LITERATURE CITED

1. G. N. Kryzhanovskii, V. D. Slepushkin, and G. K. Zoloev, Patol. Fiziol., No. 6, 47 (1987).
2. F. Z. Meerson and M. G. Pshennikova, Adaptation to Stress Situations and to Physical Exertion [in Russian], Moscow (1988).
3. E. I. Chazov, M. I. Titov, V. A. Vinogradov, et al., Vopr. Med. Khim., No. 3, 47 (1984).
4. V. N. Shatalov, V. M. Polonskii, S. A. Bulgakov, et al., Modern Methods of Diagnosis and Treatment of Internal Diseases [in Russian], Moscow (1980), pp. 97-98.
5. J. R. Neely, H. Liebermeister, E. J. Battersby, and H. E. Morgan, Am. J. Physiol., **212**, 804 (1967).

INDEXATION OF MICROCIRCULATORY CHANGES IN ANIMALS WITH EXPERIMENTAL DEHYDRATION

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The microcirculatory system (MC) is one of the functional systems of the body responsible for maintaining the fluid balance [2-5, 15]. Much research into changes in working cells of different organs during dehydration has been published [1, 8-10, 15]. Recent investigations have dealt with the state of the blood vascular system during dehydration [6, 7, 9, 11, 14]. There is evidence on changes in the structure of lymphatic microvessels during dehydration [11, 13]. There is no information in the literature on the role of the interstitial component of MC. There has likewise been no research into the reactivity of MC as a whole to stages of dehydration. This is explained by the absence of any suitable methods for solving problems in the analysis of the system as a whole [3].

The aim of this investigation was to obtain an integral evaluation of the reactivity of MC to the stages of experimental dehydration.

EXPERIMENTAL METHOD

Experiments were carried out on 160 albino rats weighing 180-200 g. The animals had free access to dry food, but were completely deprived of water for 3, 6, and 12 days. MC was studied by a combined assessment of morphological, physiological, and biophysical parameters, determining the state of the fluid balance and the hydrodynamics and permeability of its interstitial, lymphatic, blood vascular, and cellular components. The morphological experiments were carried out on the trapezius muscle, pancreas, and mesentery of the small intestine, in histological preparations, by intravital microscopy, and by electron-microscopy. Functional and biophysical parameters were determined by investigating the total, extra- and intracellular body water, the circulating volume of the blood, and its viscosity. To assess changes in MC, each of its four compartments was characterized by the three most essential indicators.

The method of morphokinetic synthesis [12] provided a basis for generalization of parameters differing in phenomenology and dimensionality. Essentially, to compare objective values of heterogeneous parameters, it uses measured values of relative levels of their deviations from the norm, expressed in points. Values of parameters with no significant deviations from

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TABLE 1. Morphological and Functional Parameters of Fluid Balance in Components of Microcirculatory System, with Their Relative Deviations and Point Ratings

Component of microcirculatory system	IC										
	control					dehydration					
	abs.	points	3 days			6 days			12 days		
			abs.	%	points	abs.	%	pts.	abs.	%	points
I											
Extracellular body water, ml	60±3	1	47±2	22	3	41±2	32	4	40±2	33	4
Stromal component of trapezius muscle, μ^2	209±6	1	142±3	32	4	183±2	12	2	346±5	66	5
Area of pericapillary space of trapezius muscle, μ^2	4,1±0,4	1	3,0±0,2	27	3	2,8±0,3	32	4	2,6±0,2	37	4
BC I		3			10			10			13
					(7)			(0)			(3)
II											
Diameter of lymphatic capillaries in mesentery of small intestine, μ	20,5±2	1	16,2±0,8	21	3	12,3±0,4	40	4	11,5±0,4	44	4
Percentage of lymphatic capillaries containing blood cells	0	1	0	0	1	34/100	34	4	73/100	73	5
Number of vasomotor reactions of lymphatics, deg/min	12±0,5	1	9±0	25	3	6±0,5°	50	5	2±0,4	83	5
BC II		3			7			13			14
					(4)			(6)			(1)
III											
Circulating blood volume, ml	18,2±0,8	1	17,3±0,3	5	1	12,7±0,5	30	3	11,1±0,8	39	4
Diameter of blood capillaries of mesentery of small intestine, μ	6,9±0,1	1	6,6±0,1	4	1	4,8±0,1	30	3	4,1±0,1	41	4
Apparent viscosity of blood, cP	6,65±0,2	1	7,1±0,2	7	1	9,1±0,3	37	4	14,2±0,4	114	5
		3		3				10			13
BC III				(0)				(7)			(3)
IV											
Intracellular body water, ml	74±0,3	1	70±2	5	1	58±2 мл	22	3	40±2	46	5
Parenchymatous component of trapezius muscle, μ^2	838±6	1	905±3	8	2	864±2	3	1	701±5	16	3
Number of muscle fibers per field of vision	9±0,3	1	10±0,5	11	1	11±0,3	22	3	15±0,5	67	5
BC IV		3			4 (1)			7 (3)			13
											(6)
SMI		12			24			40			53

