Journal of Medical Research and Health Sciences
Received 20 Sep 2021 | Revised 15 Oct 2021 | Accepted 10 Nov 2021 | Published Online 29 Nov 2021

DOI: https://doi.org/10.52845/JMRHS/2021-4-11-9
JMRHS 4 (11), 1576–1587 (2021)

ISSN (O) 2589-9031 | (P) 2589-9023

RESEARCH ARTICLE

Open Access Journal

Are there any Differences between Chemical Element Contents of Goitrous and Adenomatous Thyroid?

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Abstract

Background: Thyroid benign nodules (TBNs) are the most common lesions of this endocrine gland and are prevalent diseases around the world. Among TBNs the colloid goiter (CG) and thyroid adenoma (TA) are very frequent diseases. An evaluation of the variant of TBNs is clinically important for subsequent therapeutic interventions, as well as for more clear understanding the etiology of these disorders. **Objectives**: The aim of this exploratory study was to examine differ-ences in the content of aluminum (Al), boron (B), barium (Ba), bromine (Br), calcium (Ca), chlorine (Cl), coper (Cu), iron (Fe), I, potassium (K), lithium (Li), magnesium (Mg), manganese (Mn), sodium (Na), phosphorus (P), sulfur (S), silicon (Si), strontium (Sr), vanadium (V), and zinc (Zn) in tissues of CG and TA. **Methods**: Thyroid tissue levels of twenty chemical elements (ChE) were prospectively evaluated in 46 patients with CG and 19 patients with TA. Measurements were performed using a combination of non-destructive and destructive methods: instrumental neutron activation analysis with high resolution spectrometry of short-lived radionuclides (INAA-SLR) and inductively coupled plasma atomic emission spec-trometry (ICP-AES), respectively. Tissue samples were divided into two portions. One was used for morphological study while the other was intended for ChE analysis.

Results: It was observed that in both CG and TA tissues contents of Al, B, Br, Cl, Cu, Na, and Zn increased, content of I decreased, whereas levels of Ba, Ca, K, and Sr did not changed in comparison with normal thyroid tissue. It was not found any differences between ChE contents of CG and TA, with the exception of Br and Mg. The Br level in TA tissue was almost 11 times higher, while the Mg content was 1.5 times lower than in CG tissue.

Conclusions: From obtained results it was possible to conclude that the common characteristics of CG and TA tissue samples were elevated level of Al, B, Br, Cl, Cu, Na, and Zn and reduced level of I in comparison with normal thyroid and, therefore, these ChE can be involved in etiology and pathogenesis of such thyroid disorders as CG and TA

Keywords: Thyroid; Thyroid colloid goiter; Thyroid adenoma; Chemical elements; Neutron activation analysis; Inductively coupled plasma atomic emission spectrometry

1 | INTRODUCTION

Thyroid benign nodules (TBNs) are the most common lesions of this endocrine gland that encountered globally and frequently discovered by palpation during a physical examination, or incidentally, during clinical imaging procedures. TBNs include non-neoplastic lesions, for example, colloid goiter (CG) and neoplastic lesion such as thyroid adenoma (TA) (1–3). An evaluation of the variant of TBNs is clinically important for subsequent therapeutic interventions. For this reason the finding of specific characteristics of CG and TA is the barest necessity for the differential diagnosis of these thyroid disorders.

For over 20th century, there was the dominant opinion that TBNs is the simple consequence of iodine deficiency. However, it was found that TBNs is a frequent disease even in those countries and regions where the population is never exposed to iodine shortage (4). Moreover, it was shown that iodine excess has severe consequences on human health and associated with the presence of TBNs (5–8). It was also demonstrated that besides the iodine deficiency and excess many other dietary, environmental, and occupational factors are associated with the TBNs incidence (9–11). Among these factors a disturbance of evolutionary stable input of many chemical elements (ChE) in human body after industrial revolution plays a significant role in etiology of TBNs (12).

