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Determination of Cadmium, Copper, Zinc, and Lead in Human Renal Calculi in Both Cadmium Polluted and Non-Polluted Areas

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A number of investigators have reported about heavy metal contents in food (Feinberg et al. 1984), water (Cassidy et al. 1982), soil (Mielke et al. 1984), blood (Hundnik et al. 1984), urine (Soriano et al. 1984), and animal tissues (Munshower et al. 1983) including bone (O'Connor et al. 1980), hair (Medeiros et al. 1984), feather (Doi et al. 1983) and tooth (Mishima et al. 1982). However, few data concerning calculi are reported as yet.

Heavy metal contents in the calculi might reflect the level of metals absorbed from respiratory tract, skin and intestine. When absorbed metals from respiration are distributed in blood, a part of cadmium is accumulated in liver and kidney, and of lead is in bone, annular vessel and kidney. The remainder is excreted in the urine through the urinary tracts. From intestine, they are distributed by the blood to the liver, and excreted in the urine in the same manner of respiration. It is well known that renal calculi are produced in the urinary tract.

The present study is focused on the contents of cadmium, copper, zinc and lead in human renal calculi, samples collected from Hokuriku which is one of the most cadmium polluted areas and from Chugoku which is recognized as a non-polluted one in Japan (Friberg et al. 1974).

MATERIALS AND METHODS

Renal calculi were obtained from Department of Urology, School of Medicine, both Kanazawa University (61 samples) and Hiroshima University (57 samples). These calculi were classified into two to four groups according to sex and age.

The samples were powdered with an agate mortar and pestle, then dried over phosphorus pentaoxide under reduced pressure for 24 hours. About 50 mg of the powder was weighed accurately and digested in 61% nitric acid and 60% perchloric acid mixture. The digested solution was adjusted to 10 ml with deionized and distilled water.

Heavy metals in the solution were extracted with methyl isobutyl

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ketone (MIBK) as diethyldithiocarbamate (DDTC) complexes and determined by an atomic absorption spectrophotometer (AAS, HITACHI Model 308). The detection limit was determined above the ratio of signal to noise level was two ($S/N \geqq 2$). The detection limits of cadmium, copper, zinc and lead were calibrated to be 1.20, 1.20, 3.30 and 1.20 μg/g dry weight, respectively, by this method.

RESULTS AND DISCUSSION

Metals contents of cadmium, copper and zinc in renal calculi among the different age groups were compared with each other (Figure 1a and 1b). There was a tendency that heavy metal contents, especially cadmium increased in advanced age groups in Hokuriku district. The result supports the fact that Hokuriku is one of the most cadmium polluted areas in Japan. In Chugoku, however, the calculi had much metal content in 40-59 years old group. In both areas, cadmium content in Hokuriku is much higher level than that in Chugoku ($p<0.02$) in 40-59 years old group. And there were not significant but copper was higher and zinc was lower content in Hokuriku than in the other. Pandya et al. (1985) reported that 20-60 year old persons had more metal contents in kidney cortex in non-polluted area. These results suggest that metal contents in human renal calculi reflect at least in part the environmental contamination level. A higher metal content in kidney of these ages may reflect to be a higher metal content in renal calculi.

The biological half life of cadmium was estimated to be 14.7-16.5 years (Ellis et al. 1979). Sumino et al. (1981) reported that cadmium was accumulated under thirties and exhausted over sixties. These reports agree with the high cadmium content observed in aged groups in the Hokuriku area. No significant difference was observed in copper and zinc contents. Zinc content was almost the same over all age groups.

Although lead contents in Hokuriku (=31) and in Chugoku (=42) were determined using some samples, we could not show the result on age difference because of a lesser number of samples.

A sex difference is shown in Table 1. In Hokuriku district, male had more cadmium content than female ($p<0.05$). Zinc content was also higher in male than in female, whereas copper and zinc contents were higher in female than in male. Watanabe et al. (1985) reported that dietary cadmium intakes in man were larger than in woman. A higher content of cadmium in male may be due to a larger intake of this metal. In Chugoku, male had more zinc and lead contents than female, and had lesser copper ($p<0.05$) and cadmium. The mean value of zinc distribution indicated that there was a kind of sexual difference in both sex. Although we could not observe any significance in Chugoku, a reversed result was observed in cadmium content in both areas. It is because the mean value of cadmium content in Chugoku was below the detection limit.

