Abstract

Using atomic emission spectrometry method and nanotechnology techniques: scanning electron microscopy (SEM; FEI Quanta 200, FEI Quanta 600) and scanning transmission microscopy (STEM; FEI Nova NanoSEM) the concentration of macronutrients and micronutrients was evaluated. It was found that hypertensive patients have significant decrease in the atomic weight of all main chemical elements (N, O, Na, Mg, P, S, Cl, K, Zn) in renal tissue.

Key words: atomic emission spectrometry, nanotechnology techniques, scanning electron microscopy, scanning transmission microscopy, hypertensive patients, renal tissue, kidney tissue, hypertension

Arterial hypertension (AH) continues to be a key part of cardiorenal continuum. The relation of blood pressure (BP) increase and renal disease has been studied for decades. Recent advances in the study of AH determine the need to explore the features of target organ damage. The presence of AH influences the severity, the course and the prognosis of chronic kidney disease [1]. At that it was found that even a relatively mild course of AH is the lesion factor of renal parenchyma [2]. The results of epidemiological studies indicate that the early subclinical renal dysfunctions of kidney are an independent risk factor for cardiovascular complications (CVC) and death factor [3, 4].

The main criterion for the viability of anybody cell is an adequate metabolism [5]. A man's body contains approximately 50 chemical elements, many of which perform important biological functions. All cells in a man's body are similar by chemical composition, they include both inorganic and organic matter [6].

Salts are referred to inorganic cell substances, except for water. At that the organic matters of a cell belong mainly to carbon compounds, which include hydrogen, nitrogen and oxygen. A man's body is composed on the average of
water (60%), of organic substances (34%) and from inorganic substances (6%) [7, 8]. The inorganic substances of a man's body are presented by 22 chemical elements: Ca, P, O, Na, Mg, S, B, Cl, K, V, Mn, Fe, Co, Ni, Cu, Zn, Mo, Cr, Si, I, F, Se. The elements the content which does not exceed 3-10%, make the part of enzymes, hormones, vitamins and other essential compounds. They constitute the active centers of enzymes, make a strong impact on the conformation of the protein and nucleic structures and hence on their function. Fe, Co, Mn, Zn, Mo, V, B, W are necessary for protein, carbohydrate and fat metabolism; Mg, Mn, Fe, Co, Cu, Ni, Cr are involved in protein synthesis, Co, Ti, Cu, Mn, Ni, Zn take part in hematopoiesis; Mg, Fe, Cu, Zn, Mn and Co are involved in breathing [9]. Trace elements in the composition of enzymes speed up or slow down various biochemical processes, i.e., they act as catalysts or inhibitors. This leads to the fact that the concentration of certain proteins, fats, carbohydrates and other substances necessary for life increases or decreases.

It is known that the interactions between trace elements occur when the deficiency or excess of one (or more than one) element affects the metabolic pathway of another element, or interferes with the biological processes necessary for the full manifestation of its activity [10]. A lot of attention is given to elemental composition study and its changes occurring in the presence of certain diseases. There is the lack of knowledge for a detailed description of micronutrient participation mechanisms in different biochemical processes.

The aim of our study was the research of macroelement quantitative composition of kidney tissue among hypertensive patients.

**Materials and methods**

The work was performed on the basis of the Organ Transplantation Center at the Belgorod Regional Clinical Hospital of St. Joasaph, the department of hospital therapy and hospital surgery at Belgorod State University and the Research - Education and Innovation Center "Nanostructured Materials and Nanotechnologies» of Belgorod State University. The evaluation of quantitative macroelement composition was performed using the biological samples of lifetime kidney biopsy among 12 male patients with a verified diagnosis in hospital terms with AH diagnosis of I-II degree, subject to the surgery of the upper urinary tract [11, 12]. Exclusion criteria: concomitant acute inflammation, infection, cancer, immunocomplex diseases; chronic diseases in an acute stage; stable intraventricular conduction defects, AH of III-rd degree (blood pressure above 180/110 mm Hg), valvular heart disease or congestive heart failure; chronic liver, kidney failure, chronic lung disease with respiratory failure, the presence of heart attack and stroke in anamnesis. Each patient provided a written informed consent to participate voluntarily in the study.
according to the protocol approved by the local ethics committee. The average age of patients was 48.3 ± 1.6 years. The duration of AH made 6.3 ± 1.5 years. 15 (83.3%) patients demonstrated the severed family history of cardiovascular disease (CVD). The disorders of lipid metabolism were observed among 8 (44.4%) patients. The average body mass index made 28.9 ± 3.2 kg/m².

