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RHEOLOGICAL PROPERTIES OF BLOOD IN THE PROCESS OF PLASMAPHERESIS

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The rheological properties of the blood of donors and patients have been experimentally investigated on a rotational viscosimeter in the process of plasmapheresis at a temperature of 30 ^{o}C and rates of shear ranging from 1.7 to 54.2 sec^{-1}. The efficiency of the plasmapheresis was increased when it was performed in combination with an extracorporeal autohemomagnetotherapy. The action of the plasmapheresis and the combined action of the plasmapheresis and the extracorporeal autohemomagnetotherapy on the rheological properties of blood were compared.

Plasmapheresis (PP) and extracorporeal autohemomagnetotherapy (EAHMT) are procedures used for the treatment of patients with rheumatoid arthritis, which is a systemic disease of connective tissue predominantly affecting joints. According to the literature data [1, 2], in the majority of cases, the rheological properties of the blood of such patients change substantially as rheumatoid arthritis develops; therefore, the search for new alternative methods of treating patients with this disease is a very pressing problem. In the process of plasmapheresis, a specific amount of the blood plasma, including some pathological proteins, is removed from an organism. The plasma removed is compensated for by dextrans, amino acids, and other substances, and the protein lost is compensated for mainly by albumin and a small amount of the plasma frozen for 4–6 h after termination of the procedure [3]. In the process of EAHMT, a certain amount of the blood of a patient is exposed to a low-frequency variable magnetic field and then is introduced into the organism. The volume of blood irradiated is 1.5 $\pm$ 0.2 ml/kg of the patient's body weight. This procedure is performed using a "Gemospok" apparatus operating in regime 8 (one-polarity pulses, following with a frequency of 10 Hz and having a buoyancy frequency of 60–200 Hz create a magnetic field with an induction of 120 mT) for 10 min. The blood treated is taken from the vein into a bottle with an anticoagulant (heparin) [4]. According to the literature data [5–8], both procedures influence the functional state of the cell membranes as well as the deformation and aggregation ability of erythrocytes, with the result that the rheological properties of the blood change. The EAHMT procedure used in combination with the plasmapheresis increases its efficiency.

The aim of the present work is to determine the action of the plasmapheresis and the combined action of the plasmapheresis and EAHMT on the rheological properties of the blood of patients with rheumatoid arthritis.

To describe the rheological properties of blood, we will use a three-parameter Sirs model [9]. This model involves the hydrodynamic viscosity η_∞, the shear strength of the structure τ_s (blood can flow at a shear stress $\tau > \tau_s$), and the apparent kinematic rate of decomposition of the structure units $\dot{\gamma}_*$. According to the indicated model,

$$\eta = \eta_\infty + \tau_s/(\dot{\gamma}_* + \dot{\gamma}) .$$

The model proposed is consistent with the blood-circulation physiology and allows one to consider the apparent viscosity of blood as consisting of two components that define, respectively, a quasihomogeneous-medium flow and the interaction of aggregates that can be sensitive to a low-frequency magnetic field.

Materials. We investigated blood samples of patients with rheumatoid arthritis and those of donors. The first group included 16 patients with rheumatoid arthritis, who were subjected to plasmapheresis (2–3 procedures). The second group included 18 patients with rheumatoid arthritis, who were subjected to plasmapheresis in combination with EAHMT (2–3 procedures). The third group included 15 donors.

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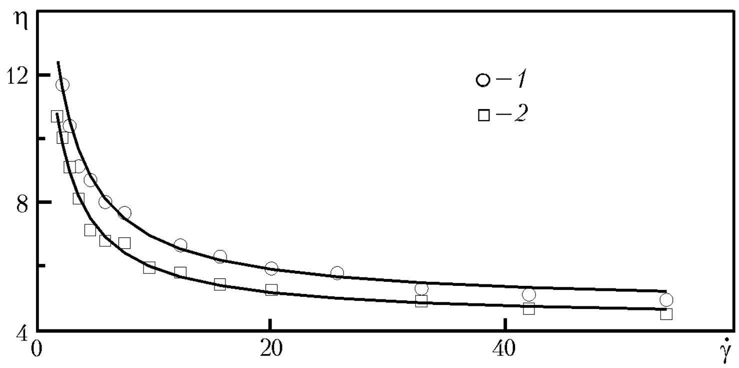

Fig. 1. Dependence of the blood viscosity on the rate of shear for patient M with rheumatoid arthritis subjected to the combined action of EAHMT and plasmapheresis: 1) before treatment, H = 41%; 2) after treatment, H = 38% (the points are experimental data, the curves represent calculated data).

