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CHARACTER OF CHANGES IN THE RHEOLOGICAL PROPERTIES OF BLOOD AND THE STATE OF PERIPHERAL BLOOD FLOW IN PATIENTS WITH HYPERTROPHIC CARDIOMYOPATHY

N. N. Samsonova, M. G. Plyushch, K. V. Borisov, E. D. Savchenko, and E. V. Zlochevskaya

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A comparative characteristic of the rheological properties of blood and the state of peripheral Blood flow in patients with hypertrophic obstructive cardiomyopathy is presented. 48% of the patients had Marked disturbances of the rheological properties of blood. It is shown that disturbances of microcirculation are in many respects due to the changes in the viscosity indices of erythrocytes and plasma.

Along with the modern data on the etiology, pathogenesis, and morphology of cardiomyopathies, of great importance is the study of the microcirculation channel and the rheological properties of blood for revealing additional mechanisms maintaining disturbances of the hemodynamics and for exercising control over the performance of medical measures [1–3].

The rheological properties of blood have a significant influence on blood flow in the microcirculation system. In recent years, many questions concerning the adequacy of estimation of the rheological behavior of blood in small-diameter vessels have arisen: arterioles, capillaries, and venules, because they are responsible for 80% of the hydrodynamic resistance in the circulation system. The conditions of blood flow in the microcirculation channel (high rates of shear and small dimensions of the vessels) differ significantly from the conditions under which the hemorheological properties of blood are investigated in viscosimeters because of the Fahraeus and Fahraeus–Lindqvist phenomena inherent in capillary blood flow, which imply that the volume concentration of erythrocytes averaged over the cross section of the vessel and the apparent viscosity of blood decrease with decreasing diameter of the vessel, while the erythrocyte concentration averaged over the volume rate of blood flow remains unchanged [4, 5].

At present there are various methods of investigating the state of microcirculation blood flow and its regulation (biomicroscopy, plethysmography, radionuclide methods, dopplerometry, etc.). The laser Doppler flowmetry is based on determination of the perfusion of a tissue with blood by measuring the Doppler frequency shift arising on probing of erythrocytes, moving in the microcirculation channel by laser radiation. The laser Doppler flowmetry is a modern highly informative noninvasive method that makes it possible to estimate the total level of the peripheral perfusion and reveal the features of the state and regulation of blood flow in the microcirculation channel. With the use of laser Doppler flowmetry, one can perform amplitude-frequency analysis of the blood flow rhythms and carry out different functional tests (respiratory, postural, occlusion, heat, cold, and medicinal), which is of great importance for estimating the reserves of microcirculation and determining the functioning of the mechanisms regulating tissuae blood flow. The application of different investigation methods makes it possible to estimate the processes occurring in the vessels of the microcirculation channel more objectively [6].

The aim of the present work is to investigate the features of the macro- and microrheological parameters of blood and the interrelation between them and the state of peripheral blood flow in patients with hypertrophic cardiomyopathy (HCMP).

Materials and Methods. We examined 25 patients with hypertrophic cardiomyopathy aged 12–63, among them 16 males and 9 females. All the patients had symptoms of cardiac insufficiency (II–IV functional class according to the NYHA classification) and the main complaints — dyspnea under physical load (and in the state of rest in some

A. N. Bakulev Scientific Center of Cardiovascular Surgery, Russian Academy of Medical Sciences, Moscow, Russia; email: plyushch@relline.home.ru. Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 76, No. 3, pp. 181–184, May–June, 2003. Original article submitted December 27, 2002.

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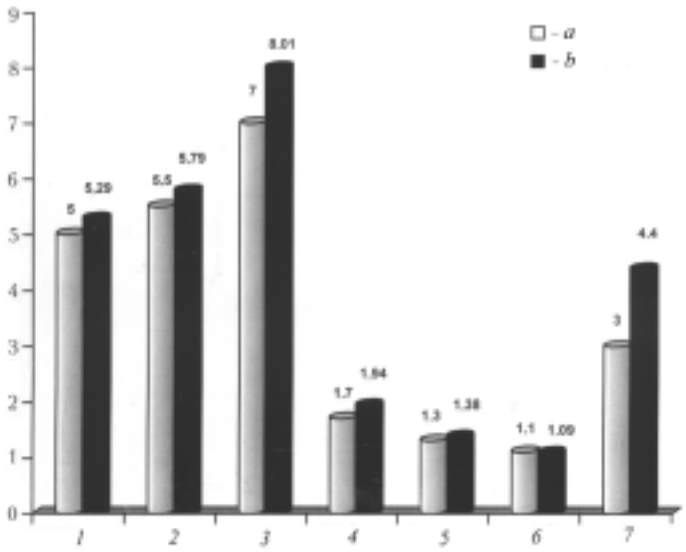

