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INTERNATIONAL SYMPOSIUM

Environmental health aspects of lead

Die gesundheitlichen Aspekte der Umweltverschmutzung durch Blei

Les problèmes sanitaires posés par le plomb présent dans l'environnement

A COMPARISON OF LEAD CONCENTRATIONS IN HUMAN BONES AND IN SOFT TISSUES

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Summary

Lead concentrations in bones are compared by ash weight and wet weight. The petrous temporal bone contains the highest concentrations of lead and female adults 35 - 40% less than males. Children contain lower concentrations of lead than adults. Bone lead concentrations increase with age, but the concentrations in the majority of soft tissues do not alter after the first decade. Occupational exposure to lead results in a three-fold increase in bone lead concentrations, but no comparable increase was noted in the majority of the soft tissues. Lead retained in bone appears to be virtually unavailable to soft tissues.

In a series of post-mortem studies upon 41 subjects of diverse age and occupations, undertaken in a largely industrialised area in the north-west of England, we examined bones of four different types for lead concentrations. The analytical results were recorded as parts per million on a basis of wet weight (or sample as received) and ash weight, to obtain a comparative ratio between these two methods of recording results. The analytical method used was that of Bambach and Burkey,[1] modified for bone analysis, as indicated in the report by Barry and Mossman of 1970.[2]

The subjects were split into three groups composed of 21 adult males, 14 adult females and six children aged two to 16 years. None had histories of occupational exposure to lead.

The four bones examined were rib, tibia, calvarium and the petrous temporal.

In Table I a summary of the results from the 41 subjects is outlined. On wet weight the mean concentration of lead in rib, at 6.21 ppm, is about one-third that of tibia and calvarium, and nearly one-fifth that of the petrous temporal bone.

Comparison of the ash weights show the mean lead concentrations in rib, tibia and calvarium to be quite close at an average value of 23.83 ppm., but the petrous temporal bone shows between 60 and 95% more at 40.93 ppm.

The ratios of ash weight to wet weight of the individual bones show the tibia, calvarium and petrous temporal to be close, average 1.46, but the ratio for rib is more than double at 3.40.

Comparison of the adult male and female groups (Table II) indicate consistently lower levels of lead in the female bones. The wet weight concentrations of lead in rib give the lowest results and are not widely divergent between the sexes at 6.70 ppm in males and 5.75 ppm in females. The male tibia and calvarium show mean values of 23.20 and 23.59 ppm lead respectively, about four times the rib values, and the male petrous temporal bone a mean value of 37.14 ppm, about six times that of rib. The equivalent female values are approximately 35 - 40% lower.

The ash weight lead concentrations in adult males show rib to contain the lowest concentration at 27.68 ppm, tibia and calvarium comparable at 37.33 and 33.11 ppm respectively, and the petrous temporal bone to contain the highest concentration of lead at 54.19 ppm; about twice the value for rib. The lead concentrations in the tibia and calvarium of females are about half the concentrations of the males, and in the rib and petrous temporal bones about two thirds the male values.

The ash weight/wet weight ratios in male adults are 4.13 for rib, and a mean of 1.50 for the other three bones, compared to respective figures of 2.94, and 1.35 in female adults. These figures indicate a slightly higher ratio of ash weight/wet weight in the bones of the adult males.

The pattern of lead concentrations in the same bones of six children differed from that of the adults. (Table III). They show much lower concentrations and on wet weight measurement the differences are comparatively small between the bones, varying between a low of 3.13 ppm in rib and a high of 4.39 ppm in petrous temporal bone. On ash weight measurement the rib shows the highest concentration at 7.82 ppm, about 40% more than the concentrations found in tibia and calvarium, and 15% more than in the petrous temporal bone. The ash weight/wet weight ratios are 2.50 in rib and a mean of 1.50 in the other three bones.

It is suggested in the American National Academy of Sciences report of 1971[3] that the measurement of lead concentrations by ash weight results in a uniform value for all bones in any one subject. Our study supports this view in respect of adults for rib, tibia and calvarium, but indicates up to a two-fold excess concentration in the dense petrous temporal bone. In children the ash weight concentration is higher in rib than in the other three bones examined.

The uniformity of lead concentrations in the bones of children on wet weight basis of measurement, as well as the differences observed in ash weight measurements, compared to the pattern in adults, suggests a difference in lead metabolism which may have some bearing on the adverse response of children to excessive lead absorption. It is suggested that children do not have the same capacity as adults to retain lead in bone, by virtue of a relative lack of dense bone in the child's skeleton, thus affording a greater opportunity for excess lead in diffusible form to appear in the soft tissues.

