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# THE ROLE OF THE FUNCTIONAL CONDITION OF ERYTHROCYTES IN DETERMINING THE PROGNOSIS IN PATIENTS WITH BURN INJURY

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## ABSTRACT

In the event of a burn injury, one of the leading pathogenetic mechanisms of complications is intravascular hemolysis of erythrocytes. Oxidative stress is the initiating factor in the development of hemolysis. The appointment of ceruloplasmin solution is pathogenetically directed at clinical signs of burn shock. Its appointment during a 10-day stay in the clinic is an important component of the intensive care unit. Determining the indices of the functional state and architecture of erythrocytes is an important component of the diagnostic program for peak trauma.

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**Introduction.** Changes in the structure and function of erythrocytes play an important role in the development of hypoxia, so the study of human [1, 2].

One of the main biophysical indicators of blood is its rheological properties. Blood rheology – fluidity, determined by the totality of the functional state of the formed elements (mobility, deformability, aggregation activity of erythrocytes, leukocytes and platelets), viscosity (concentration of proteins and lipids) and osmolarity of blood. The microcirculatory section of the vascular system is the place where the greatest resistance to blood flow is manifested [3, 4]. The key role in the formation of the rheological parameters of blood belongs to uniform elements, primarily erythrocytes, which make up 98% of the total cell population [5] and, according to the experimental data of VD Malyshev, AP Pleskova (1994), determine the fluidity of blood at the level of microvessels – in the zone where gas exchange takes place [6, 7]. The transport of substances through the erythrocyte membrane is carried out, depending on their chemical properties, in several ways: by diffusion through lipid regions, or by carrier proteins embedded in the membrane [8, 9]. The erythrocyte membrane is easily permeable to gases and anions. Some enzymes are adsorbed and transported on the membrane surface [10]. The erythrocyte membrane is not permeable to glucose, urea, potassium and sodium cations and is impermeable to proteins. Membrane ion pumps provide active transport of sodium ions and glucose molecules [11].

Of particular scientific interest is the state of erythrocytes, which are responsible, first of all, for the transport of oxygen in critical conditions of the body, when there is a threat of occurrence or is already developing hypoxia. With the onset and progression of various diseases, as well as in critical conditions, injuries accompanied by severe tissue damage, the water-electrolyte composition of the blood is disturbed [12, 13] and, as a consequence, the functioning of the blood corpuscles is impaired. There is a violation of one of the most important biophysical indicators of blood – microrheological properties. Infusion of various solutions is used as replacement therapy for critical and terminal conditions.

Hemorheological disorders contribute to the development of hypoxia, the severity and duration of which determines the likelihood of septic complications, multiple organ failure and mortality [14].

Under the influence of unfavorable factors (disease, trauma, hypo, hyperthermia), various changes can occur with erythrocytes – the structure changes, normal functioning is disrupted.

Irreversible morphological changes in the erythrocyte often end in hemolysis – the destruction of the erythrocyte wall with the release of the cell contents into the environment. This happens when cells enter a hypotonic solution. In the body, some of the cells undergo physiological hemolysis. Hemolysis of erythrocytes also occurs in some diseases – hemolytic disease of newborns [15]; acute and chronic poisoning with nitrogen oxides, nitrobenzene, sodium nitrite [16] and other diseases. In critical conditions, massive hemolysis of erythrocytes in the blood vessels occurs. In this case, under conditions of hypoxia, acidosis, and reperfusion, Fe<sup>2+</sup> ions are released [17]. In connection with the inhibition of enzymes, the metabolic process (ATP synthesis) is disrupted, the membrane permeability changes, and the ability to transport substances, including oxygen, decreases. Exposure to high temperatures is also reflected in the morphology of red blood cells. For example, with hyperthermia simulated in rats, there was a change in the diameter of erythrocytes [18], the elasticity of the cell walls decreased and tissue gas exchange worsened, and there was a significant increase in the hematocrit index [19].

At present, the issue of primary factors that initiate pathogenetically caused dysfunction of erythrocytes in burn injury in its acute period is not resolved, which is important for the timely appointment of pathogenetically determined complex of intensive care from the first minutes of hospital stay.

The aim of the article is to reduce the frequency of complications of severe burn injury in patients with impaired microcirculation of erythrocytes in the capillary bed by applying an algorithm aimed at improving their architecture and functional condition.

