DISTRIBUTION OF HEAVY METALS IN NORMAL KOREAN TISSUES

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ABSTRACT: To obtain the usual value of arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, silicon, tin, vanadium and zinc in the normal human body, the amounts of 15 metals were determined in 61 male and 30 female Korean cadavers, whose ages ranged from 12 to 87 years. Inductively coupled plasma atomic emission spectrometry was used for analysis of heavy metals in 10 autopsied human organs (liver, kidney, cerebrum, heart, spleen, lung, bone, blood, hair and nail). Distribution of arsenic, nickel, selenium, tin and vanadium in human body were almost uniform. Cadmium, mercury, manganese, molybdenum, lead and zinc were found in large quantities in the metabolic organs, whereas concentration of chromium and silicon were greatest in the tissues exposed to the exterior. Positive correlation with age was observed in the following cases: Cd in liver, kidney and cerebrum; Fe in cerebrum and bone; Pb in bone; Si in lung and bone;V in lung. Copper in heart, Hg in bone and Mn in kidney correlated negatively with age. A significantly positive correlation between Se and Hg was only observed in heart. Significant correlation coefficients between Se and As were observed in liver, kidney, heart, spleen and bone. The correlation between Cd and Zn was significant in liver and kidney, indicating that the distribution of Cd is similar to that of Zn in the liver and kidney.

KEY WORDS: Heavy metals; Human tissues; ICP-AES.

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INTRODUCTION

The heavy metal content of human tissues or organs has long been attracted attention, from the viewpoints of their essentiality and toxicity to human body, their association with disease, and the relations particularly between heavy metals and environmental pollution. In studying these problems, “standard values” or “range of standard values” are of important significance as basic information. Because environmental factors, such as living environment and eating habits, have changed rapidly, revision of the previous values and ranges is therefore urgent necessity. The purpose of the present study is to obtain standard values of heavy metals, correlations with age and correlation between heavy metals in normal Korean human body.

MATERIALS AND METHODS

Preparation of samples

The human tissues analyzed were obtained from autopsied cadavers undergoing forensic medical examinations in National Institute of Scientific Investigation of Korea, during July 1997 to March 1999. The numbers of male and female cadavers were 61 and 30, respectively (Table I). All cadavers died from accident without disease. Seven organs(liver, kidney, cerebrum, heart, lung, spleen, bone), blood, hair and nail were removed from different subjects. The tissue samples were stored at a temperature below –30°C before analysis.

TABLE I. DISTRIBUTION OF AGE AND GENDER OF INDIVIDUAL SUBJECTS

Age group	Female	Male	Total
Teens	6	2	8
Twenties	10	10	20
Thirties	3	17	20
Forties	4	15	19
Fifties	1	9	10
Sixties	3	5	8
Over seventies	3	3	6
Total	30	61	91

Analytical methods

A portion of samples (0.1–2.0 g) were digested with 6 ml of concentrated nitric acid and 1ml of hydrogen peroxide in a sealed teflon vessel (Milestone s.r.l., MLS 1200 Mega, Italy) and diluted with distilled water. As, Cd, Cr, Cu, Fe, Pb, Mn, Hg, Mo, Ni, Se, Si, Sn, V and Zn were determined by inductively coupled plasma atomic emission spectrometry (ICP-AES, Thermo Jarrell Ash Co., Atomscan 25, USA, Table II).

Statistical methods

Student t-test and calculation of Pearson's correlation coefficients were conducted using the SPSS program.

TABLE II. ANALYTICAL CONDITIONS OF ICP-AES

Gas: Flow rate	
Torch Gas: High flow	
Auxiliary gas: Medium (1.0 l/min)	
Nebulizer gas: ON (PSI): 30.1	
Approximate RF power (w): 1.350	
Slit height (mm): 3	
Observation height (mm): 14.9	
Peristaltic pump parameters	
Pump rate (RPM): 100	
Relaxation time (sec): 10	
Pump tubing type: EP-19	
Wavelength (nm):	As (189.042), Cd (228.802), Cr (267.716),
	Cu (324.754), Fe (259.940), Hg (184.950),
	Mn (257.610), Mo (202.030), Ni (231.604),
	Pb (220.353), Se (196.090), Si (251.612),
	Sn (189.989), V (309.311), Zn (213.856)

RESULTS AND DISCUSSION

Table III shows the arithmetic mean of the heavy metal concentration of Korean liver, kidney, heart, lung, spleen, cerebrum, bone, blood, hair and nail expressed in micrograms per gram wet weight. Heavy metal concentrations in organs obtained from the present study were generally in good agreement with the values previously reported. Distribution of As, Ni, Se, Sn and V in human body were almost uniform. Cd, Hg, Mn, Mo, Pb and Zn were found in large quantities in the metabolic organs, whereas concentration of Cr and Si were greatest in the tissues exposed to the exterior.

