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COMPARATIVE MORPHOLOGICAL AND FUNCTIONAL STUDY OF INDIVIDUAL RESISTANCE OF ANIMALS TO HYPOXIA

N. A. Agadzhanyan, S. S. Aleksandrova, L. V. Shevchenko, and A. I. Elfimov

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The aim of this investigation was to analyze ways of realization of the adaptive reserve capacity by phylogenetically different brain structures in animals differing in their initial resistance to hypoxia and to look for correlation between resistance to hypoxia and the dynamics of the acid–base balance.

EXPERIMENTAL METHOD

Experiments were carried out on 50 mature male rats weighing 180-200 g. Depending on their individual resistance to hypoxia the animals were divided into rats with low (LRR) and high (HRR) resistance [2]. The animals of each group were then divided into control and experimental, and exposed for 8 h daily in a pressure chamber at an "altitude" of 5000 m for 1 month.

Concentrations of cytoplasmic RNA (by Einarson's method) and total protein [3] were determined in the cerebral cortex and reticular formation (RF). These parameters were determined quantitatively on a scanning microspectrophotometer [1] and also by morphometry and karyometry.

The animals were decapitated and the brain fixed in Carnoy's fluid and embedded in paraffin wax. The acid–base balance of blood taken from the jugular vein was studied on an OP-210/2 microanalyzer.

EXPERIMENTAL RESULTS

Analysis of the results of the histochemical study of protein metabolism in HRR showed that its intensity is higher in RF than in the cortex (Table 1). Long-term adaptation was accompanied by an increase in the RNA and protein concentration both in the cortex and in RF, evidence of activation of protein metabolism. The high intensity of this process in RF is probably attributable to the fact that adaptation in these animals is maintained by high protein metabolism at the medullary level. The stability of the dimensions of the cytoplasm of cortical neurons is explained by their need to maintain a sufficiently high RNA and protein concentration, in order to sustain a high level of metabolism. In RF, against the background of a reduced area of cytoplasm, the total content of RNA and protein was reduced. These findings suggest that adaptation to hypoxia in HRR is effected mainly by subcortical structures. The RNA/protein ratio in the test structures in HRR was unchanged after training in the pressure chamber, evidently as a result of the stability of protein metabolism in the brain tissue. This perhaps also determines the high level of their adaptation to hypoxia.

The RNA content in RF was found to be higher than in the cortex in LRR (Table 1). Long-term pressure chamber training was accompanied by a fall in the RNA level in the cortex and a rise in the total protein level. Changes in protein metabolism in RF were less marked and were characterized by a synchronous fall of the RNA and protein levels in response to long-term exposure to hypoxia. Analysis of changes in protein metabolism showed that the RNA/protein ratio decreased after adaptation to hypoxia in the structures studied: not signifi-

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TABLE 1. Parameters of Morphometry and Karyometry, RNA and Protein Concentrations in Cytoplasm of Neurons of Phylogenetically Different Parts of the Brain in Animals Differing in Individual Resistance to Hypoxia, before and after Pressure Chamber Training

Brain structure	Parameter studied	LRR		HRR	
		control	experiment	control	experiment
Cerebral cortex	RNA per μ^2	0,0129±0,0004	0,0121±0,0006	0,0119±0,0006	0,0143±0,0005
	Protein per μ^2	0,0254±0,0003	0,0309±0,0015	0,0259±0,0007	0,0300±0,0002
	RNA/protein	0,509±0,02	0,402±0,05	0,385±0,007	0,476±0,02
	Area of cells	210,6±1,6	159,0±4,0	228,5±1,2	211,0±5,2
	Area of cytoplasm, μ^2	107,5±1,1	70,7±2,8	107,2±1,3	107,1±4,1
	Cytoplasmic RNA	1,388	0,860	1,200	1,529
	Cytoplasmic protein	2,727	2,292	2,800	3,213
RF	RNA per μ^2	0,0180±0,0003	0,0149±0,0013	0,0216±0,0003	0,0281±0,0001
	Protein per μ^2	0,0461±0,001	0,0426±0,0001	0,0368±0,0003	0,0481±0,0007
	RNA/protein	0,392±0,01	0,327±0,03	0,588±0,003	0,585±0,008
	Area of cells	367,0±12,4	366,7±7,0	454,1±9,2	368,6±7,0
	Area of cytoplasm, μ^2	238,1±10,7	239,8±6,0	294,1±7,5	207,7±7,1
	Cytoplasmic RNA	4,291	3,421	6,3	5,875
	Cytoplasmic protein	10,980	10,220	10,8	9,999

