TIME COURSE OF VISCERAL EDEMA IN EXPERIMENTAL BURN TRAUMA

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Information on the time course of disturbances of water and electrolyte balance and the development of edema in various organs and tissues in burns is still very contradictory [4, 5]. The aim of the investigation described below was a quantitative study of disturbances of the water content of organs and tissues connected with structural changes in tissue–blood barriers after severe burn trauma. The water content was studied by the proton magnetic relaxation method [9]. The proton spin-lattice relaxation time (T_1) was measured; its value in the cells and tissues characterizes mainly the mobility of protons of water molecules; the higher the water content, the higher the value of T_1. An increase in T_1 in the liver and kidneys in rats and mice with deep burns (5-7% of the body surface) was demonstrated previously [1, 7]. To study the state of structures of the microcirculation, an electron-microscopic investigation of the organs was undertaken.

EXPERIMENTAL METHOD

Altogether 120 SHK mice were used. A burn of the IIIB degree covering 15% of the body surface was inflicted under ether anesthesia on a previously depilated area of skin in the dorsal region by means of a metal plate at a temperature of 90-92°C (exposure 5 sec). The animals were allowed fluid to drink *ad lib.* during the experiment.

The time course of changes in T_1 in the liver, kidneys, myocardium, lungs, and brain were studied. T_1 was measured by a method developed previously, on a "Minispec p-20" radiospectrometer (Brucker, West Germany) with working frequency of 20 MHz [10]. Measurements were made 1, 3, 7, 14, 21, 35, and 49 days after burning. Each experimental point was obtained by taking tissue samples from 7-10 animals; the mean values of T_1 and standard deviations are shown in Fig. 1. For statistical analysis of the results the Student's t test was used: Changes in T_1 compared with the control were considered significant at the $P < 0.05$ level. The water content in the liver and kidneys was determined by drying the tissue samples to constant weight at 95-100°C. To determine the contribution of changes in the water content in the tissues to the change in T_1, the relaxation time was measured in the course of freeze-drying *in vacuo* (the method of successive lyophilic drying) [6]. Electron-microscopic investigations of the organs were carried out by the standard methods [3] 1, 2, and 14 days after burning.

EXPERIMENTAL RESULTS

The most pronounced changes in T_1 were observed in the liver and kidneys. Successive lyophilic drying of samples of liver and kidney tissues showed that the change in T_1 after burning was attributable to the extent of 70-80% to a change in the water content. By measuring T_1 during the development of the burn, the time course of disturbances of hydration of the organs and tissues could be studied quantitatively.

The results of measurements of T_1 for the brain and kidneys are given in Fig. 1 (a, b). For liver tissue the curves of change in T_1 were similar to curves for the kidneys, whereas those for the lungs and myocardium were similar to the curves for the brain. The results of the electron-microscopic investigations are given in Fig. 2 (a, b).

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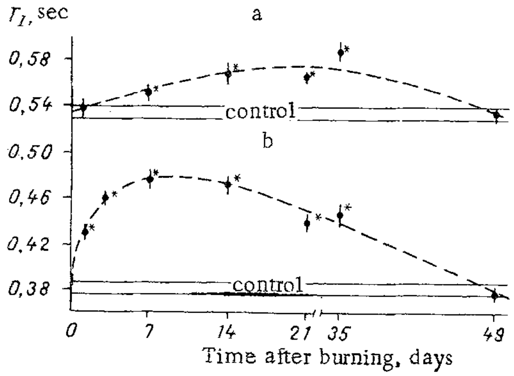

Fig. 1. Changes in T_1 of organs after burning. a) Brain, b) kidney. *Changes significant pared with control ($P < 0.05$). Abscissa, time after burning (days).

