

Occurrence of Arsenic in Selected Parts of the Human Femur Head

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Received: 28 September 2010

Accepted: 20 May 2011

Abstract

An osseous tissue represents a specific repository of many metals. Some of them are physiologically accumulated in the skeleton, while others remain in the bones as a result of exposure and can be the cause of pathological states. The aim of this study was to determine the occurrence and co-occurrence of As with trace elements in the femur head; analyzing their concentration in male and female femur head morphological sections in relation to established As contents in air dust in different locations in Silesia. The statistical characteristics of the occurrence of the element was determined using ICP (inductively coupled plasma), the spectrometry method with an Optima 3000 DV (Perkin-Elmer) apparatus. The average geometric mean values detected were the same for male and female subjects in the articular cartilage (0.09 $\mu\text{g As/g}$), cortical bone (0.16 $\mu\text{g As/g}$ and 0.09 in the male and female subjects, respectively), and trabecular bone (0.07 $\mu\text{g As/g}$ for females 0.09 $\mu\text{g As/g}$ for males). The arsenic concentrations in the specified sections of the femur head were lower than those reported in previous publications.

Keywords: arsenic, femur head

Introduction

Arsenic is an environmental element widely distributed around the world and is known as a toxic element and a human carcinogen with a high risk of cancer development in people exposed to it [1, 2]. Human exposure to this metalloid comes from well water and contaminated soil, fish, and other sea organisms rich in methylated arsenic species and from occupational exposure. It has been reported that human arsenic exposure causes several health problems such as cancer, liver damage, dermatitis, and nervous system dysfunction [3-5].

Information on the presence of arsenic in bone tissue is scarce. The average arsenic concentration in Western Europeans ranges from 0.025 to 0.03 $\mu\text{g/g}$ and elevated values may be observed in hair, nails, bones, and skin [6].

The factors influencing arsenic absorption from the digestive tract are the arsenic dose and valency of its compounds. Inorganic trivalent arsenic compounds, which are readily soluble in water, are more rapidly inhibited than those which are organic and slightly soluble. Arsenic accumulates slowly in hair, nails and skin over time, while arsenic compounds are readily expelled from body fluids.

The influence of pollution on the human population may be measured by biomarkers. A biomarker is an indicator of changes in a biological system (meaning the whole organism or specific organs, tissues, or cells) under the influence of detrimental factors. Arsenic is seldom found in tissues of non-occupationally exposed persons [7-9].

A study of the skeletal trace element concentrations of children has been published [10]. The arsenic concentration in bone tissue was reported at the exceptionally high value of 13 mg/g. Other studies have shown considerably lower As-values in human bones, e.g. Aras and Ataman [11], who

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Table 1. Statistical characteristics of arsenic occurrence in femur head [$\mu\text{g/g}$].

	Arithmetic mean	Standard deviation	Geometric mean	Percentile				Coefficient variability [%]
				10	50	90	95	
women								
Articular cartilage	0.11	0.08	0.09	0.04	0.09	0.18	0.27	71
Trabecular bone	0.08	0.04	0.07	0.04	0.07	0.13	0.19	51
Cortical bone	0.31	0.51	0.16	0.07	0.11	0.89	0.93	166
men								
Articular cartilage	0.09	0.03	0.09	0.06	0.08	0.13	0.15	32
Trabecular bone	0.14	0.12	0.09	0.03	0.13	0.32	0.32	87
Cortical bone	0.20	0.32	0.09	0.03	0.06	0.77	0.77	164

reported an average arsenic concentration of 0.35-0.13 mg/g for the cortical bone of modern bones and 0.18-0.04 mg/g for the trabecular bone.

In other research, high As-values have been found in individuals investigated from the Mesolithic sites of Nivaagaard and Nivaa-10. The average As-concentration of the nine individuals is 22-34 $\mu\text{g/g}$. Much lower As-concentrations have been seen elsewhere in Denmark; the mean concentration of As in the bones of nine human individuals for several other Mesolithic locations in Denmark is 1.1-2.1 $\mu\text{g/g}$. Two Mesolithic individuals from Taagerup in southern Sweden show intermediate As-values with a mean value of 1.3-6.8 $\mu\text{g/g}$. The anomalously high arsenic concentrations in the human bones at Nivaa-10 and Nivaagaard must be related to bone diagenesis [12].

The average arsenic value of 90 femur bones of a human from the Early Bronze Age settlement of İkiztepe was found to be 5.79-15.0 $\mu\text{g/g}$ [13].

