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EFFECTS OF GRAVITATIONAL STRESS, HYPOKINESIA AND HYPODYNAMIA ON THE STRUCTURE OF THE VASCULAR BED OF THE SPLEEN

N. T. Nesterenko

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16. Abstract Study of effects of 2 extreme factors, hypokinesia and hypodynamia, on spleen vascular bed. 3 exp. series on 180 male and female albino rats. Series I animals subjected to single continuous maximum endurable chestback stress. Series II hypokinetic 1-8 wks. Series III hypokinesia then stress of series I. Vessels studied by roentgenography, microroentgenography, clearing of sections and histology. Gravity stress yielded construction of all links of arterial bed and of order 5-7 veins. Large intraorganic vein diameters changed significantly but erratically. Hypokinesia in early phases produced pronounced spleen size reduction. Veins and arteries constricted along entire length. Later hypokinetic stages showed arteries still constricted; veins began to dilate from week 4 of hypokinesia. Sinuosity, uneven contours and varicose dilations of walls in large arteries and veins. Abrupt changes in parenchyma, e.g. atrophy of folliculi, narrowing of lumen of central arteries from thickening of muscular wall. After exposure to hypokinesia followed by gravitational stress pronounced lesions such as deformation of vascular wall, including rupture, in all vessels of the spleen vascular bed.

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EFFECTS OF GRAVITATIONAL STRESS, HYPOKINESIA AND HYPODYNAMIA ON THE STRUCTURE OF THE VASCULAR BED OF THE SPLEEN

N. T. Nesterenko
Department of Normal Anatomy (Head: Prof. M. G. Prives, Honored Scientist) First Leningrad Medical Institute im. Pavlova

The venous bed of the spleen was studied following gravitational stress in the /44* department of Normal Anatomy of the First Leningrad Medical Institute by S. G. Guseynova (1966-1968). Research on changes in the microscopic structure of the spleen under overload was done by Yu. I. Afanasyev (1963) in the department of Histology of the First Moscow Regional Medical Instituteeusing histological methods. In the available literature there was no evidence of works in which a study had been made on the effect of hypokinesia and hypodynamia as well as the combined effect of gravitational stress, hypokinesia and hypodynamia on the vascular system of the spleen.

The purpose of the present work was to study the effect of gravitational stress, hypokinesia and hypodynamia on the vascular bed of the spleen as a whole.

The experiments were conducted on 180 albino rats of both sexes; the vascular /45 bed of the spleen of 40 animals was studied under normal conditions. Stress was induced by rotating the animals on a centrifuge with a 1 m radius. Conditions of hypokinesia and hypodynamia were created by putting the animals in special narrow box cages for periods of 1, 2, 4, 6 and 8 weeks. To produce the combined effect of these two factors they were first placed in the special cages and then, after one of the above-mentioned terms was over, subjected to single continuous maximum endurable overloads in the chest-back direction and then killed with ether vapor.

The vascular bed of the spleen was studied by injecting the arterial system with a rentgenocontrast mass followed by rentgenography and microrentgenography, by injection with a Hauch mass and subsequent clearing by the Malygin method, by preparation of histological sections and subsequent Van Gieson staining and staining with hematoxylin-eosin. Extraorganic and intraorganic arteries were studied on rentgenograms and

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* Numbers in the margin indicate pagination in the foreign text.

microrentgenograms, the veins in cleared preparations. In all cases injection of the vascular bed of the spleen was done via the thoracic aorta. Due to the makeup of the organ's vascular system, an abundant venous bed and the presence of sinuses, the intraorganic veins were easily and quickly filled with the dye in transcapillar fashion.