Fig. 1. Hemorheological parameters in the HCMP patients with a disturbance of the rheological properties of blood [a) healthy persons; b) patients]: 1) viscosity of blood at 200 sec^{-1}, 2) the same at 100 sec^{-1}, 3) the same at 20 sec^{-1}, 4) viscosity of plasma, mPa·sec, 5) IAE, rel. units, 6) IDE, rel. units, and 7) fibrinogen concentration, g/liter.

patients), chest pains caused by relative coronary insufficiency, sensation of skipped beats, precollaptoid states, edemata, paresthesias, and local numbness in the lower extremity. They had a susceptibility to hypotension (the arterial pressure was 100–110/60–70 mm Hg). According to the x-ray data, the majority of patients had congestion phenomena in the lungs and a more marked tracery of the lungs because of the venous component. In the patients with hypertrophic cardiomyopathy, the echocardiography revealed a massive hypertrophy of the interventricular septum, which caused obstruction in the outlet section of the left ventricle of the heart and, in some patients, simultaneous obstruction of both ventricles. All the patients with hypertrophic cardiomyopathy took β-blockers in a dose of 25–75 mg, and the patients with diastolic dysfunction took angiotensin-converting enzyme inhibitors in low doses.

We investigated the viscosity of blood at rates of shear of 200, 100, and 20 sec^{-1} and the viscosity of plasma on an AKR-2 rheological analyzer (Russia), calculated the indices of aggregation and deformability of erythrocytes, and measured the fibrinogen concentration, the aggregation activity of thrombocytes, the hematocrit the hemoglobin, and the amount of erythrocytes and thrombocytes. The state of microcirculation was estimated on an LAKK-01 laser analyzer of capillary blood flow (Russia).

Results and Discussion. As a result of our investigations, we have revealed changes in the hemorheological parameters of 48% of the patients with hypertrophic cardiomyopathy. It has been established that the viscosity of whole blood increases (by 6%) at high and (by 14%) at low rates of shear in comparison with the control value (Fig. 1). The decrease in the flow of blood was due to its erythrocytic and plasma components to the same extent. The fibrinogen concentration was increased by 47% relative to the control value. It is known that the viscosity of plasma depends on the concentration of the high-molecular protein components, in particular, fibrinogen [7]. It is possible that the increase in the plasma proteins (fibrinogen, immunoglobulins, and others) was responsible for the increase in the viscosity of plasma by 14%, the increase in the aggregation of erythrocytes (the index of aggregation of erythrocytes (IAE) was 1.38 ± 0.09), and the decrease in the elasticity of the membranes of the red cells (the index of deformability of erythrocytes (IDE) was 1.09 ± 0.03).

The state and regulation of peripheral blood flow were investigated by the method of laser Doppler flowmetry. During the investigation, patients lay on their back, in a state of physical and mental rest. A measuring element was positioned on the outer surface of the left forearm in the Zakharin–Head's zone of the heart. The data of the laser Doppler flowmetry were processed on a computer with calculation of the total index of microcirculation (IM), the root-mean-square deviation, the variation coefficient, and the index of microcirculation efficiency (IME). With the use

