesis during comparative investigation of changes in the digital plethysmogram and rheogram (on neighboring fingers) during the orienting reflex.

EXPERIMENTAL METHOD

Besides the peripheral vascular effect, changes in the rheoencephalogram (REG), respiration,and the EEG were also considered as components of the orienting reflex. Parallel recordings were made on a sensitive ink-writing plethysmograph (digital plethysmogram, respiration) and on an encephalograph (EEG, digital rheogram, rheoencephalogram, sometimes the EKG, and also respiration). A four-channel rheograph with working frequency of 150 kHz was used. One of the rheographic electrodes was applied to the base of the finger on its dorsal aspect, the other on the palmar aspect of the terminal phalanx of the same finger. The REG was recorded by frontomastoid leads. Acoustic stimulation (tone of 1000 Hz, moderate intensity) was applied to the subject in a clear acoustic field and repeated only twice or three times during the investigation, in the course of which other function tests were used. Eight healthy persons and five patients with peripheral nerve lesions (the "healthy" side was tested) were investigated.

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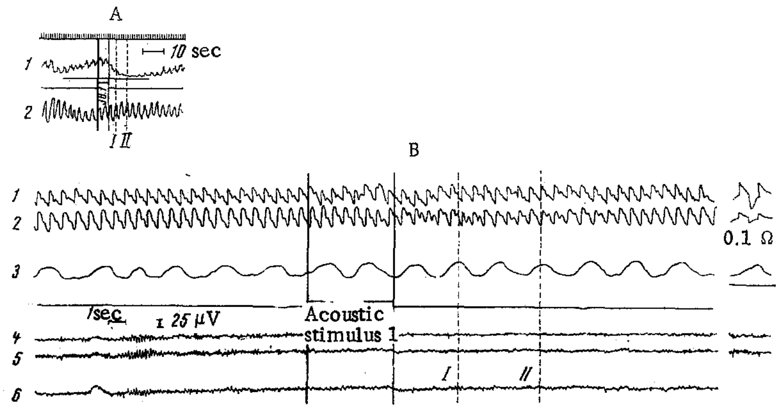

Fig. 1. Vascular orienting reaction to acoustic stimulation in healthy subject: decrease in digital blood volume with simultaneous decrease in amplitude of pulse waves on rheogram and change in their shape characteristic of "lowering of arterial tone." On plethysmograph, A: 1) plethysmogram of left ring finger; 2) respiration (inspiration upward). Above: time marker (in sec); in middle, marker of acoustic stimulation. On electroencephalograph, B: 1) rheoencephalogram (fronto-mastoid lead); 2) rheogram of left middle finger; 3) respiration (inspiration upward); 4, 5, 6) EEG (transverse occipital, transverse parietal, and transverse postfrontal leads, respectively). Broken vertical lines in A and B denote identical moments of recording.

EXPERIMENTAL RESULTS AND DISCUSSION

In response to acoustic stimulation as a rule a characteristic response of diminution of the blood volume of the finger is discovered, reflected on the plethysmogram. On the rheogram at this time, various changes in shape and amplitude of the pulse waves can be observed; these do not correspond to what is usually interpreted as an expression of "increased vascular tone," although this apparently would be expected.

Hence, in the plethysmogram given in Fig. 1 the typical picture of a degree in blood volume in response to the first presentation of the acoustic stimulus to a healthy woman aged 25 years can be seen. The amplitude of the pulse waves by the end of stimulation is reduced, but their shape not only shows no sign of "increased tone," but changes in the direction characteristic of a "decreased tone" –tapering of the systolic wave and deepening of the dicrotic wave (the beginning of which is displaced upward or downward depending on the phase of the respiratory cycle)–are observed. If changes in the shape of the pulse waves are examined, it will be concluded from comparison of the digital plethysmogram and rheogram that the decrease in blood volume in response to acoustic stimulation develops in the presence of a lowering of arterial tone. However, the decrease in amplitude of the ascending part of the wave cannot be explained from this point of view unless a decrease in the systolic output of the heart is assumed.

At the lowest point of the plethysmographic response of a decrease in blood volume, the "tone" (judging from the shape of the rheogram waves) starts to increase—the systolic wave is less pointed, the dicrotic wave is appreciably shifted upward. These changes in shape of the pulse waves reach a maximum during an increase in blood volume, i.e., during recovery of the plethysmogram after the response to acoustic stimulation. At this same time a definite increase in amplitude of the ascending part is observed, and it again cannot be reconciled with the usual rheographic pattern.