Our Own Data. Normally the splenic artery at a distance of 2-3 cm from the hilus divides into 2-3 arteries of the first order, which in turn divide into 4-8 branches of the second order and these penetrate the parenchyma of the organ, forming branches of the third order. Within the organ each of the arterial stems of the third order branch dendritically into branches of the fifth and sixth orders, which after providing blood to their segment terminate under the capsule or in the deep layers of the organ. In cleared preparations the basic mass of the vessels takes the form of reticula surrounding the lymphoid follicles and under the capsule of the organ. These are the venous sinuses that show a widespread interconnection. The flow of blood, whether from the subcapsular sinuses or from those located in the deep layers of the spleen, goes through short veins. Each of these takes in several sinuses of scattered shape so that they present the appearance of a "tuft". The veins which drain the sinus networks empty into larger trunks at various angles. Two such vessels that join each other, usually at an acute angle, form a larger vein, etc. Veins of order 7-3 lie outside the organ and those of the first and second orders within. No anastomoses were noted between the large veins. The lumen width of 7th order veins is 12-15 microns, for 6th order veins 15-25 microns, for 5th order veins 25-40 microns, for 4th order veins 60-80 microns and for 3rd order veins 80-145 microns.

In histological preparations of the spleen of albino rats there is a predominance of red pulp containing a scattering of lymphoid follicles (white pulp) of different sizes and shapes. In the area of the follicles, more often along the periphery, lie the central arteries surrounded by venous sinuses and capillaries (Fig. 1a, 1b, 1c).

In the first series of experiments the animals were subjected to single continuous maximum endurable stress in the chest-back direction. Here there were changes produced in the vascular bed of the spleen that were morphological and expressed in the following way. The intraorganic arteries of the third and fourth orders were constricted and became tortuous, presenting an uneven diameter throughout their

whole length. Arteries of the 5th and 6th orders were even more constricted and did not fill up with the contrast mass. Consequently the vascular network in the marginal areas of the spleen became more open than is normal. In this way all the links in the arterial system were contracted. In the intraorganic venous bed there were also significant changes. The small venous stems of the 5-7 orders were notably contracted in contrast to normal. Veins of the third and fourth order were contracted in places and in some portions appeared wider than normal. In places the venous network was greatly thickened. The lymphoid follicles showed good outlines and were of various sizes and shapes (Fig. 2a and 2b). Thus gravitational stress induces: 1) contraction of the large intraorganic vessels of the third and fourth order, both ar- /46
terial and venous, which become tortuous and uneven along their whole length; 2) contraction of arteries of the fifth and sixth order and veins of the 5-7 orders along their entire length; 3) weak perfusion of the arteries and peripheral portions of the spleen and in the venous portion of the vascular bed areas where there is thickening of the vascular network.

Second series of experiments. The effect of hypokinesia and hypodynamia on the vascular bed of the spleen was studied in its dynamics at the end of weeks 1, 2, 4, 6 and 8. We must note the negative effect of hypokinesia on the general condition of the animals. During week 1 they were restless and often refused food. In week 2 they began to lose weight, their fur began to drop out and some of them died. After 2 weeks hypokinesia the spleen was down to half normal size. Dissection revealed an exudate in the cavities. Further on they continued to lose weight despite normal feeding. Contraction of the joints set in. By week 8 hypokinesia had killed about /47
one third of the animals. During the first two hypokinetic weeks the intraorganic arteries of the third and fourth order were not very abnormal in diameter but showed severe sinuosity. Arteries of the fifth and sixth order were severely contracted and did not fill up with the contrast mass, so that the vascular network appeared to be very pale. The venous network had thickened greatly, particularly around the follicles and under the capsule. Veins of the 5-7 orders were significantly contracted. Those of the third and fourth order received the dye nonuniformly. Their diameter was practically normal but as they went along they became uneven and at some places there were contractions which changed off with dilatations. The lymph follicles had good outlines and filled various segments in dissection with various sizes and shapes. After week 4 of hypokinesia the spleen had gotten a bit larger than it was in the previous period. The small arteries were easier to inject, but

