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# EFFECT OF ADAPTATION TO HIGH-ALTITUDE HYPOXIA ON THE MICROCIRCULATION IN THE RAT MESENTERY

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After prolonged adaptation of rats to high-altitude hypoxia (in a pressure chamber at an "altitude" of 6500 m, for 6 h daily for 30-40 days) considerable hyperemia of the intestinal wall and mesentery was observed; the number of functioning capillaries was several times greater than in the control animals but the blood flow in the dilated microvessels was slowed and its structure was disturbed. Besides obvious hemoconcentration in the arteries and veins, hemodilution was observed in the capillaries. Definite hemorheological changes evidently connected with the polycythemia and increased hematocrit index were noted.

KEY WORDS: hypoxia; microcirculation.

Prolonged adaptation to hypoxia affects various structures and functions of the body. Its influence is seen particularly clearly in the blood [1, 3, 6] and circulatory [2, 8, 9] systems. Definite changes have been found also in the structure of the microvascular system, in the endothelial cells of the microvessels [4], and also in the regional circulation in various organs [9].

The object of this investigation was an intravital study of the state of the peripheral circulation and, in particular, of the microcirculation after prolonged keeping of animals in an atmosphere with a reduced oxygen concentration.

## EXPERIMENTAL METHOD

Experiments were carried out on 20 noninbred adult male rats divided into two groups: 1) control (10 animals), 2) experimental (hypoxia; 10 rats). The animals of the experimental group were kept for 6 h daily for 35 ± 5 days in a pressure chamber at an "altitude" of 6500 m. A constant composition of the atmosphere in the pressure chamber was maintained by forced ventilation with external atmospheric air. The animals were used for the experiments 16-20 h after the last session. Control animals were kept for the whole of this time in the animal house under ordinary conditions.

Observations on the microcirculation with photographic recording were made on the mesentery of the small intestine by means of an apparatus mounted on the base of an MBI-6 microscope, with a photographic ocular 10× and objectives 10, 20, and 40× (the last two with oil immersion). The mesentery, removed under

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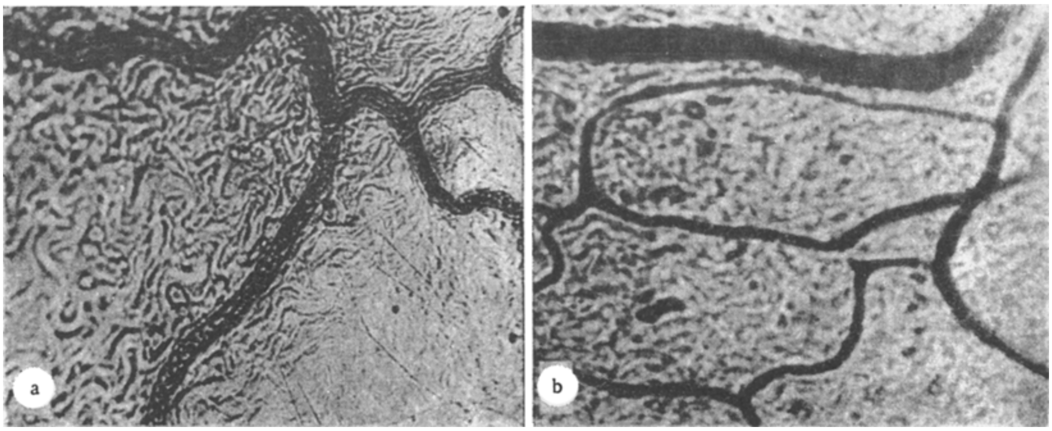

Fig. 1. Photomicrograph of mesentery of control rat (a) and of rat after prolonged adaptation to hypoxia (b) (260×).

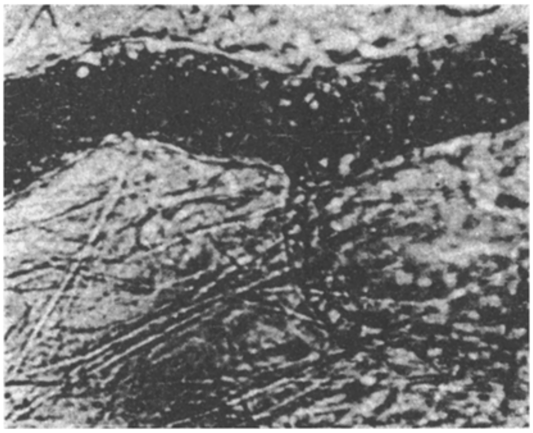

Fig. 2. Photomicrograph of mesentery of rat after prolonged adaptation to hypoxia: hemoconcentration in vein and capillary (520×).

