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Chemical Elemental Content/Calcium Ratios in Tissues of Human Hyperplastic Prostate Gland

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

Aims: The aim of this exploratory study was to evaluate whether significant deficiencies in the prostatic tissue levels of Ca and Mg, as androgen dependent chemical elements, and Br, K, Mn, and Na, as androgen independent chemical elements, exist in patients with BPH.
Methodology: It was prospectively evaluated prostatic tissue levels of these chemical elements in 27 patients with BPH and 37 healthy male inhabitants. Measurements were performed using instrumental neutron activation analysis with high resolution spectrometry of short-lived radionuclides. Beside the measurements of Br, Ca, K, Mg, Mn, and Na mass fraction the calculations of Br/Ca, K/Ca, Mg/Ca, Mn/Ca, and Na/Ca mass fraction ratios were also performed.
Results: There was no found significant difference in levels of Br, Ca, Mg, Mn, and Na contents between BPH and intact prostate. In the hyperplastic prostates, we have only observed a significant increase in value of K mass fraction ($p<0.0014$) and K/Ca mass fraction ratio ($p<0.042$).
Conclusion: The potential role of age-related chemical elements deficiency in the prostate was not confirmed as being involved in the etiology of BPH. It was hypothesized that not only a high level of some chemical elements, but also a great disturbance in the relationships of chemical elements in prostate tissue may serve as a pathogenetic factor of BPH.

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Keywords: Human prostate; chemical elements contents and relationships in prostate; benign prostate hyperplasia; chemical element supplementations.

1. INTRODUCTION

Benign prostatic hyperplasia (BPH) is an internationally important health problem of the man, particularly in developed countries, and represents the most common urologic disease among of men after the age of fifty [1-3]. BPH is histologically defined as an overgrowth of the epithelial and stromal cells from the transition zone and peri-urethral area of prostate [4,5]. The excessive cell proliferation associated with BPH causes benign prostatic enlargement, bladder outlet obstruction, and lower urinary tract symptoms, which afflict the patients [3]. Incidence of histological BPH could be over 70% at 60 years old and over 90% at 70 years old [1,6]. To date, we still have no precise knowledge of the biochemical, cellular and molecular processes underlying the pathogenesis of BPH. Although the influence of hormones, age and genetics has been demonstrated, these factors alone may not fully explain BPH development [7,8]. Recent insights at the problem have revealed novel risk factors of BPH that present new opportunities for treatment and prevention. Indeed, an exciting notion is that BPH etiology and pathogenesis may be driven by modifiable risk factors, including diet [9].

Chemical elements, including trace elements, as micronutrients have essential physiological functions such as maintenance and regulation of cell function, gene regulation, activation or inhibition of enzymatic reactions, and regulation of membrane function. Essential or toxic (mutagenic, carcinogenic) properties of chemical elements depend on tissue-specific need or tolerance, respectively [10]. Insufficient or excessive accumulation, as well as an imbalance of the chemical elements may disturb the cell functions and may result in cellular degeneration, death or, on the contrary, intensive proliferation [11,12]. Thus, the findings of the excess or deficiency in chemical elements and the perturbation in their relationships in benign hyperplastic tissue may highlight the role of these disturbances in etiology of BPH. Unfortunately, data on the effects of chemical element intake on BPH risk are inconsistent and present a very mixed picture. However, there is evidence of mineral bioavailability decreases in the elderly [13]. Proponents of “theory of deficiency” think that due to lifestyle, eating and dietary habits, and physiological effects of aging, the elderly male population is normally predisposed to conditions of chemical elements and other antioxidant deficiency, which can increase their susceptibility to BPH [14,15].

