EFFECT OF ULTRASOUND ON THE BALANCE BETWEEN OXIDATION AND REDUCTION IN ALBINO RAT TISSUES

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The kinetics of the redox potential (E_h) and the oxygen tension (PO_2) in the liver, kidneys, spleen, and muscles were investigated in vivo in 40 rats irradiated with ultrasound with an intensity of 0.15 W/cm^2 and frequency 815 Hz for 10 min. An increase in E_h was found in the liver of the irradiated animals compared with the controls. The value of E_h in the spleen was reduced, while no significant changes were found for E_h in the kidneys and muscles. The kinetics of the change in PO_2 corresponded to that of the changes in E_h in the same tissues.

The mechanism of action of ultrasound [2, 3, 5] on living tissues has not yet been finally explained. The most widely held views postulate that the action of ultrasound is connected with increased intensity of oxidation-reduction processes involving the participation of oxygen or with electrophotochemical processes developing in cavitation recesses [7, 8].

The object of this investigation was to study changes in the redox potential (E_h) and in the partial oxygen pressure (PO_2) in the tissues in vivo as the principal parameters reflecting the state of the oxidation-reduction equilibrium of the body.

EXPERIMENTAL METHOD

Forty laboratory rats were divided into 4 groups, with 10 animals in each group, of which two were control and the other two were experimental groups for the measurement of E_h and PO_2, respectively. These indices were determined in the tissues of the liver, spleen, kidneys, and muscles of animals anesthetized with hexobarbital. The measurements were made 15 min after irradiation and every 5 min for 1 h.

The abdominal region was irradiated for 10 min using oil as the contact liquid. Ultrasound with an intensity of 0.15 W/cm^2 and frequency 815 Hz was used. The value of E_h was measured with a high-ohmic potentiometer (the LPU-01 pH-meter). A platinum needle electrode was used as the measuring electrode, and the comparing electrode was a factory-made saturated calomel electrode [6]. The values of PO_2 were determined polarographically [1]. The source of power was a type ÉI-1 pulse generator giving square pulses of constant voltage with a frequency range of 0.5–2,500 Hz and a pulse duration of 0.02–100 msec.

The sensitivity of the platinum electrodes to oxygen was tested between voltages of 0.1 and 1.1 V. This showed that the polarographic plateau was most clearly defined between frequencies of 1,500 and 2,500 Hz for a pulse duration of 0.02 msec.

The magnitude of the polarographic current was measured with a type M-95 microammeter at a voltage of 0.6 V. The results of the study of the kinetics of E_h and PO_2 were analyzed by statistical methods [4].

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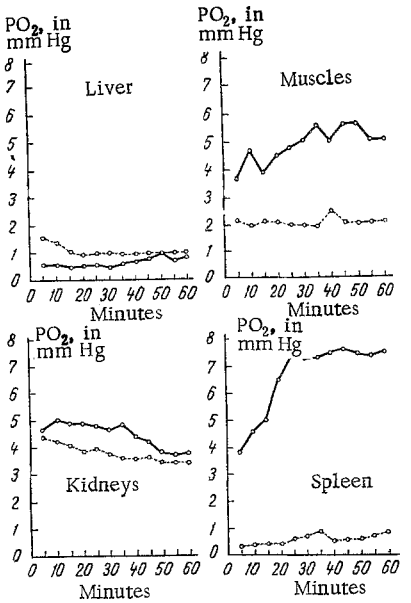

Fig. 1. Kinetics of oxygen tension in tissues of rats under the influence of ultrasound. Abscissa, time (in min); ordinate, oxygen tension (PO_2, in mm Hg).

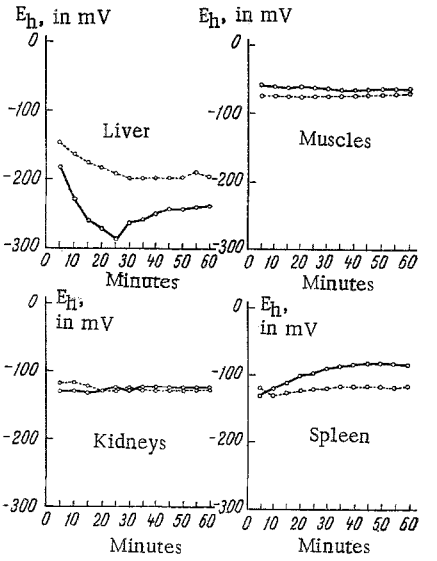

Fig. 2. Kinetics of redox potential in tissues of rats under the influence of ultrasound.

EXPERIMENTAL RESULTS AND DISCUSSION

The experimental results given in Figs. 1 and 2 show that the value of E_h differed in the different tissues of the unirradiated rats. The value of E_h in the tissues remained at a constant level, with slight fluctuations, throughout the period of investigation. The slight deviations of the index from the mean value observed in the liver and spleen tissue during the first minutes of the investigation could reflect the response of these tissues to microtrauma on insertion of the electrodes. The value of PO_2 in the tissues of the control rats remained constant throughout the experiment. The slight fluctuations in PO_2 around the mean value corresponded to the similar changes in E_h. The kinetics of E_h and PO_2 in the liver, spleen, kidneys, and muscle tissues of the unirradiated animals thus remained at a constant level characteristic for each tissue.

Changes in these indices with time relative to the control were found in the irradiated animals. The direction of the changes in PO_2 and in E_h was the same in all the tissues investigated. In the liver the values of PO_2 and E_h were increased after irradiation throughout the period of study. In the spleen, kidneys, and muscles the values of both E_h and PO_2 were reduced below normal. The most marked changes in the value of E_h were detected in the liver and spleen ($P < 0.05$), while the least changes were found in the muscles and kidneys.

The investigation of PO_2 revealed a definite decrease in its value in the spleen and muscles ($P < 0.05$). A tendency toward a decrease in PO_2 was observed in the kidneys. The oxygen tension in the liver was increased by comparison with the control.

These experiments thus showed that during the first few minutes after irradiation definite changes in the equilibrium between oxidation and reduction take place in rats, as shown by the significant changes in PO_2 and E_h in the spleen, and at certain times of investigation in the other tissues also. The absence of significant changes in the kinetics of E_h and PO_2 at certain periods of the investigation may perhaps be attributable to protective responses of the body aimed against the destructive action of the ultrasonic waves.

It can be concluded from these results that in most tissues investigated the values of E_h and PO_2 were reduced by the action of ultrasound. Only in the liver of the rats were these parameters increased. The parallel between the kinetics of PO_2 and E_h observed in the tissues of the irradiated rats investigated confirms the view that the formation of redox potentials is mainly dependent upon the oxygen concentration.

Considering that E_h in living systems reflects the total concentration of oxidative and reductive forms it can be assumed that the decrease in E_h in the tissues of the spleen, kidneys, and muscles was the result of the accumulation of incompletely oxidized products of metabolism, due to a decrease in the oxygen concentration. The increase in E_h and PO_2 in the liver tissue under the influence of ultrasound is interpreted as the result of an increase in the intensity of oxidative processes involving oxygen.

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