Besides iodine, many other ChE have also essential physiological functions (13). Essential or toxic (goitrogenic, mutagenic, carcinogenic) properties of ChE depend on tissue-specific need or tolerance, respectively (13).Excessive accumulation or an imbalance of the ChE may disturb the cell functions and may result in cellular degeneration, death, benign or malignant transformation (13–15).

In our previous studies the complex of in vivo and in vitro nuclear analytical and related methods was developed and used for the investigation of iodine and other ChE contents in the normal and pathological thyroid (16–22). Iodine level in the normal thyroid was investigated in relation to age, gender and some non-thyroidal diseases (23, 24). After that, variations of many ChE content with age in the thyroid of males and females were studied and age- and gender-dependence of some ChE was observed (25–41). Furthermore, a significant difference between some ChE contents in CG and TA in comparison with normal thyroid was demonstrated (42–44).

To date, the etiology and pathogenesis of CG and TA has to be considered as multifactorial. The present study was performed to find differences in ChE contents between CG and TA group of samples, as well as to clarify the role of some ChE in the etiology of these thyroid lesions. Having this in mind, our aim was to assess the aluminum (Al), boron (B), barium (Ba), bromine (Br), calcium (Ca), chlorine (Cl), coper (Cu), iron (Fe), I, potassium (K), lithium (Li), magnesium (Mg), manganese (Mn), sodium (Na), phosphorus (P), sulfur (S), silicon (Si), strontium (Sr), vanadium (V), and zinc (Zn) contents in CG and TA tissue samples using a combination of non-destructive and destructive methods: instrumental neutron activation analysis with high resolution spectrometry of short-lived radionuclides (INAA-SLR) and inductively coupled plasma atomic emission spectrometry (ICP-AES), respectively. A further aim was to compare the levels of these ChE in CG and TA group of samples.

All studies were approved by the Ethical Committees of the Medical Radiological Research Centre (MRRC), Obninsk. All the procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments, or with comparable ethical standards.

Supplementary information The online version of this article (https://doi.org/10.52845/JMRHS/2021-4-11-9) contains supplementary material, which is available to authorized users.

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2 | MATERIAL AND METHODS

All patients suffered from CG (n=46, mean age M±SD was 48±12 years, range 30-64) and TA (n=19, mean age M±SD was 41±11 years, range 22-55) were hospitalized in the Head and Neck Department of the Medical Radiological Research Centre. Thick-needle puncture biopsy of suspicious nodules of the thyroid was performed for every patient, to permit morphological study of thyroid tissue at these sites and to estimate their TE contents. For all patients the diagnosis has been confirmed by clinical and morphological results obtained during studies of biopsy and resected materials (46 euthyroid CG, 4 toxic TA and 15 non-toxic TA). Histological conclusion for all thyroidal lesions was the CG (16 macro-follicular, 13 micro-follicular, and 17 macro-micro-follicular) and TA (4 macro-follicular, 4 micro-follicular, 11 macro-micro follicular).

All tissue samples were divided into two portions using a titanium scalpel (45). One was used for morphological study while the other was intended for TE analysis. After the samples intended for TE analysis were weighed, they were freeze-dried and homogenized (46).

The pounded samples weighing about 10 mg (for biopsy) and 100 mg (for resected materials) were used for ChE measurement by INAA-SLR. The content of Br, Ca, Cl, I, 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 (Branch of Karpov Institute, Obninsk). After non-destructive INAA-SLR investigation the thyroid samples were used for ICP-AES. The samples were decomposed in autoclaves and aliquots of solutions were used to determine the Al, B, Ba, Ca, Cu, Fe, K, Li, Mg, Mn, Na, P, S, Si, Sr, V, and Zn mass fractions by ICP-AES using the Spectrometer ICAP-61 (Thermo Jarrell Ash, USA). Information detailing with the NAA-SLR and ICP-AES methods used and other details of the analysis were presented in our earlier publications concerning ChE contents in human thyroid, prostate, and scalp hair (33, 34, 47–52).