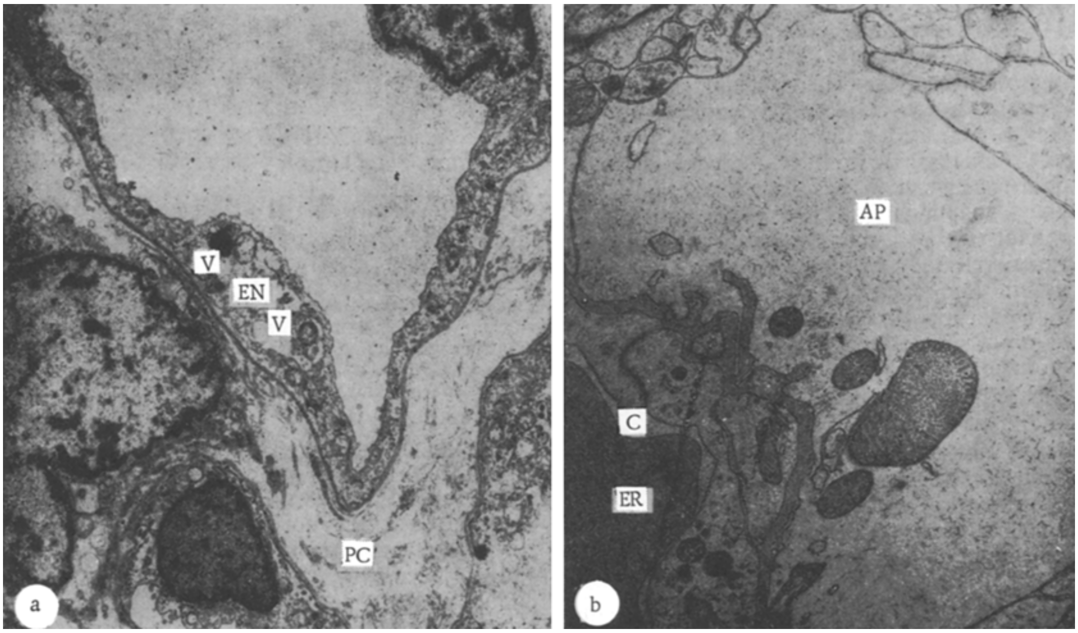

Fig. 2. Ultrastructural changes in kidneys and brain. a) Kidney 14 days after burning (× 32,000): swelling of cytoplasm of endotheliocytes (EN) in which vacuoles appear (V), thinning of cytoplasmic processes of cells, clearing of mitochondrial matrix. Widening of pericapillary space (PC). b) Brain 14 days after burning (× 42,000): edema of astrocyte processes (AP); erythrocyte (ER) in lumen of capillary (C).

Within 48 h after burning a sharp increase in capillary permeability, swelling and increased pinocytosis of endotheliocytes, and dilatation of pores were observed in the kidneys. The stratum basale was widened and swollen, its normal fibrillary structure was disturbed, many empty spaces appeared in its thickness, and the pericapillary space was widened (Fig. 2a). Structural evidence of increased reabsorption could be seen in the nephrocytes of the convoluted tubules of the kidneys: pinocytosis, vacuolation, an increase in number and hypertrophy of the mitochondria, and so on. In the later stages ultrastructural signs of increased capillary permeability persisted until healing of the burn wounds. Destructive changes in the endotheliocytes, widening of the interendothelial fenestrae, swelling of the stratum basale, and edema of astrocyte processes could be seen in the brain (Fig. 2b). The electron-microscopic investigations revealed a parallel time course of ultrastructural changes in the organs and the value of T_1 during development of burn pathology.

Analysis of the results of this investigation, together with data published in the literature, shows that the duration of the increase in T_1 in the tissues of the internal organs depended on the severity of burn trauma. With a burn covering 6% of the body surface changes in T_1 in the liver and kidneys were observed for 14-16 days after burning, whereas for a burn covering 15% of the body surface they lasted 49 days. Tissues of the liver and kidneys were the first to be affected. We know that the liver is an organ in which burn trauma most frequently causes considerable disturbances [2]. An increase in the water content in the lungs, myocardium, and brain is observed only in severe burns (15% of the body surface) and it occurs later than in the liver and kidneys, and the relative increase in water content in the brain is less than in these other organs (Fig. 1).

The cause of the increase in water content is evidently a disturbance of osmotic regulation in the tissues as a result of increased permeability of the capillary walls and changes in electrolyte balance. The results of the investigations are in agreement with data on the gradual development of a generalized disturbance of capillary permeability in burns [5]. The increase in the water content in the internal organs, incidentally, takes place at a time when edema of the wound is no longer present. This confirms the conclusion that this principal role in the development of loss of plasma after burns is played by a local increase in capillary permeability [5]. These results are in agreement with the views of Sarkisov et al. [8] on the importance of the "after-action" of burn shock [8]. Changes in water content are observed not only during the period of burn shock, but also in the later stages of burn pathology and their time course differs characteristically in different organs and tissues. Further confirmation of these views is given by the duration of persistence of the electron-microscopic changes in the tissue—blood barriers.

The time course of the development of edema after burn trauma simultaneously in all the vitally important organs has not previously been studied. By the proton magnetic relaxation method it is possible to measure quantitatively changes in the water content of the tissues much more rapidly and conveniently than by high-temperature drying. It is accordingly a valuable method for studying burns and assessing the effectiveness of various therapeutic agents.

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