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Research Article

Rheological Properties of Erythrocytes and Lipid Profiles of Blood Plasma

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Abstract

The study was carried out to evaluate the influence of lipid blood plasma in patients with stable angina on some rheological properties of the erythrocytes. Our study revealed that atherogenic lipids increased erythrocyte's aggregation, but level of high density lipoproteins has no affect on the aggregation. Erythrocyte deformability of red blood cells was not associated with the plasma lipid profile.

Keywords: erythrocyte; deformability; aggregation; lipids.

Introduction

The deformation and aggregation properties of the erythrocytes as the most abundant blood cells play a crucial role in maintaining normal bloodstream. The increase of the erythrocyte aggregation and reduction of the deformability with strengthening of blood viscosity has been demonstrated in patients with coronary heart diseases (Koenig, Ernst, 1992; Leschke, 2008; Santos et al., 2011). Nonetheless, the contribution of hemorheological alterations in the prothrombotic condition in patients with atherosclerosis remains a question of debate. We aimed to determine the association between lipid spectrum of the blood plasma and hemorheological parameters.

Materials and Methods

In the study we compared blood lipid levels in chronic patients with typical stable angina. The investigation deals with the whole blood obtained from 49 patients (men 58-74 years), chronically suffering from angina of II, III and IV functional class in the morning before a meal and drug therapy in the clinic during a periodic inspection. The systolic or diastolic blood pressure was ≥140 mm Hg or 90 mm Hg. All the patients gave a written informed consent and approved the study protocol. Heparin in concentration of 100 units/ml was used as anticoagulant. Experiments were undertaken with the understanding and verbal consent of each subject according to the conditions set forth by a Human Subjects and Ethics Review Board. The study

conforms with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

The reversible tendency to form an aggregates (**REA**) was determined by Tukhvatulin et al (1986) in our modification (Katiukhin, 2013) from analyzing the light transmission data through the whole heparinized blood samples at hematocrit 40% in a glass micro-chamber of 25 mcm height and of 16 mm diameter. The full erythrocyte disaggregation shear stress is achieved by voltage increase on piezo-crystal connected with the surface of the micro-chamber. The time of full disaggregation was interpreted as the maximum strength of erythrocyte aggregates ($\mathbf{T_{full}}$). The rate of spontaneous aggregation (**K**) was determined from a half-period reduction of the photometric transient signal through completely disaggregated blood after power-down. The

integral index of aggregation ($\mathbf{I_{aggr}}$) was calculated as ($\mathbf{T_{full}}$ x **K)**. The deformability of erythrocytes (**ED**) was studied using the method of gradient ektacytometry by Johnson (1989). Data from lipid profiles included total cholesterol (**CHOL**), triglycerides (**TG**), low-density lipoprotein (**LDL**) and high-density lipoprotein (**HDL**) levels. **CHOL**, **TG** and **HDL** concentrations were measured by a standard semi automatic method using Technicon-AA-2 unit (USA), content of **LDL** was calculated by Friedwald et al (1972). The atherogenic index ($\mathbf{I_{atherog}}$) was calculated as (**CHOL – HDL)/ HDL**. All measurements were done at constant temperature of 25°C. The results were expressed as the means ± SD. Student's unpaired t-test was used to compare the data. Statistical significance was declared when $P<0.05$.

Results

The patients were divided into groups according to **CHOL** content (less than 200, 200 -239 or more 239 mg/dl), **LDL** (less than 130, 130 -159 or more 159 mg/dl), **HDL** (more than 49, 49 - 35 or less 35 mg/dl) and **TG** (less or more than 200 mg/dl). The results are shown in Table 1.

Table 1: Rheological Properties of Red Blood Cells Depending on the Level of Lipids

Please See Table 1 in PDF Version

It can be seen that the higher the concentrations LDL and CHOL, the more **K**, $\mathbf{T_{full}}$ and $\mathbf{I_{aggr}}$ will be. When the concentration of **TG**

increased, **K** was raised only without significant increase in $\mathbf{T_{full}}$. Noteworthy is the fact that the rheological properties of erythrocytes did not change depending on the **HDL**. The correlation analysis confirms this. Thus, the **CHOL** and **LDL** positively correlated with $\mathbf{T_{full}}$ ($r = 0.49$ and 0.40, respectively, $p<0.0004$), with **K** ($r = 0.45$ and 0.51 respectively, $p<0.001$) and with $\mathbf{I_{aggr}}$ ($r = 0.69$, $p<0.0001$ in both cases). **TG** concentration in plasma was positively correlated with **K** and $\mathbf{I_{aggr}}$ ($r = 0.41$ and 0.43 respectively, $p<0.003$). **HDL** was not associated with the rheological parameters of erythrocytes.

We conducted more detailed analysis dividing all patients into 3 groups with lipid levels, corresponding to normal (less than 3), moderately increased (from 3 to 4) and the high value of atherogenic index ($\mathbf{I_{atherog}}$) (Table 2). Each group was allocated

to three subgroups characterized by the following values of **REA**: group 1 - **K** less than 0,045 S^{-1}, $\mathbf{T_{full}}$ less than 53 S and $\mathbf{I_{aggr}}$ less than 3.1 relative units; group 2 - respectively (0,045-0,050) S^{-1}, (53-62) S and (3.1-3.5) relative units; group 3 - respectively over 0,050 S^{-1}, over 62 S and over 3.5 relative units (Table 3). The overall picture of the aggregation parameters of erythrocytes in patients depending on the level of lipids is shown in Figure 1.

