

## **S21: Macro- and microrheological blood characteristics under physiological and pathological conditions**

### **S21-1 Analysis of the cutaneous blood flow responses and microvascular tone regulation in patients with type 2 diabetes mellitus. Relationship to rheological properties of blood**

Nadia Antonova<sup>a</sup>, Vasilka Paskova<sup>a</sup>, Irena Velcheva<sup>b</sup>, Nino Chaushev<sup>b</sup>, Sergey Podtaev<sup>c</sup>, Kirill Tsiberkin<sup>d</sup>

<sup>a</sup>*Institute of Mechanics to the Bulgarian Academy of Sciences, Bulgaria*

<sup>b</sup>*University Hospital of Neurology and Psychiatry "St. Naum, Bulgaria*

<sup>c</sup>*Perm State University, Russia*

<sup>d</sup>*Institute of Continuous Media Mechanics UB RAS, Russia*

The aim of the study is to analyse the changes of the cutaneous blood flow responses to cold stress and thermally induced stimulation of microvascular reactivity in patients with diabetes mellitus type 2 through wavelet analysis of the skin temperature oscillations and to estimate their relationship with the blood viscosity values. The amplitudes of the skin temperature pulsations (ASTP) were monitored by "Microtest" device ("FM-Diagnostics", Russia); the whole blood viscosity and the shear stresses were measured by Contraves LS30 viscometer, (Switzerland) at a steady flow in a group of healthy subjects and in the patients with type 2 diabetes mellitus. Different constitutive equations were applied to describe the blood rheological properties. Correlations between the parameters of these equations and the ASTP in the frequency ranges, corresponding to the myogenic, neurogenic and endothelial mechanisms of the microcirculation tone regulation were calculated and analysed during the cold stress and thermal stimulation. The results prompt manifestation of endothelial dysfunction in patients with type 2 diabetes.

### **S21-2 Relationship between rheological properties of blood and leukocyte adhesion under flow conditions in patients with type 2 diabetes mellitus**

Anika Aleksandrova<sup>a</sup>, Nadia Antonova<sup>a</sup>, Alexei Muravyov<sup>b</sup>, Ekaterina Uzikova<sup>b</sup>

<sup>a</sup>*Department of Biomechanics, Institute of Mechanics, Bulgarian Academy of Sciences, Bulgaria*

<sup>b</sup>*Department of Medicine and Biology, State Pedagogical University, Russia*

The work is aimed to evaluate the influence of aggregation and deformability of erythrocytes (RBCs) on leukocyte adhesion in patients with type 2 diabetes mellitus (T2DM) with flow microchamber. Whole blood from patients with T2DM was used to prepare samples of diluted suspensions from erythrocytes in isotonic buffer solution and Dextran 200. These samples were used to determine the erythrocyte aggregation index (EAI) and erythrocyte deformability index (EDI). Diluted suspensions from leukocytes in isotonic buffer solution were prepared for measurement of leukocyte adhesion index (LAI) and diluted suspensions in isotonic buffer solution and Dextran 200 containing both erythrocytes and leukocytes were used for

measurement of EAI, EDI and LAI. The suspensions were placed into a flow microchamber and the cells were attached to the bottom part of the chamber. The experiments were carried out at the State Pedagogical University, Yaroslavl, Russia by means of a flow microchamber. The results obtained show that with increasing shear rate from  $0 \text{ s}^{-1}$  to  $1480 \text{ s}^{-1}$  the number of adhering leukocytes to the bottom part of the chamber - model of the vascular wall is decreased. The number of adherent leukocytes at different shear rate and the number of erythrocyte aggregates at rest ( $13,125 \pm 1,705$ ) was determined. There is no statistical significant difference between EDI at constant shear rate of the examined samples of erythrocytes ( $0,223 \pm 0,014$ ) and samples of erythrocytes and leukocytes ( $0,247 \pm 0,007$ ) from the T2DM patients. The flow microchamber method allows to investigate the influence of the RBC aggregation and deformability on the leukocyte adhesion in patients with T2DM as these factors are one of the main causes of vascular complications in diabetes.

