Kistler et al. [10], who found tubular myelin in the phagosomes of the lung macrophages of rats kept for a long time in an atmosphere with an increased oxygen concentration, concluded that these structures are a "spent" form of surfactant. Other workers, while supporting this hypothesis [9], also suggested that the tubular myelin could be a "reserve" surfactant, packed in a certain way. This last hypothesis is supported by the evidence of physiological and biochemical investigations showing that the tubular myelin fraction of lung washings possesses normal surface-active properties and, in its lipid composition, is similar to the contents of the osmiophilic lamellar corpuscles of alveolar cells of the second type [8].

The pictures of direct transition of the material of the osmiophilic lamellar corpuscles into packed membranes of surfactant (Fig. 3c), observed in the lungs of the experimental animals, also indicate that these membranes belong to the "reserve" of alveolar surfactants. In the hypophase of the hypertrophied alveoli during the first 5-7 days after left-sided pneumonectomy this form of surfactant was found more often than in the alveoli of the lungs of intact animals. Meanwhile, hypertrophy of the large alveolocytes responsible for surfactant synthesis takes place in the residual lung, together with an increase in the number of osmiophilic lamellar corpuscles in them, the discharge of the material of these corpuscles into the lumen of the alveoli, and a temporary fall in the surface tension of the lung washings [5].

Considering the data described above, it can be concluded that macrophages located in the hypophase of the extracellular alveolar lining utilize the "excess" of surfactant in the hypertrophied lungs and so participate in the regulation of the surface tension of the alveoli. This suggests that the alveolar macrophages are one of the cellular components of the surfactant system of the lungs.

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VASCULAR COMPONENT OF THE RESPONSE OF THE CIRCULATORY SYSTEM TO THE ORTHOSTATIC TEST

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Marked recovery of the initially lowered blood pressure (BP) and a slight tendency toward recovery of the initially lowered cardiac output (CO) were observed in response to the

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orthostatic test (OT) in experiments on cats anesthetized with urethane. Baroreceptive reflexes from the carotid sinus were shown to have an essential role in the mechanism of the compensatory changes in BP. An artificial circulation was used to study reactivity of the resistive and capacitive vessels and pooling of blood in the vascular system during OT was estimated quantitatively. Compensatory responses of BP to OT are due principally to reflex vasoconstriction of resistive vessels and not to venomotor responses.

KEY WORDS: vascular component of systemic reaction; orthostatic test; resistive and capacitive vessels; blood cooling

Despite many investigations devoted to the analysis of changes in the hemodynamics in man and animals during orthostasis [1-4, 9, 11], the extent to which the tone of the peripheral vessels and the pumping function of the heart participate in the mechanism of the compensatory changes in the hemodynamics during exposure to this factor remains obscure. Another unsolved problem is the relative role of the resistive and capacitive vessels in these compensatory reactions.

The objects of the present investigation were to compare the dynamics of changes in the blood pressure (BP) and cardiac output (CO) during the orthostatic test, to determine the contribution of baroreceptive reflexes to the mechanism of the above-mentioned changes in BP and CO, to compare the reactivity of the resistive and capacitive vessels in response to orthostatis, and to assess the degree of blood pooling in the vascular system under these conditions.

EXPERIMENTAL METHOD

Cats were anesthetized with urethane (1 g/kg). The orthostatic test (OT) was carried out by rotating the table on which the experimental animal was fixed through 45° to the horizontal axis in 3 min. BP was recorded in the femoral artery by means of a mechanotron electromanometer [6]. CO was recorded continuously by means of the cuff transducer of the RKE-1 electromagnetic flowmeter [5], which records the volume velocity of the blood flow in the ascending aorta.

Experiments with the artificial circulation (by-passing the left ventricle) were carried out in accordance with the scheme described in [7]. The pumping function of the left ventricle was replaced by a constant delivery pump, by means of which blood was pumped into the aorta through the iliac artery at the rate of 80-100 ml/kg/min from a reservoir, into which blood passed from the left atrium through a drainage tube. Under these conditions the tone of the resistive vessels could be estimated from BP measured in the common carotoid artery. The tone of the capacitive vessels and the degree of blood pooling were judged from changes in the blood level in the reservoir mentioned above. All processes were recorded on the USChV-8 ink-writing oscillograph and subjected to statistical analysis by Student's paired t-test.