In our previous study a significant positive correlation between age and some chemical element contents in the nonhyperplastic prostate was observed [16-23]. In addition to Zn [11,12] an androgen-dependence of some other chemical element contents in the prostate, including Ca and Mg, was found [24-28]. High intraprostatic Zn concentrations are probably one of the main factors acting in prostate cell proliferation [11,12,29-31]. A strongly pronounced tendency of age-related exponential increase in Zn mass fraction as well an increase in Zn/Fe, Zn/Rb, and Zn/Sr ratios in prostate was recently demonstrated by us [32]. Moreover, a significant positive correlation was seen between the prostatic Zn and other trace element contents [32]. Hence it is possible that besides Zn, such chemical elements as Br, Ca, K, Mg, Mn, and Na and some their content relationships also play a role in the pathophysiology of the prostate.

This work had three aims. The first was to assess the Br, Ca, K, Mg, Mn, and Na contents in prostate tissue of patients, who had BPH, using instrumental neutron activation analysis with high resolution spectrometry of short-lived radionuclides (INAA-SLR). The second aim was to compare the levels of chemical elements determined in the BPH glands with those in nonhyperplastic prostate of healthy men aged over 40 years. The third aim was to calculate and to compare the chemical element/ Ca content ratios in normal and BPH glands.

2. MATERIALS AND METHODS

All patients suffered from BPH (n=27, mean age 67±6 years, range 56-78 years) were hospitalized in the Urological Department of the Medical Radiological Research Centre. Transrectal puncture biopsy of suspicious indurated regions of the prostate was performed for every patient, to permit morphological study of prostatic tissue at these sites and to estimate their chemical element contents. In all cases the diagnosis has been confirmed by clinical and morphological results obtained during studies of biopsy and resected materials.

Intact prostates were removed at necropsy from 37 men (mean age 56±11 years, range 41–87) who had died suddenly. The majority of deaths were due to trauma. A histological examination in the control group was used to control the age norm conformity, as well as to confirm the absence of microadenomatosis and latent cancer. Tissue samples were divided into two portions. One was used for morphological study while the other was intended for chemical element analysis.

After the samples intended for chemical element analysis were weighed, they were freeze-dried and homogenized. The pounded sample weighing about 100 mg was used for chemical element measurement by INAA-SLR. The samples for INAA-SLR were sealed separately in thin polyethylene films washed with acetone and rectified alcohol. The sealed samples were placed in labeled polyethylene ampoules.

To determine contents of the elements by comparison with a known standard, biological synthetic standards (BSS) prepared from phenol-formaldehyde resins and aliquots of commercial, chemically pure compounds were used as standards [33]. Ten sub-samples of certified reference material (CRM) IAEA H-4 (animal muscle) weighing about 100 mg were treated and analyzed in the same conditions that prostate samples to estimate the precision and accuracy of results.

The content of Br, Ca, K, Mg, Mn, and Na were determined by INAA-SLR using a horizontal channel equipped with the pneumatic rabbit system of the WWR-c research nuclear reactor. The neutron flux in the channel was 1.7×10^{13} n cm^{-2} s^{-1}. Ampoules with prostate samples, BSS, intralaboratory-made standards, and certified reference material were put into polyethylene rabbits and then irradiated separately for 180 s. Copper foils were used to assess neutron flux.

The measurement of each sample was made twice, 1 and 120 min after irradiation. The duration of the first and second measurements was 10 and 20 min, respectively. A coaxial 98-cm3 Ge (Li) detector and a spectrometric unit (NUC 8100), including a PC-coupled multichannel analyzer, were used for measurements. The spectrometric unit provided 2.9-keV resolution at the ^{60}Co 1,332-keV line. Details of used nuclear reactions, radionuclides, and gamma-energies were presented in our earlier publication [34].

All prostate samples intended for INAA-SLR were prepared in duplicate, and mean values of chemical element mass fractions were used in final calculation. Using the Microsoft Office Excel software, the summary of statistics, arithmetic mean, standard deviation, standard error of mean, minimum and maximum values, median, percentiles with 0.025 and 0.975 levels were calculated for chemical element mass fractions in normal and BPH prostate tissues. The reliability of difference in the results between the two groups of prostate samples was evaluated by Student's *t*-test. For the estimation of the Pearson correlation coefficient between different pairs of the chemical element mass fractions in the normal and cancerous prostate tissues the Microsoft Office Excel software was also used.

