STATE OF THE NUTRITIVE CIRCULATION IN RATS AFTER PROLONGED HYPOKINESIA

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After prolonged hypokinesia for 80-100 days considerable disturbances of the nutritive circulation were observed in experiments on rats: reduction of the network of true capillaries, emptying of the terminal arteries and arterioles, direction of the terminal blood flow mainly along the developing network of arteriovenous anastomoses, by-passing the nutritive vessels. A tendency was noted for the buffer bases to be low in the venous blood and for respiratory alkalosis to be present in the arterial blood. The hemorheological stages were not significant.

KEY WORDS: *hypokinesia; microcirculation; metabolism.*

Prolonged hypokinesia is known to adversely affect the cardiac activity [7, 8], the general hemodynamics [5, 9, 11], and metabolism [2, 3, 6]. Morphological changes have been found in the peripheral vessels, including microvessels, of experimental animals after prolonged hypokinesia [1, 4]. However, as yet no intravital study has been undertaken of the part of the circulation that is directly responsible for its nutritive function, i.e., the microcirculatory system. On the basis of Chernukh's general conception [10] of the unity of the blood supply, metabolism, neurohumoral regulation, and functions of organs, the writers consider that the integrative interpretation of all the events taking place in each functional element of the organs and in the organism as a whole would otherwise be imposible.

This paper describes the results of an experimental study of the effect of prolonged hypokinesia of the microcirculation and acid–base balance of the body, which reflects the state of metabolism in the tissues.

EXPERIMENTAL METHOD

Experiments were carried out on 40 male Wistar rats weighing 130-140 g. The animals were divided into two groups: 1) experimental, 2) control. The animals of the experimental group were kept for 80-100 days in standard restrictive cages, in which their motor activity was minimal. Control rats of the same weight were kept in ordinary cages in the animal house, for the same period of time. The control and experimental animals received the same diet (dry pellets, carrot, cabbage) at the rate of 20 g per rat per day, and water ad lib.

The microcirculation was observed under pentobarbital anesthesia in the mesentery on an apparatus based on the MBI-6 microscope. During the observations the mesentery was kept under constant temperature conditions and irrigated with Ringer's solution containing gelatin, heated to 37.5°C. After the end of the observation of the microcirculation blood samples were taken from three blood vessels (carotid artery, femoral and portal veins) for further tests. Indices of the acid–base balance were determined with the AZIV-2 apparatus (USSR), the hemoglobin concentration by Sahli's method, the erythrocyte sedimentation rate by Panchenkov's method, the hematocrit index by centrifugation at 3000 rpm for 15 min, and the index of the degree of aggregation of the blood cells and suspension stability of the blood by the method of Dintenfass [12]. The numerical data were subjected to statistical analysis involving calculation of Student's t criterion and P on the Saratov computer.

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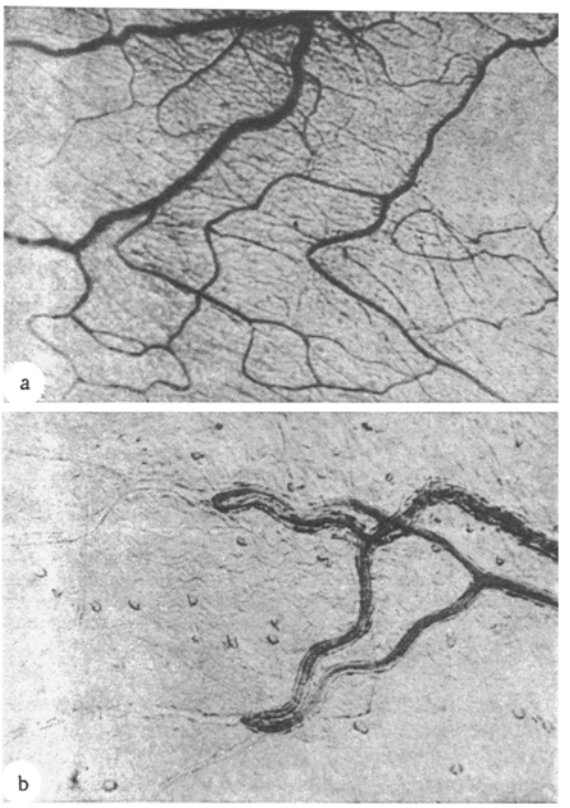

Fig. 1. Photomicrographs of first segment of mesentery of small intestine of control rat (a) and rat after 84 days of hypokinesia (b). a) Rich network of true capillaries, arterioles, and venules; structure of blood flow in microvessels normal, distribution of cells in plasma uniform; b) blood flow directed along arteriovenous anastomoses; emptying of arterioles and venules; no functioning true capillaries are visible; 250×.