**Materials and methods.** This study is based on the analysis of the results of a comprehensive clinical-instrumental and laboratory dynamic study of hemodynamic parameters, biochemical markers of erythrocyte functional status and evaluation of the effectiveness of the proposed method of prevention and treatment in a cohort prospective randomized open clinical study in 96 patients with burn trauma. from the 1st day to 1 month from the moment of admission to the clinic, who were treated in Kharkiv City Clinical Hospital of Ambulance in the period 2018 – 2020.

The conditions for selecting patients for the study were age up to 60 years, the presence of burn injury, the possibility of productive contact with the patient at the time of admission (14-15 points for GCG), obtaining informed consent, compensation at the time of injury of any comorbidities, no history blood diseases, cancer, severe heredity, alcoholism, mental disorders, allergic reactions, blood transfusions, the use of immunocorrectors, glucocorticoids.

All patients were divided into 3 groups: group I, 32 patients, whose treatment was carried out according to the generally accepted protocol of the medical institution; group II – 32 patients who in addition to the main complex of intensive care was prescribed a solution of ceruloplasmin 1 time per day intravenously 6 mg / kg body weight at a rate of 30 drops per minute for 10 days; group III – 32 patients who in addition to the main complex of intensive care was prescribed a solution of D-fructose-1,6-diphosphate sodium salt hydrate intravenously at a rate of 10 ml per minute 150 mg / kg 2 times a day for 10 days.

All patients were in a state of burn shock, as determined by an integrated scale (Spronk P.E. et al., 2004). According to the rectal-skin temperature gradient, which normally averages  $5.7 \pm 0.4^{\circ}\text{C}$ , patients had a second degree of burn shock with corresponding disorders of microcirculation. The average figures of the temperature gradient at the time of admission in all patients were  $11.72 \pm 1.1^{\circ}$ .

Since changes in peripheral blood, such as hemoconcentration and increased viscosity, contribute to microcirculation during burns, and anemia is masked by hemoconcentration, it is important to determine the percentage of erythrocyte hemolysis, which is one of the prognostic criteria for burn injury.

Clinical blood test was performed on a GEM apparatus.

The level of haptoglobin in the blood was determined by immunoturbidimetry.

To determine the functional state of erythrocytes and their ability to deform, we used the method of scanning electron microscopy.

The method of scanning electron microscopy allows us to assess the surface architecture of cells, in our case – the resistance of erythrocyte membranes to mechanical impact. Control and test

samples were fixed with 2.5% glutaraldehyde solution at 4°C for 1 hour. Carried out dehydration of cells by centrifugation in a series of aqueous solutions of ethanol in ascending concentrations of 30, 50, 70, 90% and then – acetone. The prepared cell suspension was applied to aluminum substrates and dried in a thermostat at 37 ° C. To ensure the electrical conductivity of objects, they were sprayed with a thin film of gold. The preparations were examined on a scanning electron microscope JSM – 6380LU (Japan) at an accelerated voltage of 20-25 kV.

Patients in each group underwent smears and performed a general blood test, studied the morphometry of blood smears.

For a detailed analysis of changes in the surface architecture of erythrocytes, a number of indices were calculated:

TI – transformation index – quantitative assessment of the ratio of pathological and normal forms of erythrocytes:

$$TI = (RD\% + ID\%) / D\%;$$

IOR – index of reversible transformation

$$IOR = OD\% / D\%;$$

IOI - index of irreversible transformation

$$IOI = ND\% / D\% \text{ (D – discocytes, ND – irreversible discocytes, OD – reversible discocytes).}$$

The definition of these indices is based on the fact that normally most erythrocytes are represented by discocytamia. forms (Bessis M., Mohandas N., 1975).

The day of admission, the 3rd and 10th days of treatment were selected as control points. The criteria for the effectiveness of the prescribed therapy was to determine the number of days of treatment in the intensive care unit and the number and quality of complications that occurred in the studied patients.

To be able to use the Student's t test, the Fischer-Snedekor test was calculated – the ratio of the larger variance to the smaller one. All mathematical operations and graphical constructions were performed using the software packages "Microsoft Office XP": "Microsoft XP Home" and "Microsoft Excel XP".

**Results of the research.** When analyzing the aggregate and functional state of erythrocytes, we took into account the fact that the oxygenation of cells and tissues of the body largely depends not only on the ability of hemoglobin to bind and release oxygen, but also on the rheological properties of blood, which are largely determined by erythrocytes to deformation and aggregation, as their functions are carried out through the free surface of the membranes. It was important to statistically compare the studied indicators at the beginning of treatment, at the time of admission to the clinic (table 1), on the 3rd day of intensive care, as this term in terms of positive consequences in most cases coincides with the end of clinical manifestations of burn shock (table 2), and on the 10th day of treatment, when the additional prescribed substances have already taken effect, and you can determine the effectiveness of their use (table 3).

