# DIELECTRIC PERMEABILITY AND STATE OF WATER IN RAT BLOOD SERUM DURING EXPOSURE TO EXTREMAL FACTORS

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Measurement of the superhigh-frequency dielectric permeability showed that during laparotomy under ether anesthesia there is a regular increase in the volume of free water in the blood serum of rats. These changes were linked with changes in the total protein concentration and, if such changes were excluded, with changes in the sodium concentration. Correlations and equations connecting the changes in the protein and sodium concentrations with the volumes of free and bound water in the blood serum were obtained.

The development of adequate methods of correcting disturbances of the water and salt balance, a regular feature of exposure of the living organism to extremal factors [1, 3-5, 8], requires a more profound study of the mechanisms of these disturbances. Since water is not an inert solvent in the body but an active participant in the biochemical reactions taking place there [9, 10], changes in its state under extremal conditions could be among the causes of the biochemical and physicochemical disturbances observed.

## EXPERIMENTAL METHOD

To study the state of the water in the blood serum the active part of its dielectric permeability ($\varepsilon'$) was measured. For biological fluids at a frequency f = 9820 MHz its value as a first approximation is proportional to the relative content of free water in the object [7].

The blood serum of 60 noninbred male rats weighing 170-250 g, arranged in random order in eight experimental series, was investigated: intact animals (series I), rats on which laparotomy was performed under ether anesthesia (series II), rats killed under ether anesthesia (series III), and rats laparotomized without anesthesia (series IV).

In series V, VI, VII, and VIII the animals were treated in the manner described above after preliminary hydration carried out by the method described previously [2]. Each series included seven or eight rats. Simultaneously with $\varepsilon'$, the total protein concentration (refractometrically) and the concentrations of Na and K ions (by flame photometry) were determined in samples of blood serum. The experimental results were analyzed by variance and correlation methods [6].

## EXPERIMENTAL RESULTS

In intact animals the superhigh-frequency dielectric permeability of the blood serum was $56.4 \pm 0.2$, corresponding to an estimated $881 \pm 3$ ml free water in 1 liter blood serum. The volume of bound water, determined as the difference between the unit volume of serum and the fractions by volume of free water and proteins, was 65 ml/liter serum. As Fig. 1a shows, ether anesthesia and laparotomy carried out under

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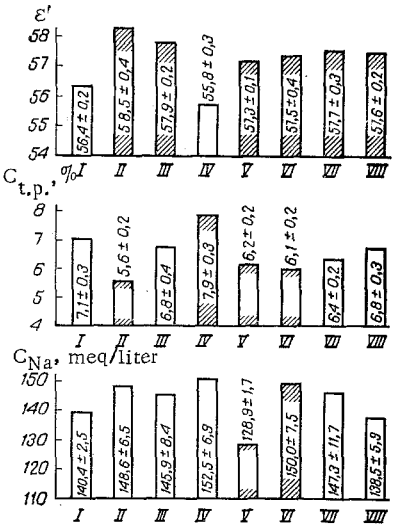


Fig. 1

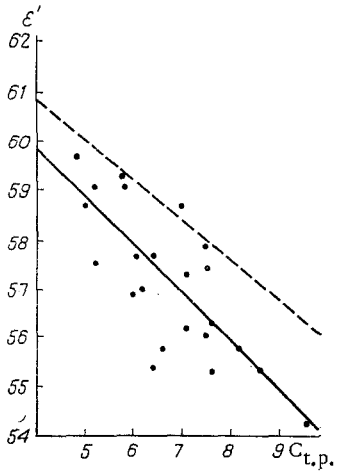


Fig. 2

Fig. 1. Changes in dielectric permeability (a), total protein concentration (b), and Na concentration (c) in blood serum of rats of series I-VIII.

Fig. 2. Regression line describing dependence of $\varepsilon'$ on total protein concentration (1). Data for dielectric permeability of serum albumin solutions of the same concentrations are given for comparison (2).

