SOME BIOCHEMICAL AND HEMATOLOGICAL CHANGES DURING HEMOPERFUSION IN ACUTE STAGE OF THE LONG-TERM CRUSH SYNDROME

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A pathogenetic factor aggravating the long-term crush syndrome (LTCS) is the toxic factor, which is particularly dangerous after release of the limb from compression as a result of the inflow of tissue poisons into the blood stream [3]. The first organ to react is the liver, on which falls the main load of detoxification of toxic substances entering the body after release of the limb from compression. Of the toxic products the most important are considered to be myoglobin, free hemoglobin, and potassium [1, 2, 4, 5, 9, 10].

The object of this investigation was to use the hemoperfusion method in the acute stage of LTCS to remove toxic substances from the blood.

EXPERIMENTAL METHOD

Experiments were carried out on 30 adult dogs weighing 13.5-25 kg. Mechanical trauma to the soft tissues of the thigh was caused by crushing it with a special press with a force of 7-8 kgf/cm^2 for 6 h. At the beginning of the experiment the dogs were anesthetized with hexobarbital. In 10 cases hemoperfusion using charcoal adsorbents (IGI type) was carried out 2 h after decompression with the aim of removing myoglobin, potassium, and other possible toxins from the blood. The biochemical and hematological tests were carried out before crushing and 30 min and 1, 2, 3, and 6 h after decompression, and again after 1 and 3-4 days and 1, 2, 3, and 4 weeks of the period of observation. In animals treated by hemoperfusion, blood samples were taken before and 2 h after compression, and again 15, 30, and 60 min after the beginning of hemoperfusion. The tests were repeated 1 h, 1 day, and 3-4 days after hemoperfusion. The concentrations of myoglobin, free hemoglobin, total protein, and creatinine, creatine phosphokinase activity, concentrations of potassium, magnesium, and phosphorus, leukocyte and erythrocyte counts, hematocrit index, and hemoglobin concentration were determined in the blood.

EXPERIMENTAL RESULTS

The state of areactivity of the animals 1 h after removal of the press was particularly marked. The pulse and respiration rates were sharply increased. After decompression, the thigh of the crushed limb appeared flattened, unusually pale, and cold to the touch. Sensation in the limb was virtually absent. Pulsation in the femoral artery reappeared after 3-5 min. The limb gradually became warm to the touch and increased quickly in volume on account of developing edema.

During long-term crushing of the soft tissues of the limb reactive changes were most marked in the early period after removal of the press and restoration of the blood flow in the limb. Table 1 shows a sharp rise in the myoglobin level in the blood from the first minutes after decompression, to peak values 6 h after crushing. After 1 day the myoglobin level in the surviving dogs was sharply reduced, although it continued to remain higher than normal. The highest potassium level was reached 2 h after removal of the press, when it was increased by 1.33 times on average ($P < 0.01$). Hyperkaliemia continued even after 1 month of observation. Table 1 also shows that the animals had slight hyperproteinemia. The intensity of

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TABLE 1. Changes in Some Biochemical Parameters during Long-Term Crush Syndrome (M ± m)

Time of decompression	Parameter							
	myoglobin, g/liter	potassium, mM	CPK, U/liter	plasma hemoglobin, mg %	protein, g %	creatinine, mM	magnesium, mM	phosphorus, mg/liter
Initial level	0,09±0,01	5,18±0,19	17,3±1,4	37,1±3,9	7,99±0,5	0,72±0,05	1,45±0,03	9,3±0,2
15—30 min	1,86±0,2	6,66±0,4	74,03±5	286±13	9,05±0,5	—	—	—
After decompression								
1 h	2,36±0,27	8,82±0,5	78,6±8,2	262±15	8,2±0,4	1,13±0,01	—	—
2 h	1,88±0,3	8,78±0,4	116,4±13	283±16	8,5±0,3	1,25±0,02	2,053±0,02	10,3±0,1
3 h	4,4±1,14	7,05±0,42	132,5±6,3	70±5,3	8,2±0,5	—	—	—
6 h	4,26±1,56	8,74±0,94	122,6±4,5	49,3±3	9,5±0,6*	—	—	—
1 day	2,88±0,8	9,67±2,9*	105,7±14,4*	54,8±5	—	—	—	—
4 days	1,11±0,3	7,25±0,97	62,65±19,3*	63,6±6	—	—	—	—
1 month	0,82±0,03	9,7±0,4*	112,6±8,4	423,6±18*	7,9±0,5	1,17±0,02	—	—