To determine contents of the ChE by comparison with a known standard, biological synthetic standards (BSS) prepared from phenol-formaldehyde resins were used (53).In addition to BSS, aliquots of commercial, chemically pure compounds were also used as standards. Ten sub-samples of certified reference material (CRM) IAEA H-4 (animal muscle) and five sub-samples of CRM of the Institute of Nuclear Chemistry and Technology (INCT, Warszawa, Poland) INCT-SBF-4 Soya Bean Flour, INCT-TL-1 Tea Leaves, and INCT-MPH-2 Mixed Polish Herbs were treated and analyzed in the same conditions that thyroid samples to estimate the precision and accuracy of results

A dedicated computer program for INAA-SLR mode optimization was used (54). All thyroid samples were prepared in duplicate, and mean values of ChE contents were used in final calculation. Mean values of ChE contents were used in final calculation for the Ca, K, Mg, Mn, and Na mass fractions measured by two methods. Using Microsoft Office Excel software, a summary of the statistics, including, arithmetic mean, standard deviation, standard error of mean, and range (minimal - maximal value), was calculated for ChE contents in CG and TA tissue samples. The difference in the results between two groups of samples was evaluated by the parametric Student's t-test and non-parametric Wilcoxon-Mann-Whitney U-test.

3 | RESULTS

resents certain statistical parameters (arithmetic mean, standard deviation, standard error of mean, and range) of the Al, B, Ba, Br, Ca, Cl, Cu, Fe, I, K, Li, Mg, Mn, Na, P, S, Si, Sr, V, and Zn mass fraction in CG and TA tissue samples.

The ratios of means and the comparison of mean values of Al, B, Ba, Br, Ca, Cl, Cu, Fe, I, K, Li, Mg, Mn, Na, P, S, Si, Sr, V, and Zn mass fractions in CG and TA are presented in Table 2.

epicts the results of comparison the contents of Al, B, Ba, Br, Ca, Cl, Cu, Fe, I, K, Li, Mg,Mn, Na, P, S, Si, Sr, V, and Zn in CG and TA sample groups with those in normal thyroid (from data analysis of previous publications (43, 44)), as well as comparison the contents of these ChE in CG and TA sample groups.

Table 1: Some statistical parameters of Al, B, Ba, Br, Ca, Cl, Cu, Fe, I, K, Li, Mg,Mn, Na, P, S, Si, Sr, V, and Zn mass fraction (mg/kg, dry mass basis) in thyroid colloid goiter and adenoma

Element	Nodular colloid goiter (n=46)				Thyroid adenoma (n=19)			
	Mean	SD	SEM	Range	Mean	SD	SEM	Range
Al	27.1	24.7	5.3	6.60-95.1	34.3	24.1	9.1	8.70-78.4
B	1.71	1.19	0.26	0.90-5.00	3.38	2.74	1.12	1.00-7.30
Ba	1.43	1.75	0.37	0.18-8.20	3.06	4.07	1.54	0.410-11.7
Br	36.3	31.3	6.99	8.0-131	394	397	125	11.6-1080
Ca	1422	834	164	288-4333	1370	1030	311	52.0-3582
Cl	9117	3866	1223	4226-16786	7722	3785	1262	1757-13824
Cu	8.51	7.15	1.60	2.90-34.8	17.6	14.0	5.7	4.10-35.2
Fe	337	321	51	62.0-1350	429	405	108	52.3-1360
I	1310	1433	221	29.0-8260	962	1013	232	131-3906
K	6610	2233	430	3353-12222	5603	2727	756	797-10099
Li	0.0281	.0.0117	0.0030	0.007-0.054	0.0401	.0.0236	0.0100	0.019-0.068
Mg	356	119	23	63.0-612	236	108	30	15.0-397
Mn	1.77	1.13	0.23	0.450-5.50	1.67	1.88	0.54	0.100-6.12
Na	11782	4342	836	7229-28481	9747	4746	1316	2319-18734
P	5181	1798	383	2890-9637	4930	1945	735	2982-8932
S	10961	2091	446	5591-14970	10536	2968	1122	7865-16706
Si	81.3	57.3	12.5	7.80-182	114	106	40	15.2-346
Sr	5.87	8.42	1.59	0.93-32.0	3.30	2.18	0.63	0.420-6.70
V	0.152	0.074	0.016	0.043-0.370	0.140	0.041	0.020	0.110-0.200
Zn	120.5	50.8	7.8	47.0-264	129	50	13	57.7-251

