Journal of the Neurological Sciences 258 (2007) 132–136

Journal of the Neurological Sciences

www.elsevier.com/locate/jns

Hemorheological changes dependent on the time from the onset of ischemic stroke

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Received 12 September 2006; received in revised form 22 February 2007; accepted 15 March 2007
Available online 2 May 2007

Abstract

This work aimed at estimation and comparison of chosen rheological parameters of blood in two group of patients in acute and remote stroke phase. The analysis included the values of shear stress, plasma viscosity, relative blood viscosity, hematocrit value and the parameters of rheological Quemada model of blood flow. The main two groups (30 persons each) consisted of patients after cerebral ischemic episode, remaining under permanent medical control, the first one in the acute and the second in the remote phase. The reference group (20 persons) included the patients who never suffered from any circulatory system disorders and who did not take any drugs affecting the hemorheological parameters. The results suggest that after a distinct increase of most of the hemorheological parameters in the acute stroke phase, a gradual improvement was observed in the remote phase. Since in the latter group the plasma viscosity remained on elevated level, we suggest a creation of a specific feedback mechanism leading to a decrease of the blood viscosity and thus better perfusion of brain. The analysis of Quemada model parameters indicates that the decrease of blood viscosity may result from the increased red cell deformability.

Keywords: Blood viscosity; Cerebral stroke; Hemorheology

1. Introduction

The condition of cerebral stroke is accompanied with perturbations in the peripheral circulation and changes in hemorheological parameters [1,2]. Observed changes may concern both the plasma and morphotic components. The red cells change their count, increase the aggregability and decrease the deformability. The white cells increase their count and also become less elastic. The platelets tend to aggregate more easily. The changes of the plasma properties manifest in elevated fibrinogen and other proteins' levels and a shift of the lipid fractions. Some hemorheological changes seem to have a specific character in relation to a certain vascular pathology [3].

The parameters analyzed in blood rheology are: hematocrit value, whole blood viscosity, plasma viscosity, erythrocyte deformability and aggregability, lipids profile, plasma proteins composition (fibrinogen level) [4].

A convenient way to describe the hemorheological properties is the use of mathematical rheological models. The model which simultaneously takes into account the hematocrit value, the shear rate and plasma viscosity is the one proposed by Quemada in late 80s (Eqs. (1), (2)) [4–7].

$$\tau(\gamma') = \eta_p \left[1 - \frac{1}{2} k_Q \cdot Hct\right]^{-2} \cdot \gamma' \quad (1)$$

where:

$$k_Q = \frac{k_0 + k_\infty (\gamma'/\gamma_c')^{1/2}}{1 + (\gamma'/\gamma_c')^{1/2}} \quad (2)$$

In the Quemada equation Eqs.(1), (2) the quantity k_Q has a sense of so called intrinsic erythrocyte viscosity and the

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doi:10.1016/j.jns.2007.03.011

Table 1
The values of blood rheological parameters in the group of patients after cerebral ischemic episode and in the reference group

Rheological parameter	Group				
	Acute phase stroke group (n=30)		Control group (n=20)		Remote phase stroke group (n=30)
Hematocrit	43.2±0.8	–	44.0±0.9	–	43.2±0.7
Shear stress at 100 s^{-1}	0.496±0.014 ***	$p<0.016$	0.449±0.01	–	0.452±0.01
Shear stress at 6 s^{-1}	0.0579±0.003	$p<0.016$	0.049±0.002	–	0.052±0.002
Shear stress at 0.1 s^{-1}	0.0033±0.0004	–	0.0034±0.0002	–	0.0038±0.0002
Plasma viscosity	1.49±0.03	$p<0.001$	1.284±0.013	$p<0.001$	1.45±0.03
Relative blood viscosity at 0.1 s^{-1}	34.9±4.2**	–	28.0±1.7	$p<0.002$	21±2
Relative blood viscosity at 1 s^{-1}	18.5±1.2*	$p<0.0003$	12.5±0.6	–	11.3±0.6
Relative blood viscosity at 10 s^{-1}	8.44±0.37*	$p<0.0001$	5.76±0.2	$p<0.03$	5.1±0.2
Relative blood viscosity at 100 s^{-1}	4.96±0.14*	$p<0.0001$	3.50±0.07	$p<0.005$	3.1±0.1
Quemada model parameter k_0	4.08±0.07	–	4.04±0.08	–	4.00±0.06
Quemada model parameter k_∞	1.75±0.16	–	1.78±0.05	$p<0.001$	1.51±0.05
Quemada model parameter γ'_c	7.33±0.78	$p<0.009$	4.3±0.7	$p<0.02$	8.51±1.3
Fibrinogen level			366±20	–	342±21

