EFFECT OF STRESS ON THE RHEOLOGICAL PROPERTIES OF THE BLOOD SERUM

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Correlations are given between the viscosity of the blood serum, its concentrations of Na, K, Cl, and proteins, its dielectric permeability in an shf field (ε), and the thermal coagulation time (t_k) established in the course of parallel determinations of these parameters in intact rats and rats exposed to stress. A decrease in the viscosity of the serum was found under the influence of experimental operative trauma and ether anesthesia, the decrease was found in viscosity during trauma of the abdominal organs without anesthesia. Quantitative empirical relationships were obtained between the above parameters, from which it was concluded that the state of water plays an important role in the process of ion–protein interaction giving rise to the observed changes in viscosity of the intravascular fluid.

Disturbances of the microcirculation are among the most important elements in the pathogenesis of traumatic states leading to severe disturbances of tissue metabolism [9-11, 14, 15]. An important role in these disturbances is played by changes in the rheological characteristics of its fluid part [16].

Studies of the physicochemical properties of the intravascular fluid [2, 4, 5, 6] have shown that blood plasma (serum) is an extremely complex ion–protein–water system the state of which is determined not only by the quantity and properties of the nonaqueous components dissolved in it, but also by their interaction with each other and with the solvent – water – itself.

This paper describes the results of a study of the role of these physicochemical processes in the changes in viscosity of the blood serum in animals exposed to stress.

EXPERIMENTAL METHOD

Parallel determinations were made of the relative viscosity (with the VK-4 viscosimeter), the concentration of Na and K ions (by flame photometry) and Cl ions (by Levinson's method), the concentration of total protein (refractometrically) and the protein fractions (by electrophoresis on paper), the dielectric permeability (in an shf field) [13], and the thermal coagulation time (t_k) [7] in samples of blood serum obtained from 82 noninbred male albino rats of which 52 received no treatment, seven underwent laparotomy and mechanical stimulation of the root of the mesentery under ether anesthesia, eight the same procedure without anesthesia, eight were killed while fully anesthetized with ether, and seven were killed at the height of traumatic shock produced by mechanical trauma to the limb. The resulting pairs of values were compared by correlation analysis [8].

EXPERIMENTAL RESULTS AND DISCUSSION

In the intact animals the mean relative viscosity of the serum was 1.76 ± 0.06 cP, falling ($P < 0.001$) as a result both of ether anesthesia (1.41 ± 0.05 cP) and of experimental operative trauma (1.43 ± 0.06 cP). Meanwhile mechanical trauma to the limb led to an increase ($P < 0.05$) in the viscosity values (1.93 ± 0.05

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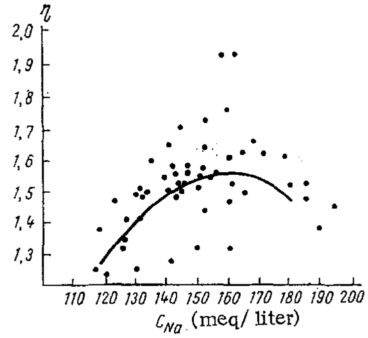

Fig. 1

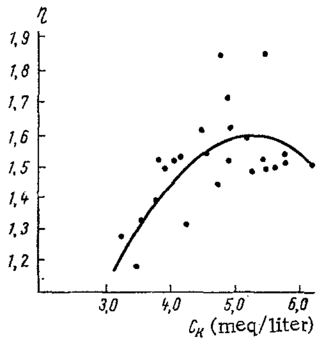

Fig. 2

Fig. 1. Correlation between changes in viscosity of blood serum and Na concentration.

Fig. 2. Correlation between changes in viscosity of blood serum and K concentration.

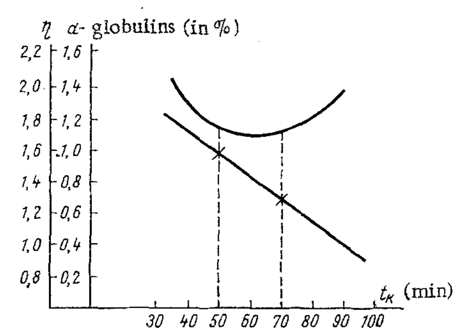

Fig. 3. Correlation between changes in viscosity, level of α-globulins, and thermal coagulation time.

cP) while trauma to the abdominal organs, without anesthesia, had no effect on the viscosity (1.68 ± 0.09 cP; $P > 0.05$).