3. RESULTS

Table 1 depicts a comparison of our data for Br, Ca, K, Mg, Mn, and Na mass fractions in ten sub-samples of CRM IAEA H-4 (animal muscle) with the certified values of this material.

Table 1. NAA-SLR data of chemical element contents in certified reference material IAEA H-4 (animal muscle) compared to certified values (mg/kg, dry mass basis)

Element	IAEA H-4 (animal muscle)	This work results
	95% confidence interval	Mean±SD
Br	3.5 – 4.7[a]	5.0±0.9
Ca	163 – 213[a]	238±59
K	15300 – 16400[a]	16200±3800
Mg	990 – 1110[a]	1100±190
Mn	0.48 – 0.55[b]	0.55±0.11
Na	1930 – 2180[a]	2190±140

Mean arithmetical mean, SD standard deviation, a certified value, b non-certified value

Table 2 presents basic statistical parameters (arithmetic mean, standard deviation, standard error of mean, minimal and maximal values, median, percentiles with 0.025 and 0.975 levels) of the Br, Ca, K, Mg, Mn, and Na mass fraction as well as the Br/Ca, K/Ca, Mg/Ca, and Na/Ca mass fraction ratios in normal and BPH prostate tissue.

Median, minimum and maximum value of means of Br, Ca, K, Mg, Mn, and Na contents in normal and benign hyperplastic prostate tissue (BPH) according to data from the literature [35-49] in comparison with our results (mg/kg, dry mass basis) are shown in Table 3.

The ratios of means and the reliability of difference between mean values of Br, Ca, K, Mg, Mn, and Na mass fractions as well as between mean values of Br/Ca, K/Ca, Mg/Ca, and Na/Ca mass fraction ratios in normal and BPH prostate tissue are presented in Table 4.

Table 5 depicts means values of Ca mass fraction in nonhyperplastic (or intact tissue) and hyperplastic prostate glands, according to data from the literature in comparison with our results. Data of the studies, where the Ca mass fractions were investigated in both nonhyperplastic and hyperplastic prostate glands, were presented in Table 5.

To estimate the effect of age on the Br, Ca, K, Mg, Mn, and Na mass fractions as well as on the Br/Ca, K/Ca, Mg/Ca, and Na/Ca mass fraction ratios in BPH tissue we examined two age groups: the first comprised persons with ages ranging from 56 to 65 years (mean age 62.5±2.9 years, n=13) and the second comprised those with ages ranging from 66 to 87 years (mean age 71.6±3.5 years, n=14). The means, the ratios of means and the reliability of difference between mean values of chemical element mass fractions and ratios in two age groups are presented in Table 6.

Table 2. Certain statistical characteristics of Br, Ca, K, Mg, Mn, and Na mass fractions (mg/kg, dry mass basis) as well as Br/Ca, K/Ca, Mg/Ca, Mn/Ca, and Na/Ca mass fraction ratios in normal and benign hyperplastic prostate tissue (BPH)