M – arithmetic mean, SD – standard deviation, SEM – standard error of mean.

Table 2. Differences between mean values (M±SEM) of Al, B, Ba, Br, Ca, Cl, Cu, Fe, I, K, Li, Mg, Mn, Na, P, S, Si, Sr, V, and Zn mass fraction (mg/kg, dry mass basis) in goitrous and adenomatous thyroid

Element	Thyroid tissue				Ratio
	Colloid goiter (CG)	Adenoma (TA)	Student's t-test, $p\leq$	U-test, p	CG / TA
Al	27.1±5.3	34.3±9.1	0.515	>0.05	0.79
B	1.71±0.26	3.38±1.12	0.199	>0.05	0.51
Ba	1.43±0.37	3.06±1.54	0.340	>0.05	0.47
Br	36.3±6.99	394±125	**0.019**	**=0.01**	0.092
Ca	1422±164	1370±311	0.885	>0.05	1.04
Cl	9117±1223	7722±1262	0.438	>0.05	1.18
Cu	8.51±1.60	17.6±5.7	0.178	>0.05	0.48
Fe	337±51	429±108	0.451	>0.05	0.79
I	1310±221	962±232	0.282	>0.05	1.36
K	6610±430	5603±756	0.261	>0.05	1.18
Li	0.0281±0.0030	0.0401±0.0100	0.275	>0.05	0.70
Mg	356±23	236±30	**0.0036**	**=0.01**	1.51
Mn	1.77±0.23	1.67±0.54	0.875	>0.05	1.06
Na	11782±836	9747±1316	0.205	>0.05	1.21
P	5181±383	4930±735	0.769	>0.05	1.05
S	10961±446	10536±1122	0.734	>0.05	1.04
Si	81.3±12.5	114±40	0.455	>0.05	0.71
Sr	5.87±1.59	3.30±0.63	0.142	>0.05	1.78
V	0.152±0.016	0.140±0.020	0.666	>0.05	1.09
Zn	120.5±7.8	129±13	0.577	>0.05	0.93

M – arithmetic mean, SEM – standard error of mean, Significant values are in **bold**.

Table 3. Comparison the contents of Al, B, Ba, Br, Ca, Cl, Cu, Fe, I, K, Li, Mg, Mn, Na, P, S, Si, Sr, V, and Zn in different pathological transformation of thyroid

Comparison with:	Normal thyroid*		Colloid Goiter
Element	Colloid Goiter	Adenoma	Adenoma
Al	↑	↑	=
B	↑	↑	=
Ba	=	=	=
Br	↑	↑	↑
Ca	=	=	=
Cl	↑	↑	=
Cu	↑	↑	=
Fe	↑	=	=
I	↓	↓	=
K	=	=	=
Li	↑	=	=
Mg	↑	=	↓
Mn	↑	=	=
Na	↑	↑	=
P	↑	=	=
S	↑	=	=
Si	↑	=	=
Sr	=	=	=
V	↑	=	=
Zn	↑	↑	=

* From analysis of previous publications (43, 44), ↑ - content is higher, ↓ - content is lower, = - no difference.

4 | DISCUSSION

As was shown before (33, 34, 47–52) good agreement of the Al, B, Ba, Br, Ca, Cl, Cu, Fe, I, K, Mg, Mn, Na, P, S, Sr, V, and Zn mass fractions in CRM IAEA H-4, INCT-SBF-4, INCT-TL-1, and INCT-MPH-2 samples determined by both INAA-SLR and ICP-AES methods with the certified data of these CRMs indicates acceptable accuracy of the results obtained in the study of CG and TA samples and presented in Tables 1–3.

