Changes of the Total Water Content and Magnetic Relaxation Characteristics of the Liver and Small Intestine in Vagotomy

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Bilateral subdiaphragmatic truncal vagotomy in rats results in a disturbance of water metabolism in the liver and small intestine which manifests itself in an increase of the total water content, prolongation of the spin-lattice and spin-spin relaxation, and in a distortion of the correlation between them. The dynamics of water metabolism is of a one-peak nature in the liver with a maximum after 7 days, whereas in the small intestine it is of a dual-peak type with peaks at 7 and 30 days. Near-normalization of the water balance in the digestive organs occurs 220 days later.

Key Words: *water; time of magnetic relaxation; liver; small intestine; vagotomy*

The aim of the present investigation was to study the water balance and water state (structure and mobility) in organs of the rat digestive system at different periods of postvagotomy syndrome. This type of study was needed in order to clarify the role of the autonomic nervous system (especially of its parasympathetic division) in the regulation of water-electrolyte metabolism, to define the pathogenetic mechanisms of neurodystrophy, and to design appropriate methods of its correction. Another factor considered was the wide use of vagotomy in the surgical treatment of duodenal and gastric ulcer [8,15].

MATERIALS AND METHODS

Fifty-seven outbred male albino rats with initial weight 180-210 g were used in the experiment. Bilateral subdiaphragmatic truncal vagotomy was performed under ether anesthesia in 36 animals, while the others (intact and sham-operated 1 and 3 days later) served as a control. Rats were sacrificed after 1, 3, 7, 14, 30, and 220 days postoperation and 16-18 hours after the last feeding. The total water content was determined in liver (left lobe) and intestinal (proximal part) samples by weighing on an ADV-200 M precision balance. This parameter was calculated by the following formula: $TW=M_{wet}-M_{dry}/M_{we}\times 3100\%$, where TW is the total water content (%), M_{wet} the initial weight of the wet sample, and M_{dry} the weight of the same sample after drying in an incubator at 60°C for 5 days. Magnetic relaxation characteristics (times of the spin-lattice and spin-spin relaxation - T_1 and T_2, respectively) were recorded with a Minispec PC-120 apparatus at 20 MHz working frequency at 30±1°C. Two-pulse series 180°-τ-90° were used for the determination of T_1 with the constraint $T_1>>T_2$, and T_2 was determined after Kerr-Parcel. One-hundred fifty points were recorded for T_2 step-by-step on the decline of the curve. The resulting curve was obtained by averaging 25 of the plotted points. The reliability of differences between the experimental and control data was estimated as described elsewhere [11]. For integrative quantitation of the changes in the ag-

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TABLE 1. Changes of Water Metabolism Parameters in the Liver under Conditions of Vagotomy

Series and times of experiments	Total water content, %	T_1	T_2	T_1/T_2	Coefficient of correlation between T_1 and T_2	b	II
Intact control	100±0.6	295.9±0.9	42.1±0.9	7.03±0.21	0.889+	0.183	–
Sham operation:							
Day 1	102.7±1.1	331.4±5.3*	42.3±0.2	7.43±0.13	0.814+	0.230	0.457
Day 3	103.2±0.8*	496.2±5.3*	50.6±0.5*	9.77±0.05*	0.923+	0.199	0.140
Vagotomy:							
Day 1	102.9±0.7*	329.6±1.7*	43.7±0.5	7.57±0.09	0.790+	0.284	0.508
Day 3	103.6±0.9*	483.2±8.3*	47.5±0.8*	10.2±0.05*	0.977+	0.120	1.117
Day 7	103.8±1.0*	338.2±9.8*	48.2±1.6*	7.56±0.09	0.371	0.090	0.633
Day 14	103.1±0.8*	305.9±3.8	45.2±0.5	6.77±0.06	0.704	0.155	0.419
Day 30	102.5±0.8	300.6±3.0	44.3±0.2	6.78±1.64	0.490	−0.024	0.359
Day 220	101.2±0.9	295.0±3.0	41.8±0.2	7.06±0.01	0.726+	0.168	0.163

Note. Here and in Table 2: b is a parameter from the linear regression equation $y=a+bx$, where $y=T_2$ and $x=T_1$; *$p<0.05$: in comparison with intact rats, +$p<0.05$: reliability of the correlation coefficient.

gregate of parameters studied, the integral index (II) was computed according to the formula:

$$II = ([X_e-X_c]/X_c+[Y_e-Y_c]/Y_c+...)^{1/2},$$

where X and Y, ... are parameters, X_e-X_c is the difference of the value of parameter X for the experiment (X_e) and the control (X_c) taken as a modulus. Correlation and regression analysis was used to reveal the functional correlation between the studied indexes and its quantitative characteristics. The coefficients and parameters were computed using computer software.