TABLE 1. Change in the Average Model Parameters of Patients with Rheumatoid Arthritis after Different Medical Procedures

Procedure	η_∞		τ_s		$\dot{\gamma}_*$		H	
	before	after	before	after	before	after	before	after
PP	4.4 ± 0.7	4.4 ± 1.0	30.3 ± 3.3	21.2 ± 0.3	2.1 ± 0.5	1.3 ± 0.4	40 ± 1	37 ± 1
PP + EAHMT	4.7 ± 0.5	4.6 ± 0.7	31.2 ± 4.1	22.0 ± 0.8	2.2 ± 0.5	2.1 ± 0.6	42 ± 1	39 ± 1
Donors	4.0 ± 0.2		41.0 ± 5.9		4.2 ± 0.9		45	

Experimental. Measurements were performed at a temperature of 30^{o}C on a VIR-78MÉ coaxial-cylindrical viscosimeter with a temperature-controlled working cell of volume ~3 ml at rates of shear ranging from 1.7 to 54.2. Samples of the heparinized blood were placed in the working unit (heated in advance to a definite temperature) of the viscosimeter, and then the dependence of the shear stress on the rate of shear was measured and the blood viscosity was calculated.

At the same time, the packed cell volume was measured on a Microspin microhematocrit centrifuge for correction of the blood viscosity.

Results and Their Discussion. The model parameters were determined by the method of least squares from those experimental data that were in good agreement with the theoretical ones. The correlation of each of the parameters with the packed cell volume was determined. A linear correlation was obtained only for the parameter η_∞, which, for the purpose of uniformity, was mathematically brought into correspondence with the packed cell volume H = 45%.

The viscosity of the blood of the patients subjected to the combined action of the EAHMT and the plasmapheresis was somewhat decreased (see Fig. 1) and close to the viscosity of the donor blood. The average model parameters obtained for the patients with rheumatoid arthritis and presented in Table 1 were used in clinical practice. It follows from this table that all the model parameters of the patients with rheumatoid arthritis are changed as compared to those of the donors: the parameter η_∞ (brought into correspondence with the packed cell volume H = 45%) was increased and the parameters τ_s and $\dot{\gamma}_*$ were decreased, which points to a low structural strength of the blood of the patients with rheumatoid arthritis.

Our investigations of the rheological properties of the blood of donors and patients with rheumatoid arthritis have shown that, as a result of the combined action of plasmapheresis and EAHMT, the apparent viscosity of the blood decreases by approximately 9%, the packed cell volume decreases by 8%, and the parameter τ_s decreases by 24%. Note that in the patients subjected to only the plasmapheresis procedure, these characteristics were decreased to a lesser degree. The parameter $\dot{\gamma}_*$ decreased by 50% after the plasmapheresis and remained practically unchanged after the combined action of the EAHMT and the plasmapheresis: it decreased by 30% for one group of patients and increased by 50% for the other groups, which is apparently due to the fact that a low-frequency variable magnetic field acts selectively. However, the rheological properties of the blood normalized neither in the process of plasmapheresis nor as a result of the combined action of the plasmapheresis and the EAHMT.

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NOTATION

H, measured packed cell volume, %; $\dot{\gamma}$, gradient of the rate of shear, sec^{-1}; $\dot{\gamma}_*$, constant of the apparent kinetic rate of decomposition of structural units, sec^{-1}; η, apparent viscosity of blood, mPa·sec; η_∞, viscosity at an infinitely large rate of shear (hydrodynamic viscosity), mPa·sec; τ_s, strength of the structure formed by solid elements of blood, mPa. Subscripts: s, structure.

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