Bull. Environm. Contam. Toxicol. 20, 618-623 (1978)

Lead and Cadmium in Hair as an Indicator of Body Burden in Rats of Different Age

Dinko Kello and Krista Kostial[1]
Institute for Medical Research and Occupational Health, Zagreb, Yugoslavia

Several authors found a significant correlation between lead and cadmium concentration in hair and exposure levels, body burden and clinical symptoms of these metals (JAWOROWSKI 1965; JAWOROWSKI et al 1966; KOPITO et al 1967; PUESCHEL et al 1972; KOPITO and SHWACHMAN 1975; HAMMER et al 1971; REEVES et al 1975; OLERU 1975). Therefore the scalp hair, which is also easily removed, collected, stored and analysed, is often considered as an ideal material for epidemiological studies (i.e. HAMMER et al 1971). However, several authors found that other factors like age or sex might influence the concentration of heavy metals in hair and therefore hair as a biopsy material has not been fully exploited (KLEVAY and FORKS 1973). A higher concentration in scalp hair was noticed in children for lead (WEIS et al 1972; KLEVAY and FORKS 1973; PETERING et al 1973; CREASON et al 1975; KOPITO and SHWACHMAN 1975) and cadmium (GROSS et al 1976). Whether this increased hair content of lead and cadmium indicates a higher body burden in children is still disputable.

The purpose of our work was to determine in a controlled animal study whether age influences lead and cadmium accumulation in hair. In our experimental conditions the ^{203}Pb retention in hair was a good indicator of lead body burden in both young and old rats. However, the ^{115m}Cd hair values would give misleadingly higher values of the total body burden in young rats if based on hair analysis only.

MATERIAL AND METHODS

Two experiments were performed: one with the purpose of studying lead and the other of studying cadmium retention in the whole body and hair in relation to age. Each experiment was performed on two groups of female albino rats aged 18 weeks (10 animals) and 2 weeks (3 litters of 6 animals in each). Adult rats and three animals of each litter received a single intraperitoneal dose of ^{203}Pb or ^{115m}Cd. The uninjected animals in each litter served as controls for surface contamination. The radioactive solution

[1]Address correspondence to: Prof. K. Kostial, Inst. for Medical Research, 4100 Zagreb, 158 Mose Pijade, Yugoslavia

0007-4861/78/0020-0618 $01.20

of $^{203}PbCl_2$ (carrier free isotope supplied from Gustaf Werner Institute, Uppsala, Sweden) contained in a dose about 3 µCi in 0.1 ml; the $^{115m}CdCl_2$ solution (spec. act. 0.5-1 mCi/mg of Cd, supplied from the Radiochemical Center Amersham, England) contained in a dose about 10 µCi in 0.1 ml.

Seven days after the radioisotope administration the weight of all animals was determined and the whole body retention of ^{203}Pb or ^{115m}Cd was measured in a two-crystal scintillation detector for gama-radiation. Because practically no radioactivity was detected in the hair from uninjected controls, washing of the hair was not performed. After that all animals were exsanguinated in ether narcosis and their hair was removed with skin. Fresh weight of hair (including skin) was determined and the radioactivity was measured. The retention of ^{203}Pb and ^{115m}Cd in the whole body and hair was expressed as the percentage of the radioactivity in relation to the radioactivity of the phantom (standard injection solution diluted to adequate volume) in the same way as described previously for non-ashed biological samples (HARMUT et al 1968). The significance of the difference between the groups was calculated by Student´s t-test.

RESULTS

Young rats retained a significantly higher percentage of lead (Table 1) and cadmium (Table 2) in the whole body and hair than adults. However, if we express the lead hair values as the percentage of the dose retained in the whole body the values were almost the same for young and adult rats showing no difference related to age (Table 1).

TABLE 1

Retention of ^{203}Pb in rats seven days after intraperitoneal administration (means ± SEM)

		Young (2 weeks)	Adults (18 weeks)	Ratio young: adults
No. of animals		9	10	
% of dose	Whole body	80.12±0.83	43.90±1.63*	1.83
	Hair	1.59±0.12	0.85±0.06*	1.87
	Hair as % of whole body	1.97±0.15	1.93±0.36	1.02
% of dose per gram	Whole body	1.76±0.09	0.20±0.01*	8.80
	Hair	0.21±0.02	0.02±0.002*	10.50
	Hair as % of whole body	11.85±0.80	11.43±0.69	1.03

*Level of statistical significance between two age groups, $p<0.001$

When cadmium hair values are expressed in the same way, young animals retain in hair a significantly higher amount of the total body burden than adults. Similar results were obtained when the results were expressed as percentage of the dose per gram of fresh tissue.

TABLE 2

Retention of ^{115m}Cd in rats seven days after intraperitoneal administration (means ± SEM)

		Young (2 weeks)	Adults (18 weeks)	Ratio young: adults
No. of animals		9	10	
% of dose	Whole body	95.77±0.63	82.61±0.69*	1.16
	Hair	8.87±1.30	3.11±0.12*	2.85
	Hair as % of whole body	9.28±1.35	3.81±0.15*	2.44
% of dose per gram	Whole body	2.59±0.10	0.42±0.02*	6.20
	Hair	1.45±0.12	0.09±0.004*	16.11
	Hair as % of whole body	56.96±6.02	23.13±1.60*	2.46

*Level of statistical significance between two age groups, $p<0.001$

DISCUSSION

Results of numerous investigations indicate that age might be an important factor in the metabolism of heavy metals (JUGO 1977). Our previous experiments showed that suckling rats have a higher absorption of lead and cadmium from the intestine (KOSTIAL et al 1971; KELLO and KOSTIAL 1977a), a decreased elimination from the body (KOSTIAL et al 1973; KELLO and KOSTIAL 1977b) and a different organ distribution (MOMČILOVIĆ and KOSTIAL 1964; KELLO and KOSTIAL 1977b). The evidence that age influences metal metabolism in humans is still scarce. Data on concentration of heavy metals in human hair in relation to age are therefore of special importance. Our results show that the lead content in hair might be a good indicator of the lead body burden irrelevant of age. This might indicate that higher lead concentrations found in children's hair (KOPITO and SHWACHMAN 1975; KLEVAY and FORKS 1973; PETERING et al 1973; WEIS et al 1972; CREASON et al 1975) could be a real indicator of a higher lead body burden. The higher lead body burden might be the result of increased exposure (pica) or higher lead absorption from the intestine in this age group (ALEXANDER et al 1974 - in humans; KOSTIAL et al 1971 - in rats).