the norm are assessed at one point. Moderate deviations of the parameters, not exceeding 15% of the initial values, were taken as two points. The mean range of deviations of the parameters (from 15 to 30% of the norms) was assessed at three points. Considerable deviations (from 30 to 45%) from the original values were assessed at four points, and marked deviations (over 45%) were rated at five points. Point ratings of the three parameters tested for each component of action were described as initial components (IC) and distinguiShed by numbers from 1 to 12. The point ratings of each component of MC were expressed as the sum of IC. They were called basic components (BC) and described by the roman numerals I (interstitial component), II (lymphatic component), III (blood vascular component), and IV (cellular component). The sum of the point ratings of the above-mentioned four components of MC constituted a general assessment of its state and was described as the systemic microcirculatory index (SMI).

EXPERIMENTAL RESULTS

Table 1 gives absolute values of the IC of the microcirculatory system for analysis, the relative values of their deviations from the norm, and also the point ratings of these deviations in the course of the experiment. Summation of the data in vertical columns determines the values of SMI at each stage of the experiment. For instance, the control Value of SMI is the sum of four BC, which include normal values of three IC, each of which is equal to 1 point. Consequently, the point rating of SMI of the control animals is 12, and written out in full it appears as follows:

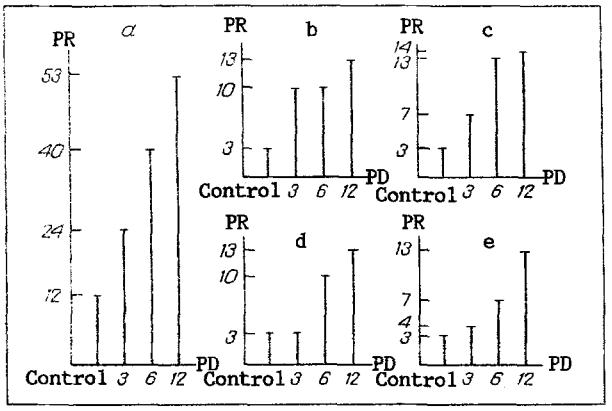

Fig. 1. Basal changes in systemic microcirculatory index (a) and also of basic components of interstitial (b), lymphatic (c), blood vascular (d), and cellular (e) compartments of microcirculatory system in rats with experimental dehydration. PD) periods of dehydration; PR) point ratings.

$$SMI_c = \begin{matrix}1(1)\\2(1)\\3(1)\end{matrix} \text{ I } + \text{II } \begin{matrix}4(1)\\5(1)\\6(1)\end{matrix} + \text{III } \begin{matrix}7(1)\\8(1)\\9(1)\end{matrix} + \text{IV } \begin{matrix}10(1)\\11(1)\\12(1)\end{matrix} = 12 \quad (1)$$

At the 3-day stage of dehydration, considerable and average deviations of IC were found in the interstitial and lymphatic components of MC, in the absence of any significant changes in its blood vascular component and in the presence of moderate changes in the cellular component. These changes lead to an increase in SMI to 24:

$$SMI_{d\ -3} = \begin{matrix}1(3)\\2(4)\\3(3)\end{matrix} \text{ I } + \text{II } \begin{matrix}4(3)\\5(1)\\6(3)\end{matrix} + \text{III } \begin{matrix}7(1)\\8(1)\\9(1)\end{matrix} + \text{IV } \begin{matrix}10(1)\\11(2)\\12(1)\end{matrix} = 24 \quad (2)$$

The 6-day stage of dehydration, characterized by some change in IC of the interstitial component, was characterized by no change in its BC, by an increase in the changes of IC of the lymphatic component to considerable, and to marked changes, whereas changes in parameters of the blood vascular system were average and considerable, and changes in the cellular component were moderate and average. This was responsible for an increase in the SMI to 40:

$$SMI_{d\ -6} = \begin{matrix}1(4)\\2(2)\\3(4)\end{matrix} \text{ I } + \text{II } \begin{matrix}4(4)\\5(4)\\6(5)\end{matrix} + \text{III } \begin{matrix}7(3)\\8(3)\\9(4)\end{matrix} + \text{IV } \begin{matrix}10(3)\\11(1)\\12(3)\end{matrix} = 40 \quad (3)$$