A district difference was observed in cadmium and zinc contents in human renal calculi. Cadmium was more abundant in Hokuriku ($p<0.01$)

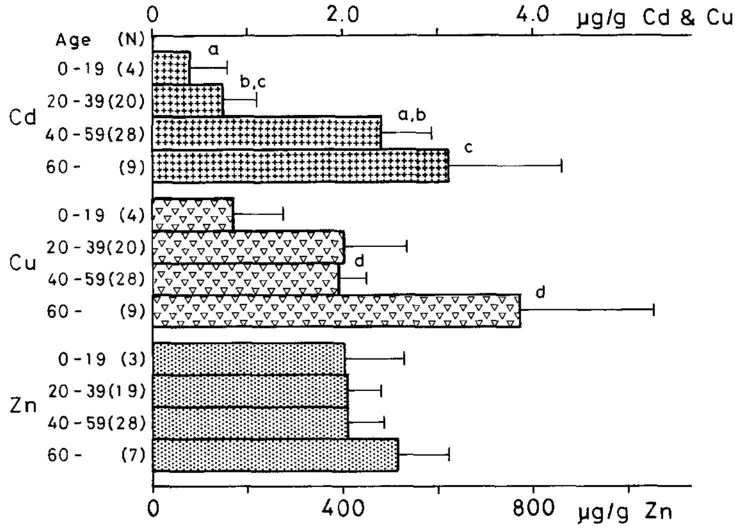

Figure 1a. Comparison of cadmium, copper and zinc content in human renal calculi of different ages (Hokuriku district)
a,b,d; $p<0.05$, c; $p<0.02$

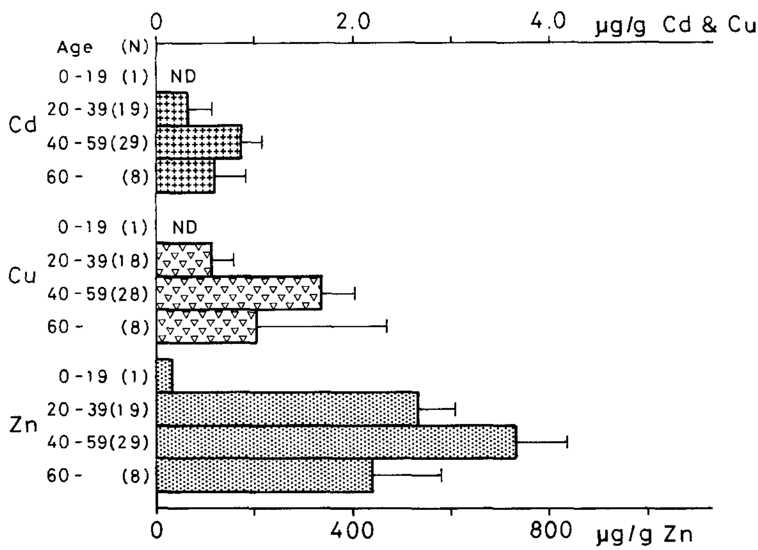

Figure 1b. Comparison of cadmium, copper and zinc content in human renal calculi of different ages (Chugoku district)
ND; not detected

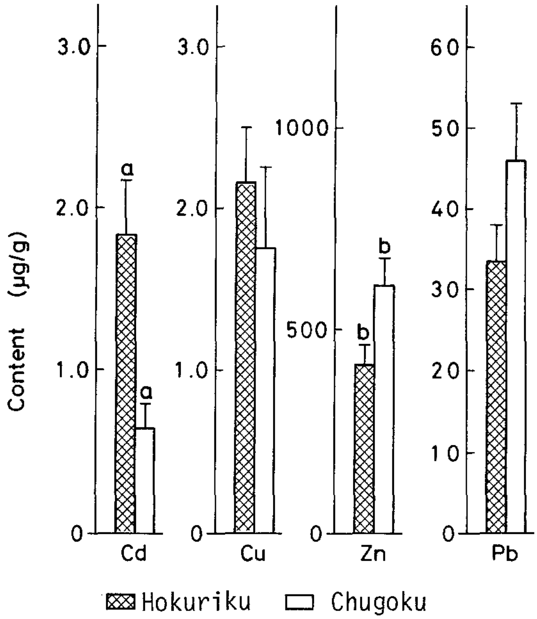

Figure 2. District difference in metal content of human renal calculi
a; $p<0.01$, b; $p<0.05$