Table 2: Lipid Concentrations Corresponding to the Normal, Moderately Increased and High Values of Atherogenic Index

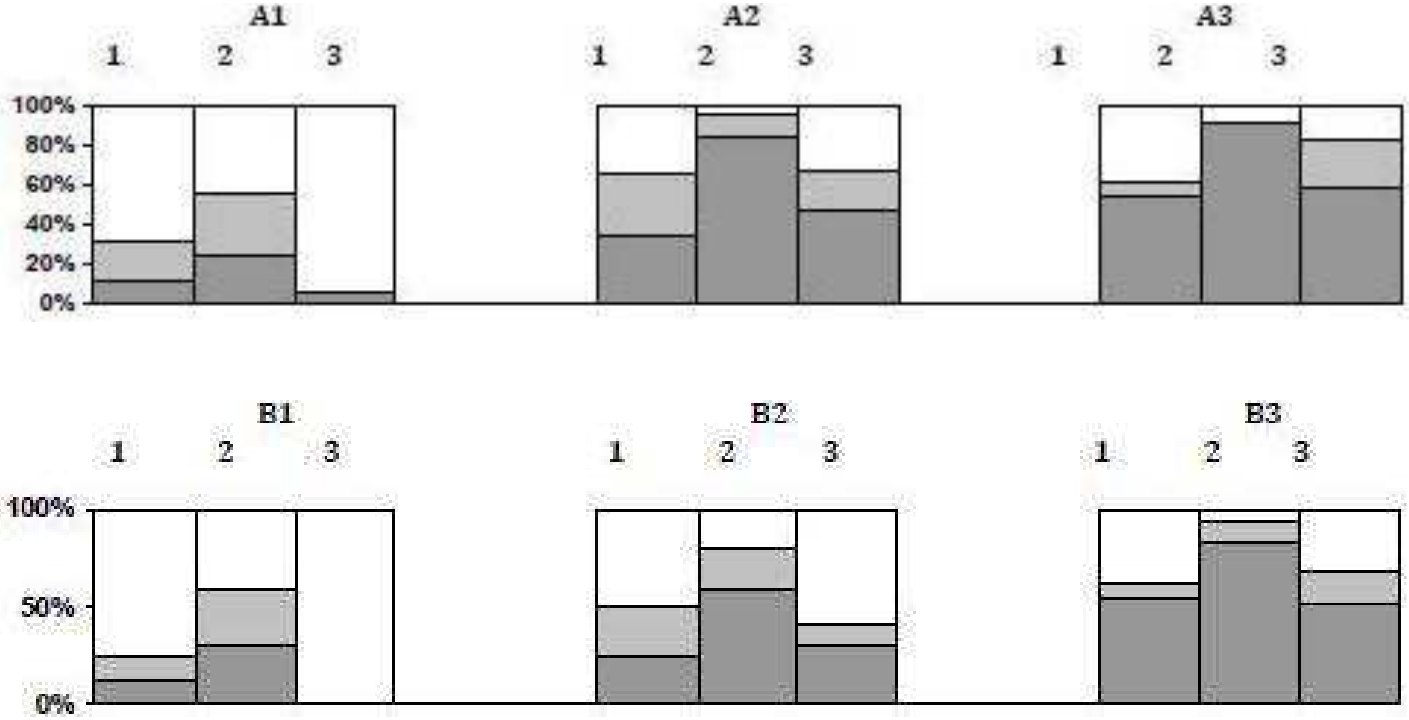
A1 – **CHOL** < 200	A2 – 200 **< CHOL** < 239	A3 – **CHOL** > 239
B1 – **LDL <** 130	B2 – 130 **< LDL <** 159	B3 – **LDL** > 159
C1 **– HDL >** 49	C2 – 35 **< HDL** < 49	C3 – **HDL** < 35
D1 **– $I_{atherog}$ <** 3	D2 – 3 **< $I_{atherog}$** < 4	D3 – **$I_{atherog}$** > 4
E1 – **TG <** 200	E2 **– TG >** 200	

Table 3: Lipid Subgroups Corresponding to Low, Medium and High Values of Aggregation

			
1	**K** < 0.045 C^{-1}	0.045 C^{-1} < **K** < 0.050 C^{-1}	**K** > 0.050 C^{-1}
2	T_{full} < 53 C	53 C < T_{full} < 62 C	T_{full} > 62 C
3	I_{aggr} < 3.1	3.1 < I_{aggr} < 3.5	I_{aggr} > 3.5

As the figure shows, among patients with high CHOL (group A) and LDL (group B) the percentage of patients with enhanced REA is higher than among patients with low levels of these lipids. A similar pattern is observed in groups D and E ($I_{atherog}$ and **TG**).