The cadmium content in hair was however age dependent because of a higher selective accumulation of cadmium in the hair of young animals and therefore was not a good indicator of the total body burden. This is in agreement with the data reported by GROSS et al (1976) who found in their postmortem analysis a surprisingly higher concentration of cadmium in the hair of young children than in adults which was not associated with a higher concentration in the kidney and liver. This indicates that precaution should be taken in estimating the body burden of cadmium in subjects of different age on the basis of hair analysis only.

It might be disputable whether our results obtained in short-term radioactive tracer experiments on rats can be relevant for interpreting data on hair concentrations of lead and cadmium in humans since it is known that human internal hair contamination with metals is a slow process (HOPP 1977). We therefore estimated lead and cadmium retention not only in the hair but also in the skin in order to include the radioactive metals in hair follicules where endogenous metal deposition is likely to start (HOPP 1977). Also, NORDBERG and NISHIYAMA (1972) found a high correlation between the cadmium content in the hair and skin and the cadmium in the whole body in mice irrelevant of the time after the parenteral application of ^{109}Cd. Although our results cannot be directly applied to human data there are a definite indication that age should be taken into consideration when taking hair concentration as an indicator of the body burden of some metals.

SUMMARY

The purpose of this work was to evaluate whether hair values of lead and cadmium can be used as an indicator of the body burden of these metals in different age groups.

The experiments were performed on rats aged 2 and 18 weeks, which received ^{203}Pb and ^{115m}Cd by intraperitoneal injection. The whole body retention and the retention of these radioisotopes in the hair (including the skin) was determined 7 days later. Younger animals showed a higher retention in the whole body and hair of radioactive lead and cadmium. The hair values when expressed as the percentage of the whole body retention were for ^{203}Pb the same in young

and adult rats but for ^{115m}Cd they were 2 to 3 times higher in young animals than in adults. It is concluded that lead hair values are a good indicator of the total body burden in both age groups. However, the cadmium body burden of young animals would be greatly overestimated if based on hair values only. This findings might be relevant for interpreting results of hair concentrations of lead and cadmium in children.

ACKNOWLEDGMENT

This work was partially supported by a Research Grant from the U.S. Environmental Protection Agency.

REFERENCES

ALEXANDER, F. W., B. E. CLAYTON and H. T. DELVES: Q. Y. Med. New Series, 43, 89 (1974).
CREASON, J. P., T. A. HINNERS, J. E. BUMGARNER and C. PINKERTON: Clin. Chem., 21, 603 (1975).
GROSS,S. B., D. W. YEAGER and M. S. MIDDENDORF: J. Tox. Environ. Health, 2, 603 (1975).
HAMMER, D. I., J. F. FINKLEA, R. H. HENDRICKS, C. M. SHY and R. J. M. HORTON: Amer. J. Epidemiol., 93, 84 (1971).
HARMUT, M., T. MALJKOVIĆ and K. KOSTIAL: Arh. hig. rada, 19, 61 (1968).
HOPPS, H. C.: Sci. Tot. Environ., 7, 71 (1977).
JAWOROWSKI, Z. S.: Atompraxis, 11, 271 (1965).
JAWOROWSKI, Z., J. BILKIEWICZ and W. KOSTANECKI: Int. J. Radiat. Biol., 11, 563 (1966).
JUGO, S.: Environ. Res., 13, 36 (1977).
KELLO, D. and K. KOSTIAL: Toxicol. Appl. Pharmacol., 40, 277 (1977a).
KELLO, D. and K. KOSTIAL: Environ. Res., 14, (1977b).
KLEVAY, L. M. and G. FORKS: Arch. Environ. Health, 26, 169 (1973).
KOPITO, L., R. K. BYERS and H. SHWACHMAN: New England J. Med., 276, 949 (1967).
KOPITO, L. E. and H. SHWACHMAN: J. Invest. Dermatol., 64, 342 (1975).
KOSTIAL, K., I. ŠIMONOVIĆ and M. PIŠONIĆ: Nature, 233, 564 (1971).
KOSTIAL, K., D. KELLO and G. E. HARRISON: Int. Arch. Arbeitsmed., 31, 159 (1973).
MOMČILOVIĆ, B. and K. KOSTIAL: Environ. Res., 8, 214 (1974).
NORDBERG, G. F. and K. NISHIYAMA: Arch. Environ. Health, 24, 209 (1972).
OLERU, U. G.: Amer. Ind. Hyg. Ass. J., 36, 229 (1975).
PETERING, H. G., D. W. YEAGER and S. O. WITHERUP: Arch. Environ. Health, 27, 327 (1973).

PUESCHEL, S. M., L. KOPITO and H. SHWACHMAN: JAMA, 222, 462 (1972).
REEVES, R. D., K. W. JOLLEY and P. D. BUCKLEY: Bull. Environ. Contam. Toxicol., 14, 579 (1975).
WEIS, D., B. WHITTEN and D. LEDDY: Science, 178, 69 (1972).