Hence, in this example, changes in the shape of the rheographic waves interpreted according to the most widely held views of "morphologic plethysmography" do not confirm that the decrease in peripheral blood volume in the orienting reaction takes place, as may be expected, on account of reflex constriction of the arterioles. Meanwhile, the dynamics of the change in amplitude of the rheographic waves does not contradict this concept of the mechanism of the vascular orienting reflex.

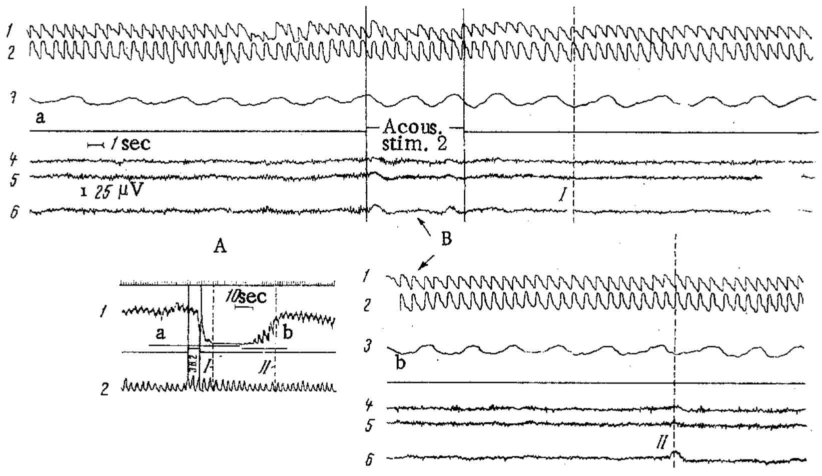

Fig. 2. Orienting reaction to repeated acoustic stimulation of the same subject; at moment of decrease of digital blood volume, amplitude of pulse waves rises, and their shape changes to correspond to an "increase of tone" (remainder of explanation in text). a and b) Underlined segments of plethysmogram corresponding to segments of recording on electroencephalograph. Remainder of legend as in Fig. 1.

The direction of changes in the amplitude of the pulse waves on the rheoencephalogram during the response to acoustic stimulation is similar to that observed on the digital rheogram: their shape, although slightly modified by the action of acoustic stimulation, is generally speaking much more stable than on the peripheral rheogram.

The problem of the functional significance of changes in the shape of the pulse waves is further complicated by the fact that the decrease in blood volume against the background of the orienting reaction may take place even though the dynamics of changes in the pulse waves is completely different from that described above.

When a second acoustic stimulus was applied to this same subject (after she had been tested for 1 h), a still more marked orienting reaction was observed in the form of a decrease in blood volume (Fig. 2). However, as the rheogram shows, the amplitude of the pulse waves against the background of a decrease in blood volume did not fall this time, but increased above its initial value, and this was accompanied by signs of an "increase in arterial tone" —at the apex of the pulse waves a plateau appeared, and the dicrotic wave was shifted appreciably upward; the changes described above in the rheogram waves gradually diminished when the decrease in blood volume had reached its minimum, and toward the end of this reaction their shape was similar to that observed initially.

Hence, in response to a second acoustic stimulus, the complex of changes in the rheogram waves was opposite in shape and amplitude to that observed in response to the first acoustic stimulus*. At the same time, in the latter case changes in the shape of the rheogram corresponded to those usually interpreted as expressing an "increase in tone of the arterial vessels," and the increase in amplitude contradicted this.

It follows from these findings that analysis of the rheogram on the basis of traditional concepts of "morphologic plethysmography" cannot provide an explanation of the mechanism of the vascular orienting reflex. At the same time, however, rheographic data unquestionably show that the mechanisms of this reflex, expressed as a decrease in the peripheral blood volume, may be different (including, evidently, different effector components), a most important conclusion.

Rheographic investigation thus reveals specific features where the plethysmographic effect is, on the whole, similar. It must be added that the rheoencephalographic data during the subject's response to the second acoustic stimulus also show differences compared with the first response: the shape of the pulse waves of the REG changes in the same direction as in the digital rheogram, but this time the changes are

*The first type of response is usual; the second is less common.