Table 1. Indicators of haptoglobin and surface architecture of erythrocytes in groups I, II and III in patients with burn trauma at the time of admission to the clinic

Indicators	Group I n = 32	Group II n = 32	Group II n = 32
Hemoglobin, g / l	151,2±9,2	154,1±9,4	152,6±7,4
Haptoglobin, g / l	0,3±0,01	0,3±0,02	0,3±0,01
Discocytes, %	64,6±6,1	64,9±4,2	64,8±9,4
Reverse discocytes, %	14,6±2,6	16,1±0,9	15,6±1,74
Irreversible discocytes, %	22,8±2,4	19,7±1,4	20,1±1,6
TI, %	0,57±0,02	0,55±0,04	0,56±0,02
IOR, %	0,24±0,01	0,24±0,01	0,24±0,02
IOI, %	0,34±0,02	0,32±0,01	0,31±0,02

An important point in determining the effect of additional prescribed substances in intensive care in patients with burn injury was the analysis of erythrocyte hemolysis. The statistical analysis of hemoglobin and haptoglobin levels in the blood of patients in groups I, II and III did not reveal significant differences, which confirmed the correct randomization of patients into groups at the screening stage in the study. Similar data were used to determine the indices that characterize the surface architecture of erythrocytes.

Table 2. Indicators of haptoglobin and superficial architecture of erythrocytes in groups I, II and III in patients with burn injury on the 3rd day of treatment

Indicators	Group I n = 32	Group II n = 32	Group II n = 32
Hemoglobin, g / l	117,4±6,8	128,1±2,6	122,6±7,4
Haptoglobin, g / l	0,1±0,01	0,6±0,04* <sup>1,2</sup>	0,3±0,02* <sup>2,3</sup>
Discocytes, %	62,6±4,2	71,9±2,9* <sup>1,2</sup>	64,7±3,1* <sup>2,3</sup>
Reverse discocytes, %	13,9±2,1	18,2±2,7	14,6±1,74
Irreversible discocytes, %	24,1±2,2	10,7±2,1* <sup>1,2</sup>	21,1±1,9* <sup>2,3</sup>
TI, %	0,61±0,01	0,41±0,02	0,55±0,02
IOR, %	0,22±0,02	0,25±0,01	0,22±0,02
IOI, %	0,38±0,02	0,14±0,01* <sup>1,2</sup>	0,32±0,02* <sup>2,3</sup>

Note: \* –  $p < 0.05$

On the 3rd day of treatment under conditions of strict infusion-transfusion therapy, in patients of group II, who were additionally prescribed a solution of ceruloplasmin, the level of hemoglobin in the blood was  $128.1 \pm 2.6$  g / l, which was slightly higher indicators among other groups of patients. The level of haptoglobin in the blood turned out to be important data. Thus, in patients of group I, who used the classical algorithm of intensive care of burn injury, a sharp decrease in its numbers was determined,  $0.1 \pm 0.01$  g / l, which against the background of hypohemoglobinemia,  $117.4 \pm 6.8$  g / l, indicated in favor of advanced hemolysis.

Table 3. Indicators of haptoglobin and superficial architecture of erythrocytes in groups I, II and III in patients with burn injury on the 10th day of treatment

Indicators	Group I n = 32	Group II n = 32	Group II n = 32
Hemoglobin, g / l	123,6±7,1	134,1±2,1	126,2±2,2
Haptoglobin, g / l	0,2±0,04	1,2±0,04* <sup>1,2</sup>	0,3±0,08* <sup>2,3</sup>
Discocytes, %	64,2±4,1	78,4±2,9* <sup>1,2</sup>	69,8±3,7* <sup>2,3</sup>
Reverse discocytes, %	16,4±2,6	16,1±0,9	16,6±2,24
Irreversible discocytes, %	19,6±4,2	7,2±1,2* <sup>1,2</sup>	14,1±1,9* <sup>2,3</sup>
TI, %	0,56±0,04	0,29±0,01* <sup>1,2</sup>	0,44±0,01* <sup>2,3</sup>
IOR, %	0,26±0,02	0,21±0,04	0,24±0,01
IOI, %	0,31±0,02	0,11±0,02* <sup>1,2</sup>	0,21±0,04* <sup>2,3</sup>