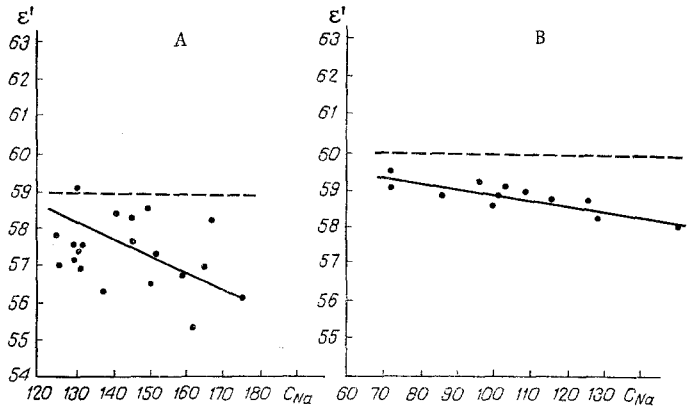


Fig. 3. Regression lines between $\varepsilon'$ and Na concentration: A) series V-VIII – native serum; B) series I-IV – diluted serum. Levels of $\varepsilon'$ of corresponding concentrations of serum albumin (5 and 6.4%) are shown.

ether anesthesia led to a significant increase in the value of $\varepsilon'$ ($P < 0.05$), i. e., to an increase in the content of free water. The relative content of free water also was increased during hyperhydration, during which exposure to stress did not lead to significant changes in the value of $\varepsilon'$.

The simultaneous determination of the total protein concentration (Fig. 1b) showed that changes in the value of $\varepsilon'$ of the blood serum in the rats of series I-IV were accompanied by changes in the protein concentration in the opposite direction. This was reflected in the close negative correlation between these parameters ($r = -0.76$; $P < 0.01$), described by the regression equation (Fig. 2)

$$\varepsilon' = 63.4 - 0.90\ (C_{pr}), \quad (1)$$

where Cpr is the total protein concentration (in g%). In intact animals $r = -0.96$ ($P < 0.001$), and the regression line is described by the equation

$$\varepsilon' = 60.2 - 0.53\ (C_{pr}). \quad (2)$$

In accordance with previous observations [7], the content of free water, calculated per liter of serum by means of Eq. (1), for the first four series of animals was

$$V_{H_2O} = 990.6 - 14.1\ (C_{pr}) \quad (3)$$

and for intact rats, using Eq. (2), it was

$$V_{H_2O} = 940.6 - 8.3\ (C_{pr}). \quad (4)$$

In Eq. (3) and (4) $V_{H_2O}$ is the quantity of free water (in ml/liter).

Taking the specific volume of protein to be 0.75 $cm^3/g$ the content of bound water in the rats of series I-IV can be determined by the equation

$$V_{H_2O} = 9.4 + 6.6\ (C_{pr}) \quad (5)$$

and for intact rats (series I)

$$V_{H_2O} = 59.4 + 0.8\ (C_{pr}), \quad (6)$$

where $V_{H_2O}$ is the content of bound water (in ml/liter).

By contrast with protein, Na ions had no appreciable effect on the changes in the value of $\varepsilon'$ of the blood serum of the animals of series I-IV ($r=-0.24$). In the "hydrated" animals, on the other hand, in which significant changes in the Na ion concentration were observed under the influence of the experimental procedures (Fig. 1c), this correlation was significant ($r=-0.45$; $P < 0.05$) and was described by the straight line (Fig. 3A):

$$\varepsilon' = 64 - 0.045\ (C_{Na}), \quad (7)$$

where $C_{Na}$ is the Na concentration (in meq/liter).

The dependence of $\varepsilon'$ on the Na concentration is valid because of the fact that in the animals of series VI-VII there was no significant change in the total protein concentration in the blood serum (relative to series V), and changes in the protein concentration made virtually no contribution to the changes in $\varepsilon'$. This conclusion was confirmed by diluting the blood serum of the animals of series I-IV with bidistilled water to a constant protein concentration (5 g%), when the dependence of $\varepsilon'$ on the Na concentration was very close ($r=-0.65$; Fig. 3B). The regression line in this case was described by the following equation:

$$\varepsilon_{,} = 60.3 - 0.014\ (C_{Na}). \quad (8)$$

The results of these investigations show that during exposure of the organism to extremal conditions regular changes are observed in the state of the water in the blood serum, the direction and intensity of which depend on the intensity of trauma. The quantitative characteristics of the volume of free water are determined primarily by changes in the protein concentration, but if such changes are eliminated, they are determined by changes in the concentration of electrolytes and, in particular, of sodium ions.

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