Table 1. Sex difference in metal content of human renal calculi

District	Metal	Content (μg/g) Male	(N)	Female	(N)
Hokuriku	Cd	2.04 ± 0.27a	(35)	1.08 ± 0.31a	(26)
	Cu	2.26 ± 0.43	(35)	2.04 ± 0.55	(26)
	Zn	487.5 ± 64.7	(32)	324.5 ± 56.8	(25)
	Pb	32.11 ± 5.19	(18)	35.49 ± 7.90	(13)
Chugoku	Cd	0.55 ± 0.15	(41)	0.90 ± 0.59	(16)
	Cu	1.13 ± 0.25b	(41)	3.39 ± 1.53b	(16)
	Zn	638.0 ± 83.6	(41)	544.7 ± 78.5	(16)
	Pb	50.99 ± 10.55	(28)	35.88 ± 8.47	(14)

Each value showed mean ± S.E., a,b; $p<0.05$

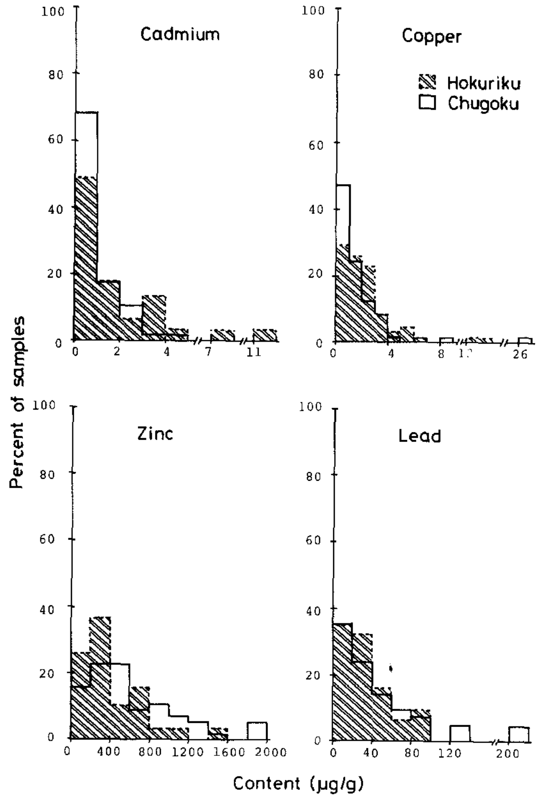

Figure 3. Distribution of metal content in human renal calculi

Table 2. Metal content and range in human renal calculi

Metal	N	Content (μg/g)	Range (μg/g)
Cd	118	1.26 $\pm$ 0.20	ND - 11.89
Cu	118	1.79 $\pm$ 0.30	ND - 26.77
Zn	114	517.9 $\pm$ 39.83	20.00 - 1940
Pb	73	40.67 $\pm$ 4.78	ND - 204.8

Each value showed mean $\pm$ S.E., ND; not detected and zinc was in Chugoku ($p<0.02$), and there was some tendency that copper content in Hokuriku was more abundant than that in Chugoku (Figure 2). These results indicate that the heavy metal contents such as cadmium and lead in the samples may show the contamination levels in the environment at these areas. Cadmium, copper and zinc atoms are exchanged each other on the binding sites of metallothionein (Evance et al. 1970). The similar interaction might also have occured in our samples.

The mean $\pm$ S.E. and the range are presented in Figure 3 and Table 2. Heavy metal contents in renal calculi were in order of zinc > lead > copper > cadmium and the proportion was approximately 500 : 40 : 1 : 1, respectively.

Copper and zinc are essential metals for human body. In this study copper content was less than that of lead in renal calculi. Our previous study indicated that copper level in gallstones is higher than in renal calculi (Yamamoto et al. 1981, Yamamoto et al. 1982).

Cadmium content in the calculi was greater in Hokuriku than in Chugoku and Hokuriku is one of the most cadmium polluted areas in Japan (Yamamoto et al. 1972). Since there were few reports of heavy metal content in calculi, we compared our data with those of the human tooth (Mishima et al. 1982) and bone (Munshower et al. 1979).

Cadmium, zinc and lead in human renal calculi were 30-, 3- and 2000-fold of those in enamel, and 40-, 3- and 850-fold of those in dentin, respectively. Zinc content of the calculi was about 4-fold of that in skeletal bone. Essential metal content such as zinc in renal calculi was similar to that of the tooth and bone, and environmental contaminants such as cadmium and lead in the samples were more abundant than in tooth and bone. These metals may be indices of environmental contamination.

This study showed that cadmium content in renal calculi in a cadmium polluted area was much higher compared to a non-polluted area and there were some difference in age and sex. We should do another experiment to obtain mechanism information and to investigate how metals bind with other components in calculi.

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