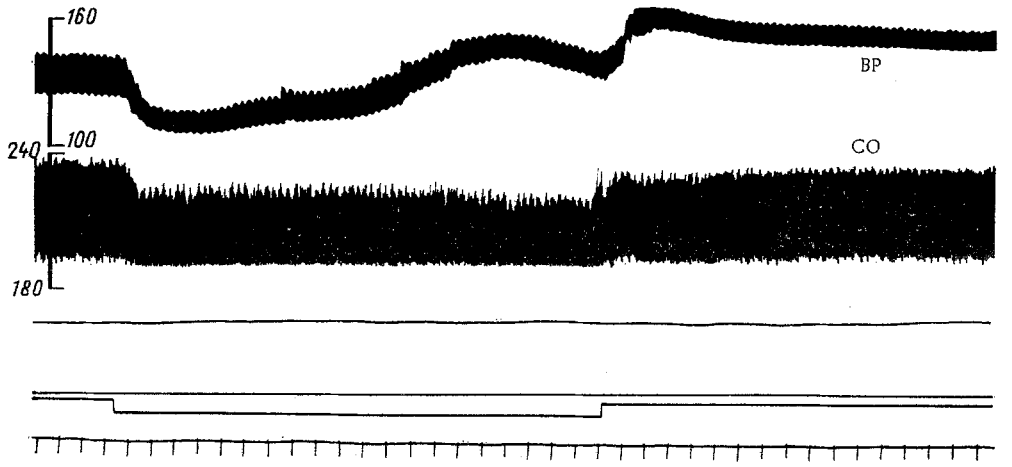

Fig. 1. Effect of orthostasis on dynamics of blood pressure (BP) and cardiac output (CO). From top to bottom curves denote: BP) in mm Hg; CO) in ml/min; base line, marker of OT, time marker (10 sec).

TABLE 1. Effect of Orthostasis on BP and CO (mean data of 28 observations)

Index	Initial value	Changes during orthostasis		P
		20 sec	60 sec	
BP, mm Hg	122±22	−21±4,7	−6,3±2,7	<0,01
CO, ml/min	276±28	−57±14,2	−31±16,5	>0,1

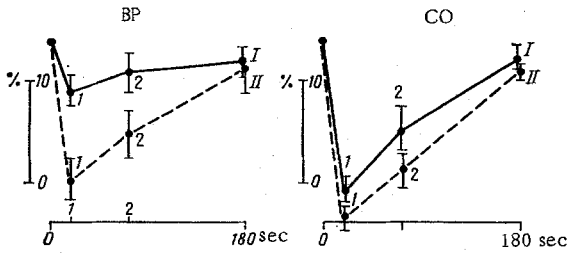

Fig. 2

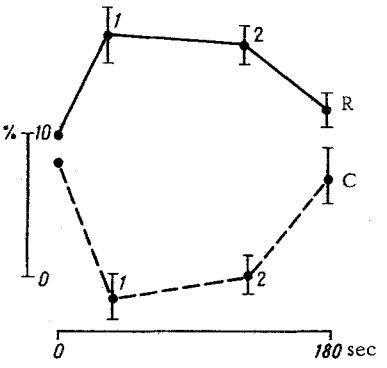

Fig. 3

Fig. 2. Effect of blocking of baroreceptor reflexes from carotid sinus on changes in BP and CO during orthostatic test (OT). I) Intact carotid sinuses; II) after blocking carotid sinuses. Point 1 corresponds to maximal decrease (at 20th sec of OT), point 2 to maximal recovery (at 60th sec of OT) of BP and CO. Changes in BP and CO shown as percentages of initial level.

Fig. 3. Changes in tone of resistive (R) and capacitive (C) vessels during OT. Experiment with artificial circulation by-passing the left ventricle. Points 1 and 2 correspond to 30th and 120th sec of OT. Changes in R and C given in percentages of initial level of BP and of calculated blood volume in cats (100 mg/kg) [10].