Parameter	M	SD	SEM	Min	Max	Med	Per. 0.025	Per. 0.975
Normal (Age M±SEM 56±11 years, range 41-87 years, n = 37)								
Br	29.8	15.5	3.0	12.0	74.1	25.2	12.4	64.6
Ca	2428	1232	233	1180	6893	2195	1197	5553
K	11650	2340	434	6325	18198	11403	7352	15489
Mg	1071	409	76	447	2060	1017	520	1955
Mn	1.32	0.42	0.08	0.75	2.80	1.30	0.84	2.23
Na	10987	2158	394	6415	15300	10911	6719	15151
$(Br/Ca)10^2$	1.44	0.90	0.21	0.333	4.00	1.36	0.437	3.69
K/Ca	5.69	1.74	0.38	2.50	8.23	5.92	2.52	8.20
Mg/Ca	0.511	0.211	0.045	0.229	1.03	0.449	0.242	0.932
$(Mn/Ca)10^3$	0.623	0.256	0.062	0.100	1.08	0.592	0.192	1.05
Na/Ca	5.58	2.24	0.48	1.73	10.6	5.51	2.29	10.3
BPH (Age M±SEM 67±6 years, range 56-78 years, n = 27								
Br	30.4	18.4	3.6	5.5	77	25.6	5.75	66.7
Ca	2032	547	165	1168	2762	1898	1173	2757
K	14472	2454	740	11683	20519	13552	12025	19744
Mg	1201	276	83	687	1585	1263	749	1552
Mn	1.19	0.31	0.09	0.80	1.80	1.20	0.80	1.73
Na	11612	2882	869	7762	15503	10564	7893	15400
$(Br/Ca)10^2$	1.76	1.11	0.33	0.454	3.65	1.70	0.519	3.55
K/Ca	7.69	2.69	0.81	4.62	12.2	7.14	4.79	12.0
Mg/Ca	0.613	0.148	0.045	0.397	0.871	0.574	0.424	0.868
$(Mn/Ca)10^3$	0.626	0.228	0.069	0.335	1.03	0.591	0.357	1.01
Na/Ca	6.21	2.33	0.70	3.02	9.25	6.66	3.03	9.07

M arithmetic mean, SD standard deviation of mean, SEM standard error of mean, Min minimum value, Max maximum value, Med median, Per.0.025 percentile with 0.025 level, Per.0.975 percentile with 0.975 level

Table 3. Median, minimum and maximum value of means of chemical element contents (mg/kg, dry mass basis) in normal prostate and BPH according to data from the literature in comparison with our results

Tissue	El	Published data [Reference]			This work results
		Median of means (*n*)*	Minimum of means M or M±SD, (*n*)**	Maximum of means M or M±SD, (*n*)**	M±SD n=37
Normal	Br	14 (3)	12±8 (4) [35]	21 (12) [36]	30±15
	Ca	1870(14)	430±120 (21) [37]	7500±12300 (57) [38]	2428±1232
	K	9900(12)	3840 (8) [39]	12200±1500 (8) [40]	11650±2340
	Mg	900(12)	498±172 (13) [38]	2056±476 (21) [41]	1071±409
	Mn	6.0 (11)	<0.47 (12) [36]	106±18 (5) [42]	1.32±0.42
	Na	6100(7)	23±26 (13) [38]	13700±3500 (4) [43]	10987±2158
BPH	Br	19.8 (2)	18.0±9.5 (27) [44]	21.5±13.0 (9) [45]	33±12
	Ca	2100 (7)	600±120 (2) [46]	5100±3200(9) [45]	2032±547
	K	7400 (6)	1010±95 (27) [44]	12800±1900 (43) [40]	14472±2454
	Mg	820 (6)	566±130 (25) [47]	1560±50 (10) [48]	1201±276
	Mn	10.8 (4)	6.5 (-) [46]	23±13 (27) [44]	1.19±0.31
	Na	7800 (1)	7800 (34) [49]	7800 (34) [49]	11612±2882

El element, M arithmetic mean, SD standard deviation, (n) number of all references, (n)** number of samples*

Table 4. Comparison of mean values (M±SEM) of Br, Ca, K, Mg, Mn, and Na mass fractions (mg/kg, dry mass basis) and also Br/Ca, K/Ca, Mg/Ca, Mn/Ca, and Na/Ca mass fraction ratios in normal and benign hyperplastic prostate tissue (BPH)