Studies of arsenic changes in southern Poland were conducted by Kwapuliński and Wiechuła [14, 15] – in air, Pacyna [16] – in soil and water, Ahnert et al. [17] – in gallstone.

Material and Methods

The research was conducted on samples from three Silesian cities: Siemianowice Śląskie, Katowice, and Piekary Śląskie (which had very high levels of industrial emission of As in previous studies) taken during endoprosthesoplasty of coxa of 68 women and 24 men. Samples of femur capitulum from patients with different levels of coxarthrosis were used. Femur heads were obtained during hip replacement operations, conducted in a hospital in Siemianowice Śląskie on the basis of the agreement of the Bioethical Commission at the Medical University of Silesia in Katowice. Femur head deformation mainly consisted in flattening and fungoid bone outgrowths that appeared mostly neighboring the head and the femoral neck. There was also the defect of joint surface as well as in the upper-external part of the femur head. The sections were divided into

articular cartilage, cortical bone and trabecular bone samples. The subject average age was 71.7 years old for women and 62.1 for men.

Samples weighing 1 g were reduced to ash at 420°C in the muffle oven. The reducing process was conducted first at 100°C and then at 420°C. The ash was diluted in 2 ml HNO_3 (V) Supra pure by Merck. The solution was transferred quantitatively to 25 ml flask and was filled with the redistilled water.

The arsenic concentration was determined by the ICP spectrometry method using an Optima 3000 DV (Perkin-Elmer) apparatus. The determination precision was 4.3% at the detection level of 0.01 $\mu\text{g As/g}$. The method was validated by comparison with NIST-1400 and NIST-1486 referential ashed bone samples. The difference in the obtained results was 7.3%.

The As contents in the air and air dust were determined and the change of distribution of this element throughout Silesia formed the basis for analyzing its occurrence using osseous tissue as a biomarker.

Result and Discussion

The range of arsenic changes in the female femur heads equaled: (in $\mu\text{g As/g}$) 0.02-0.42 for articular cartilage, 0.05-2.33 for cortical bone, and 0.03-0.32 for trabecular bone. For men, the values were: 0.05-0.15, 0.03-0.77, and 0.03-0.32, respectively.

The average geometric mean values detected were the same for male and female subjects in the articular cartilage (0.09 $\mu\text{g As/g}$), in the cortical bone (0.16 $\mu\text{g As/g}$ and 0.09 $\mu\text{g As/g}$ in the male and female subjects, respectively) and in the trabecular bone (0.07 for females, 0.09 $\mu\text{g As/g}$ for males) (Table 1).

The arsenic concentration was two times higher in samples taken from non-smoking ($n=58$) subjects – 0.24 $\mu\text{g As/g}$ than the smoking ones ($n=34$). The values were confirmed with the gender groups; females: non-smoking ($n=39$) – 0.25 $\mu\text{g As/g}$, smoking ($n=29$) – 0.12 $\mu\text{g As/g}$ and

males: non-smoking (n=19) – 0.22 µg As/g, smoking (n=5) – 0.10 µg As/g.

In non-smoking patients increasing the As content in comparison with smokers may be due to increased environmental exposure. Patients in the questionnaires often do not give the truth in the case of smoking habits.

The twice higher arsenic concentration was among Piekary Śląskie inhabitants living within the Orzeł Biały non-ferrous metal plant emission range, who were – 0.22 µg As/g in comparison to those from Katowice 0.11 µg As/g.

The highest coefficient variability in arsenic occurrence was detected for male and female cortical bones – 164%; for the articular cartilage, it was 32% for men and twice higher for women. In the case of trabecular bones, the As occurrence coefficient variability was 87% for men and 51% for women.

The environmental arsenic concentration (in 10 percentiles) in sections of the femur head was approximately 0.04 µg/g, with the exception of women’s cortical bone, where it was 0.07 µg/g. The marginal arsenic concentration (95 percentiles) was the highest in the female 0.93 µg/g and male 0.77 µg/g cortical bones.

The arsenic concentration changed in relation to the changes in the concentrations of Co, Cd, Mn (r=0.48-0.99, p=0.002). These separate relationships concerned Fe in the

cortical and trabecular bones (r=0.67); Cu, Zn and Sr in the articular cartilage (0.42-0.82); and As-Ag (0.74) in the trabecular bone. The results are shown in Fig. 1.