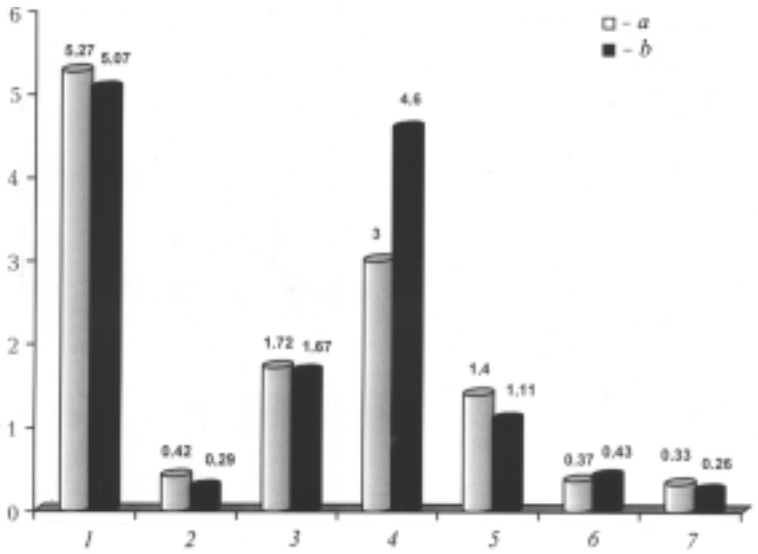

Fig. 2. Characteristics of capillary blood flow in patients with a disturbance of the rheological properties of blood [a) healthy persons; b) patients]: 1) IM, p. units; 2) ICCF, %; 3) IME, p. units; 4) IVR, %; 5) LF, %; 6) HF, %; and 7) CF, %.

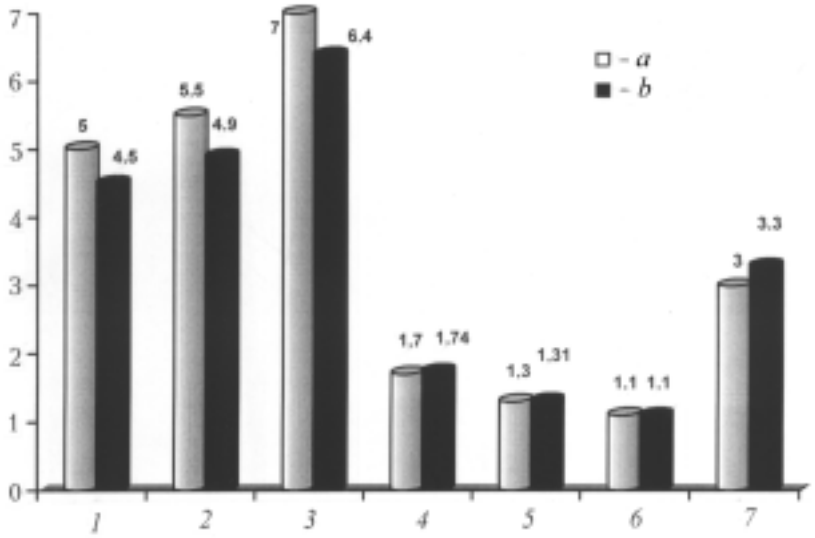

Fig. 3. Hemorheological parameters in the HCMP patients with no changes in the rheological status [a) healthy persons; b) patients]: 1–7) the same notation as in Fig. 1.

of amplitude-frequency analysis of vibrations of blood flow, we estimated the value of the active (low-frequency (LF)) and passive (high-frequency (HF)) vibrations and the cardiac rhythms (CF); the mechanisms of regulation of blood flow, the intravascular resistance (IVR) — ACF/IM; and the index of concentration of cardiac rhythm — ICCF characterizing the degree of conduction of cardiac rhythm in the microcirculation system (rheological factor). The analysis of the data obtained has shown that in the patients with a disturbance of the rheological status there were changes in the peripheral hemodynamics (Fig. 2). We have revealed a decrease in the average index of microcirculation (5.07 ± 1.80 p. units) in comparison with the control group (5.27 ± 0.31 p. units). The intravascular resistance, characterized by the ratio ACF/IM, was increased by 53%. The amplitude of the low-frequency vibrations was decreased, the amplitude of the high-frequency vibrations was increased, and the amplitude of the cardiac rhythms was decreased. The results obtained allow the suggestion that in these patients there is a congestion in the venous section of micro-