urethane anesthesia, was kept at a constant temperature of 37°C in a medium consisting of biologically neutral PMS-500 silicone fluid to prevent drying; this fluid served simultaneously as the immersion medium. The constancy of temperature of the medium was maintained by a water ultrathermostat. The blood pressure in the carotid artery was measured by a mercury manometer. The hemoglobin concentration (by Sahli's method), hematocrit index, and erythrocyte sedimentation rate were determined in blood samples from the carotid artery and right heart; the index of the degree of erythrocyte aggregation and the suspension stability of the blood, by Dintenfass' method [5], also were determined.

## EXPERIMENTAL RESULTS

Prolonged adaptation to high-altitude hypoxia affected the general physical state of the animals. The weight of the animals of the experimental group was somewhat lower than that of the control group. The behavior of the control animals was normal and their mean blood pressure was 102 ± 3.5 mm Hg. The experimental rats were disinclined to move and inhibited, their hair was untidy, and their snout enematous; they had slight hypertension (their mean blood pressure was 127 ± 3.5 mm Hg; $P < 0.001$).

The state of the microcirculation in the mesentery of the control animals was normal, the capillary network functioned as usual, and the velocity and character of the terminal blood flow were indistinguishable from those usually observed in healthy animals (Fig. 1A). In the animals of the experimental group, on the other hand, a conspicuous feature was considerable hyperemia of the intestinal wall and mesentery. The network of microvessels in them was denser and the number of functioning capillaries per field of vision in the experimental animals was 5 to 10 times greater than the number of these capillaries in the control rats (Fig. 1B). Dilatation of the microvessels, especially capillaries, venules, and collector veins, slowing of the velocity of

TABLE 1. Hemorheological and Hematological Indices in Rats after a Long Stay in a Rarefied Atmosphere (M ± m)

| Group and number of animals | Hemoglobin concentration, g/liter | | Hematocrit index, % | | Erythrocyte sedimentation rate, mm/h |
|---|---|---|---|---|---|
| | blood from artery | blood from heart | blood from artery | blood from heart | blood from artery |
| Control (eight) | 165±1,9 | 167±2,3 | 51±2,5 | 55±1,36 | 1,1±0,12 |
| Experimental (chronic hypoxia) (nine) | 200±7,4‡ | 200±9,3* | 67±2,1‡ | 64±2,75† | 0,2±0,046† |

| Group and number of animals | Erythrocyte sedimentation rate, mm/h | Index of erythrocyte aggregation, relative units | | Suspension stability of blood, relative units | |
|---|---|---|---|---|---|
| | blood from heart | blood from artery | blood from heart | blood from artery | blood from heart |
| Control (eight) | 1,0±0,13 | 1,65±0,63 | 1,57±0,61 | 96,9±0,53 | 97,7±0,39 |
| Experimental (chronic hypoxia)(nine) | 0,2±0,025‡ | 1,43±0,5‡ | 1,53±0,78 | 99,4±1,86 | 99,4±0.18† |

*P < 0.02.
†P < 0.01.
‡P < 0.001.

the blood flow, and some disturbance of its structure, evidently in connection with it, were characteristic: The axial character of the blood flow was less marked, especially in the venous portion of the vascular system; in some veins the impression was obtained of a grainy type of porridge creeping along them (Fig. 2). In the arteries and veins definite hemoconcentration was observed. It was also very noticeable that in the capillaries the layers of plasma between the erythrocytes moving along them were wider than in the control experiments. No aggregation of blood cells was observed. Intravascular leukocytosis was well marked, and compared with the control the leukocytes occupied a more peripheral position in the vessels.

The data showing changes in some hemorheological and hematological indices in the animals studied are given in Table 1. Clearly one result of prolonged hypoxia was a significant increase in the hematocrit index and hemoglobin concentration, due to the compensatory polycythemia constantly observed after a long stay in a rarefied atmosphere [1, 6, 7]. The erythrocyte sedimentation rate was reduced and the erythrocyte aggregation index was unchanged; this is evidence of the absence of any tendency of the erythrocytes to aggregate. The index of suspension stability of the erythrocytes in venous blood, moreover, was actually increased.

A long stay in a rarefied atmosphere thus leads not only to changes in the composition of the blood, but also to substantial changes in the microcirculation.

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