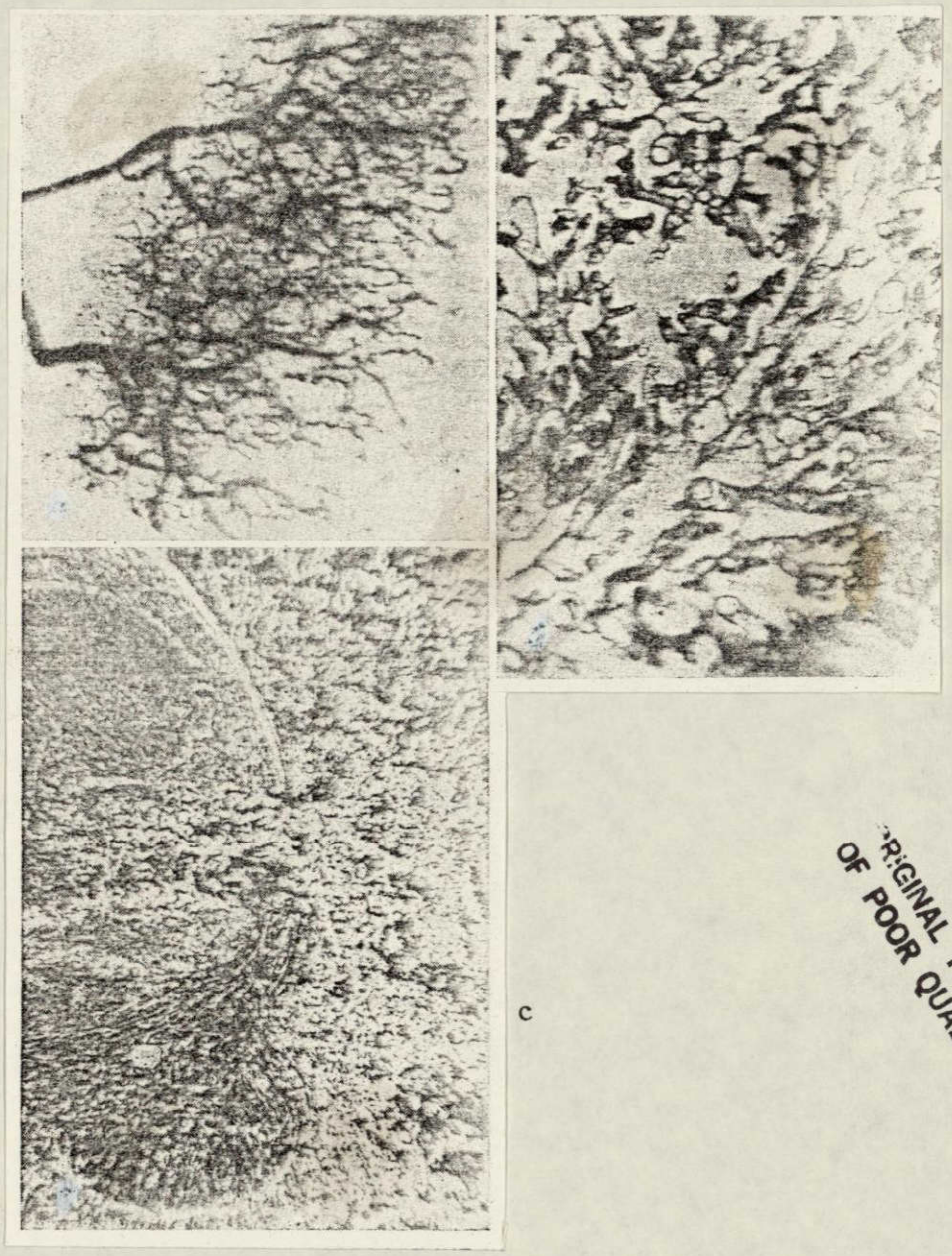
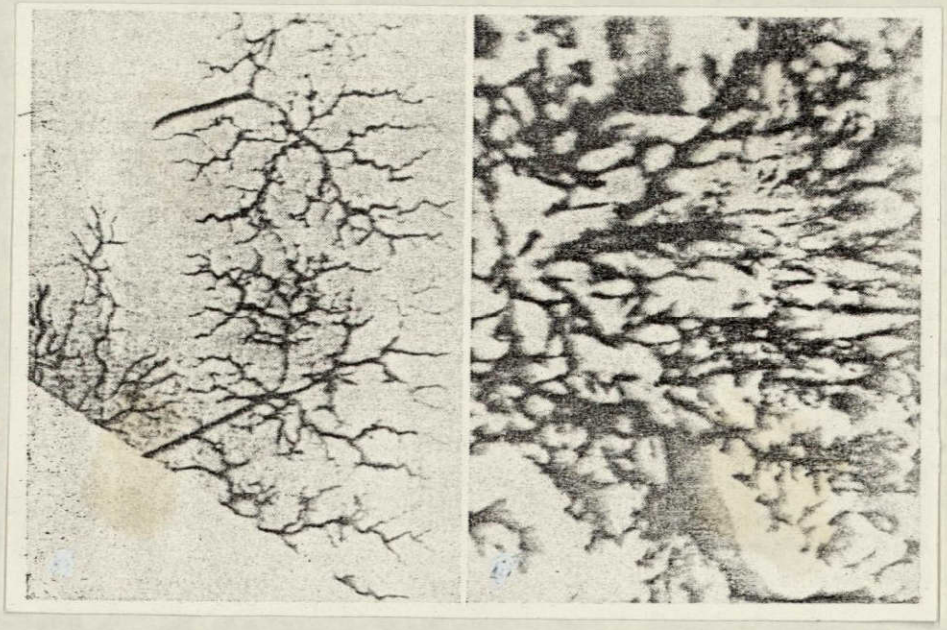