Significance of comparison between acute and remote phase of stroke: * $p<0.0001$; ** $p<0.004$; *** $p<0.01$.

parameters k_0 *i* k_∞ denote its limiting values at zero and infinite shear rate, respectively. The quantity γ'_c is interpreted as the shear rate value at which the process of rouleaux formation begins.

2. Materials and methods

A group of 80 patients took part in this study aimed at the estimation of chosen hemorheological parameters (shear stress, plasma viscosity, hematocrit value, relative blood viscosity). The patients formed three sub-groups. The reference group included 20 patients aged 34–70 (average age 63) without detectable in a clinical examination symptoms of neurological or general disorders. The main group included two sub-groups of patients after cerebral ischaemic episode: the first one in the acute (blood sample taken less than 12 h after the stroke) and the other one in the remote phase 3–6 months after stroke onset, who received anti−aggregant and nootropic drugs or pentoxifilline specimens. The first group contained 30 patients at the age of 28–68 (average age 56) and the other one 30 patients at the age of 41–87 (average age 67), all remaining under permanent medical control. Some patients in both groups suffered from other diseases: diabetes mellitus (5 and 5, respectively), arterial hypertension (10 and 12, respectively), myocardial infarction episode (2 and 2, respectively). No thrombolysis therapy was used in our acute ischemic stroke group.

Blood viscosity measurements were performed by means of a rotary-oscillatory reometer Contraves LS 40. The blood (up to 10 ml) was taken to disposable syringes containing anti−coagulant (1.6 mg EDTA/ml blood). The flow curve was measured at the temperature of 37 °C in the shear rate range from 0.01 to 100 s^{-1} (descending order) within 5 min [8,9]. For each blood sample hematocrit value was checked using the standard method. Plasma viscosity was estimated from linear regression analysis of the flow curve measured with the same instrument.

The experimentally obtained data were analyzed in terms of Quemada rheological model and its characteristic parameters were recorded for statistical analysis.

3. Results

The values of relative blood viscosity (whole blood viscosity divided by the plasma viscosity) and plasma viscosity are presented in Table 1 together with other hemorheological parameters estimated for all three groups of patients. The hematocrit values amounted to (44.0±0.9) % in the reference group and (43.2±0.8) % in the acute phase sub-group and (43.2±0.7) % in the remote phase group. These numbers are not markedly different in the statistical sense.

Analysis of the shear stress values revealed elevated value of this parameter in the acute phase group of patients measured at shear rate of 100 and 6 s^{-1}, while for smaller shear rates the differences between the groups were not significant. In the acute phase of stroke the plasma viscosity was higher compared to the reference group and remained at elevated (although slightly lower) level also in the remote stroke phase group. The relative blood viscosity in the whole studied range of shear rates shows a clear and statistically significant tendency: in the acute phase of stroke the relative viscosity was higher than in the reference group and in the remote phase group was lower compared to the reference values.

Concerning the Quemada model parameters, in the acute phase only γ'_c was significantly different (larger) from its value in the reference group. In the remote stroke phase γ'_c remained at elevated level but k_∞ decreased significantly. The value of k_0 was almost identical for all groups of patients.

4. Discussion

The main purpose of our study was the analysis of rheological parameters' values in the group of patients after