RESULTS

The data show (Tables 1 and 2) that marked alterations were noted in water metabolism in the liver and small intestine in the early period of postvagotomy syndrome (days 1-3). These changes manifested themselves in an increase of the total water content, a rise of T_1 and T_2, and in a distortion of the correlation between T_1 and T_2 (the latter was mainly distorted in the small intestine). Because the same shifts in the water balance were found in sham-operated rats, they can be classified as nonspecific alterations. At later times after vagotomy (days 7-30), the changes in the water metabolism preserve the initial direction and the range of manifestation in the liver, while in the small intestine their values approximate the control level after 14 days (temporary and relative normalization). Considerable shifts in parameters of water metabolism were not found in the organs under study in the long term (220 days).

The results suggest that vagotomy lead to a significant change in the water metabolism of the digestive organs, the dynamics of which is of a one-peak nature in the liver with a maximum at 7 days, whereas in the small intestine it is of a dual-peak type with peaks at 7 and 30 days. The nonspecific nature of changes in water metabolism in the early periods (1 and 3 days) makes it difficult to take them into consideration. As a whole, the described dynamics of water metabolism in the liver and small intestine when vagal innervation is interrupted agrees with the temporal structure of the neurodystrophic process taking place in these organs under the given conditions [2,3]. Swollen cytoplasm of hepatocytes is clearly seen under the electron microscope one week postdenervation [2]. The shifts of the water balance in the liver and intestine postvagotomy consist not only in a rise of the total water (edema), but also in a change of the state of the water. Thus, an increase in the time of magnetic relaxation of protons (more than 80% of which derives from water [6]) attests to a decrease in the degree of water structuring and to an increase of its mobility [14,16]. It may be assumed that the key factors in the development of postvagotomic edema in digestive organs (particularly in the liver and small intestine) are as follows: disturbance of the microcirculation [13], a change in the permeability of capillaries and hepatocyte plasmalemma (as a result of a local imbalance of neurotransmitters, hypoxia, impeded release of biologically active substances by tissue basophils, etc.) primarily for proteins and electrolytes [4,10], a rise of the oncotic and osmotic pressure in the interstitium due to a local disturbance of tissue metabolism [5], activation of proliferation, usually accompanied by the accumulation of water in the tissue [1,9], and a drop of the albumin concentration in the plasma

TABLE 2. Changes of Water Metabolism Parameters in the Small Intestine under Conditions of Vagotomy

Series and times of experiments	Total water content, %	T_1	T_2	T_1/T_2	Coefficient of correlation between T_1 and T_2	b	II
Intact control	100±0.4	334.6±5.9	69.0±1.5	4.85±0.14	0.867+	0.076	–
Sham operation:							
Day 1	101.6±0.4	359.5±6.0*	71.4±6.9	5.05±0.13	0.450	0.049	0.408
Day 3	101.9±0.5*	382.4±7.1*	75.5±4.1	5.06±0.15	0.376	0.051	0.547
Vagotomy:							
Day 1	101.7±0.4	362.3±6.0*	70.0±3.7	5.18±0.26	0.394	0.055	0.427
Day 3	101.9±0.5*	374.1±9.9*	76.3±2.0*	4.90±0.18	0.401	0.047	0.503
Day 7	102.1±0.6*	395.2±8.9*	71.0±2.6	5.57±0.12*	0.899+	0.046	0.616
Day 14	100.3±0.5	340.2±10.2	69.5±4.5	4.89±0.11	0.746	0.069	0.188
Day 30	101.8±0.4*	377.6±7.8*	75.0±1.3*	5.03±0.11	−0.999+	−0.180	0.519
Day 220	99.0±0.7	336.2±9.0	67.5±2.8	4.98±0.20	0.770+	0.066	0.252

(leading to a fall of its oncotic pressure) due to diminished protein synthesis in the liver. It should be noted that the development of edema in the digestive organs after vagotomy may have something to do with metabolic disturbances in mineral components such as sodium, potassium, calcium, phosphorus, iron, and copper [12]. A specific role of neural regulation in the pathogenesis of postvagotomic edema cannot be ruled out either. For example, pathological impulses from the central ends of the cut vagus nerves may lead to the formation of a focus of pathological excitation in the hypothalamus and thereby disturb the function of the higher centers responsible for the regulation of the water-electrolyte balance that are located in this region of the brain.

Thus, the results of our study suggest that interruption of the parasympathetic innervation of the liver and small intestine brings about disturbances of the water metabolism in these organs, manifested in a rise of the total water content (edema), a decrease of the degree of structuredness of the water, and an increase of its mobility.

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