Fig. 1. Vascular bed and histostructure of normal spleen of the rat. a - intraorganic arteries, microrentgenogram; b - intraorganic veins, cleared preparation, x 56; c - histological section, hematoxylin-eosin, x 56.

the end vessels, as before, were not perfused with the contrast substance, so that the vascular network below the splenic capsule was poor due to the presence of spasmic foci. The vessels continued to be sinuous. The small veins of the 5-7 orders were also constricted. The venous network was thick particularly around the follicles. These had gotten smaller and their contours were losing definition. In places there

a



b

Fig. 2. Intraorganic arteries and veins affected by single, continuous, maximum endurable stress in the direction chest-back. a.- intraorganic arteries: contraction of arteries of all orders, weak perfusion of arteries in peripheral portions of spleen; b - intraorganic veins: even contraction of small branches. Cleared preparation, x 56.

was seepage of the dye beyond the confines of the vascular bed.

In the later hypokinetic periods, after 6-8 weeks, the dimensions of the spleen were close to normal. In the vascular bed there was no sign of significant architectonic changes. Arteries of the 3-4 orders were uneven and sinuous and in places the contrast substance transgressed the borders of the vascular bed. Arteries of the 5-6 orders were still contracted, were scarcely or not at all perfused by the rentgenocontrast substance and the vascular network appeared very sparse, particularly at /48 the limits of ramification of each of the segmental arteries and under the capsule.

There was also a significant change in the architectonics of the intraorganic vascular bed. The whole vascular network became homogeneous both under the capsule and in the deep layers of the organ. The small veins of the 5-7 orders appeared dilated and took up the entire visual field. The follicules were not discrete and only in places could one see bits of their distribution. The course of the large veins of the 3-4 orders could not be followed. In places the dye transgressed the limits of the vascular bed (disruption of penetrability of vascular wall). At the same time hi-