In a general sense variations found for Al, B, Ba, Br, Ca, Cl, Cu, I, K, Na, Sr, and Zn contents in CG and TA tissue samples were similar in comparison with normal thyroid tissue (Table 3). In affected tissues contents of Al, B, Br, Cl, Cu, Na, and Zn increased, content of I decreased, whereas levels of Ba, Ca, K, and Sr did not changed. There was not found any differences between ChE contents of CG and TA, with the exception of Br and Mg (Tables 2 and 3). The Br level in TA tissue was almost 11 times higher, while the Mg content was 1.5 times lower than in CG tissue.

Published data on comparison of Al, B, Ba, Br, Ca, Cl, Cu, Fe, I, K, Li, Mg, Mn, Na, P, S, Si, Sr, V, and Zn levels in CG and TA were not found.

Thus, from obtained results it was possible to conclude that the common characteristics of CG and TA tissue samples were elevated level of Al, B, Br, Cl, Cu, Na, and Zn and reduced level of I in comparison with normal thyroid and, therefore, these ChE can be involved in etiology and pathogenesis of such thyroid disorders as CG and TA.

Aluminum

Al is the most widely distributed metal in the environment. Environmental media may be contaminated by Al from anthropogenic sources and through the weathering of rocks and minerals (55). The trace element Al is not described as essential, because no biochemical function has been directly connected to it. Toxic actions of Al induce oxidative stress, immunologic alterations, genotoxicity, and other disorders, including cell membrane perturbation, apoptosis, necrosis and dysplasia (55). Furthermore, it was shown in experimental and epidemiological studies that Al can affect thyroid iodide uptake and hormones secretion (56, 57).

Boron

Trace element B is known to influence the activity of many enzymes (58). Numerous studies have demonstrated beneficial effects of B on human health, including anti-inflammatory stimulus - reduces levels of inflammatory biomarkers, such as high-sensitivity C-reactive protein (hs-CRP) and tumor necrosis factor α (TNF-α); as well as raises levels of antioxidant enzymes, such as superoxide dismutase (SOD), catalase, and glutathione peroxidase (59). Why B content in adenomatous thyroid is higher than normal level and how an excess of B acts on thyroid are still to be cleared.

Bromine

Br is one of the most abundant and ubiquitous of the recognized ChE in the biosphere. Inorganic bromide is the ionic form of bromine which exerts therapeutic as well as toxic effects. An enhanced intake of bromide could interfere with the metabolism of iodine at the whole-body level. In the thyroid gland the biological behavior of bromide is more similar to the biological behavior of iodide (60). A significant age-related increase of Br content in human thyroid (25) (26–28) correlated well with age-related prevalence of CG and TA (61, 62) (63) . The main source of natural Br for human body is food. Food and environment media polluted by artificial Br-contained compounds, for example such as polybrominated biphenyls (PBBs) and diphenyl ethers (PBDEs), is other source. PBBs and PBDEs impact on thyroid function and thyroid hormones metabolism (64) Thus, on the one hand, the accumulated data suggest that Br level in thyroid tissue might be responsible for CG, and TA development. But, on the other hand, Br compounds, especially potassium bromide (KBr), sodium bromide (NaBr), and ammonium bromide (NH_4Br), are frequently used as sedatives in Russia (65). It may be the reason for elevated levels of Br in specimens of patients with CG, and TA in comparison with normal thyroid. A nonuniform level of this TE in tissue of thyroid legions TA Br > CG Br may be explained by the different strength of emotional reactions of persons on the diagnosis TA and CG, and, as consiquence, different dozes of Br-conteined sedatives, which were used.