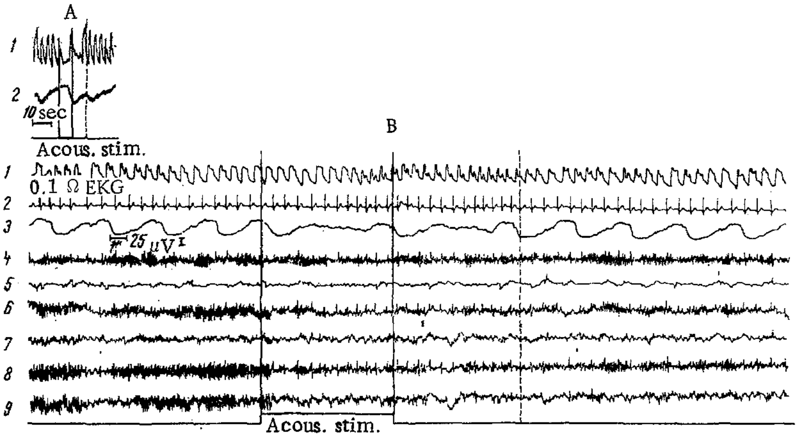

Fig. 3. Relationship between direction of fluctuations in digital blood volume and changes in shape and amplitude of pulse variations in its volume in patient (aged 19 years) after operation for injury to left brachial plexus (see background tracing and response to acoustic stimulation). In A: 1) respiration; 2) plethysmogram of right ring finger. Below, marker of acoustic stimulation. In B: 1) rheogram of right middle finger; 2) EKG; 3) respiration; 4, 5, 6, 7, 8, 9) EEG (transverse occipital lead, transverse postfrontal lead, left vertico-occipital lead, left vertico-postfrontal lead, right occipito-postfrontal lead, left occipito-postfrontal lead. Broken vertical lines denote identical moments of tracing of plethysmograph and electroencephalograph.

more lasting (Fig. 2). On the other hand, the dynamics of changes in the amplitude of the REG in this case is different from that in the digital rheogram. Changes in the state of the vascular system in the second case compared with the first are also indicated by differences in the character of the background plethysmogram. It is also clear that the curves of respiration and its changes in response to acoustic stimulation were different in both cases, for in the second case stimulation produced a more prolonged increase in respiration. In the EEG during the orienting reaction a lasting desynchronization of the cortical rhythm developed, and against this background the fast waves in the second case were rather less clearly defined.

Evidently, depending on the initial state, the typical (and, probably, biologically important) response of a decrease in the peripheral blood volume in response to exteroceptive stimulation may take place through different mechanisms. However, the rheogram cannot be used to assess the blood volume of an organ, and the functional role of changes in the shape of the rheographic waves certainly requires considerable further study. In the literature on "morphologic plethysmography" data are published [6] which contradict in many respects the widely held interpretation of the rheogram as described above.

Recordings made during investigation of a patient following an operation on the left brachial plexus, in whom sharp fluctuations in the heart rate and in the shape and amplitude of the pulse waves and digital blood volume were observed, are shown in Fig. 3. If the plethysmogram and rheogram are compared (for fingers on the intact side of the body), different combinations and changes in these indices will be seen both in the background curve and in the response to acoustic stimulation.

During the study of changes in the pulse variations and total blood volume under the influence of various physiological and pathological factors, it is sometimes possible to find states in which changes in the plethysmogram and rheogram take place apparently in the same direction, and can easily be interpreted as expressing changes in the arterial tone, in accordance with the usual rheographic interpretation. However, this is only a special case among many others.

However, the contradictions between the results of plethysmographic and rheographic investigations which were demonstrated above do not detract from the importance of the facts obtained by these methods, but merely emphasize the limits of the possibilities of each method and the conventional nature of the interpretation of some indices of the rheogram.

LITERATURE CITED

1. V. L. Anzimirov, Rheoencephalography in Clinical Neurosurgery. Candidate's Dissertation [in Russian], Moscow (1967).
2. Nguen Zui-zung, Ter. Arkh., No. 7, 86 (1963).
3. Kh. Kh. Yarullin, Clinical Rheoencephalography [in Russian], Leningrad (1967).
4. J. B. Dillon and A. B. Hertzman, Am. Heart J., 21, 172 (1941).
5. F. L. Jenkner, Rheoencephalography. A Method for the Continuous Registration of Cerebrovascular Changes. Springfield (1962).
6. F. Kaindl, Arch. Kreisl.-Forsch., 20, 274 (1954).
7. A. Kappert, Cardiologiya (Basel), 24, 353 (1954).
8. H. Mann, Proc. Soc. Exp. Biol. (New York), 36, 670 (1937).