The distribution pattern of indicators **REA** in the subgroup with different **HDL** (group C) shows that the content of **HDL** is not reflected on erythrocyte aggregation. The analysis showed that the deformation properties of red blood cells were not associated with the plasma lipid profile.



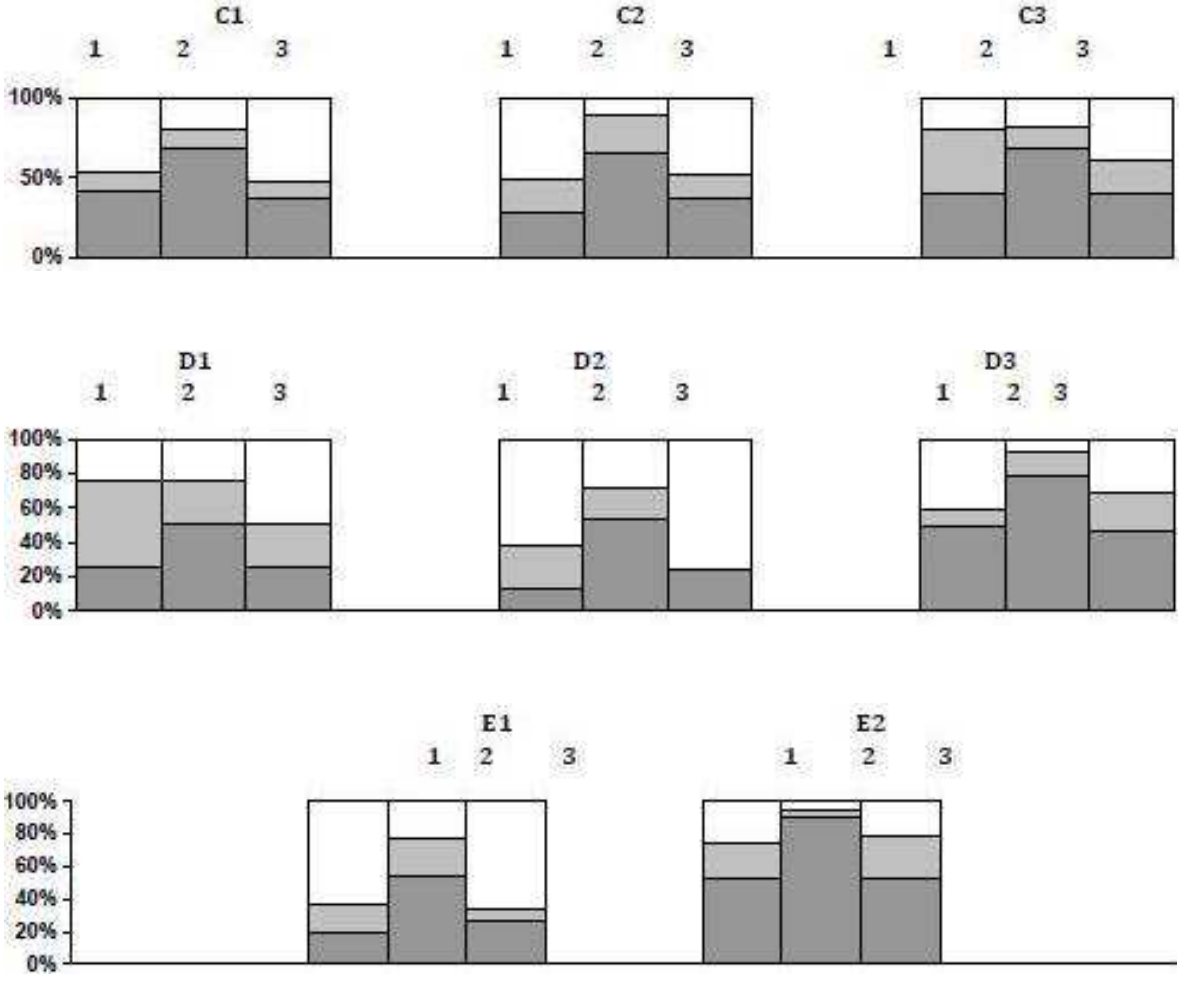


Figure 1: The Reversible tendency of RBC to Form Aggregates Depending on the Level of Lipids in the Blood

Discussion

According to the modern concepts in hematology, the mammalian blood is a structure similar to the gel where aggregates of red blood cells can break and be formed again. Therefore, the aggregation and deformation of erythrocytes as the most abundant blood cell abilities have a leading importance for this process and play a crucial role in maintaining normal bloodstream structure. Many researchers have viewed the low high-density lipoprotein cholesterol (HDL) as a risk factor for growth of atherosclerotic cardiovascular disease (Moriarty, Gibson, 2005; Subedi et al., 2014). Modern medicine has used the increased level of HDL like an attractive strategy of treatment, but there are no clear guidelines for such treatment due to the lack of solid outcomes data for HDL specific therapies. In conclusion, no relation was found between content of high density

lipoproteins and the erythrocyte's aggregation, while aggregation increased with increasing concentration of low-density lipoproteins in the blood. Known anti-atherogenic properties of this class lipoproteins apparently did not related to their effect on blood rheology.

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