Parameter	Prostatic tissue			Ratio
	Normal 41-79 year n=37	BPH 56-75 year n=26	Student's t-test *p*≤	BPH to normal
Br	29.8±3.0	30.4±3.6	0.617	1.02
Ca	2428±233	2032±165	0.316	0.84
K	11650±434	14472±740	**0.00135**	1.24
Mg	1071±76	1201±83	0.468	1.12
Mn	1.32±0.08	1.19±0.09	0.700	0.90
Na	10987±394	11612±869	0.602	1.06
$(Br/Ca)10^2$	1.44±0.21	1.76±0.33	0.437	1.22
K/Ca	5.69±0.38	7.69±0.81	**0.0418**	1.35
Mg/Ca	0.511±0.045	0.613±0.045	0.123	1.20
$(Mn/Ca)10^3$	0.623±0.062	0.626±0.069	0.974	1.00
Na/Ca	5.58±0.48	6.21±0.70	0.464	1.11

M arithmetic mean, SEM standard error of mean, Statistically significant values are in **bold**

Table 7 presents intercorrelations (*r* – the Pearson correlation coefficient) of pairs of the chemical element mass fractions or mass fraction ratios in BPH and normal prostate glands of adults.

4. DISCUSSION

As was shown by us [16,24,32,50], the use of CRM IAEA H-4 as a CRM for the analysis of samples of prostate tissue can be seen as quite acceptable. The mass fractions of six elements (Br, Ca, K, Mg, Mn, and Na) that cover the range of 6 elements with certified (Br, Ca, K, Mg, and Na) and informative (Mn) values in CRM IAEA H-4 (animal muscle) were determined. Mean values (±SD) for all six elements (Table 1) were in the range of 95% confidence interval of the certificate. Good agreement with the certified data of CRM IAEA H-4 (animal muscle) indicate an acceptable accuracy of the results obtained in this study.

When our results were compared with data of literature, a number of values for chemical element mass fractions were not expressed on a dry mass basis by the authors of the cited references. However, we calculated these values using the medians of published data for water –83% [48] and ash – 1% on wet mass basis [51] contents in nonhyperplastic prostate of adult men, and also for water - 80% in BPH tissue [52]. The obtained values for Ca, K, Mg, Mn, and Na mass fractions in normal prostate tissue agreed well with median of means cited by other researches for the nonhyperplastic prostate glands of adult males, including samples received from persons who died from various diseases, but the mean for Br was somewhat higher than the maximum mean value of previously reported data. For BPH tissue the obtained means of Ca and Mg agreed well with median of means cited, but means of Br, K, and Na were somewhat higher while mean of Mn was lower, than the respective mean's range of previously reported data. The mean of this work for Mn was 5.5 times lower than the minimal mean value cited.

Table 5. Means values of Ca mass fraction in nonhyperplastic (Norm) and hyperplastic prostate glands (BPH), according to data from the literature in comparison with our results

Ref year	Meth	Treatment of samples	Ca (mg/kg on a dry mass basis)					BPH to Norm
			Nonhyperplastic (Norm)			BPH		
			n	Age years	M±SD	n	M±SD	
[49] 1970	AAS	A, AD	20	71-90	1000	34	1000	1.00
[44] 2007	PIXE	H.Press	27	38-68	4510±700	27	4000±300	0.89
[53] 2009	AAS	AD	11	49-67	1790±390	27	2100±300	1.17
[39] 2014	SR-TXRF	W, D, AD	8	18-30	2720±1210	44	860±90	0.32
This work	NAA-SLR	Without treatment	37	41-79	2428±1232	26	2032±547	0.84
Median of Means					2428		2100	0.84 0.86*
Range of Means					1000-4510		860-4000	0.32 -1.17

*Ref reference, Meth method, M arithmetic mean, SD standard deviation of mean, AAS atomic absorption spectrometry, PIXE proton induced X-ray emission, SR-TXRF synchrotron radiation total reflection X-ray fluorescence analysis, NAA-SLR instrumental neutron activation analysis with high resolution spectrometry of short-lived radionuclides; A ashing, AD acid digestion, H.Press compressed using a 10-ton hydraulic press, W washing with water, D thermal drying; * Median of Means for BPH/ Median of Means for Norm*

