PATHOLOGICAL PHYSIOLOGY AND GENERAL PATHOLOGY

EFFECT OF SUBDIAPHRAGMATIC VAGOTOMY ON THE SODIUM AND POTASSIUM DISTRIBUTION IN RATS

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The state of metabolism of sodium and potassium in male rats 1, 7, 14 and 19 days after bilateral subdiaphragmatic vagotomy was investigated by mapping the distribution of the elements in individual organs. Vagotomy was shown to disturb electrolyte metabolism, most severely one and seven days after the operation. Relative normalization of sodium and potassium metabolism was observed after 14 and 19 days.
KEY WORDS: *sodium; potassium; metabolism; vagotomy.*

The important role of the integrative systems of the body (especially nervous and endocrine) is the regulation of water and salt metabolism has been conclusively demonstrated by experimental investigations and clinical observations [2, 6]. Whereas the role of hormonal mechanisms in this regulation has been investigated in reasonably adequate detail [2], the role of the nervous system has received only little study. The effect of certain parts of the central and peripheral nervous system has been investigated chiefly on the diuretic function of the kidneys [6]; only in isolated cases has the concentration of electrolytes in the general blood stream been determined as an additional index [6]. Despite the fact that the kidneys play a central role in the system of water and electrolyte metabolism, determination of diuretic indices only, even if combined with recording the level of the blood electrolytes, does not enable a sufficiently complete picture to be drawn of the state of their metabolism on the scale of the whole organism or of the contribution of the nervous system (in autonomic division, particularly) in the regulation of this process. Meanwhile the study of this problem is of great theoretical and practical importance, on the one hand, for a deeper understanding of the character and mechanisms of the influence of the nervous system on electrolyte metabolism, and on the other hand in connection with the question of organ transplantation and also the widespread use of division of nerves (vagotomy) for the surgical treatment of gastric and duodenal ulcer.

The role of the vagus nerve in the regulation of electrolyte metabolism was studied in the investigation described below; for this purpose the concentration of sodium and potassium was determined in certain organs (and biological materials) of rats after bilateral subdiaphragmatic vagotomy.

EXPERIMENTAL METHOD

Experiments were carried out on 59 male albino rats weighing 150-170 g, 29 of which underwent bilateral subdiaphragmatic vagotomy whereas the rest served as the control. The animals were killed in pairs (experiment—control; at least 6 pairs at each time) 1, 7 14, and 19 days after the operation and 24 h after the last meal. Samples of blood, liver, stomach, jejunum and illeum, excreta, kidneys, and skeletal muscles were taken for quantitative determination of sodium and potassium. The concentrations of the elements in the samples were determined by arc atomic emission spectrography on the ISP-28 quartz spectrograph. The plates were subjected to photometry on a Zeiss spectral laboratory microphotometer. The results of the measurements were subjected to statistical analysis by Strelkov's method [5].

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TABLE 1. Sodium Distribution (in percent) in Vagotomized Rats (M ± m)

Time after vagotomy, days	Blood	Stomach	Jejunum	Ileum	Excreta	Liver	Kidneys	Skeletal muscles
1	115,2±9,3	92,5±7,8	72,2±3,8*	100,9±6,1	102,3±6,1	131,4±2,9*	89,6±4,1	97,1±4,8
7	74,3±4,8*	119,4±5,7*	139,3±11,5*	120,3±5,9*	101,6±2,5	112,1±3,2*	114,9±3,2	77,7±2,8*
14	109,0±7,9	107,7±4,4	102,6±5,5	90,3±4,3	104,7±10,0	114,5±2,8*	95,8±3,4	102,5±3,1
19	98,1±3,9	81,9±4,6*	103,7±8,0	117,6±1,0	98,2±7,2	108,2±6,8	100,7±3,6	97,7±9,5

Legend to Tables 1 and 2: 1) control value taken as 100%; 2) Asterisk — $P < 0.05$.

TABLE 2. Potassium Distribution (in percent) in Vagotomized Rats (M ± m)

Time after vagotomy, days	Blood	Stomach	Jejunum	Ileum	Excreta	Liver	Kidneys	Skeletal muscles
1	118,5±8,9	101,6±10,4	62,6±3,8*	99,7±7,3	94,7±7,1	138,4±8,8*	70,9±3,5*	92,5±6,8
7	101,9±9,5	127,5±6,9*	161,6±19,3*	159,0±16,9*	124,1±0,5*	137,9±9,1*	68,6±7,8*	75,3±4,3*
14	96,7±8,8	101,7±6,4	104,7±15,7	93,3±12,4	112,5±1,2*	119,2±4,7	97,1±9,7	96,7±12,0
19	107,4±12,9	70,8±5,5*	107,4±7,8	127,7±10,1	101,3±6,9	90,5±16,6	111,0±13,9	100,0±15,2