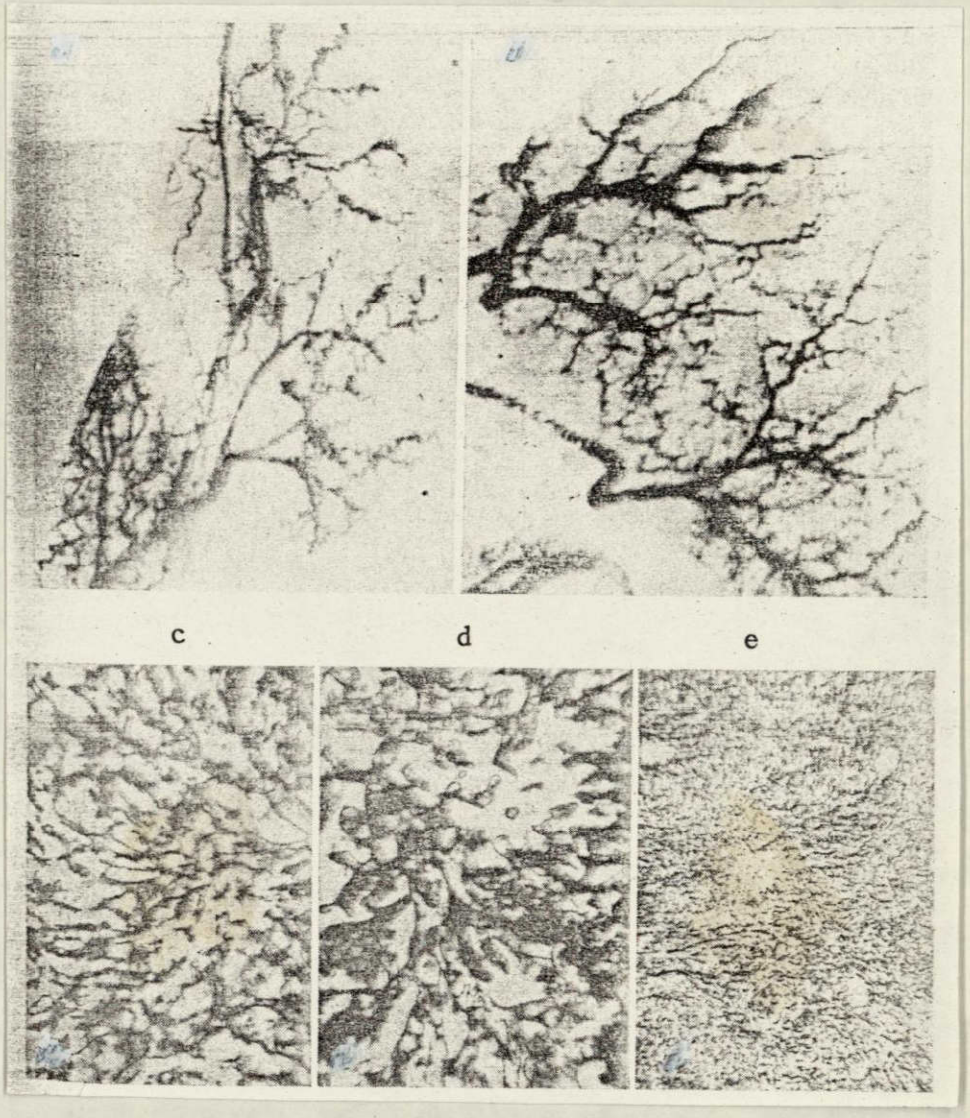


Fig. 3. Vascular bed and structure of spleen affected by hypokinesia and hypodynamia viewed dynamically. a - intraorganic arteries after 2 weeks hypokinesia: extreme sinuosity and nonperfusion of small branches; b - intraorganic arteries after 8 weeks hypokinesia: large branches sinuous, small ones contracted and scarcely receptive of contrast mass; c - intraorganic veins after 2 weeks hypokinesia: even contraction along entire length, cleared preparation, x 56; d - intraorganic veins after 8 weeks hypokinesia: dilatation of veins of 5-7 orders, cleared preparation, x 56; e - histological section: structure of spleen affected by 8 weeks hypokinesia: contraction of central arterial follicles, atrophy of follicles, hematoxylin-eosin, x 56.

stologically striking changes were also noted in the structure of the organ. Atrophy of the follicles could be seen. The lumen of their central vessels was minimal. In some follicles it was closed and the wall of the central arteries thickened (Fig. 3a,

