Effect of Boron on the Ultrastructure of Parathyrocytes and Atrial Cardiomyocytes

Yu. N. Korolev, L. N. Panova, and M. S. Geniatulina

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Ultrastructural shifts in parathyrocytes and atrial cardiomyocytes induced by long-term treatment with boron-containing water (250 mg/liter) were found against the background of boron accumulation. These changes are indicative of enhanced secretory activity of these cells. It is hypothesized that boron modulates the effect of parathyroid hormone and atrial natriuretic factor and the rate calcium-sodium exchange.

Key Words: *boron; parathyrocytes; atrial cardiomyocytes; ultrastructural changes*

Published data and our previous studies have demonstrated that boron affects the structure of cell membranes [6] and calcium and magnesium metabolism [15], enhances diuresis [12], and reduces blood pressure [1]. It can be hypothesized that boron affects the functioning of the parathyroid gland and production of parathyroid hormone (PTH) which regulates blood calcium level and reduces blood pressure [4]. Moreover, one can expect structural and functional shifts in atrial cardiomyocytes, since atrial natriuretic factor (ANF) is involved into regulation of sodium-calcium exchange and exerts a pronounced antipressor effect [10].

There are no published data on the effect of boron on the ultrastructure of parathyrocytes and atrial cardiomyocytes, therefore, these questions were the focus of our investigation.

MATERIALS AND METHODS

Experiments were carried out on 20 male albino rats weighing 220-250 g. The animals were given sodium tetraborate dissolved in water (250 mg/liter in a volume of 3 ml, pH 8.0, *per os*). This concentration naturally occurs in mineral water used for the treatment and rehabilitation. Daily dose of boron was 3.75 mg/kg. Control animals received tap water. The total course consisted of 24 procedures. The animals were decapitated after 15 or 24 procedures, and the boron content in the thyroid-parathyroid complex (the parathyroid glands in rats are submerged into the thyroid tissue) and in the heart was determined spectrophotometrically using H-resorcin [9]. Electron microscopy of the parathyroid gland and left atrium was performed after 15 procedures (the maximum tissue accumulation of boron). To this end, specimens were fixed in 2.5% glutaraldehyde and post-fixed with OsO_4, dehydrated in alcohol of ascending concentrations and acetone, and embedded in Epon-Araldite. Ultrathin sections were examined under JEM-100C and JEM-100CX electron microscopes. Quantitative parameters of parathyrocytes and atrial cardiomyocytes were analyzed stereologically and by automorphometry with an MOP-Videoplan device. The volume portion and number of mitochondria, volume portion of granular endoplasmic reticulum (GER), Golgi apparatus, and the area of secretory granules in atrial cardiomyocytes were calculated.

RESULTS

Maximum accumulation of boron was noted after 15 procedures: its concentration in the thyroid-parathyroid complex and heart increased 3.4-fold ($p< 0.05$) and 8-fold ($p<0.001$), respectively (Table 1). By

Laboratory of Morphology, Russian Center of Rehabilitation and Physiotherapy, Ministry of Health of the Russian Federation, Moscow

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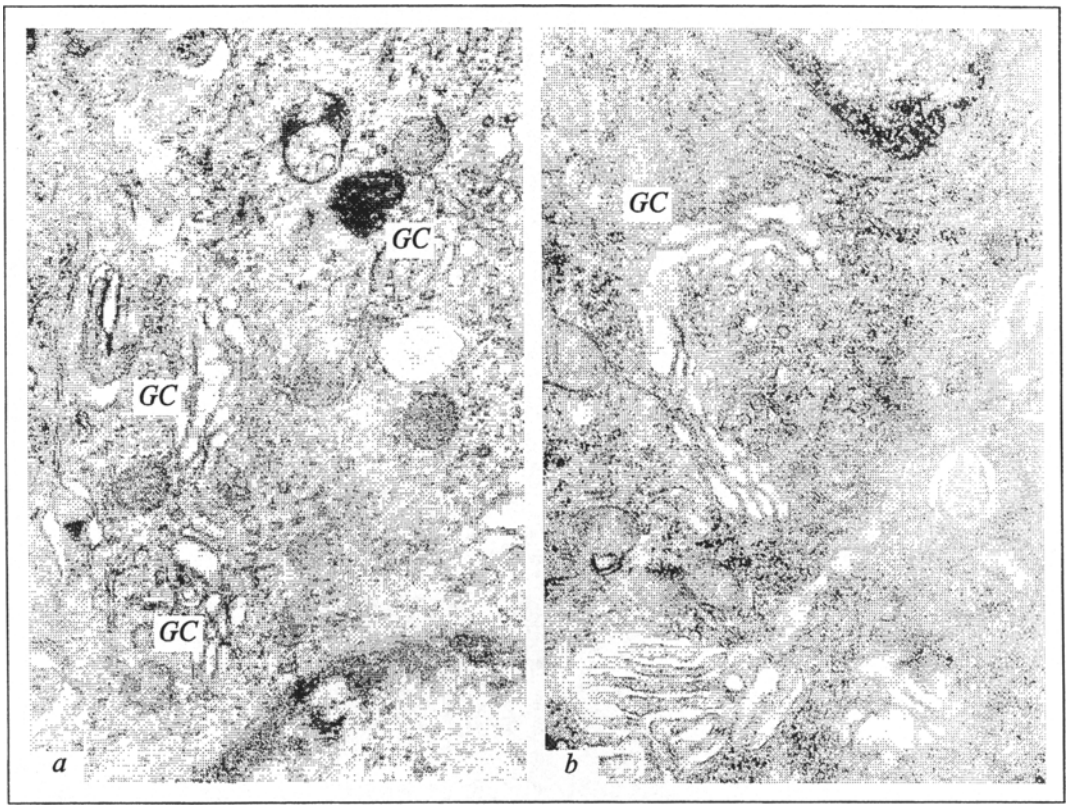

