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HEMORHEOLOGY AND ERYTHRODIERESIS IN PATIENTS WITH ISCHEMIC HEART DISEASE. MEDICAL PLASMAPHERESIS

N. A. Gorbunova, L. I. Ershova, Z. M. Likhovetskaya, G. N. Kurbanova, A. A. Postnikov, and A. A. Bozh'ev

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It has been established that in patients with ischemic heart disease the viscosity of the blood plasma and the aggregation activity of erythrocytes are increased, which increases the degree of circulatory disturbances, decreases the acidic resistance of erythrocytes, and increases the level of free hemoglobin (enhanced erythrodieresis), with the result that the disseminated intravascular coagulation of blood is activated. Medical plasmapheresis, i.e., substitution of an isotonic solution for 30–40% of the circulating-plasma volume, improves the hemorheological indices and decreases the level of free hemoglobin in the blood without changing significantly the indices of acidic erythrograms.

Hemorheological disturbances, along with the degree of atherosclerosis affection of arteries and shifts in the system of blood coagulation, significantly influence the circulatory disturbance. The basis for these disturbances in patients with cardiovascular diseases is formed by changes in the protein, lipid, and electrolytic composition of the blood plasma [1]. Deterioration of the rheological properties of blood significantly influences the degree of microcirculatory disturbances and the development of complications of ischemic heart disease (IHD) [2].

Waldenstrom [3] was the first to report the use of medical plasmapheresis (MPP) for decreasing blood viscosity in a patient with macroglobulinemia. In Russia, plasmapheresis was applied for the first time to treatment of the hyperviscose syndrome in patients with paraproteinemic hemoblastosises by R. A. Mokeeva et al. [4]. Then there appeared works in which it has been shown that plasma substitution influences the blood viscosity in different cases [5–7].

At the same time, the removal of large plasma volumes with substitutive introduction of preserved components and preparations of blood and colloidal and salt blood substitutes causes a nonspecific reaction of adaptation of red blood, i.e., erythrodieresis, which manifests itself as a change in the ratios between the erythrocyte groups with different acidic resistances [8].

In the present work, we analyze the influence of the substitution of a physiological salt solution for plasma on the rheological properties of blood and the acidic hemolytic stability of erythrocytes in patients with ischemic heart disease.

We examined 20 patients. The main group included patients (n = 15) with stenocardia of II–IV functional class and unstable stenocardia, half of which had earlier myocardial infarction. The patients were aged 43 to 77. The control group included patients (n = 5) without symptoms of ischemic heart disease. The plasma substitution was carried out predominantly on a PF-05 continuous production fiber classifier and, in single cases, on Vivacell DT 790 DE and Autopheresis-C apparatus or on refrigerator centrifuges. In one session of medical plasmapheresis, we removed in the patients 30–40% of the circulating-plasma volume (750–1450 ml) and substituted a sesqui-double volume of an isotonic solution of sodium chloride for it under the control of the arterial pressure and the cardiac rate.

To investigate the hemorheological properties of blood, on a "Low Shear 30" rotary flow meter of the Contraves Corp. (Switzerland) at a temperature of 37°C we investigated the plasma viscosity, the asymptotic viscosity of blood, and the dependence of the blood viscosity on the rate of shear in the range of its variation from 0.1 to 98 sec^{-1} at a temperature of 37°C. The deformability of erythrocytes was determined by the filtration method based on passing them through filters with 3-μm pores of thickness 10–15 μm with the help of an IDA-1 device and estimated by the rigidity index, i.e., by the quantity that is inversely related to the deformability of erythrocytes. The aggregation

Hematologic Scientific Center, Moscow, Russia; email: eli@blood.ru. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 76, No. 3, pp. 176–178, May–June, 2003. Original article submitted November 12, 2002.

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TABLE 1. Influence of Medical Plasmapheresis on the Hemorheological Indices, Acidic Resistance, and Stromatolysis of Erythrocytes in Patients with Ischemic Heart Disease

Indices	Control (n = 5)	Patients with IHD (n = 15)	
		before MPP	after MPP
Hematocrit, liter/liter	0.43±0.02	0.42±0.01	0.42±0.01
Asymptotic viscosity of blood, mPa·sec	4.25±0.22	4.74±0.22	4.20±0.14
Plasma viscosity, mPa·sec	1.37±0.02	1.52±0.03**	1.31±0.02**
Rigidity index of erythrocytes, conv. units	25.0±5.6	29.0±2.2	31.0±2.6
Aggregation of erythrocytes, mm	80±11	107.0±6.6*	78.0±7.8**
Total resistance, %·min	608±11	576±13	569±12
Erythrocytes, %:			
low-stability	13.7±1.9	19.4±2.03	20.4±1.7
moderate-stability	77.1±1.5	74.7±1.3	74.6±1.1
high-stability	9.2±1.4	5.8±1.1	4.4±1.9
Maximum hemolysis, min	5.8±0.2	5.2±0.1	5.1±0.1
Maximum hemolysis, %	28.0±1.0	28.6±1.7	29.0±1.3
Duration of hemolysis, min	10.8±0.4	9.6±0.3	9.4±0.2
Free hemoglobin, mg/dliter	< 7	15.3±3.3	10.1±3.6

Note: $^{*}p > 0.05$ and $^{**}p > 0.001$.

of erythrocytes was measured by the photometric method in a Goryaev chamber [9], and the acidic stability was determined from the parameters of the erythrograms [10].