Table 6. Differences between mean values (M±SEM) of Br, Ca, K, Mg, Mn, and Na (mg/kg, dry mass basis) and between mean values of Br/Ca, K/Ca, Mg/Ca, Mn/Ca, and Na/Ca mass fraction ratios in hyperplastic prostate glands of two age groups

Parameter	BPH			Ratio
	Age group 1 56-65 year n=13	Age group 2 66-78 year n=14	Student's t-test *p*≤	Group 2/ Group 1
Br	32.6±6.0	28.7±4.6	0.606	0.88
Ca	2104±277	1972±217	0.717	0.94
K	15438±1584	13666±221	0.328	0.89
Mg	1255±112	1156±127	0.574	0.92
Mn	1.16±0.15	1.22±0.13	0.795	1.05
Na	11494±1620	11712±1008	0.912	1.02
$(Br/Ca)10^2$	1.23±0.27	2.20±0.52	0.141	1.79
K/Ca	8.05±1.53	7.39±0.90	0.722	0.92
Mg/Ca	0.640±0.095	0.590±0.032	0.638	0.92
$(Mn/Ca)10^3$	0.583±0.83	0.662±0.110	0.584	1.14
Na/Ca	6.10±1.32	6.30±0.80	0.901	1.03

M arithmetic mean, SEM standard error of mean

Table 7. Intercorrelations of pairs of the chemical element mass fractions or mass fraction ratios in BPH and normal prostate glands of adults (*r* – coefficient of correlation)

Parameter	Ca	K	Mg	Mn	Na	Br/Ca	K/Ca	Mg/Ca	Mn/Ca	Na/Ca
Normal prostate tissue										
Br	-0.35	-0.16	-0.28	0.29	0.05	0.87^{c}	0.15	0.01	0.45^{a}	0.20
Ca	**1.00**	0.01	0.57^{b}	0.10	-0.25	-0.71^{c}	-0.87^{c}	-0.60^{b}	-0.71^{c}	-0.88^{c}
K		**1.00**	0.55^{b}	0.06	0.26	-0.14	0.43^{a}	0.53^{b}	0.06	0.17
Mg			**1.00**	-0.17	0.38	-0.58^{b}	-0.30	0.30	-0.62^{c}	-0.22
Mn				**1.00**	-0.21	0.17	-0.11	-0.34	0.60^{b}	-0.28
Na					**1.00**	0.03	0.20	0.57^{b}	-0.8	0.66^{c}
Br/Ca						**1.00**	0.52^{b}	0.17	0.70^{c}	0.50^{b}
K/Ca							**1.00**	0.75^{c}	0.64^{c}	0.81^{c}
Mg/Ca								**1.00**	0.16	0.78^{c}
Mn/Ca									**1.00**	0.44^{a}
Na/Ca										**1.00**
Hyperplastic prostate tissue										
Br	0.25	-0.34	0.17	-0.11	-0.07	0.73^{b}	-0.21	-0.12	0.26	-0.23
Ca	**1.00**	0.26	0.22	-0.37	-0.13	-0.42	-0.83^{b}	-0.53	-0.85^{c}	-0.80^{b}
K		**1.00**	-0.36	-0.17	-0.13	-0.36	0.20	-0.34	-0.28	-0.22
Mg			**1.00**	-0.06	0.42	-0.19	-0.34	0.64^{a}	-0.29	-0.01
Mn				**1.00**	0.39	0.30	0.16	0.33	0.68^{a}	0.32
Na					**1.00**	0.21	0.33	0.56	0.57	0.57
Br/Ca						**1.00**	0.36	0.15	0.54	0.39
K/Ca							**1.00**	0.40	0.68^{a}	0.81^{b}
Mg/Ca								**1.00**	0.53	0.71^{a}
Mn/Ca									**1.00**	0.87^{c}
Na/Ca										**1.00**