Fig. 1. Hyperplasia of Golgi complex (GC) in parathyrocytes after treatment with boron water solution. Increased number of GC in a cell (*a*) and dictyosomes of GC (*b*).×24,000.

the 24th procedure the content of boron in the heart decreased 2-fold, while in the thyroid-parathyroid complex in remained practically unchanged.

Ultrastructural studies of the parathyroid gland after 15 procedures revealed a rise in GER profiles and in the number of free ribosomes and polysomes. Morphometry showed that the volume portion of GER increased by 42.2% ($p<0.05$) in comparison with the control (Table 2). Hyperplasia of the Golgi apparatus was noted: the number of these structures in the cell increased to 3-5 (Fig. 1, *a*) and their volume portion increased 2-fold ($p<0.05$). These changes attest to activation of protein synthesis and secretion in parathyrocytes. On the other hand, the number and volume portion of mitochondria were practically unchanged.

In atrial cardiomyocytes, hyperplasia of the Golgi apparatus was less pronounced. The most typical changes were seen in secretory granules (Fig. 2, *a*, *b*): their number and mean area decreased by 24.6% and 23.5%, respectively, ($p<0.01$, Table 2). The simultaneous decrease in these parameters attested to enhanced secretion and release of ANF from cardiomyocytes [7]. The secretory granules were nonuniform in their structure: apart from abundant electron dense granules, light granules with fine-grained contents occurred more often than in the control (Fig. 2, *c*). It can be assumed that these morphological

TABLE 1. Content of Boron in the Thyroid-Parathyroid Complex and Cardiomyocytes of Rats Treated with Boron Water Solution (μg/g)

Organ	Control	Experiment
15 procedures		
Thyroid-parathyroid complex	5.34±0.89	18.03±4.42*
Heart	0.16±0.02	1.26±0.19***
24 procedures		
Thyroid-parathyroid complex	5.92±0.95	20.71±3.61**
Heart	0.11±0.03	0.62±0.09***

Note: Here and in Table 2: *$p<0.05$, **$p<0.01$, ***$p<0.001$ compared with the control.