In the studied women, a correlation between As from Fe, Mn, Cd, and Co (0.52-0.99) was found. However, in the studied men, As was correlated with Mn, Cd, and Co (0.44-0.99). In the case of the As-Sr (-0.41) correlation, an antagonism was determined.

Concentration analysis confirmed the results of correlation analysis (p≤0.05) and the high probability of the co-occurrence of arsenic with manganese, cadmium, and cobalt (Fig. 2).

Changes in the concentration of arsenic in the femur head differed significantly between the women and men, as well as in the smoking and non-smoking groups. In the case of selected parts of the femur head arsenic contents differ significantly. In the articular cartilage and cortical bone and the trabecular bone and cortical bone, the content of arsenic also differed significantly.

The observed tendencies were in accordance with the results of As concerning gallstones, which also serve as long-term biomarkers [17].

To evaluate the level of population endangerment, the tissues and organs that accumulate large amounts of xenobiotics may be used because of their long purging times. Accumulation of this chemical element depends on its bioavailability to the body [18].

The femur head, like gallstones, can accumulate enough arsenic to be detected by this method and may be used as supportive biological material to evaluate the risk of population endangerment.

The average geometrical mean content of arsenic in gallstones (0.54 µg As/g) and the variability range of the changes are both higher (0.46-0.85 µg As/g) than in the femur head. The arsenic concentration in the femur head is lower for non-smokers (0.55 µg As/g) than smokers (0.54 µg As/g); the same dependency may be observed for gallstones [17].

According to other research, the arsenic concentration in the bones is higher (3.60 µg/g) and the arsenic concentration changes with the age of the subject and is the highest for people above 80. Arsenic accumulation in bones is an age-dependant function [19].

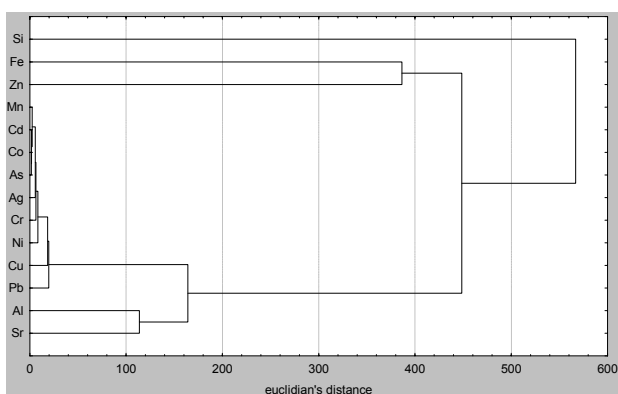


Fig. 1. Similarity of metal occurrence in femur head.

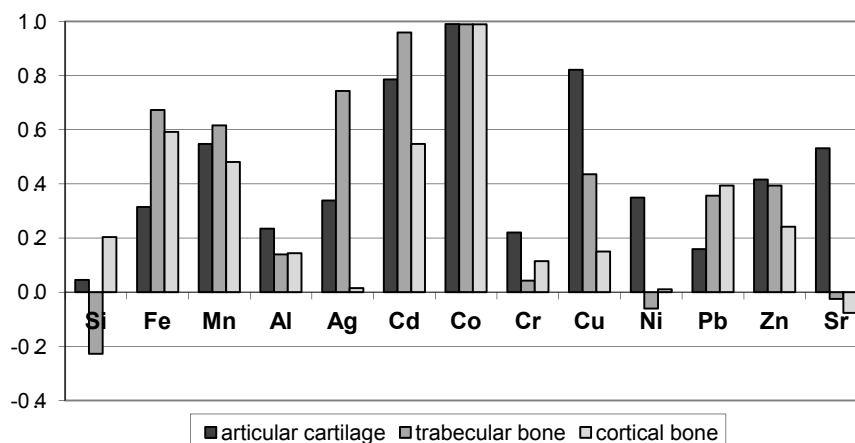


Fig. 2. The correlation As in comparison to other elements in femur head.

Arsenic concentration in the femur head increases slightly with age. In the age group up to 60, the arsenic concentration equivalent to geometric mean is 0.09 µg/g, while in the age group over 80 it is above – 0.11 µg/g [19].

Conclusion

Arsenic concentration in femur heads was higher for inhabitants of areas within the zones of dust emissions originating from non-ferrous metal works and power plants (besides Pb and Cd, arsenic is a characteristic element of those emissions).

The femur head may be postulated as a long-term biomarker of exposure to As.

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