NEUTRON ACTIVATION ANALYSIS OF Ag, Co, Cr, Fe, Hg, Rb, Sb, Se, AND Zn CONTENTS IN BENIGN GIANT CELL TUMOR OF BONE

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Introduction

The effects of trace elements are related to content and recorded observations range from a deficiency state, to function as biologically essential components, to an unbalance when excess of one element interferes with the function of another, to pharmacologically active doses, and finally to toxic and even life-threatening levels.[1, 2] There is a tissues and fluids homeostasis of trace elements in normal environmental and health conditions. An unbalance of trace element homeostasis could be a causative factor for many diseases, including cancer.

It is well known that tissues of human body differ greatly in their contents of chemical elements. Particularly it concerns the chemical composition of bone tissue investigated by us in details in our previous studies.[3-31] Bone tumors are a heterogeneous group of tumors that all arise from bone tissue, which consists of cartilaginous, osteoid and fibrous tissue, and bone marrow elements. Each tissue can give rise to benign or malignant tumors. Thus, it can be expected that bone tumors of a different origin would have specific elemental composition. Moreover, significant differences in the contents of trace elements in normal and cancerous bone tissues suggested that these variations could be a causative factor to cancer.

To our knowledge, no data are available about the trace element contents of bone tumors with respect to different origin of disease. Therefore, we determined the Ag, Co, Cr, Fe, Hg, Rb, Sb, Se, and Zn contents in the benign giant cell tumor of bone and intact bone tissue using instrumental neutron-activation analysis with high resolution spectrometry of long-lived radionuclides (INAA-LLR).

Experimental part

Samples of benign giant cell tumor of bone were obtained from 10 patients (2 females and 8males aged 11-47 years). All patients were hospitalized at the Medical Radiological Research Centre. In all cases the diagnosis has been confirmed by clinical and morphological data. The tumor samples for INAA-LLR were received from open biopsy and resected specimens. The control group consisted of 10 patients with intact bone (2 females and 8 males aged 20-44 years) who died from different deceases. The intact cortical bone samples of femur and tibia were collected at the Department of Pathology, Obninsk City Hospital. A titanium tool was used to cut and to scrub samples.[32, 33] All bone and tumor tissue samples were freeze dried, until constant mass was obtained, and homogenized. Then samples weighing about 100 mg were wrapped separately in high-purity aluminum foil washed with rectified alcohol beforehand and placed in a nitric acid-washed quartz ampoule.

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. Corrected certified values of BSS element contents were reported by us before.[34] Ten certified reference material (CRM) IAEA H-5 (Animal Bone) and standard reference material (SRM) NIST 1486 (Bone Meal) sub-samples weighing about 100 mg were analyzed in the same conditions as bone and tumor samples to estimate the precision and accuracy of results.

A vertical channel of the WWR-c research nuclear reactor was applied to determine the mass fraction of Ag, Co, Cr, Fe, Hg, Rb, Sb, Se, and Zn by INAA-LLR. The quartz ampoule with bone samples, tumor samples, standards, CRM, and SRM was soldered, positioned in a transport aluminum container and exposed to a 100-hour neutron irradiation in a vertical channel with a thermal neutron flux about 10^{13} $n \cdot cm^{-2} \cdot s^{-1}$. Two months after irradiation samples were reweighed and repacked. The duration of each measurement was from 1 to 10 hours. To reduce the high intensity of ^{32}P β-particles ($T_{1/2}$=14.3 d) background, a berillium filter was used. A coaxial 98 cm^3 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 1332 keV line. The information of used nuclear reactions, radionuclides, gamma-energies, and other details of the analysis including the quality control of results were reported by us before.[22, 34-36]

A dedicated computer program of INAA mode optimization was used.[37] Using the Microsoft Office Excel programs, 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 different trace element mass fractions. The reliability of difference in the results between intact bone and benign giant cell tumor of bone was evaluated by Student’s t-test.

Results and discussion

Table 1 represents certain 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 Ag, Co, Cr, Fe, Hg, Rb, Sb, Se, and Zn mass fractions in intact cortical bone and benign giant cell tumor of bone samples.