TABLE 2. Parameters of Acid–Base Balance of Venous Blood from Rats Differing in Individual Resistance to Hypoxia (M ± m)

Parameter studied	LRR		HRR	
	control	experiment	control	experiment
pH	7,354±0,02	7,306±0,02	7,285±0,02	7,315±0,02
pO_2	42,29±4,80	47,17±3,93	41,50±3,02	40,50±9,43
pCO_2	39,63±1,44	41,58±1,70	51,00±3,27	42,20±1,35
BB	45,09±1,58	41,75±0,77	42,25±1,76	45,38±1,31
BE	—2,90±0,63	—5,59±0,98	—3,13±1,82	—5,10±0,88
AB	21,96±0,61	20,32±0,58	23,88±2,08	20,63±0,59

TABLE 3. Correlation between Parameters of Protein Metabolism of Brain and Acid–Base Balance of Venous Blood in Animals Differing in Resistance to Altitude

Group of animals	Parameter studied	Mean value of parameters of brain protein metabolism (cortex, cerebellum, reticular formation)					
		RNA		protein		RNA/protein	
		control	experiment	control	experiment	control	experiment
LRR	pH	+0,14	+0,20	+0,24	−0,78	−0,11	+0,03
	pO_2	−0,95	+0,69	+0,05	−0,11	−0,65	+0,62
	BB	+0,97	+0,72	−0,03	−0,50	+0,65	+0,69
	AB	+0,85	−0,93	+0,33	−0,14	+0,34	−0,89
	BB—AB	+0,95	+0,93	−0,42	−0,19	+0,90	+0,88
HRR	pH	−0,27	−0,43	−0,91	−0,14	+0,60	−0,24
	pO_2	−0,39	+0,99	+0,97	−0,80	−0,97	+0,98
	BB	+0,27	−0,10	−0,99	−0,49	+0,93	+0,05
	AB	+0,68	−0,60	−0,83	+0,48	+0,99	−0,52
	BB—AB	−0,99	+0,13	+0,16	−0,62	−0,61	+0,23
LRR + HRR	pH	+0,71	+0,34	+0,67	−0,39	+0,02	+0,34
	pO_2	+0,37	−0,10	+0,64	−0,02	−0,56	−0,05
	BB	+0,42	+0,74	+0,08	−0,73	+0,63	+0,72
	AB	+0,13	+0,27	−0,12	−0,42	+0,43	+0,32
	BB—AB	+0,48	+0,47	+0,33	−0,38	+0,32	+0,43

cantly in RF but significantly in the cortex (Table 1). It can be tentatively suggested that this parameter is closely linked with the resistance and the plasticity of the structures during exposure of the animal to extremal factors.

The results of morphometry and karyometry showed that in both LRR and HRR the area of the neurons decreased after training in the structures tested. However, whereas in the cortex these changes were accompanied by a significant decrease in area of the cytoplasm, and by a fall in the level of cytoplasmic RNA (by 1.6 times) and protein (by 1.2 times) compared with the control, some increase in the area of the cytoplasm was observed in RF, thus maintaining a sufficiently high level of protein metabolism in this structure as a whole.

It can be concluded from comparison and analysis of the results that animals differing in their individual resistance to hypoxia have a strictly individual level of protein metabolism in their brain tissue and that they realize their reserve capacity differently during adaptation to hypoxia.

Analysis of the results for the acid–base balance of the blood showed that its parameters differed in LRR and HRR. The blood in HRR was more saturated with carbon dioxide and had a lower pH, whereas the oxygen and buffer base levels were virtually identical (Table 2). Significant correlation was found between pH, pO_2, the protein component of the buffer bases (BB–AB), and the altitude resistance of the control animals ($r = -0.53$, $r = -0.77$, and $r = -0.60$ respectively).

Pressure chamber training led to elevation of pH (on account of lowering of pCO_2 in HRR and to a fall of pH in LRR, which was accompanied by a fall in the buffer base level (Table 2). The concentration of buffer bases fell in LRR after training but in HRR it was unchanged. This is explained by reduction of the protein component in LRR, but by an increase in the protein and a decrease in the bicarbonate component in HRR. If these data are compared with the coefficients of correlation between the blood buffer bases and parameters of brain protein metabolism (Table 3) definite correlation can be observed between the significant increase in the mean RNA level and the relative rise of the protein component of the buffer bases in HRR after training. This is also shown by reversal of the sign of correlation between the parameters examined. No marked change in correlation between the parameters studied could be found in LRR.

It can be concluded from the experimental results that there is a definite connection between the level of protein metabolism in brain tissue, the acid–base balance of blood flowing from the brain, and the functional state of the animal as a whole, characterized by individual resistance to hypoxia.

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