Chlorine and Sodium

Cl and Na are ubiquitous, extracellular electrolytes essential to more than one metabolic pathway. In the body, Cl and Na mostly present as sodium chloride. Therefore, as usual, there is a correlation between Na and Cl contents in tissues and fluids of human body. Because Cl is halogen like I and Br, in the thyroid gland the biological behavior of chloride has to be similar to the biological behavior of iodide. The main source of natural Cl for human body is salt in food and chlorinated drinking water. Environment (air, water and food) polluted by artificial nonorganic Cl-contained compounds, for example such as sodium chlorate ($NaClO_3$), and organic Cl-contained compounds, for example such as polychlorinated biphenyls (PCBs) and dioxin, is other source. There is a clear association between using chlorinated drinking water, levels $NaClO_3$, PCBs and dioxin in environment and thyroid disorders, including cancer (64) (66) (67) (68) (69). Thus, on the one hand, the accumulated data suggest that Cl level in thyroid tissue might be responsible for CG and TA development. However, on the other hand, it is well known that Cl and Na mass fractions in human tissue samples depend mainly on the extracellular water volume (70) . Goitrous and adenomatous tissues can contain more colloid that normal thyroid. Because colloid is extracellular liquid, it is possible to speculate that CG and TA are characterized by an increase of the mean value of the Cl and Na mass fractions because the relative content of colloid in these thyroid lesions is higher than that in normal thyroid tissue. Overall, the elevated levels of Cl in goutrous and adenomatous thyroids could possibly be explored for diagnosis of CG and TA.

Coper

Cu is a ubiquitous trace metal in the human body which plays many roles at different levels. Various Cu-enzymes (such as amine oxidase, ceruloplasmin, cytochrome-c oxidase, dopamine-monooxygenase, extracellular superoxide dismutase, lysyl oxidase, peptidylglycineamidating monoxygenase, Cu/Zn superoxide dismutase, and tyrosinase) mediate the effects of Cu deficiency or excess. Cu excess can have severe negative impacts. Cu generates oxygen radicals and many investigators have hypothesized that excess copper might cause cellular injury via an oxidative pathway, giving rise to enhanced lipid peroxidation, thiol oxidation, and, ultimately, DNA damage (71) (72) (73). Thus, Cu accumulation in thyroid parenchyma with age (25) (26), as well as excessive Cu intake with diet or other environmental sources, may be involved in oxidative stress, dwindling gland function, and increasing risk of thyroid nodules, including CG and TA. The significantly elevated level of Cu in CG and TA tissue, observed in the present study, supports this speculation. The difference between Cu levels in CG and TA was not found (Table 2 and 3). Therefore, it is reasonable to conclude that role of Cu excess in etiology and pathogenesis of CG and TA is similar. However, an overall comprehension of Cu homeostasis and physiology, which is not yet acquired, is mandatory to establish Cu exact role in the CG and TA etiology and metabolism.

Iodine

Compared to other soft tissues, the human thyroid gland has higher levels of I, because this element plays an important role in its normal functions, through the production of thyroid hormones (thyroxin and triiodothyronine) which are essential for cellular oxidation, growth, reproduction, and the activity of the central and autonomic nervous system. Goitrous and adenomatous transformation are probably accompanied by a partial loss of tissue-specific functional features, which leads to a modest reduction in I content associated with functional characteristics of the human thyroid tissue.

Zinc

Zn as a trace metal has structural, catalytic and regulatory roles in normal and pathophysiology. This ChE is a constituent of more than 3000 proteins and is a cofactor for over 300 enzymes (74). Zn is an essential mediator of cell proliferation and differentiation through the regulation of DNA synthesis and mitosis. Zn also affects DNA repair pathways by regulating multiple intracellular signaling pathways and altering proteins involved in DNA maintenance (75). This metal also maintenance the balance of a cellular redox (76). Thus, Zn is important cofactors in diverse cellular processes. Concern the thyroid function, Zn is involved in the synthesis of TSH and important for the proper functioning of T3 because T3 nuclear receptors contain Zn ions (64). However, high Zn concentrations are toxic to the cells and the elevated level of Zn mass fractions in thyroid tissue may contribute to harmful effects on the gland. There are good reasons for such speculations since. experimental and epidemiological data support the hypothesis that Zn overload is a risk factor for benign and malignant tumors (75) (77) (78) (79).

