REGULATION OF THE CIRCULATING BLOOD MASS AFTER EXCLUSION OF VARIOUS AMOUNTS OF LUNG TISSUE FROM FUNCTION

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In experiments on dogs, exclusion of 58.3 and 84.5% of the lung tissue while the carotid sinus zones remained intact was accompanied by an increase in the circulating blood mass on account of emptying of the blood depots. This resulted in a more complete development of the compensatory changes and the establishment of the circulation at a new level. After denervation of the carotid sinuses the response of the blood depots to a change in the conditions of the circulation was abolished, so that reversal of the initial hemodynamic changes took place to a lesser degree.

Exclusion of a certain quantity of lung tissue from function is accompanied by marked changes in the hemodynamics of the systemic circulation [7]. Results described in the literature suggest that these changes are largely due to changes in the circulating blood mass (CBM) [2, 3].

The object of the present investigation was to examine the mechanisms of regulation of the CBM after exclusion of various amounts of lung tissue from function.

EXPERIMENTAL METHOD

Experiments were carried out on 20 male mongrel dogs weighing 16-25.6 kg. The animals were divided into two groups with 10 in each group. The carotid sinuses of the dogs of group 1 were left intact, while in the dogs of group 2 they were denervated.

Bilateral thoracotomy through an incision in the 5th intercostal space was performed under chloralose-amylobarbital anesthesia after morphine premedication, and the thorax was widely opened. Artificial respiration was applied at a constant rate of 16 cycles/min. The volume of inspired air was regulated automatically by a water valve. Flexible gastric clamps were applied to the roots of the lungs. The common carotid arteries were dissected at their points of bifurcation and ligatures placed beneath them. In the animals used in the experiments of series II, the ligatures were tied and the carotid sinuses completely excised. After stabilization of the hemodynamics the experiment was carried out by the same method as in series I: the right lung (58.3% of the lung tissue) was excluded, and 10 min later the lower lobe of the left lung (26.2% of the lung tissue) also was excluded [11]. The total time taken by this procedure was 20 min. The clamps were then removed and the animals kept under observation during the next 10 min.

In group 2 the inital data used were the values measured after denervation of the carotid sinuses. The pressure inside the aorta and the heart rate were recorded continuously. The CBM was measured after 5, 10, 20, 25, and 30 min of the experiment by the dye dilution method.

EXPERIMENTAL RESULTS

The initial values of the CBM, the mass of the circulating erythrocytes (CME), and the plasma volume (PV) differed only slightly in the animals of the 2 groups, and their mean values were 1655 ± 124 and 1710 ±

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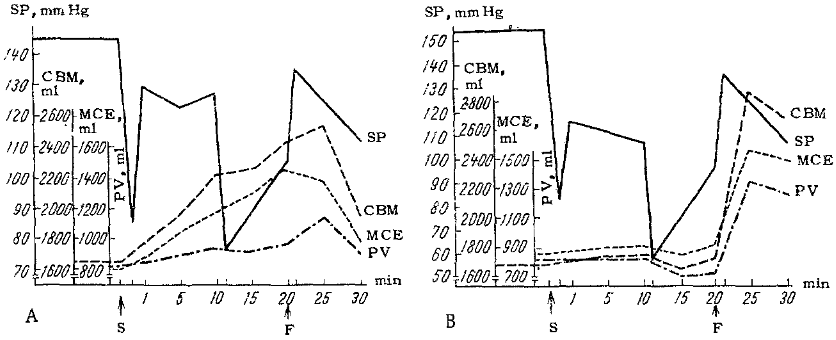

Fig. 1. Dynamics of systolic pressure (SP), circulating blood mass (CBM), mass of circulating erythrocytes (MCE), and plasma volume (PV) in animals with intact (a) and denervated (b) carotid sinuses. S) start of exclusion of lungs; F) finish of exclusion of lungs.

103 ml, 823 ± 71 and 872 ± 57 ml, and 832 ± 63 and 838 ± 42 ml respectively. After denervation of the carotid sinuses there was no change in the values of CBM, MCE, and PV. The original values of the systolic (P_s) and diastolic (P_d) blood pressure in the aorta and of the heart rate were about equal in the 2 groups of animals: P_s 145 and 142 mm Hg, P_d 76 and 78 mm Hg, heart rate 161 and 182/min respectively. After denervation of the carotid sinuses the parameters were increased: P_s to 174, P_d to 102 mm Hg, and the heart rate to 195/min.