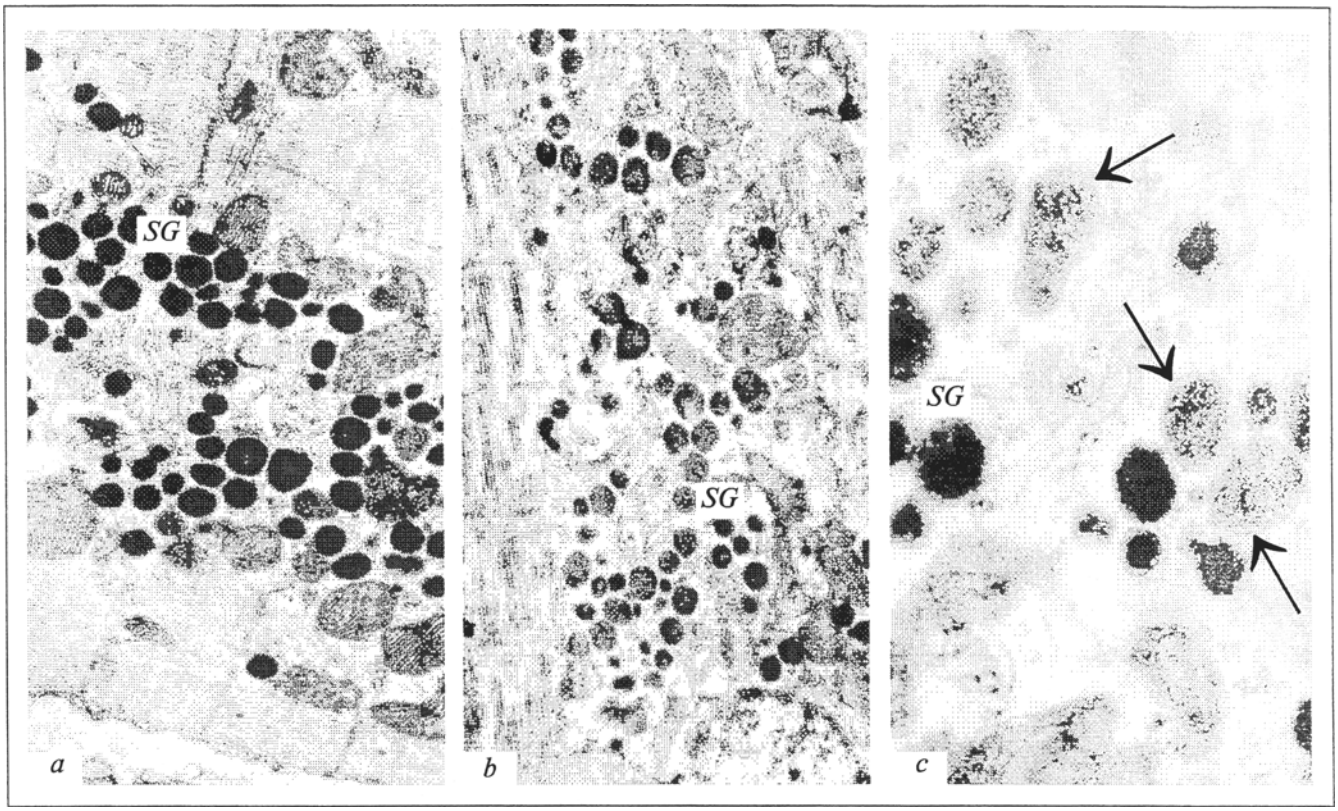

Fig. 2. Changes in secretory granules of atrial cardiomyocytes after treatment with boron water solution. *a*) secretory granules in perinuclear zone of cardiomyocyte, control; *b*) boron-induced decrease in the number and area of secretory granules; *c*) boron-induced clarification of some granules (arrows). *SG*: secretory granules. Magnification: *a* and *b*: 16,000, *c*: 50,000

changes reflect ANF processing and transformation from high-molecular inactive form contained in the dense granules into more active low-molecular form [2]. The enhanced secretion of ANF in cardiomyocytes probably led to its accelerated processing.

Thus, in both parathyrocytes and cardiomyocytes we observed ultrastructural signs of boron-induced enhancement of their secretory activity. It is likely that boron, apart from the direct action, as evidenced by its accumulation in the studied organs, also exerts an indirect effect. Specifically, stimulation of parathyrocytes can be triggered by a decrease in blood calcium, which is a specific signal activating synthesis and secretion of PTH [3]. This agrees with previous data that the number of C-cells in the thyroid gland undergoes phase changes and that thyroid function markedly decreases when the accumulation of boron attains the maximum [5,8]. These shifts in parathyrocytes probably affect atrial cardiomyocytes, because PTH activates calcium entry into cardiomyocytes [3] and ANF secretion is a calcium-dependent process [13,14]. These findings suggest that the observed ultrastructural changes in parathyrocytes and atrial cardiomyocytes as well as diuretic and hypotensive effect of boron [4,11] can be realized through regulation of PTH, calcium-sodium exchange, and ANF.

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TABLE 2. Effect of Boron Water Solution on Morphometrical Characteristics of Parathyrocytes and Atrial Cardiomyocytes

Group	Parathyrocytes				Cardiomyocytes	
	mitochondria	mitochondria	GER	Golgi apparatus	secretory granules	
	number	volume, %			number	area, m^2
Control	0.63±0.06	17.9±1.4	25.1±3.3	8.1±1.5	47.5±3.0	0.047±0.0008
Experiment	0.61±0.04	19.5±1.1	35.8±2.0**	16.7±1.7***	35.9±2.6**	0.036±0.0007**

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