In a total of 18 children aged 16 years and under, including the six already considered, we found a mean value of lead in rib of 1.89 ppm and in tibia of 2.27 ppm, wet weight. These values are rather lower than those recorded in Table III.

Among the group in Table III two of the children, both under the age of 4 years, showed concentrations of lead in bone in excess of the remainder. They also showed elevated faecal lead concentrations. The lead concentrations in various tissues of these two are compared in Table IV with those of four other children from our series of 18, in the age range one day to two years, from whom faecal samples were obtained. It is apparent that the two with high faecal lead content contain four to five times the concentration of lead in their bones than in the other four children; the lead concentrations in their soft tissues are also higher by 2 to 5 times, apart from the brain in which the concentrations are comparable. These findings suggest that the habit of pica may have been responsible for the higher lead concentrations found in the tissues of the two children with the high faecal lead content.

By comparison the bone lead concentrations of the two children are about 38% of the adult female tibia, but their soft tissue concentrations are in general comparable to those of male adults, which are themselves higher than the female values. These findings seem to lend support to the view of a difference in lead metabolism between children and adults.

In our total series of non-occupationally exposed adults, comprising 58 males and 36 females, the concentrations of lead in rib and tibia, recorded by wet weight, are comparable with the results outlined in Table II. In both sexes the lead concentrations in the bones increase with age, more noticeably in males and in the more dense tibial bone (Figs. 1 and 2). No such change was noted in the soft tissues, with the exception of the aorta.

Decalcification with osteoporosis is a common finding in the bones of elderly people, and it might be thought reasonable that in these circumstances lead would be released from their bones. However our results do not seem to support a hypothesis of lead release in a process of decalcification.

Schroeder and Tipton reported in 1968[4] to find lead concentrations in bone to decrease after about the fifth decade of life. In this respect our findings run counter to theirs. We believe, without disrespect to the work of these investigators, that had they extended their series in the region of the elder age groups, our respective findings would not have been divergent.

The bone lead concentrations in a group of seven male adults from our series, with occupational exposure to lead (Table V), exceeded the concentrations in the unexposed groups by more than an order of three. The lead concentrations in the soft tissues of the exposed group were marginally higher than in the unexposed group, with the exception of the brain and aorta in the most heavily exposed individual which showed much higher concentrations.

None of the subjects with occupational exposure to lead were known to have suffered from overt clinical lead poisoning during their lives. The high concentrations of lead in their bones provides evidence of the capacity of bone in adults to take up and retain lead in relatively large amounts, particularly in the more dense bone.

Conclusion

On the basis of our evidence it would seem probable that lead is retained in the deep matrix of bone in a fixed and non-diffusible form. The concentrations of lead in the majority of soft tissues do not alter with age in either sex and bear no relationship to the concentrations in bone. If lead is released from bone it would seem to be at a rate so small as not to cause a change in the equilibrium in soft tissues.

The evidence for the release of lead from bone in disease states involving febrile illness or altered metabolic activity is inconclusive and so far largely speculative. More positive information is required on this point before a definitive conclusion can be reached.

References

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TABLE I
TOTAL OF 41 SUBJECTS
LEAD CONCENTRATIONS IN BONE PPM

		MEAN	RANGE	RATIO
RIB	Ash	21.10	3.50 to 105.00	3.40
	Wet	6.21	0.90 to 21.00	
TIBIA	Ash	26.29	1.80 to 205.00	1.53
	Wet	17.22	1.40 to 73.00	
CALVARIUM	Ash	24.11	1.70 to 135.00	1.41
	Wet	17.15	1.10 to 79.00	
PETROUS TEMPORAL	Ash	40.93	0.37 to 150.00	1.45
	Wet	28.24	0.25 to 89.00	

TABLE II
LEAD CONCENTRATIONS IN BONE PPM

TOTAL OF 21 MALE ADULTS	RIB		TIBIA		CALVARIUM		PETROUS TEMPORAL	
	Ash	Wet	Ash	Wet	Ash	Wet	Ash	Wet
MEAN	27.68	6.70	37.33	23.20	33.91	23.59	54.19	37.14
RANGE	4.00 to 105.00	0.90 to 21.00	4.00 to 205.00	3.00 to 73.00	9.60 to 135.00	3.90 to 79.00	9.60 to 150.00	6.70 to 89.00
RATIO	4.13		1.61		1.44		1.46	
TOTAL OF 14 FEMALE ADULTS	**RIB**		**TIBIA**		**CALVARIUM**		**PETROUS TEMPORAL**	
	Ash	Wet	Ash	Wet	Ash	Wet	Ash	Wet
MEAN	16.93	5.75	18.64	14.10	17.29	13.12	35.68	25.12
RANGE	4.10 to 32.00	1.20 to 12.00	4.40 to 53.00	3.50 to 42.00	6.50 to 39.00	5.00 to 33.00	9.50 to 88.00	7.60 to 62.00
RATIO	2.94		1.32		1.32		1.42	