### **S21-3 Hemorheological disturbances as the thrombosis-developing factor**

Eugene Roitman<sup>a</sup>, Alla Shabalina<sup>a</sup>, Marine Tanashyan<sup>b</sup>, Irina Kolesnikova<sup>b</sup>

<sup>a</sup> *Pirogov Russian National Research Medical University, Russia*

<sup>b</sup> *Research Center of Neurology, Russia*

The study have compared features of blood rheological behavior in 115 patients with myeloproliferative neoplasms (MPNs), in 118 patients with chronic cerebrovascular diseases (CCVD), in 96 patients with CCVD comorbid with Ph-negative MPNs, in 174 patients with acute ischemic stroke, and in 96 patients followed up within 12 months after acute ischemic stroke. Hemorheologic analyses has used rotational viscometry (AKR-2, Russia), measurement was performed under decreasing of shear rates (from 300 to  $5 \text{ s}^{-1}$ ) followed under an increasing of shear rates (from 5 to  $300 \text{ s}^{-1}$ ). No sample extracting from device till the analysis is performed. RBC aggregation/desaggregation and erythrocyte deformability have assayed with laser-assisted optical rotational cell analysis (LORCA, Netherlands). Additionally we measured 98 biomarkers reflecting coagulation, anticoagulation, platelets, vascular wall, angiogenesis, fibrinolysis, inflammation, etc. Non-parametric statistics and multivariate analysis has performed for obtained data.

All patients showed abnormal blood viscosity values after the adjustment to  $Ht=40\%$ . Gender-linked features were found within each group of patients. Other hemorheological differences between patient groups were appearing for erythrocytes aggregation/disaggregation, and for the composition as well hydrodynamic resistance of cell conglomerates under high shear rates.

The magnitude of the difference in viscosity values obtained at the same shear rates have correlated with thrombogenicity. Most of hemorheological parameters have proven to be middle-forced predictors in the thrombogenic pattern.

The comparison of patients with and without thrombotic events showed the hemorheologic disorders are able to become a trigger shifting the thrombogenicity to thrombosis.

## **S21-4 Gender-linked hemorheologic features in patients during and after acute stroke**

Alla Shabalina

*Pirogov Russian National Research Medical University, Russia*

## **S21-5 Local carotid stiffness in patients with cerebral small vessel disease. Relation to blood viscosity**

Irena Velcheva<sup>a</sup>, Nadia Antonova<sup>b</sup>, Tsocho Kmetski<sup>a</sup>, Galina Tsonevska<sup>a</sup>, Anika Alexandrova<sup>b</sup>

<sup>a</sup>*Department of Neurology, Univerity Hospital, Bulgaria*

<sup>b</sup>*Department Biomechanics, Institute of Mechanics, Bulgarian Academy of Sciences, Bulgaria*

The carotid stiffness is an important factor in the pathogenesis of the cerebrovascular diseases and especially of the cerebral small vessel disease (SVD). Its major determinants are the vessel wall structure and function and the blood pressure values. However the role of blood viscosity is not enough studied. The aim of our study was to evaluate the local arterial stiffness of the common carotid artery (CCA) and its relation to blood viscosity in patients with SVD. Thirty patients with SVD aged 63 to 84 years and 20 age-matched controls were examined. The inclusion criteria of SVD patients were consistent with the neuroimaging diagnosis standards.

An ultrasound examination with a real-time automatic measurement of the CCA intima-media thickness (IMT), the parameters of local CCA stiffness: distensibility (DC) and compliance coefficients (CC), alpha and beta stiffness indices and pulse wave velocity (PWV) was performed by using radio frequency (RF) - data technology (MyLabSeven, Esaote, Italy). Whole blood (WBV) and plasma viscosity (PV) at shear rates of 0.0237 s<sup>-1</sup> to 128.5 s<sup>-1</sup> were also examined in patients and controls. The results revealed higher values of IMT, significant decrease of DC and CC and increase of  $\alpha$  and  $\beta$  stiffness indices and PWV in the patients with SVD as compared to the control group. Parallel significant increase of WBV was found within the range of shear rates 0.0237 s<sup>-1</sup> to 128.5 s<sup>-1</sup>.

In the patients with SVD the increased CCA stiffness was associated with increased WBV.