Legend. Asterisk indicates that changes are not statistically significant. Remaining values significant at $P \leqslant 0.05$ level.

TABLE 2. Changes in Hematological Parameters during Hemoperfusion for Crush Syndrome (M ± m)

Time of investigation	Hemoglobin, g/liter	Erythrocytes, 10^{12}/liter	Hematocrit, vol. %	Mean erythrocyte volume, μm	Leukocytes, 10^9/liter
Initial level	144±9	4,59±0,3	43±1,8	93±1,5	8,4±1,5
2 h after decompression	229±7,0*	5,8±0,2*	59±2,3*	102±2,3	19,5±1,7*
15 min of hemoperfusion	284±6,0*	5,85±0,4	60±6,4	102±2,0	12,1±3,2*
30 min »	263±6,0*	5,92±0,4	60,5±5,6	102±1,9	7,38±2,1*
60 min »	250±2,0	5,73±0,2	58±2,4	101±1,7	5,86±1,71*
1 h after hemoperfusion	241±1,0	5,81±0,12	59,2±2	102±0,9	9,25±2,3*
1 day after hemoperfusion	146,6±8,1*	5,1±0,3	47,6±3	93,3±3,0	23,8±4,1
3-4 days after hemoperfusion	165±4,7*	4,64±0,11	40±6,4	86,2±2,2	16,1±3,3

Legend. Statistically significant changes ($P \leqslant 0.05$) indicated by asterisk.

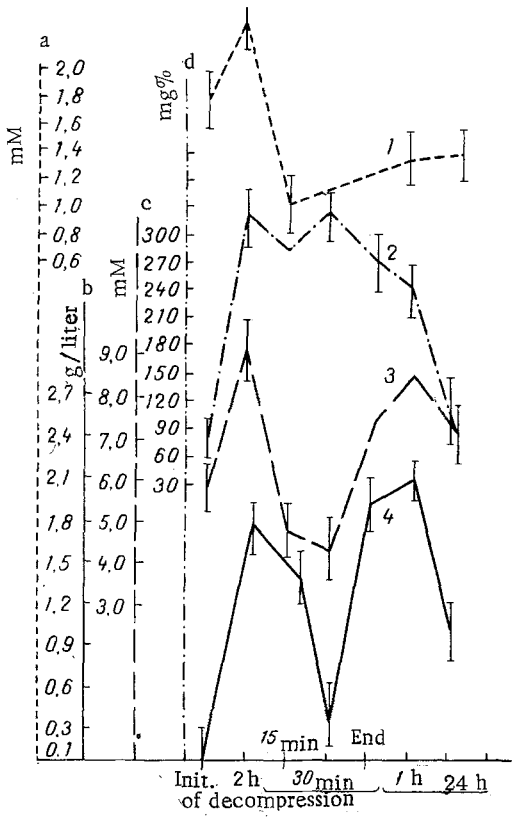

Fig. 1. Changes in hemolysis (2) and in blood magnesium (1), potassium (3), and myoglobin (4) concentrations during hemoperfusion after decompression. Abscissa, time after decompression; ordinate, concentrations of: a) magnesium (in mM), b) myoglobin (in g/liter), c) potassium (in mM); d) hemolysis (in mg %).

hemolysis, 3 h after decompression was increased about sevenfold. The magnesium, phosphorus and creatinine concentrations and creatine phosphokinase activity were sharply increased.