Note: \* –  $p < 0.05$

In turn, in patients of group II, the maximum level of haptoglobin in the blood was determined on the 3rd day of observation,  $0.6 \pm 0.04$  g / l, which was probably ( $p < 0.05$ ) higher than its figures in the groups I and III. Identical dynamics was determined in the study of erythrocyte transformation indices. Thus, in patients of group II the total number of discocytes in the blood was  $71.9 \pm 2.9\%$ , which was probably ( $p < 0.05$ ) higher than in groups I and III, the number of irreversible discocytes in group II was probable ( $p < 0.05$ ) less than in groups I and III ( $10.7 \pm 2.1\%$ ), the index of irreversible transformation of erythrocytes also repeated this trend. At the same time, in patients of group III all these indicators differed significantly from the data in group I, but there were no significant differences between them due to the large variation of indicators in the variation range of patients.

On the 10th day of treatment, the trend towards the dynamics of changes in the studied indicators did not change. Thus, in patients of group I was determined the lowest level of hemoglobin in the blood,  $123.6 \pm 7.1$  g / l, the lowest level of haptoglobin in the blood –  $0.2 \pm 0.04$  g / l, which indicated in favor of hemolysis, which persisted even after 10 days of intensive care. These changes are also reflected in the indices of erythrocyte architectonics.

In group II, the level of haptoglobin was maximum,  $1.2 \pm 0.04$  g / l, which was probably ( $p < 0.05$ ) higher than in groups I and II, was the maximum percentage of total discocytes,  $78.4 \pm 2.9\%$ , which was also likely ( $p < 0.05$ ) higher than in groups I and III, the minimum percentage of irreversible discocytes,  $7.2 \pm 1.2\%$ , which was also likely ( $p < 0.05$ ) lower than in groups I and III. The index of irreversible transformation of erythrocytes in patients of group II was also minimal,  $0.14 \pm 0.01\%$ , which was probably ( $p < 0.05$ ) less than this figure in groups I and III.

Given the fundamentally different mechanism of action of substances additionally assigned to the complex of intensive care of burn injury – ceruloplasmin solution and solution of D-fructose-1,6-

diphosphate sodium salt of hydrate – it can be noted that the leading mechanism of erythrocyte dysfunction in patients with burn injury shock at the time of admission to the clinic is a violation of the mechanism of lipid peroxidation. The resulting oxidative stress contributes to the developed hemolysis of erythrocytes, which negatively affects the course of burn disease and its long-term consequences. Violation of the energy mechanisms of erythrocyte function is also significant. Given the significant changes in the studied parameters in patients of groups I and III, it can be argued about the important impact of erythrocyte membrane disorders with subsequent disruption of phosphate metabolism on the course of burn disease. Therefore, in the future it makes sense to investigate the combination of a solution of ceruloplasmin and a solution of D-fructose-1,6-diphosphate sodium salt hydrate in one algorithm of intensive care in this category of patients.

### Conclusions.

The leading mechanism of complications in patients with burn injuries is oxidative stress.

Additional administration of ceruloplasmin solution probably reduces the severity of intravascular hemolysis and promotes faster recovery of erythrocytes.

Determination of erythrocyte transformation indices is an important point in determining the prognosis of the disease in patients with burn trauma with clinical signs of shock.