The information of the effect of neoplasm transformation on the trace element contents in bone tissue is presented in Table 2. From Tables 2, it is observed that in benign giant cell tumor of bone tissue the mass fractions of Ag ($p \leq 0.05$), Co ($p \leq 0.05$), Fe ($p \leq 0.01$), Se ($p \leq 0.001$), and Zn ($p \leq 0.05$) are higher, than in normal tissues. A significant increase of Ag, Co, Fe, Se, and Zn mass fractions suggest potential of these trace element levels as benign giant cell tumor markers.

Conclusions

INAA-LLR is the adequate analytical tools for the non-destructive determination of Ag, Co, Cr, Fe, Hg, Rb, Sb, Se, and Zn contents in the human bone samples and samples of intraosseous lesions weighing about 100 mg. In benign giant cell tumor of bone the mass fractions of Ag, Co, Fe, Se, and Zn are significantly higher, than in normal bone tissues.

Table 1. Some statistical parameters of Ag, Co, Cr, Fe, Hg, Rb, Sb, Se, and Zn mass fractions in intact cortical bone and benign giant cell tumor of bone (g·kg^{-1}, dry mass basis)

Tissue	Element	M	SD	SEM	Min	Max	Med	P0.025	P0.975
Intact	Ag	0.0027	0.0015	0.0005	0.0003	0.0047	0.0028	0.0003	0.0046
cortical	Co	0.0148	0.0096	0.0030	0.0037	0.0345	0.0117	0.0046	0.0324
bone	Cr	0.274	0.182	0.057	0.110	0.669	0.202	0.117	0.629
n=10	Fe	63.7	50.0	15.8	9.20	173	52.6	10.1	157
	Hg	0.0057	0.0044	0.0014	0.0010	0.0138	0.0053	0.0100	0.0133
	Rb	3.77	1.64	0.52	0.970	6.57	3.47	1.36	6.42
	Sb	0.0151	0.0102	0.0032	0.0060	0.0420	0.0139	0.0060	0.0364
	Se	0.156	0.092	0.029	0.0550	0.358	0.169	0.0633	0.336
	Zn	91.1	14.1	4.4	70.0	115	84.9	71.0	113
Benign	Ag	0.0045	0.0014	0.0005	0.0018	0.0059	0.0045	0.0021	0.0059
giant	Co	0.034	0.020	0.007	0.0030	0.0608	0.0304	0.0053	0.0600
cell	Cr	0.320	0.222	0.074	0.0560	0.761	0.224	0.0758	0.719
tumor	Fe	353	181	81	155	606	301	163	592
n=10	Hg	0.0055	0.0028	0.0009	0.0008	0.0091	0.0061	0.00094	0.0090
	Rb	≤1.2	-	-	0.2DL	6.55	-	-	-
	Sb	0.031	0.034	0.011	0.0030	0.0973	0.0179	0.00426	0.0942
	Se	1.51	1.02	0.36	0.373	3.21	1.50	0.406	3.04
	Zn	115	23.5	7.8	64.5	149	119	71.5	139

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

Table 2. Comparison between mean values (M±SEM, g·kg^{-1} dry mass basis) of Ag, Co, Cr, Fe, Hg, Rb, Sb, Se, and Zn mass fraction in intact cortical bone and benign giant cell tumor

Element	Intact cortical bone (M_c) n=10	Benign giant cell tumor (M_t) n=10	Ratio M_t to M_c	M_c and M_t Student's *t*-test ≤*p*
Ag	0.0027±0.0005	0.0045±0.0005	1.66	≤0.05
Co	0.0148±0.0030	0.0340±0.0070	2.30	≤0.05
Cr	0.274±0.057	0.320±0.074	1.17	NS
Fe	63.7±15.8	353±81	5.54	≤0.01
Hg	0.0057±0.0014	0.0055±0.0009	0.96	NS
Rb	3.77±0.52	≤1.2	≥ 0.32	-
Sb	0.0151±0.0032	0.0310±0.0110	2.05	NS
Se	0.156±0.029	1.51±0.36	9.68	≤0.001
Zn	91.1±4.4	115±7.8	1.26	≤0.05

M – arithmetic mean, SEM – standard error of mean, NS – non significant

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