EFFECT OF BLOOD FLOW VELOCITY IN THE CAROTID ARTERY ON HEMATOCRIT INDEX OF BLOOD DISTRIBUTED TO THE BRAIN

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Changes in the erythrocyte concentration in blood flowing along the peripheral vessels depending on the intensity of th local blood flow is a phenomenon which was discovered 25 years ago. It has been studied since that time in the microcirculatory system of various organs and also in model experiments [2, 3, 5-8]. As regards the brain it has been shown that, corresponding to the high intensity of its blood supply, the blood in its vessels contains 20% more erythrocytes than in the limbs [4].

The object of this investigation was to determine whether the phenomenon of redistribution of erythrocytes is observed only in the microvascular system or whether it is also found in the successive ramifications of arteries along which blood is distributed to a given organ.

EXPERIMENTAL METHOD

Experiments were carried out on 14 adult rabbits of both sexes anesthetized with urethane (1 g/kg body weight). A skin incision was made on the animal's neck in the mid-sagittal line, a tracheotomy tube was introduced, and the common carotid artery was divided in two places: near the sternum (for a length of about 1 cm) to apply a thick ligature, and in the region of the bifurcation. The external carotid artery was ligated peripherally and used for obtaining blood samples, whereas the internal carotid artery was left intact and the blood flow continued along it toward the brain. For obtaining control blood samples either a muscular branch of the right femoral artery (five animals) or the left external carotid artery (five animals) was used. In each experiment blood samples were taken from the right carotid artery and from one of the control arteries named above: the first drop of blood which escaped was dried and the next portion of blood (1-2 drops), withdrawn immediately after it, was taken for investigation. The capacity of the arterial branches through which blood samples were taken (a segment of the external carotid artery and the muscular branch of the femoral artery) was very small, so that only blood from the test arteries (the right common carotid or the corresponding control artery) was present in the samples. Erythrocytes were counted in the blood thus withdrawn in a Goryaev's hemocytometer by the standard method and the hematocrit index was determined by centrifugation. The velocity of the blood flow in the right common carotid artery was recorded continuously by means of a Doppler ultrasonic blood flowmeter (model BFM315, from Bach-Simpson, Canada), the detector of which was located above the artery in the middle part of the animal's neck. To measure the systemic arterial pressure the catheter was introduced into the left femoral artery. The velocity of the blood flow and arterial pressure were recorded on a Mingograph-81 apparatus (Elema, Sweden). After the operation the animals were given an intravenous injection of heparin in a dose of 1500 i.u./kg body weight. The experimental procedure included three stages: 1) taking blood samples from the right carotid and the control arteries, 2) partial constriction of the right carotid artery by means of a ligature followed (1-2 min later) by the taking of blood samples from the same arteries, and 3) untying of the ligature on the right carotid artery followed (1-2 min later) by the taking of blood samples from the two arteries mentioned above. Each stage

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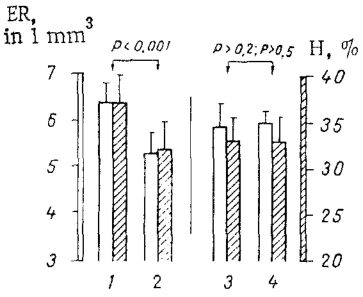

Fig. 1

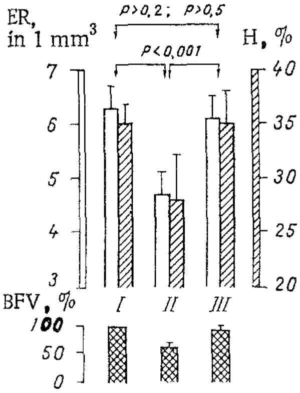

Fig. 2

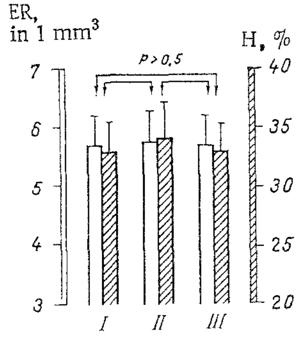

Fig. 3

Fig. 1. Erythrocyte count — Er (unshaded columns) and hematocrit index — H (shaded columns) in blood flowing along right carotid (1 and 3) and control arteries (2 — femoral and 4 — left carotid) at beginning of experiment.

Fig. 2. Erythrocyte count — Er (unshaded columns) and hematocrit index — H (shaded columns) in blood flowing along right carotid arterty at beginning (I) of experiment, after a decrease in blood flow velocity (II), andafter restoration of initial blood flow velocity (III). BFV) Blood flow velocity.