Calculation of the correlation between these parameters showed that the changes in viscosity of the serum correlated significantly ($P < 0.05$) with changes in the concentrations of Na ($r = 0.78$, Fig. 1) and K ions ($r = 0.54$, Fig. 2); the relationship between these values can be expressed by the following equations:

$$\eta = -2.5484 + 0.0511\,(C_{Na}) - 0.00016\,(C_{Na})^2,$$
$$\eta = -1.0219 + 0.9969\,(C_K) - 0.0944\,(C_K)^2,$$

where η is the relative viscosity (in cP), C_{Na} and C_K are the concentrations of Na and K respectively (in meq/liter).

The viscosity was found to be positive linear function of the chloride level ($r = 0.55$, $P < 0.05$), expressed as the equation:

$$\eta = 0.7027 + 0.0086\,(C_{Cl}),$$

where C_{Cl} is the concentration of chlorides (in meq/liter).

Similarly viscosity was directly dependent ($r = 0.56$, $P < 0.05$) on the total protein concentration:

$$\eta = 0.5484 + 0.1538\,(C_{pr}),$$

where C_{pr} is the total concentration of proteins (in g %), among which the albumins were responsible for this effect ($r = 0.604$, $P < 0.05$):

$$\eta = 0.5902 + 0.2822\,(C_{alb}),$$

where C_{alb} is the concentration of albumins (in g %).

Changes in the level of the other serum protein fractions did not correlate with changes in the relative viscosity.

An essential factor to be considered during the evaluation of the mechanism of the effect of proteins is that in aqueous solutions, such as the intravascular fluid, proteins are components which essentially modify the state of the solvent – water. To study whether this mechanism of action of proteins on the relative viscosity is possible, the changes in viscosity were compared with changes in the dielectric permeability in an shf field (ε), a parameter directly reflecting the quantity of free water in a biological fluid [6, 13]. As was to be expected, an inverse linear relationship was found between viscosity and the values of ε ($r = -0.69$; $P < 0.05$):

$$\eta = 6.1355 - 0.0811 \cdot \varepsilon$$

showing that changes in the ratio between the quantities of free and bound water could be one of the mechanisms of the action of proteins on the relative viscosity of the blood serum.

So far as the mechanism of action of electrolytes is concerned, the effects of monovalent cations were biphasic in character (Figs. 1 and 2), and the right branch of the curve (inverse) deserves special attention.

Such a decrease in viscosity with an increase in the total concentration of an electrolyte could take place only if the electrolyte was bound, for example, by proteins, which in turn must lead to: 1) a change in the active concentration of the particular ion; 2) a change in the conformation and, consequently, the degree of hydration of the protein macromolecules.

To assess this second possibility changes in the viscosity of the serum were compared with its thermal coagulation time (t_c), a measure of the conformational rigidity of protein macromolecules [1]. Correlation analysis showed that the viscosity is in fact linked with the values of the thermal coagulation time ($r = 0.98$, $P < 0.05$). This relationship can be expressed in the form (Fig. 3)

$$\eta = 3.3266 - 0.0521\,(t_c) + 0.0004\,(t_c)^2,$$

and t_c, in turn, is inversely related to the α-globulin level ($t_c = 75.183 - 21.6378 \times C_{\alpha\text{-glob}}$, $r = -0.56$; $P < 0.05$).

It is clear from Fig. 3 that the minimal values of viscosity of the serum are observed with normal values of the thermal coagulation time and a normal level of α-globulins. On the other hand, an increase in viscosity may be observed in the presence of both an increased concentration and a low level of α-globulins. The increase in the thermal coagulation time is evidence that, in the latter case, their conformational rigidity is increased.

These investigations thus suggest that the influence of proteins on the viscosity of the serum is determined chiefly by the fractions of albumins and α-globulins; whereas the albumins exert their effect purely through quantitative changes, the α-globulins do so also through changes in their conformation. However, in either case the final physiochemical mechanism of this effect is evidently a change in the ratio between free and bound water in the intravascular fluid.

Presumably ions exert their influence on the relative viscosity through this mechanism also. If the concentrations of ions are low or normal this contribution is brought about by their own hydrated shells; processes of ion–protein interaction, modifying the conformational properties and the hydrating activity of the proteins, are evidently brought into play.

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