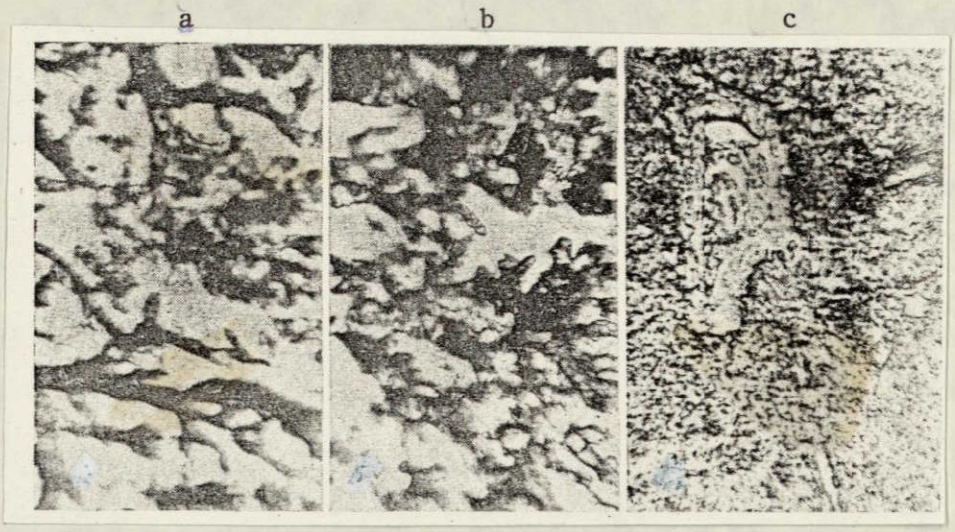


Fig. 4. Vascular bed of spleen and structure of spleen affected by combined effect of hypokinesia and stress. a - intraorganic veins after hypokinesia in week 2 and subsequent stress: small veins contracted, cleared preparation, x 56; b - intraorganic veins after hyperkinesia in week 8 and subsequent stress: severe dilatation of all portions of the venous system of the spleen, cleared preparation, x 56; c - histological section: structure of spleen after hypokinesia in week 8 and subsequent stress: atrophy of follicles, deformation of vascular wall, hematoxylin-eosin, x 56.

3b-e).

Thus, we may conclude on the basis of the experimental material, that in the early periods of hypokinesia the large intraorganic vessels, whether arteries or veins, become uneven along their entire length. Their diameter is narrower in some places and broader in others and they take on sinuosity. Meanwhile the small vessels, both arteries of the 5-6 orders and veins of the 5-7 orders, contract during the early periods of hypokinesia and continue so till the 4th week. In the latter hypokinetic periods the large intraorganic arteries and veins show even greater changes. Along the course of the arteries one often encounters varicose dilations to the point of disruption of their walls. Small arteries remain constricted. In the intraorganic venous bed it is no longer possible to follow the course of the large branches. The small veins of the 5-7 orders dilate during the latter hypokinetic periods (disruption of adaptation reserves). In experimental series III the animals were subjected to the action of two factors: first hypokinesia, then overload. Following periods of hypokinesia of 1, 2, 4, 6 and 8 weeks the animals were subjected to gravitational stress in the chest-back direction at the rate of 9 units in 20 minutes. It should be

In histological preparations, aside from the parenchymatic changes previously described, which occur during the later periods of hypokinesia (atrophy of the follicles and changes in the vascular walls), one finds deformation of the vessels in the form of protrusions of the wall and rupturing with ensuing loss of blood components (Fig. 4a-c).

The results of the third series of our experiments showed, that when there is combined action by two extreme factors on the vascular bed of the spleen the changes in it take on a very pronounced character. Beginning with the second week of hypokinesia gravitational stress intensifies morphological changes in the vascular system and organic stroma taking the form of disruptions of the wall of the arteries and especially of the veins. These changes are most severe in the later periods of hypokinesia.

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