Fig. 3. Erythrocyte count — Er (unshaded columns) and hematocrit index — H (shaded columns) in blood flowing along control arteries (femoral and left carotid) and taken at same stages of experiments (I, II, and III) as in Fig. 2.

lasted 3-5 min. The procedure described above was repeated on 11 of the 14 animals. The data given below are arithmetic mean values and standard deviations.

EXPERIMENTAL RESULTS

The initial data are shown in Fig. 1. In one group of animals (the four columns on the left) blood flowing through the right common carotid into the internal carotid artery contained 6,464,000 ± 421,000 erythrocytes in 1 mm^3 and its hematocrit index was 37 ± 2.9%. Blood flowing into the limb along the femoral artery, however, contained significantly fewer erythrocytes, namely 5,275,000 ± 505,000 in 1 mm^3 and its hematocrit index was 32.6 ± 2.8%; differences from the right carotid artery were statistically significant ($P < 0.001$). Blood flowing along the carotid artery toward the brain thus contains significantly more erythrocytes and has a higher hematocrit index than blood distributed to the hind limb. In another group of animals (Fig. 1, the four columns on the right) blood samples taken from the two carotid arteries were compared: The erythrocyte count in blood from the right carotid artery was 5,998,000 + 212,000 in 1 mm^3 and its hematocrit index was 33 + 2.5%, whereas the erythrocyte count in blood from the left carotid artery was 6,088,000 + 201,000 in 1 mm^3 and its hematocrit index was 33 + 2.3%; the differences were not statistically significant ($P > 0.2$ for the erythrocyte count and $P > 0.5$ for the hematocrit).

The data showing the effect of a change in blood flow velocity in the right common carotid artery (as a result of partial local constriction of its lumen) on the erythrocyte concentration and hematocrit index of blood flowing along it toward the brain are illustrated in Fig. 2. Initially the erythrocyte count in blood from this artery was 6,292,000 ± 419,000 in 1 mm^3 and the hematocrit index was 35 ± 3.3% (Fig. 2, I). After partial constriction of the common carotid artery, when the blood flow velocity in it had fallen to 62 ± 9.9% of the initial value (taken as 100%), blood flowing along this artery contained significantly fewer erythrocytes, namely 4,712,000 ± 413,000 in 1 mm^3, and its hematocrit index was 28 ± 4.6%; the differences were statistically significant ($P < 0.001$) (Fig. 2, II). After restoration of the initial lumen of the carotid artery, when the blood flow velocity in it reached 95.5 ± 13.6% of its initial value the erythrocyte count in blood flowing along this artery rose again to 6,143,000 + 413,000 in 1 mm^3 and the hematocrit index was 35 + 3.2% (Fig. 2, III). Differences from values obtained during the period of constriction of the artery were statistically significant ($P < 0.001$), whereas those from the initial values were not significant ($P > 0.2$ for the erythrocyte count and $P > 0.5$ for the hematocrit).

The results of determination of the erythrocyte concentration and the hematocrit index in blood samples taken from control arteries (femoral and left carotid) and, at the same time, from the right carotid artery (during periods corresponding to I, II, and III in Fig. 2) are shown in Fig. 3. Initially the erythrocyte count in the control arteries was 5,705,000 ± 554,000 in 1 mm^3 and the hematocrit index was 33 ± 2.5% (Fig. 3, I), during partial constriction of the right carotid artery the parameters were 5,607,000 + 580,000 and 34 +3.3%, respectively (Fig. 3, II), and after restoration of the initial blood flow in it they were 5,740,000 ± 437,000 and 33 ± 3.1% (Fig. 3, III), none of these differences are statistically significant ($P > 0.5$).

The level of the systemic arterial pressure at the beginning of the experiments averaged 100.6 + 25 mm Hg and it did not change regularly in any particular direction after partial constriction of the right carotid artery: in 54% of cases it was unchanged, in 25% of cases it was increased by about 8%, and in 21% of cases it was reduced by about 7%.

The site of partial constriction of the right carotid artery was located about 1.5 cm from its origin and constriction caused only an additional increase to the resistance, which led to a decrease in the velocity of the blood flow in it (by about one-third of its initial value). The constriction was a long way short of that which would create mechanical obstruction to movement of erythrocytes in the lumen of the vessel. Dependence of the change in the erythrocyte count and hematocrit index in the blood on changes in the blood velocity was linear: The coefficient of correlation (r) for these relationships was 0.76 and 0.77, respectively, in both cases $P < 0.001$.

Consequently, the phenomonen of separation of erythrocytes and blood plasma takes place not only in the microcirculation, as might be supposed on the basis of previous experimental data [2,3, 5-8], but also in the wide arterial branches carrying blood to the organ. The present experiments showed that positive correlation exists between the blood flow velocity in a given arterial branch (even a large one), arising from the aorta, and the erythrocyte concentration and hematocrit index in the blood flowing along it, as one of us (G.I.M.) showed previously [1].

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