ENERGY POTENTIAL OF THE LIVER IN THE EARLY STAGES OF THE CRUSH SYNDROME

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There have been many investigations of the pathogenesis of the crush syndrome [4, 8]. However, the character of the functional and metabolic disturbances developing in the liver in the crush syndrome has been inadequately studied. The writers showed previously [2] that severe crush injury is accompanied by disturbances of the regional circulation and by a decrease in the volume of blood in the liver.

This paper gives the results of a study of the energy potential of the liver in the early period of the crush syndrome.

EXPERIMENTAL METHOD

Experiments were carried out on 104 male albino rats weighing 150-200 g. Severe crushing of the soft tissues of the hind limbs was applied for 4 h [5]. The rats were killed by immersion in liquid nitrogen. Adenine nucleotides were extracted from weighed samples of the liver with 6% $HClO_4$ solution. Tissue extracts were applied by micropipet to Silufol UV-254 plates (from Chemapol), in a final volume of 10 μl. Adenine nucleotides were separated in a system of dioxane–isopropanol–ammonia–water [3]. Concentrations of ATP, ADP, and AMP were determined by fluorometric scanning of thin-layer chromatograms on an MPF-4 spectrofluorometer (Hitachi, Japan) [1]. Chromatographically pure adenosine-5-mono-, di-, and triphosphates (Sigma) were used as reference substances. Inorganic phosphate was determined by the method of Fiske and Subba Row [10]. The energy potential of the liver was judged by concentrations of individual adenine nucleotides and the energy charge of the adenine-nucleotide system, calculated by the method of Atkinson [9]. The numerical results were subjected to statistical analysis by Student's t test.

EXPERIMENTAL RESULTS

The distribution of the experiments by series and the results are given in Table 1. They show that immobilization of rats for 4 h led to a significant fall in the ATP concentration and an increase in the concentrations of ADP, AMP, and inorganic phosphate in the liver, and a reduction in the energy charge of the adenine-nucleotide system. Changes in energy potential in the rat liver were most marked 6 h after immobilization and disappeared toward the end of 24 h. Severe crush injury was accompanied by more profound disturbances of energy metabolism in the liver than immobilization stress. Immediately after trauma the ATP concentration was down by 48%, the ADP and AMP concentrations were up by 36 and 49% respectively, and the energy charge was down by 21% compared with the control animals. A tendency for the ADP and AMP concentrations in the rat liver to rise was observed 12 h after trauma. Concentrations of the various metabolites studied in the liver of animals surviving 72 h after trauma, except ADP, reached the characteristic values for the control rats.

Marked changes in the energy potential of the liver were thus observed in rats in the early postcompression period of the crush syndrome, evidence of disturbances of energy production in this vitally important organ.

Disturbances of energy production in the liver in the crush syndrome are very complex in their mechanism, but it can be tentatively suggested that they are due mainly to two factors: disturbances of the systemic hemodynamics and blood supply of the liver and the direct action

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TABLE 1. Concentrations of Adenine Nucleotides and Inorganic Phosphate (μmoles/g wet weight of tissue) in rat liver in early period of crush syndrome (M ± m)

Time after procedure, h	Procedure	n	Adenine nucleotides			Energy charge of ATP-ADP-AMP system	Inorganic phosphate
			ATP	ADP	AMP		
Control	—	10	2,86±0,02	0,84±0,02	0,41±0,02	0,80±0,003	5,16±0,17
0	Immobilization	5	2,08±0,05*	1,02±0,04*	0,53±0,02*	0,71±0,005*	6,85±0,53*
	Trauma	15	1,48±0,09**	1,14±0,06**	0,61±0,01**	0,63±0,014**	16,90±1,70
6	Immobilization	5	1,87±0,17*	0,95±0,15*	0,68±0,13*	0,68±0,030*	7,45±0,86*
	Trauma	15	1,51±0,24**	1,19±0,17**	1,12±0,13**	0,54±0,020**	10,80±0,70**
12	Immobilization	5	2,28±0,03*	0,79±0,02*	0,57±0,07*	0,74±0,013*	6,70±0,40*
	Trauma	15	1,60±0,18**	0,92±0,07**	0,97±10**	0,58±0,030**	11,10±0,050**
24	Immobilization	5	2,74±0,64	0,60±0,17*	0,39±0,09	0,78±0,071	5,60±0,70
	Trauma	15	1,87±0,25**	0,63±0,16	0,84±0,09**	0,59±0,036**	9,60±1,00**
72	Immobilization	5	2,84±0,050	0,78±0,15	0,58±0,08	0,78±0,030	6,00±0,50
	Trauma	9	2,60±0,30	0,51±0,10	0,60±0,07	0,77±0,030	6,00±0,70

Legend. *) Difference statistically significant ($P < 0.05$-0.01) between control and immobilized rats; **) between immobilized animals and rats with crush syndrome.

of an ischemic toxin of protein nature, circulating in the blood stream, on the liver. Severe crush injuries, as has been observed previously [2, 6], are accompanied by a decrease in the circulating blood volume, dilatation of the capacitive vessels of the skin, skeletal muscles, and some internal organs, and a reduction in the volume of blood in the liver. The reduction in the volume of the blood in the liver under these conditions is connected with the use of the intrahepatic "blood depot" in the system of the general circulation and it can be regarded as a protective reaction. However, considering the barrier function of the liver and its polyfunctional role in the body, this reaction to trauma and shock as a whole must be interpreted as pathological, for it leads to ischemia of the liver. Acute ischemia disturbs energy metabolism in the liver and lowers its energy potential [11]. Ischemic toxin in turn can interact with the liver mitochondria and disturbs ATP synthesis [7].

These two factors may thus lead to a disturbance of energy metabolism in the liver in the early period of the crush syndrome.

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