Table IV summarizes the age-related variation in the heavy metal concentrations in the organs. Positive correlation with age was observed in the following cases: Cd in liver, kidney (Figure 1) and cerebrum; Fe in cerebrum and bone; Pb in bone (Figure 2); Si in lung (Figure 3) and bone; V in lung. Copper in heart, Hg in bone and Mn in kidney correlated negatively with age. The accumulation of Cd in kidney with age up to fifties followed by a decrease thereafter was observed. This result was similar with the previous reports, but the cause of this variation is still obscure.

TABLE III. CONCENTRATION OF HEAVY METALS [μg/g WET WEIGHT] IN ORGANS OF KOREAN

Heavy metal	Liver		Kidney		Heart		Lung		Spleen	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
As	80	0.60 (0.55)	87	3.0 (1.6)	70	0.47 (0.33)	87	3.1 (3.3)	74	13 (14)
Cd	85	0.06 (0.07)	88	0.15 (0.17)	83	0.23 (0.21)	84	0.18 (0.27)	78	1.1 (1.8)
Cr	86	0.21 (0.14)	83	1.6 (0.58)	86	0.56 (0.29)	86	0.80 (0.82)	75	3.4 (3.5)
Cu	91	3.1 (0.92)	83	0.57 (0.35)	89	0.97 (0.46)	85	9.3 (5.2)	81	9.3 (8.2)
Fe	88	49 (12)	87	71 (34)	85	369 (137)	84	75 (90)	80	181 (165)
Hg	88	0.12 (0.15)	88	2.7 (0.81)	81	0.15 (0.12)	86	1.2 (0.81)	76	1.4 (2.8)
Mn	90	0.30 (0.10)	87	0.12 (0.12)	83	0.11 (0.09)	86	1.9 (2.1)	82	4.6 (5.8)
Mo	88	0.12 (0.18)	81	0.11 (0.17)	80	0.09 (0.09)	83	0.32 (0.42)	79	2.9 (4.5)
Ni	84	0.12 (0.19)	79	0.20 (0.32)	77	0.12 (0.16)	82	0.91 (1.2)	81	8.2 (9.2)
Pb	84	0.24 (0.27)	87	1.5 (0.82)	75	0.22 (0.17)	85	3.4 (3.5)	79	11 (9.3)
Se	47	0.58 (0.51)	46	0.94 (1.1)	41	1.2 (0.58)	45	1.4 (1.3)	37	3.7 (4.8)
Si	80	11 (12)	81	50 (50)	78	6.1 (7.0)	84	156 (115)	73	311 (286)
Sn	90	0.21 (0.25)	85	1.0 (0.74)	77	0.17 (0.17)	88	0.92 (0.95)	79	3.2 (4.3)
V	88	0.48 (0.19)	87	3.8 (1.3)	76	0.24 (0.13)	85	1.2 (1.1)	76	3.9 (4.7)
Zn	91	11 (3.5)	88	40 (12)	87	8.7 (4.2)	88	141 (56)	81	100 (42)

N – number of specimens, SD – standard deviation.

TABLE III. CONCENTRATION OF HEAVY METALS [μg/g WET WEIGHT] IN ORGANS OF KOREAN (CONTINUATION)

Heavy metal	Cerebrum		Bone		Blood		Hair		Nail	
	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)	N	Mean (SD)
As	86	0.81 (0.82)	86	0.78 (0.80)	84	0.72 (0.71)	90	0.95 (1.1)	82	0.74 (0.71)
Cd	91	3.0 (2.4)	87	33 (17)	88	0.13 (0.15)	88	0.30 (0.27)	90	0.40 (0.43)
Cr	90	0.42 (0.24)	90	0.27 (0.21)	88	0.24 (0.19)	87	0.57 (0.40)	85	0.54 (0.31)
Cu	90	5.6 (2.8)	88	1.8 (0.54)	90	2.4 (0.59)	87	0.97 (0.57)	89	0.88 (0.42)
Fe	88	192 (91)	90	83 (35)	88	55 (15)	87	237 (98)	87	330 (202)
Hg	87	0.22 (0.22)	88	0.33 (0.31)	86	0.13 (0.18)	84	0.15 (0.19)	85	0.14 (0.17)
Mn	90	1.5 (0.57)	89	0.99 (0.31)	90	0.33 (0.15)	87	0.23 (0.17)	89	0.22 (0.16)
Mo	87	0.71 (0.39)	87	0.27 (0.18)	87	0.14 (0.18)	88	0.15 (0.20)	89	0.14 (0.20)
Ni	83	0.15 (0.23)	84	0.21 (0.31)	84	0.25 (0.37)	80	0.24 (0.35)	83	0.20 (0.29)
Pb	81	0.34 (0.34)	88	0.44 (0.53)	87	0.33 (0.50)	81	0.30 (0.26)	87	0.35 (0.38)
Se	45	1.0 (0.60)	47	1.3 (0.52)	46	0.66 (0.34)	47	0.97 (0.77)	47	1.2 (0.76)
Si	84	9.6 (10)	81	11 (13)	89	18 (30)	88	49 (49)	82	11 (14)
Sn	85	0.38 (0.35)	90	0.35 (0.39)	91	0.28 (0.37)	88	0.32 (0.39)	89	0.30 (0.35)
V	91	0.57 (0.24)	89	0.49 (0.26)	89	0.72 (0.31)	85	0.45 (0.32)	88	0.52 (0.23)
Zn	90	49 (20)	89	41 (15)	89	22 (5.3)	86	10 (4.0)	90	16 (5.8)