EXPERIMENTAL RESULTS

It will be clear from Table 1 that one day after vagotomy the sodium concentration was increased in the liver and reduced in the jejunum. In all other organs and biological material from the vagotomized rats studied its level was unchanged. After seven days, against a background of marked hyponatriemia, a significant increase in the sodium concentration was found in the stomach, jejunum and ileum, liver, and kidneys, and a decrease in the skeletal muscles. The sodium concentration in the excreta showed no significant change. After 14 and 19 days the sodium concentration in all the organs and biological materials studied was the same as in the control, except in the liver (the sodium concentration was increased after 14 days) and the stomach (the sodium concentration in this organ was reduced after 19 days).

The following results were obtained for the potassium concentration (Table 2). Its concentration in the liver one day after vagotomy was increased, whereas in the jejunum and kidneys it was reduced. In the other organs and biological materials it was the same as in the control. After seven days, when the potassium level in the blood was normal, an increase in its concentration was found in the stomach, jejunum, ileum, liver, and excreta and a decrease in the skeletal muscles and kidneys. After 14 days a very small increase in the potassium concentration was observed in the excreta and also in the liver; in the remaining organs it was indistinguishable from the control. After 19 days, only in the wall of the stomach was the potassium concentration reduced.

It can thus be concluded from the results described above that the most marked disturbances of the mechanisms of regulation of sodium and potassium metabolism occur seven days after vagotomy; later (8-19 days) a gradual restoration of normal electrolyte metabolism is observed.

In connection with the discussion of the pathogenetic mechanisms of the distrubance of water and electrolyte metabolism observed after vagotomy, comparative analysis of the changes in the sodium and potassium concentration in the various organs and biological materials of vagotomized rats are of particular interest. The increase in the sodium and potassium concentrations in the liver and their decrease in the wall of the jejunum one day after vagotomy in all probability reflect a redistribution of these elements between these organs and are not the result of their increased absorption from the alimentary canal (in man, at least, vagotomy does not lead to the intensification of this process in the early stages after the operation [10]). The pattern of the sodium distribution among the organs seven days after vagotomy suggests with a high degree of probability that under these conditions a "sodium paradox" is observed — a unique phenomenon characterized by hyponatriemia (dilution), increased sodium excretion in the urine, and an increased volume of extracellular fluid [11].

This hypothesis is confirmed by the following result obtained in the present investigation: In vagotomized rats the blood sodium level was lowered, the sodium concentration in all the digestive organs studied was increased (a sufficiently reliable indicator of an increase in the volume of the extracellular fluid in them, if it is remembered that sodium is principally an extracellular ion [10]), and the sodium concentration in the kidneys was increased (indirectly pointing to activation of sodium excretion). The classical phenomenon of "sodium paradox" is based on hyperproduction of antidiuretic hormones by the corresponding neurosecretory nuclei of the hypothalamus, induced by some form of nonspecific stimulation of the brain [11]. After vagotomy, pathological impulses from the central ends of the divided vagus nerves may be the trigger mechanism of this pathophysiological reaction [4]. In addition, the hyponatriemia and increased sodium excretion seven days after vagotomy may be connected, according to the results of these experiments, with the development of relative hyperadrenalinemia under these conditions and also with a decrease in the threshold of sensitivity of the kidneys to adrenalin [2]. Similar results have been obtained with cats and dogs under similar experimental conditions [6]. Finally, this phenomenon will also be based on hypofunction of the adrenal cortex, a fact observed in rats at the same period after vagotomy [9]. It is a very remarkable fact that in practically all the internal organs in the zone of denervation (stomach, jejunum and ileum, liver) the potassium concentration was increased. The possibility cannot be ruled out that the accumulation of potassium in the denervated organs is compensatory in character and is aimed at maintaining the local balance of mediator metabolism, for on the one hand it has been shown that potassium has an activating effect on acetylcholine and an inhibitory effect on cholinesterase [1], and on the other hand, the acetylcholine level in organs deprived of their vagus innervation is lowered [3]. The increase in the potassium concentration in the excreta of the vagotomized rats seven (and to a lesser degree 14) days after the operation was evidently the result of intensification of destructive processes in organs with a disturbed innervation, for these processes are known to be accompanied by the liberation of intracellular potassium and by its increased excretion by the intestine [8]. The almost complete "equalization" of the picture of sodium and potassium distribution among the organs 14 and 19 days after vagotomy may perhaps be evidence that during this period after the operation compensatory processes aimed at restoring the normal electrolyte metabolism are beginning to develop.

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