The CBM and MCE in the animals of group 1 were appreciably increased at the 5th minute of the experiment, whereas in the animals of group 2 they were unchanged (Fig. 1). This difference is statistically significant ($P < 0.05$). Later, in the animals of group 1, CBM and MCE rose constantly in the course of the experiment, with a small increase in PV (Fig. 1A). In the animals of group 2, on the other hand, these parameters fell slightly (Fig. 1B).

At the beginning of the after-period an increase in CBM and PV was observed in the animals of both groups, but in group 2 the increase was relatively less marked. Meanwhile MCE was increased only in the animals of group 2, and in the dogs of group 1 it was slightly reduced (Fig. 1). By the end of this period all the CBM indices in the animals of group 1 were close to their initial values, whereas in the animals of group 2 their level was much higher than initially.

The dynamics of CBM in the animals in both series of experiments gives a clear idea of the role of the carotid sinuses in the regulation of this parameter. The increase in CBM with the carotid sinuses intact was evidently due to emptying of the blood depots under the influence of impulses from these receptor zones. Experiments have shown that the carotid sinuses participate directly in the regulation of the CBM [4, 5, 9] and have an influence on the intensity of formation of the blood cells [8]. The decrease in blood pressure in the carotid sinus region after clamping of the common carotid arteries in dogs is accompanied by sharp increase in the erythrocyte count in the circulating blood as the result of contraction of the spleen [10].

The decrease in blood pressure in the aorta after occlusion of the right lung in the present experiments (Fig. 1) was also accompanied by a fall of blood pressure in the carotid sinus region. This evidently caused reflex contraction of the spleen, with expulsion of the blood stored in it into the general circulation. As a result, the CBM increased because of the large increase in the number of erythrocytes in the circulating blood, as confirmed by the dynamics of the MCE (Fig. 1A). Denervation of the carotid sinus abolished the reaction of the blood depots to the change in circulatory conditions, and this was reflected in the absence of increase in MCE and CBM (Fig. 1B). This conclusion is confirmed by data in the literature showing disappearance of the rapid response of the spleen to hyper- and hypovolemia after denervation of the carotid sinus zones [9].

The increase in CBM with the carotid sinuses zones intact can also be considered to have been caused by the need to improve the transport function of the blood when the possibility of hypoxia threatened. For instance, after occlusion of one lung, the oxygenation of the blood is reduced by 7-10% [6]. It was natural to assume that after the exclusion of more than 80% of the lung tissue, as in the present experiments, the level of blood oxygenation could fall even lower. This, in turn, would cause the development of compensatory reactions of the blood system and, in particular, emptying of the blood depots. Since the reflex responses of the blood depots are largely triggered by receptors of the carotid sinuses, denervation of these receptors delays or abolishes these responses.

The carotid sinus chemoreceptors play an important role in regulating the activity of the blood depots [1]. It can also be postulated that the baroreceptors also play an important role in this case. The increase in CBM in the present experiments evidently led to the development and formation of compensatory responses of the cardiovascular system. This is confirmed by the comparative dynamics of CBM and SP in the animals of group 1 (Fig. 1A). In the absence of an increase in CBM, when the carotid sinuses were denervated, the development and formation of compensatory circulatory responses was less marked (Fig. 1B). Since these responses develop as a result of a pressor reflex from the carotic sinus baroreceptors in this case, this reflex probably exerts some influence also on the activity of the blood depots.

The sharp increase in CBM in the animals with denervated carotid sinuses in the after-period was probably due to the entry into the circulation of blood blocked in the occluded pulmonary vessels and stored in the systemic vessels. A similar situation also arises in animals with intact carotid sinuses, as was confirmed by the slight increase in CBM in the after-period in this group of animals also. However, in that case there was the parallel development of the reverse process of blood storage, as shown by the decrease in MCE (Fig. 1A). By the end of the after-period,the reverse process of blood storage was complete in the animals with intact carotid sinuses,and the values of CBM, MCE, and PV had returned almost to their initial level. This was not the case in the animal's denervated carotid sinuses. This result is in agreement with data in the literature to the effect that denervation of the carotid sinuses induces more severe disturbances of regulation of the CBM in hypervolemia than in hypovolemia [9].

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