Statistically significant difference: ^{a} *- p≤0.05,* ^{b} *- p≤0.01,* ^{c} *- p≤0.0*

In BPH tissue the K mass fraction and K/Ca mass fraction ratio is significantly higher than in normal tissue. Prostatic tissue level of Ca in BPH (Ca BPH) is some lower than in normal gland (Ca Norm) and (Ca BPH)/(Ca Norm) ratio amounts 0.84. Investigation of this ratio has a long and conflicting story in scientific literature. With due consideration of the evidence amassed over approximately 45 years of reported clinical studies on (Ca BPH)/(Ca Norm) ratio [39,44,49,53], we found that median of published means equals 0.84 or 0.86. These values agree with our result and should lead to the conclusion that a small decrease in Ca level is involved in the pathogenesis of BPH.

The Ca means reported in the literature for nonhyperplastic (from 430 to 7500 mg/kg on dry mass basis) and for untreated hyperplastic prostate (from 600 to 5100 mg/kg on dry mass basis) vary widely. This can be explained by a dependence of Ca content on many factors, including the region of the prostate, from which the sample was taken, age, ethnicity, mass of the gland, and the stage of BPH. Not all these factors were strictly controlled in the studies. An additional and, in our opinion, leading cause of interobserver variability was insufficient quality control of results in the past studies. In many reported studies tissue samples were ashed or dried at high temperature for many hours. In other cases, prostate samples were acid digested or treated with solvents (distilled water, ethanol, formalin etc). There is evidence that by use of these methods some quantities of certain chemical elements, including Ca, are lost as a result of this treatment [54,55].

In our previous publications [16,18,20,21,23] it was shown that in the histologically normal prostates of males in the sixth to ninth decades, the magnitude of mass fractions of Br, Ca, K, Mg, Mn, and Na were maintained at near constant levels. No age-related differences in mass fraction of these elements in the hyperplastic prostate glands of men aged from 56 to 78 years were found in this study.

Inter-element correlations between chemical elements are significantly altered in BPH tissue as compared to their relationships in normal prostate tissue. In hyperplastic prostates many significant correlations between chemical elements found in the control group are no longer evident. For example, in prostate gland of healthy men the Ca mass fractions have significant positive correlation with Mg mass fractions, as well as the Mg mass fractions have significant positive correlation with K mass fractions. Thus, if we accept the relationships of chemical element mass fraction in prostate glands of males in the control group as a norm, we have to conclude that with a hyperplastic transformation the relationships between Ca, Mg and some other chemical elements in prostate significantly changed. No published data referring to correlations between chemical elements mass fractions in BPH tissue were found.

In the hyperplastic prostates, we have observed an increase in mass fraction of K and K/Ca mass fraction ratio in comparison with the histologically normal prostates. It is well known that K is the major cation of the intracellular fluid and cells are the main pool of this electrolyte in human body [56]. Thus, because the major characteristic of BPH is an overgrowth of the prostatic cells [4,5,57], becomes clear why an increase in the prostatic K mass fractions has respect to a hyperplastic transformation.

5. CONCLUSION

This work revealed that there is a significant tendency for an increase in K mass fraction and K/Ca mass fraction ratio in hyperplastic prostates. In the sixth to eighth decades the mass fractions of all chemical elements investigated in BHP tissue were maintained at approximately stable levels. Our finding of correlation between pairs of prostatic chemical element mass fractions indicates that there is a great disturbance of prostatic chemical element relationships with a hyperplastic transformation. Because the biochemical changes preceded the morphological transformations, we can hypothesize that not only a high level of some chemical elements, but also a great disturbance in the relationships of chemical elements in prostate tissue may serve as a pathogenetic factor of BPH.

ETHICAL APPROVAL

All studies were approved by the Ethical Committee of the Medical Radiological Research Center, Obninsk.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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