EXPERIMENTAL RESULTS

At the end of the period of confinement in the cages the weight of the control animals was 342 ± 16.7 g; the animals were active, mobile, and their hair was clean. The experimental rats at this time weighed 180 ± 3.7 g, they were lethargic and inhibited, their movement coordination was disturbed, they had areas of baldness, and their hair was dirty, despite careful maintenance (their cages were kept clean).

Investigation of the microcirculation showed definite changes in the experimental animals compared with the controls in the structure of the microcirculatory system and the blood flow in it (Fig. 1). The network of microvessels was reduced, the decrease in the number of true capillaries was particularly marked, and in some cases the decrease was so great that no capillaries could be found outside the adipose tissue of the mesentery. Such capillaries as existed were short and straight. Meanwhile plasmatic and nonfunctioning capillaries, and empty capillaries, venules, and other microvessels could be seen. There were many functioning arteriovenous and arteriovenular anastomoses of varied caliber. Consequently, blood was discharged from the arterial part of the circulation into the venous part through anastomoses, by-passing the nutritive capillary system. The velocity of the blood flow in the experimental animals was somewhat slower than in the controls, and this also was reflected in its structure: Its laminar character was disturbed not only in the venous, but also in the arterial microvessels.

Of the hemorheological indices, the most substantial changes affected the erythrocyte

sedimentation rate in samples from the carotid artery and femoral vein (a decrease) and the suspension stability of the blood in the sample from the carotid artery (an increase). Changes in the other hemorheological indices were not statistically significant.

Indices of the acid–base balance in the venous blood of the animals of the experimental and control groups did not differ significantly, but a tendency was observed for the buffer bases to be reduced in samples from the femoral and portal veins after hypokinesia, evidence of exhaustion of the alkali reserves of the blood of the hypokinetic rats. This exhaustion of the alkali reserves of the blood can be explained on the grounds that acid metabolites, especially lactic and pyruvic acids, accumulated in the territories of distribution of these veins, on account of the disturbance of the blood supply to the tissues [2], and a larger quantity of buffer bases was required for their neutralization. In the arterial blood, on the other hand, some degree of alkalification was observed (a statistically significant increase in pH, to 7.40 ± 0.016 in the experimental rats compared with 7.35 ± 0.016 in the control; $P < 0.05$), which most probably bore the character of compensatory respiratory alkalosis.

These results indicate that prolonged hypokinesia has a marked effect on rats. The most important integral index of this effect was the general state of the animals and, in particular, their relatively lower body weight after 80-100 days of hypokinesia. As a result of the sharp decrease in the energy expenditure of these animals compared with the controls, there was a sharp reduction in the perfusion of the tissues through the network of true capillaries, the number of which was appreciably reduced.

LITERATURE CITED

1. L. A. Aleksina, Arkh. Anat., No. 10, 45 (1975).
2. E. N. Ashcheulova and G. G. Yakhnovich, in: Aviation and Space Medicine [in Russian], Moscow (1969), pp. 35-38.
3. Yu. S. Galushko, I. A. Abakumova, and I. A. Nitochkina, in: Current Problems in Space Biology and Medicine [in Russian], No. 1, Moscow (1971), pp. 77-78.
4. E. A. Dyskin, É. N. Bellendir, N. M. Patlas, et al., Arkh. Anat., No. 4, 45 (1976).
5. L. I. Kakurin, in: Physiological Problems of the State of Being Out of Training [in Russian], Moscow (1968), pp. 34-43.
6. E. A. Kovalenko, Kosmich. Biol., No. 1, 3 (1976).
7. I. G. Krasnykh, Voen. Med. Zh., No. 12, 54 (1973).
8. V. V. Parin, T. N. Krupina, G. P. Mikhailovskii, et al., Kosmich. Biol., No. 5, 59 (1970).
9. S. M. Peregontsev, Voen. Med. Zh., No. 11, 63 (1972).
10. A. M. Chernukh, P. N. Aleksandrov, and O. V. Alekseev, The Microcirculation [in Russian], Moscow (1975).
11. A. Chobanian, R. Lille, A. Tereyak, et al., Circulation, 49, 551 (1974).
12. L. Dintenfass, Circ. Res., 11, 233 (1972).