The sampling of kidney was performed during an autopsy of 18 healthy individuals without CCD. These individual died in road traffic accidents with verified healthy tissue results in terms of forensic medical examination, and the presence of a tissue sample weight no less than 2.1 g. There were no significant differences in age and body weight index among hypertensive patients and the control group (CG).

The determination of the tissue elemental composition was performed using nanotechnology techniques: scanning (SEM; FEI Quanta 200, FEI Quanta 600) and scanning transmission (STEM; FEI Nova NanoSEM) microscopy.

**Results and discussion**

The results of the performed elemental composition of kidney tissue revealed (Figure 1) that the atomic concentration of macroelement C among hypertensive patients had the tendency to increase as compared to the CG, exceeding the performance of CG by 9% (Δ = 6.69; p>0.05).

![Fig. 1. Elemental composition of kidney tissue A, B - control groups, C, D - HT groups.](image-url)
At that there was a significant decrease of all major chemical elements among hypertensive patients. The comparative analysis of kidney tissue elemental composition among hypertensive patients and the group of healthy subjects is presented in Table. 1.

Table 1: Determination of kidney tissue elemental composition among the patients with arterial hypertension (Me (Me₀; Meₐ)).

<table>
<thead>
<tr>
<th>Elements, A%</th>
<th>Na</th>
<th>Mg</th>
<th>P</th>
<th>S</th>
<th>CL</th>
<th>K</th>
<th>Zn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gr. 1 (AH) n=12</td>
<td>Me</td>
<td>0.09</td>
<td>0.02</td>
<td>0.24</td>
<td>0.32</td>
<td>0.01</td>
<td>0.04</td>
</tr>
<tr>
<td>Мен-</td>
<td>0.05-</td>
<td>0.21-</td>
<td>0.022-</td>
<td>0.009-</td>
<td>0.038-</td>
<td>0.001-0.005</td>
<td></td>
</tr>
<tr>
<td>Мев</td>
<td>0.14</td>
<td>0.27</td>
<td>0.43</td>
<td>0.02</td>
<td>0.042</td>
<td>0.001-0.005</td>
<td></td>
</tr>
<tr>
<td>Gr. 2 (CG) n=18</td>
<td>Me</td>
<td>0.55</td>
<td>0.19</td>
<td>0.67</td>
<td>0.56</td>
<td>0.37</td>
<td>0.48</td>
</tr>
<tr>
<td>Мен-</td>
<td>0.51-</td>
<td>0.64-</td>
<td>0.33-</td>
<td>0.42-</td>
<td>0.05-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Мев</td>
<td>0.59</td>
<td>0.71</td>
<td>0.55-0.57</td>
<td>0.42</td>
<td>0.56</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Δ, %</td>
<td>167</td>
<td>179</td>
<td>128</td>
<td>86</td>
<td>195</td>
<td>183</td>
<td>188</td>
</tr>
<tr>
<td>Δ</td>
<td>0.46</td>
<td>0.17</td>
<td>0.43</td>
<td>0.24</td>
<td>0.36</td>
<td>0.44</td>
<td>0.075</td>
</tr>
<tr>
<td>p</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.01</td>
<td>&lt;0.05</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

In our study the decrease of atomic N content in kidney tissue by 24% (Δ = 1.36; p <0.05), O - by 26% (Δ = 3.98; p <0.05) as compared with the control group (p <0.05) Fig. 2.