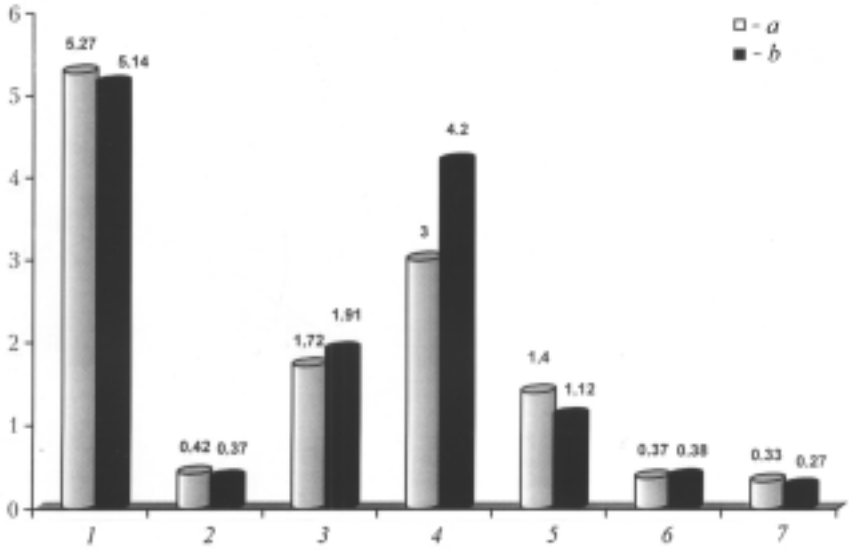

Fig. 4. Characteristic of capillary blood flow in the HCMP patients with no changes in the rheological status [a) healthy persons; b) patients]: 1–7) the same notation as in Fig. 2.

circulation. The index of cardiac rhythm concentration (rheological factor) was lower than the control level by 31% and correlated with the change in the rheological properties of blood.

In 52% of the patients with hypertrophic cardiomyopathy there were no marked changes in the rheological status, which can be due to the symptomatic treatment of the disease (Fig. 3). The estimation of microcirculation had revealed a less pronounced disturbance in the state of capillary blood flow (Fig. 4). The viscosity of blood was in norm and the fibrinogen concentration and the aggregation ability of erythrocytes were decreased, while the average index of microcirculation, the index of microcirculation efficiency, and the index of cardiac rhythm concentration were increased.

The data obtained on the hemorheological properties and the indices of microcirculation blood flow in patients with a different rheological status point to the fact that the changes in the viscosity parameters and in the functional properties of erythrocytes influence the state of the hemodynamics in the patients with hypertrophic cardiomyopathy.

The results of the rheological tests *in vitro* characterize the behavior of erythrocytes in microcirculation in the organism of a patient, widen the general view of the changes in the peripheral hemodynamics, determine the place of the erythrocytic and plasma components in the development of the pathologic process, and make it possible to select effective methods of correction.

NOTATION

FC, functional class; NYHA, New York Heart Association; AP, arterial pressure; IAE, index of aggregation of erythrocytes, rel. units; IDE, index of deformability of erythrocytes, rel. units; IM, index of microcirculation, characterizes the flow of erythrocytes in a unit time through a unit volume of the tissue and is measured in relative and perfusion units (p. units); LF, slow (low-frequency) vasomotor vibrations, slow waves of flux motions — LF-rhythm zone (frequency range 0.05–0.2 Hz) (%); HF, fast (high-frequency) vibrations, fast waves of flux motions — HF-rhythm zone (frequency range 0.2–0.4 Hz), coincides in frequency with respiration act and so is additionally called the respiratory vibrations (%); CF, cardiac rhythm, pulsatory waves of flux motions, pulsatory vibrations — CF-rhythm zone (cardiodependent frequency) (frequency range 0.8–1.5 Hz), coincides with the frequency of systoles (%); ACF/IM, intravascular resistance (IVR), ratio of the cardiac rhythm amplitude (pulsatory vibrations) to the index of microcirculation (%); IME, index of microcirculation efficiency, reflects the relation between the different mechanisms (myogenic, respiratory, neurogenic, cardiac, rheological) in the regulation of blood flow in the microcirculation system (p. units); ETA, angiotensin-converting enzyme; ICCF, index of concentration of cardiac rhythm (%) — dependence of the changes in the cardiac rhythm amplitude on the viscosity of blood.

REFERENCES

1. I. M. Mukharlyamov, *Cardiomyopathies* [in Russian], Moscow (1990).
2. L. A. Bokeriya and E. Z. Golukhova (eds.), *Lectures on Cardiology* [in Russian], in 3 vols., Vol. 3, Moscow (2001).
3. J. R. Teerlink, *Am. Heart J.*, **121**, 1852–1853 (1991).
4. V. S. Zadionchenko, V. V. Sidorov, E. V. Gorbacheva, et al., in: *Proc. III All-Russia Symp. "Use of Laser Doppler Flowmetry in Medicinal Practice"* [in Russian], Moscow (2000), pp. 73–76.
5. Yu. I. Shmakov, in: *Rheological Studies in Medicine* [in Russian], Moscow (2000), pp. 161–172.
6. V. I. Makolkin, V. V. Bran'ko, E. A. Bogdanova, et al., *Method of Laser Doppler Flowmetry in Cardiology: Manual for Doctors* [in Russian], Moscow (1999).
7. V. A. Shabanov, *General and Clinical Problems of Hemorheology: Manual* [in Russian], N. Novgorod (1998).