Characteristically, elevated or reduced levels of ChE observed in thyroid nodules are discussed in terms of their potential role in the initiation and promotion of these thyroid lesions. In other words, using the low or high levels of the ChE in affected thyroid tissues researchers try to determine the role of the deficiency or excess of each ChE in the etiology and pathogenesis of thyroid diseases. In our opinion, abnormal levels of many ChE in TBNs could be and cause, and also effect of thyroid tissue transformation. From the results of such kind studies, it is not always possible to decide whether the measured decrease or increase in ChE level in pathologically altered tissue is the reason for alterations or vice versa.

5 | LIMITATIONS

This study has several limitations. Firstly, analytical techniques employed in this study measure only twenty ChE (Al, B, Ba, Br, Ca, Cl, Cu, Fe, I, K, Li, Mg, Mn, Na, P, S, Si, Sr, V, and Zn) mass fractions. Future studies should be directed toward using other analytical methods which will extend the list of ChE investigated in normal thyroid and in pathologically altered tissue. Secondly, the sample size of CG group and, particularly, of TA group was relatively small and prevented investigations of ChE contents in these groups using differentials like gender, histological types of CG and TA, nodules functional activity, stage of disease, dietary habits of patients with CG and TA. Lastly, generalization of our results may be limited to Russian population. Despite these limitations, this study provides evidence on TBNs-specific tissue Al, B, Br, Cl, Cu, I, Na, and Zn level alteration and shows the necessity to continue ChE research of TBNs.

6 | CONCLUSION

In this work, ChE analysis was carried out in the tissue samples of CG and TA using non-destructive analytical method INAA-SLR and destructive analytical method ICP-AES. It was shown that combination of these methods is an adequate analytical tool for the determination of twenty ChE (Al, B, Ba, Br, Ca, Cl, Cu, Fe, I, K, Li, Mg, Mn, Na, P, S, Si, Sr, V, and Zn) content in the tissue samples of human thyroid in norm and pathology, including needle-biopsy specimens. It was observed that in both CG and TA tissues tissues contents of Al, B, Br, Cl, Cu, Na, and Zn increased, content of I decreased, whereas levels of Ba, Ca, K, and Sr did not changed in comparison with normal thyroid tissue. It was not found any differences between ChE contents of CG and TA, with the exception of Br and Mg. The Br level in TA tissue was almost 11 times higher, while the Mg content was 1.5 times lower than in CG tissue.

From obtained results it was possible to conclude that the common characteristics of CG and TA tissue samples were elevated level of Al, B, Br, Cl, Cu, Na, and Zn and reduced level of I in comparison with normal thyroid and, therefore, these ChE can be involved in etiology and pathogenesis of such thyroid disorders as CG and TA.

Declaration of Conflicting Interests

The author has not declared any conflict of interests.

7 | FUNDING

The author received no financial support for this study and for publication of this article.

ACKNOWLEDGEMENTS

The author is extremely grateful to Profs. Vtyurin BM and Medvedev VS, Medical Radiological Research Center, Obninsk, as well as to Dr. Choporov Yu, former Head of the Forensic Medicine Department of City Hospital, Obninsk, for supplying thyroid samples. The author is also grateful to Dr. Karandaschev V, Dr. Nosenko S, and Moskvina I, Institute of Microelectronics Technology and High Purity Materials, Chernogolovka, Russia, for their help in ICP-AES analysis.

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How to cite this article: Zaichick V. **Are there any Differences between Chemical Element Contents of Goitrous and Adenoma-tous Thyroid?**. Journal of Medical Research and Health Sciences. 2021;1576–1587. https://doi.org /10.52845/JMRHS/2021-4-11-9