In the patients with ischemic heart disease, in the original state we observed an increased plasma viscosity, an enhanced aggregation of erythrocytes, and the tendency toward an increase in the blood viscosity at all rates of shear. The deformability of erythrocytes was within the limits of the physiological norm. In this case, the acidic erythrograms revealed an original decrease of 50–60%·min in the total resistance with decrease in the number of high-stability erythrocytes and increase in the number of low-stability erythrocytes and an increase in the level of free hemoglobin in the blood serum in 40–50% of the cases (see Table 1).

Despite the sesqui-double excess of the volume of the substitutive introduction of sodium chloride over the volume of the removed plasma, the hematocrit was at the same level after the medical plasmapheresis. The stable level of the hematocrit in this case is an indication of the constancy of the circulating-blood volume upon the excess substitutive introduction of the isotonic solution of sodium chloride. The decrease in the total amount of protein from 76.5 $\pm$ 0.9 to 58.3 $\pm$ 0.9 g/liter ($p < 0.001$) after the medical plasmapheresis and, as a consequence, the ability to confine a fairly large volume of water to the bed require a certain controlled "upthrust" of the substitutive introduction of the salt solution, since a considerable part of it escapes from the vascular bed for the above-indicated reasons. At the same time, in individual cases of the double excess of the substitutive introduction of the salt solution, the hematocrit level increased 5–10% in comparison with the initial data after the medical plasmapheresis.

The significant decrease in the plasma viscosity from 1.52 $\pm$ 0.03 to 1.31 $\pm$ 0.02 mPa·sec is attained by removal of fibrinogen and other proteins and lipoproteins together with the plasma and by corresponding substitutive dilution of it with an isotonic salt solution.

The decrease in the amount of proteins, especially of coarse-grained ones, explains the significant decrease in the aggregation of erythrocytes from 107.0 $\pm$ 6.6 to 78.0 $\pm$ 7.8 mm ($p < 0.001$) after the medical plasmapheresis. It has been found that in atherosclerosis patients a significant part of fibrinogen is bound to the membranes of erythrocytes. Medical plasmapheresis partially or completely clears the blood cells of the near-membrane fibrinogen [11].

A decrease in the plasma viscosity decreases the viscosity of blood from 4.74 ± 0.02 to 4.20 ± 0.14 mPa·sec and a decrease in the aggregation of erythrocytes creates favorable conditions for improvement of microcirculation and a decrease in the peripheral resistance and in the load on the cardiac muscle.

The original increase in the prehemolytic forms of erythrocytes and their stromatolysis in patients with ischemic heart disease is in all probability one reason for the disseminated intravascular coagulation of blood, the degree of which significantly decreases after the medical plasmapheresis [12].

The medical plasmapheresis insignificantly influenced the indices of the originally changed acidic erythrograms. We only observed a tendency toward the redistribution of erythrocytes in stability groups at a constant total resistance: the number of low-stability erythrocytes increased insignificantly (from 19.4 ± 2.0 to 20.4 ± 1.7% ($p > 0.05$), the number of moderate-stability forms was at the earlier level (74.7 ± 1.3 and 74.6 ± 1.1%), and the content of high-stability erythrocytes decreased (from 5.8 ± 0.1 to 4.4 ± 0.9%). It is probable that the tendency toward a shift of the erythrograms to the left and their shortening is due to the mechanical effect of the plasmapheresis (the maximum hemolysis was 5.2 ± 0.1 and 5.1 ± 0.1 min or 28.6 ± 1.7 and 29.0 ± 1.3% ($p > 0.05$) and its duration was 9.6 ± 0.3 and 9.4 ± 0.2 min). This can be considered as evidence of the low-invasive action of the apparatus plasma substitution on the erythrocytes in the regime considered.

The decrease in the originally increased level of free hemoglobin in the blood serum from 15.3 ± 3.3 to 10.3 ± 3.5 mg/dl after the medical plasmapheresis is explained by its partial removal from the composition of the extracted plasma and points to the absence of any appreciable stromatolysis in the process of plasma substitution.

Thus, in the patients with ischemic heart disease we have revealed unfavorable shifts. This manifests itself as a significant increase in the plasma viscosity and in the aggregation of erythrocytes and as the tendency toward a decrease in the blood viscosity, an increase in the fraction of erythrocytes with a low acidic stability, a decrease in the number of high-stability fractions of erythrocytes, and, as a result, an increase in the level of free hemoglobin in the blood serum. The medical substitution of an isotonic solution of sodium chloride for 30–40% of the volume of circulating plasma has a favourable influence on the hemorheological indices and decreases the level of free hemoglobin in the blood serum, insignificantly changing the indices of acidic hemolysis and stromatolysis of erythrocytes.

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