**Conflict of interest.** The authors do not declare a conflict of interest.

### REFERENCES

1. Bashkyn, Y. N., Korzh, V. P. (2008). Problemy sportyvnoi' farmakologii' na suchasnomu etapi. Ljudyna, sport i zdorov'ja. Kyiv, 23–27.
2. Velichko, E. B., Gribunina, T. V. (2004). Problemy adaptacii v sporte. Fizicheskaja kul'tura, sport, zdorovyj obraz zhizni v 21 veke. Mogilev, 50–51.
3. Maevs'kij, E. I., Grishina, E. V., Rozenfel'd, A. S., Kondrashova, M. N. (2006). Vzaimodejstvie anajerobnogo obrazovanija sukcinata i glikoliza kak osnova povyshenija ustojchivosti kletok k kislorodnomu golodanju. Terapija jekstremal'nyh sostojanij. Obninsk, 123–134.
4. Gunina, L. M. (2011). Vplyv sukcinatu natriju na erytrocyty za oksynogo stresu pry intensyvnyh fizychnyh navantazhen'jah. Fiziologichnyj zhurnal, 56 (6), 71–79.
5. Gunina, L. M. (2012). Obosnovannost' ispol'zovanija kompozicij na osnove jantarnoj kisloty v sporte vysshih dostizhenij. Pedagogika, psihologija i mediko-biologicheskie problemy fizicheskogo vospitanija i sporta, 5, 50–54.
6. Denisenko, Ju. P., Vysochin, Ju. V., Jacenko, L. G. (2009). Fiziologicheskie mehanizmy adaptacii organizma sportsmenov k jekstremal'nym vozdejstv'jam. Teorija i praktika fiz. kul'tury, 11, 27–32.
7. Derimedved', L. V., Timchenko, V. A. (2002). BADy na osnove jantarnoj kisloty. Farmakologicheskij analiz. Provizor, 13, 10–13.
8. Vercamest L. Hemolysis in cardiac surgery patients undergoing cardiopulmonary bypass: A review in search of a treatment algorithm. J Extra Corporeal Technology. 2008; 40 (4): 257–267. 6. Chumaqova S.P., Urazova O.I., Shipulin V.M. i dr. Strukturny'e osobennosti membrany` e`ritrotcitov pri postperfuzionnom gemolize razlichnoi` stepeni vy`razhennosti. Vestneyq ural'sqoi` meditsinsqoi` aqademiesqoi` nauqi. 2011; 33 (1): 73–76
9. Kondrashova, M. N. (1986). Projavlenie stressa na urovne mitohondrij. Zhurnal obshei biologii, 4, 516–526.
10. Bashkin, I. M., Evdokimov, E. I., Golec', V. O., Prysjazhnjuk, O. A. (2002). Prykladni aspekty biokhimichnogo kontrolju dlja optymizacii` trenoval'nogo procesu. "Moloda sportyvna nauka Ukrainy", 2 (6), 260–262.
11. Maevs'kij, E. I., Grishina, E. V., Rozenfel'd, A. S. et. al (2000). Anajerobnoe obrazovanie sukcinata i oblegchenie ego okislenija – vozmozhnye mehanizmy adaptacii kletki k kislorodnomu golodanju. Biofizika, 45 (3), 509–513.
12. Taegtmeyer, H. (1978). Metabolic responses to cardiac hypoxia. Increased production of succinate by rabbit papillary muscles. Circulation Research, 43 (5), 808–815. doi: 10.1161/01.res.43.5.808
13. Kondrashova, M. N., Fedotcheva, N. I., Saakjan, I. R., Sirota, T. V., Zaharchenko, M. V., Leont'ev, D. S., Ignat'ev, D. A., Temnov, A. V., Samohvalov, V. A. (2003). Substratno-gormonal'naja sistema reguljacii fiziologicheskogo sostojanija. Uslovija ee vyjavlenija. Ispol'zovanie v praktike. Gorizonty biofiziki. ONTI; NCBI; Pushhino, 147–154.
14. Tajrova, M. R. (2000). Rol' ishodnogo sostojanija sistemy gemostaza v reakcijah gemokoaguljacii i fibrinoliza na fizicheskiju nagruzku. Saransk, 40.
15. Chernjev, O. V. (2012). Zminy v peryferijnij krovi sportsmeniv pid chas odnorazovyh fizychnyh navantazhen'. Zagal'na patologija ta patologichna fiziologija, 7 (4 (A)), 137–142.
16. Dutqevich I.G. Taqtika e`qstrennoi` diagnostiqi i lecheniia gemolitchesqikh gemotransfuzionny`kh oslozhnenii`. Vestneyq hirurgii im. I.I. Greqova. 2007; 166 (6): 77–80.
17. Rozhdestvensqaia M.A. Opredelenie gemoglobina v plazme qonservirovanoi` qrovi Aqtual`ny`e voprosy` perelivaniia qrovi. 1955; 4: 55.
18. Ganitqevich Ia.V., Chernenqo L.I. Metodiqa opredeleniia mehanichesqoi` rezistentnosti e`ritrotcitov. Laboratornoe delo. 1978; 2: 116–117.
19. Kopy`tova T.V. Issledovanie sorbtcionnoi` emqosti membran e`ritrotcitov dlja ocenqi haraqtera e`ndogennoi` intoqsicatcii pri dermatozakh. Clinicheskaja laboratornaia diagnostiq. 2006; 1: 18–19.