The concentration of other macronutrients (Na and K) was also changed dynamically in kidneys. The vital elements for a man Na and K operate together. At reabsorption Na passively flows through an electrochemical gradient into a cell, it moves along it to the basal plasmatic membrane using the "sodium pumps" situated in it (Na/K ion exchange pump, electrogenic Na pump, etc.) and is ejected into an extracellular fluid. K secretion of intercellular fluid enters a
The reabsorption of different substances is regulated by neural and hormonal factors. The absorption of water increases under the influence of vasopressin, the reabsorption of Na increases and it is reduced by aldosterone natriuretic factor, the absorption Ca and phosphate is influenced by parathyroid hormone, thyrocalcitonin, etc. [15].

The kidney of hypertensive patients is an incretory organ, as renin is developed in the cells of a juxtaglomerular apparatus. At that it was found that the secretion of renin increases with the renal blood pressure decrease, reducing the content of Na and Cl in a body [16]. The results obtained by ud indicate that the amount of Cl in kidney tissue among hypertensive patients decreased reliably in 2 times as compared with the CG (p <0.001). In our opinion, a significant drop of atomic trace element content takes place in the target organ tissues due to glomerular filtration rate decrease and tubulointerstitial fibrosis at the early stages of hypertension. Also hypertensive patients determined a significant decrease of Mg, P and S (Fig. 3).

Fig. 3. Atomic percent comparison of Mg%, P%, S% in HT kidney tissues and control group tissues. * p < 0.05; ** p < 0.01; *** < 0.001 - group comparison.

The findings on atomic zinc content in kidney tissue are noteworthy among hypertensive patients. Zinc is an important chemical element and it is involved in the basic body functions such as protein, DNA and cell growth synthesis. Zinc plays a key role for immune system development. Zn is absorbed in the small intestine, and then it is transported in blood along with albumin [17]. The reduction of Zn concentration is related with neurohormonal activation, hyperaldosteronism, homeostasis, and an antioxidant system activity decrease [18]. We stated a significant decrease of Zn atomic masses in kidney biopsy tissue among hypertensive patients compared to healthy tissue content. So the concentration of Zn in AH group was 0.005 (0.001, 0.01) A%, and it made 0.08 (0.05-0.1) A% in CG,
which was almost 2 times lower (188%; Δ = 0.075) p<0.001. Zinc exists only in biological systems, such as Zn2+, yaking into account its complete d shell. However, it was found that zinc deficiency is associated with oxidative stress condition.

According to the latest epidemiological research ESSE 48% of Russian men and 40% of Russian women have hypertension. The prevalence of hypertension increased from 40 to 44% in the last 6 years, and the increase of people [19] suffering from high blood pressure levels up to half a billion is predicted by 2025. Scientific trend aimed on the study of mechanism features concerning target organ damage, as well as the assessment of the chemical element participation in the tissues of different organs, where biochemical reactions occur is an important one for the determination of target organ involvement degree.

**Summary**

The mechanisms of hypertension influence on the functional deterioration of an affected target organ, and also the relationship of tissue trace elements and hypertension flow are extremely complex ones. Considering the obtained data our work confirmed that hypertensive patients had a significant reduction of atomic mass among all basic chemicals (N, O, Na, Mg, P, S, Cl, K, Zn) in kidney tissues.

It was shown that the activation of free radical oxidation processes has a damaging effect on the normal course of biochemical processes and the function of tissue structures for cardio renal continuum, the decrease of zinc concentration in the biological tissues of renal biopsy among hypertensive patients. The mechanisms of antioxidant defense system participation are set in the form of Zn reduction, which makes the part of it. The obtained results of kidney tissue composition elemental assessment during the diseases of the cardiovascular system will open new opportunities of the therapeutic effect on the early mechanisms of target organ damage.

**References**


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