In the acute stage of the LTCS hemoconcentration, erythrocytosis, and pleiochromia developed. An increase also was observed in the erythrocyte volume, on average by 14% ($P < 0.05$). By the end of the second hour of decompression the mean hematocrit index was increased from 43.0 ± 1.8 to 59.0 ± 2.3 vols. % ($P < 0.001$). The erythrocyte/plasma cell ratio was increased from 0.75 to 1.44 ($P < 0.05$), evidence of hemoconcentrations. Leukocytosis, due to redistribution of the liquid part of the blood and also to release of neutrophils from the bone marrow [6, 7], was present in all animals. By the end of the first day hemoconcentration was reduced and a tendency toward normalization of the erythrocyte composition of the blood appeared. The leukocyte count remained high throughout the so-called intermediate period, covering the first few days after trauma.

The character and degree of the biochemical and hematological changes thus demonstrate the severity of the animal's condition as a result of LTCS and the ensuing toxemia.

It was interesting to discover how the animal's state changes under the influence of hemoperfusion for LTCS. When the optimal time was chosen for hemoperfusion, the decision made was 2 h, when the blood myoglobin and potassium concentrations reached dangerous values threatening life. The myoglobin level 30 min after the beginning of hemoperfusion with charcoal absorbents was found to be reduced by 75% ($P < 0.001$; Fig. 1). The free hemoglobin concentration in the blood plasma also was reduced.

A sharp fall in the potassium level and a small but not significant fall in the creatinine concentration in the blood were observed. Hypoproteinemia, hypomagnesemia, and a fall of creatine phosphokinase activity also were observed. However, 1 h after the beginning of hemoperfusion and, in particular, 1 h after its end, the myoglobin and potassium concentra-

tions rose again on account of saturation of the adsorbent. The total protein and free hemoglobin concentrations in the plasma became stabilized after 24 h but concentrations of myoglobin and potassium and creatine phosphokinase activity continued to remain at an extremely high level. This is evidence that a single hemoperfusion procedure improves the biochemical parameters only temporarily and incompletely.

Attention was concentrated in particular in this investigation on the dynamics of myoglobin and potassium ions, the level of which rose sharply after decompression (Table 1). Hypermyoglobinemia is the cause of development of acute renal failure in these patients as a result of mechanical obstruction to the convoluted tubules of the kidneys, but the high potassium ion concentration in the plasma may have a toxic action on heart muscle, leading to the development of paroxysmal tachycardia. After a single hemoperfusion procedure, the level of these parameters was found to be considerably reduced.

Table 2 shows that hemoperfusion caused no fundamental changes to the dynamics of the red blood picture during crushing. The erythrocyte count, hemoglobin concentration, and hematocrit index remained high throughout the period of hemoperfusion. The leukocyte count, on the other hand, fell (on average by 70%; $P < 0.01$) which reflected the general pattern of the trend of the leukocyte count during hemoperfusion. The writers showed previously that leukopenia develops during hemoperfusion not as a result of increased destruction of leukocytes, but as a result of emergency sequestration and storage of white blood cells, which has a preventive and protective role [8].

As a result of prolonged crushing of the soft tissues in dogs, a symptom complex of disturbances characteristic for LTCS was discovered: shock-like disorders in the acute stage of trauma, characteristic changes affecting the injured limb, and also a number of hemobiochemical and hemomorphological changes: hypermyoglobinemia, hyperkaliemia, hypermagnesemia, hyperproteinemia, and also hemoconcentration, leading to erythrocytosis, pleiochromia, leukocytosis, and a high plasma level of free hemoglobin. At the beginning of hemoperfusion with charcoal adsorbents the concentrations of myoglobin, potassium, and magnesium in the blood fell regularly. In the writers' view, these findings may be highly relevant to definitive treatment and emergency aid for the victims of crushing injuries.

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