N – number of specimens, SD – standard deviation.

Table V summarizes the correlation coefficients between heavy metals in Korean tissues. When correlation analyses were conducted on each organ using heavy metal concentrations as variables, significantly positive correlation between heavy metals were obtained in all organs examined.

TABLE IV. CORRELATION COEFFICIENTS OF HEAVY METAL CONCENTRATION WITH AGE

Element	Liver	Kidney	Heart	Lung	Spleen	Cerebrum	Bone
Cd	0.286**	0.508**	–	–	–	0.222*	–
Cu	–	–	–0.373**	–	–	–	–
Fe	–	–	–	–	–	0.210*	0.218*
Hg	–	–	–	–	–	–	–0.248*
Mn	–	0.406**	–	–	–	–	–
Pb	–	–	–	–	–	–	0.338**
Si	–	–	–	0.517**	–	–	0.365**
V	–	–	–	0.244*	–	–	–

Figures in the table are coefficients between elemental concentration and age which are significant at 5% (*) and 1% (**), respectively.

TABLE V. CORRELATION COEFFICIENTS BETWEEN HEAVY METALS IN KOREAN TISSUES

Element correlation	Liver	Kidney	Heart	Lung	Spleen	Cerebrum	Bone
Se/Hg	–	–	0.314*	–	–	–	–
Se/As	0.515**	0.331*	0.367*	–	0.557**	–	0.303*
Se/Cd	–	–	0.298*	0.419**	–	–	0.330*
Se/Zn	–	–	–	–	–	–	–
Se/Cu	–	0.306*	–	–	–	0.370*	–
Cd/Zn	0.331**	0.476**	–	–	–	–	–
Cd/Cu	0.401**	0.221*	–	0.322**	–	–	–
Zn/Cu	0.381**	0.224*	–	0.435**	0.412**	0.229*	–0.296**
Hg/Zn	0.362**	–	–	–	–	–	0.485**

Figures in the table are coefficients between elemental concentration and age which are significant at 5% (*) and 1% (**), respectively.

In the case of Cd, this element correlated with Zn (Figure 4) and with Cu in the liver and kidney. And significant correlations between Se and As were observed in the liver and spleen (Figure 5), kidney, heart and bone. The present positive correlations between Cd and Zn particularly those in kidney, may indicate the involvement of metallothionein in the accumulation of Cd in the kidney. From the present study, correlations between essential elements, such as Se, Zn and Cu, and toxic elements, Hg, As and Cd were observed in human organs, especially in liver and kidney. These results might be a reflection of the protective effects of essential elements against toxic elements, a phenomenon which has already been indicated in experimental animals.

CONCLUSION

To obtain the usual values of heavy metals, correlations with age and correlations between heavy metals, the amounts of 15 metals were determined by ICP-AES in 91 Korean cadavers.

1. Distribution of As, Ni, Se, Sn and V in human body were almost uniform. Cd, Hg, Mn, Mo, Pb and Zn were found in large quantities in the metabolic organs, whereas concentration of Cr and Si were greatest in the tissues exposed to the exterior.
2. Positive correlation with age was observed in the following cases: Cd in liver, kidney and cerebrum; Fe in cerebrum and bone; Pb in bone; V in lung. Copper in heart, Hg in bone and Mn in kidney correlated negatively with age.
3. A significantly positive correlation between Se and Hg was only observed in heart. Significant correlation coefficients between Se and As were observed in liver, kidney, heart, spleen and bone. The correlation between Cd and Zn was significant in liver and kidney, indicating that the distribution of Cd is similar to that of Zn in the liver and kidney.