The sublethal stage of dehydration was characterized by an increase in the changes of IC in the interstitial, lymphatic, and blood vascular components of MC to considerable and to marked, in the presence of marked changes in the analogous components of the cellular compartment. Under these circumstances SMI reached 53:

$$SMI_{d\ -12} = \begin{matrix}1(4)\\2(5)\\3(4)\end{matrix} \text{ I } + \text{II } \begin{matrix}4(4)\\5(5)\\6(5)\end{matrix} + \text{III } \begin{matrix}7(4)\\8(4)\\9(5)\end{matrix} + \text{IV } \begin{matrix}10(5)\\11(3)\\12(5)\end{matrix} = 53 \quad (4)$$

These results demonstrate the informativeness of the technique of morphokinetic synthesis for the integral assessment of reactivity of MC during dehydration. Deviations of SMI from the norm determine the range of changes of MC in the course of dehydration and also the contribution of each of its components to changes developing at the stages of the experiment. If the initial value of SMI is taken as 100%, it will be seen that in the early periods of dehydration it was doubled in value, at the intermediate stage it was more than trebled, and at the sublethal stage. It was increased by almost 4.5 times (40% of the control) (Fig. 1a). Consequently, the maximal level of changes in SMI was determined at the 12-day period of dehydration. However, the maximal level of the rise in SMI (16 points) was discovered between the 3rd and 6th days of the experiment. With the aid of the extended algorithms of SMI (1-4) the contribution of each component of MC at each stage during mobilization of the intracorporeal fluid reserves can be estimated. For instance, the maximal level of changes in the interstitial component (7 points) occurred at the 3-day stage of the experiment, and by the sublethal stage it increased by a further 3 points (Fig. 1b).

Changes in the lymphatic component of MC at the 3-day stage of dehydration amounted to 4 points, at the intermediate stage to 5 points, and ak the sublethal stage to 2 points. Consequently, the maximal level of changes in the lymphatic component of MC was determined at the intermediate stage of dehydration (Fig. 1c).

The early stages of dehydration were not accompanied by changes in the point ratings of the blood vascular component of MC. At the intermediate stage of dehydration, changes in the blood vascular bed reached 7 points, and by the sublethal stage they rose by a further 3 points (Fig. 1d).

The cellular elements of MC in the early stages of dehydration also showed moderate changes (1 point). In the intermediate stage of dehydration, BC of the cellular component was increased by 3 points, and by the subcellular stage, it was increased by 6 points (Fig. 1e).

The earliest changes in SMI during dehydration were thus due to the interstitial component of MC. A leading role in the changes in the vascular components is played by reactivity of the lymphatic bed. Maximal changes in the blood vascular and lymphatic components were noted at the intermediate stages of dehydration. The cellular component of MC, which remained virtually unchanged in the early stage of dehydration, responds moderately to the intermediate stage, and undergoes marked changes at the sublethal period of dehydration.

LITERATURE CITED

1. V. A. Kalishchuk, Functional Mechanisms of Adaptation in Animals Under Conditions of the Arid Zones [in Russian], Novosibirsk (1970), pp. 30-39.
2. V. I. Kozlov, Arkh. Anat., **78**, No. 4, 87 (1980).
3. V. V. Kupriyanov, Arkh. Anat., **62**, No. 3, 14 (1972).
4. V. V. Kupriyanov, Current Problems in General Pathology and Pathophysiology [in Russian], Moscow (1976), pp. 249-261.
5. V. V. Kupriyanov, Usp. Sov. Biol., **88**, No. 5, 241 (1979).
6. V. V. Kupriyanov, M. A. Magomedov, and A. N. Tikhomirov, Arkh. Anat., **77**, No. 8, 5 (1979).
7. M. A. Magomedov, Arkh. Anat., **75**, No. 11, 47 (1978).
8. A. D. Soboleva and G. S. Shishkin, Materials on Ecologic Morphology [in Russian], Novosibirsk (1973), pp. 123-129.
9. A. D. Soboleva and N. V. Ustyuzhanova, Materials on Ecologic Morphology [in Russian], Novosibirsk (1973), pp. 83-90.
10. A. D. Soboleva, Response of Cells and Tissues to Dehydration [in Russian], Novosibirsk (1975).
11. S. B. Stefanov, Arkh. Anat., **88**, No. 2, 78 (1985).
12. N. V. Synkova and N. R. Karelina, Problems in Lymphology [in Russian], Novosibirsk (1988), p. 68.
13. A. N. Tikhomirov and M. A. Magomedov, Functional Morphology of Lymph Nodes and Other Organs of the Immune System and Their Role in Immune Processes [in Russian], Moscow (1983), pp. 168-169.
14. A. N. Tikhomirov and E. A. Lyubimtseva, Byull. Éksp. Biol. Med., No. 9, 369 (1987).
15. A. M. Chernukh, Inflammation [in Russian], Moscow (1979).