EXPERIMENTAL RESULTS

In 28 observations made in the course of 14 experiments the dynamics of the changes in BP and CO in the course of the OT differed in character. Whereas the initial fall in BP, taking place during the first 20-25 sec of OT, as a rule was followed by a phase of recovery, the tendency toward recovery of CO was only very slight and in fact CO remained low throughout OT (Fig. 1). Characteristically, compensation of BP was well marked in 88% of observations, and in 40% BP was restored completely to its initial level. Meanwhile a tendency toward compensation of CO was observed in only 28% of observations. This was reflected in the results of comparative quantitative assessment of the changes in BP and CO after 20 (maximal fall) and 60 sec (Table 1).

Such sharp differences in the intensity of the changes in BP and CO suggest that compensation of orthostatic hypotension is due mainly to the vascular component of the systemic reaction, whereas the cardiac component of this reaction is either initially very weak or it is secondary to changes in peripheral vascular tone. This conclusion is deduced from the undisputed fact that any change in BP can be brought about by either the vascular or the cardiac component of the systemic reaction. Interaction between these factors evidently takes place and it is this which ultimately determines the level of BP.

For a closer analysis of this problem in seven experiments the degree to which blocking of baroreceptor reflexes is reflected in the character of the changes in BP and CO during the orthostatic test was investigated. Blocking the baroreceptor zones of the carotid sinuses by clamping the common carotid arteries was found to affect only the character of the changes in BP but to have virtually no effect on the dynamics of CO during OT (Fig. 2).

Whereas the maximal decrease in BP during the OT with the carotid sinuses intact averaged 5% of the initial level and the corresponding decrease in CO was 15%, after blocking of the carotid baroreceptor zones the maximal decrease in BP increased to 14% ($P < 0.01$), but the decrease in CO was 19% ($P > 0.1$). As regards

the magnitude of the compensatory changes, after blocking of the carotid sinuses the tendency toward compensation of the initial deviations of BP was significantly reduced, whereas for CO it remained unchanged. This follows from the fact that, when the carotid sinuses were intact, the mean compensation of BP during OT reached 97% of the initial level, and that of CO reached 90%; after blocking of these zones the average compensation of BP was 85% ($P < 0.05$) whereas that of CO amounted to 87% ($P > 0.1$).

Under the conditions of the OT, baroreceptor reflexes were manifested in the compensatory responses of BP mainly in connection with the vascular factor. This fact also shows that the compensatory reactions of the cardiovascular system to the orthostatic test are predominantly vascular in nature and are largely due to the influence of baroreceptor reflexes on peripheral vascular tone. This effect is evidently expressed as the prevention of a sharp fall in BP during the OT.

The question of the character and degree of reactivity of the resistive and capacitive vessels under the influence of orthostatis is of considerable interest. The experimental conditions, involving the use of an artificial circulation with by-passing of the left ventricle, enabled changes in the state of these divisions of the vascular system to be assessed separately. In all seven experiments of this series systemic constriction of the resistive vessels was observed up to a mean degree of 8% of the initial level of BP ($P < 0.05$). Meanwhile, the dynamics of blood pooling, assessed from changes in the level of blood in the reservoir of the artificial circulation system, showed no significant tendency toward a compensatory change (Fig. 3). However, in five of the seven experiments the blood level in the reservoir recovered to some extent after its initial fall, although this was not more than 20-25% of the magnitude of the initial decrease in this index.

This initial fall in the blood level in the reservoir reflected the degree of blood pooling in the experimental animals and it averaged 20-25 ml, i.e., about 10% of the circulating blood volume in cats weighing 3-3.5 kg [10]. This corresponds to the data on blood pooling in man during the OT [13]. Blood pooling in the vascular system is known to be a function chiefly of the capacitive properties of the veins.

The very slight and irregular reaction of the capacitive vessels compared with that of the resistive vessels accords with Gauer's view [9] of the passive role of the venous reservoir during the orthostatic test. At the same time, it contradicts the other evidence which has accumulated [8, 12] of the venomotor reflexes and their role in the maintenance of the venous return to the heart.

The compensatory reaction of the resistive vessels, with its marked constrictor character, probably is more effective from the standpoint of maintaining the BP level. Although this reaction is probably mainly reflex in nature and connected with baroreceptor activation, cell-regulatory constrictor responses of the smooth muscles of the resistive vessels in the lower half of the body in response to an increase in the hydrostatic blood pressure under the conditions of OT likewise cannot be ruled out [2, 3]. The relationship between nervous reflex mechanisms and local self-regulatory mechanisms of the responses of these vessels remains a matter for investigation.

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