References:

1. Cappon C. J., Smith J. C., Mercury and selenium content and chemical form in human and animal tissue, *Journal of Analytical Toxicology* 1981, vol. 5, p. 90.
2. Drasch G., Müller R. K., Grasemann F., Adang M., Roider G., Wowra D., Comparison of the burden of the population in the region of Leipzig and Munich with the heavy metals cadmium, lead and mercury – an investigation on human tissues, *Gesundheitswesen* 1994, vol. 56, pp. 263.
3. Elinder C.G., Kjellstrom T., Friberg L., Lind B., Linnman L., Cadmium in kidney cortex, liver and pancreas from Swedish autopsies, *Archives of Environmental Health* 1976, vol. 31, p. 292.
4. Katz A., Mercury pollution: The making of an environmental crises, C*ritical Reviews Environmental Control* 1972, vol. 2, p. 517.
5. Kari T., Kauranen P., Mercury and selenium contents of seals from fresh and brackish waters in Finland, *Bulletin of Environmental Contamination and Toxicology* 1978, vol. 19, p. 273.
6. Kido T., Tsuritani I., Honda R., Yamaya H., Ishizaki M., Yamada Y., Nagawa K., Selenium, zinc, copper and cadmium concentration in livers and kidneys of people exposed to environmental cadmium, *Journal of Trace Elements in Electrolytes Health Dis.* 1988, vol. 2, p. 101.
7. Kjellstrom T., Exposure and accumulation of cadmium in populations from Japan, the United States, and Sweden, *Environmental Health Perspectives* 1978, vol. 28, p. 169.
8. Koeman J. H., Peeters W. H. M., Koudstaal-Hol C. H. M., Tjioe P. S., de Goeji J. J. M., Mercury-selenium correlations in marine mammal, *Nature* 1973, vol. 245, p. 385.

9. Koeman J. H., van de Ven W. S. M., de Goeji J. J. M., Tjioe P. S., van Haaften J. L., Mercury and selenium in marine mammals and birds, *Science of the Total Environment* 1975, vol. 3, p. 279.
10. Liebscher K, Smith H., Essential and nonessential trace elements. A method of determining whether an element is essential or nonessential in human tissue, *Archives of Environmental Health* 1968, vol. 17, p. 881.
11. Livingston H. D., Measurement and distribution of zinc, cadmium, and mercury in human kidney tissue, *Clinical Chemistry* 1972, vol. 18, p. 67.
12. Norstrom R. J., Schweinberg R. E., Collins B. T., Heavy metals and essential elements in livers of the polar bear (Ursus maritimus) in the Canadian Arctic, *Science of the Total Environment* 1986, vol. 48, p. 195.
13. Oldereid N. B., Thomassen Y., Attramadal A., Olaisen B., Purvis K., Concentrations of lead, cadmium and zinc in the tissues of reproductive organs of men, *Journal of Reproduction and Fertility* 1993, vol. 99, p. 421.
14. Schmidt R., Wilber C. G., Mercury and lead content of human body tissues from a selected population, *Medicine Science and the Law* 1978, vol. 18, p. 155.
15. Spickett J. T., Lazner J., Cadmium concentrations in human kidney and liver tissues from western Australia, *Bulletin of Environmental Contamination and Toxicology* 1979, vol. 23, p. 627.
16. Sumino K., Hayakawa K., Shibata T. Kitamura S., Heavy metals in normal Japanese tissues, *Archives of Environmental Health* 1975, vol. 30, p. 487.
17. Ujioka T., Analytical studies on methylmercury in animal organs and foodstuffs, *Journal of Kumamoto Medical Sciences* 1960, vol. 34 (Suppl. 1), p. 383.
18. Underwood E. J., Trace elements in human and animal nutrition, Academic Press, New York 1977, p. 398.
19. Weiner J. A., Nylander M., The relationship between mercury concentration in human organs and different predictor variables, *Science of the Total Environment* 1993, vol. 138, p. 101.
20. Yamamoto Y., Ushiyama I., Nishi K., Neutron activation analysis of trace elements in human organs, *Evaluation and Statistics* 1997, vol. 73.
21. Yoshinaga J., Matsuo N., Imai H., Nakazawa M., Suzuki T., Morita M., Akagi H., Interrelationship between the concentrations of some elements in the organs of Japanese with special reference to selenium-heavy metal relationships, *Science of the Total Environment* 1990, vol. 91, p. 127.
22. Yukawa M., Amano K., Yasumoto M. S., Terai M., Distribution of trace elements in the human body determined by neutron activation analysis, *Archives of Environmental Health* 1980, vol. 35, p. 36.