TABLE III
TOTAL OF 6 CHILDREN AGE 16 YEARS AND UNDER
LEAD CONCENTRATIONS IN BONE PPM

		MEAN	RANGE	RATIO
RIB	Ash	7.82	3.50 to 12.00	2.50
	Wet	3.13	1.00 to 5.50	
TIBIA	Ash	5.45	1.80 to 10.90	1.51
	Wet	3.60	1.40 to 6.20	
CALVARIUM	Ash	5.78	1.70 to 10.30	1.43
	Wet	4.05	1.10 to 6.60	
PETROUS TEMPORAL	Ash	6.80	0.37 to 14.30	1.55
	Wet	4.39	0.25 to 7.20	

TABLE V
BONE LEAD CONCENTRATIONS IN ADULTS (PPM WET WEIGHT)

NON-OCCUPATIONAL EXPOSURE

	TISSUE	MEAN	S.D.	RANGE
36 FEMALES AGE 18 - 94	RIB	6.77	5.084	0.85 to 22.60
	TIBIA	16.13	12.534	1.50 to 48.00
58 MALES AGE 18 - 84	RIB	8.80	5.823	0.90 to 28.50
	TIBIA	23.18	15.480	1.50 to 73.00

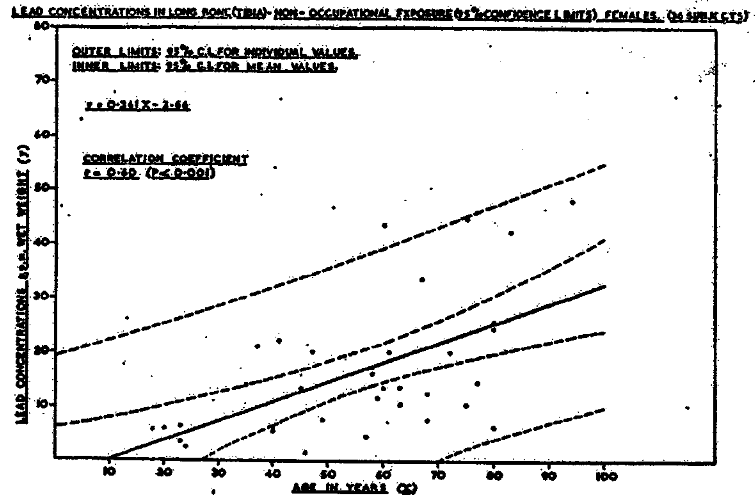
OCCUPATIONAL EXPOSURE

	TISSUE	MEAN	S.D.	RANGE
7 MALES AGE 29 - 82	RIB	32.79	17.629	8.70 to 61.00
	TIBIA	77.03	67.301	16.60 to 221.00

TABLE IV
LEAD CONCENTRATIONS IN PPM BY WET WEIGHT MEASUREMENT IN THE TISSUES OF 6 CHILDREN

	HIGH FAECAL LEAD CONTENT (Age 2 & 3 yrs (females))			LOW FAECAL LEAD CONTENT (Age 1 day - 2 yrs (2 female, 2 male))		
TISSUE	No. S.	MEAN	RANGE	No. S.	MEAN	RANGE
	2	0.72	0.68 - 0.75	4	0.02	0.01 - 0.04
	2	4.95	4.40 - 5.50	4	1.15	0.44 - 1.94
	2	5.30	4.40 - 6.20	4	0.96	0.21 - 1.49
	2	0.88	0.72 - 1.03	4	0.36	0.12 - 0.55
	2	0.20	0.16 - 0.23	4	0.14	0.06 - 0.18
CORTEX	2	0.97	0.74 - 1.20	4	0.18	0.05 - 0.49
MEDULLA	2	0.65	0.57 - 0.73	4	0.12	0.05 - 0.30
CT	2	0.20	0.12 - 0.32	4	0.06	0.05 - 0.09
	2	0.21	0.09 - 0.32	4	0.11	0.02 - 0.18
CORTEX	2	0.06	0.03 - 0.08	4	0.04	<0.01 - 0.09
PANCREAS	2	0.45	0.31 - 0.58	3	0.17	0.04 - 0.31
THYROID	2	0.48	0.16 - 0.80	3	0.15	0.01 - 0.26
ADRENAL	2	0.78	0.25 - 1.30	2	0.15	0.14 - 0.20
	2	0.18	0.06 - 0.30	4	0.04	0.02 - 0.06
	2	0.08	0.05 - 0.10	4	0.04	<0.01 - 0.11

LEAD CONCENTRATIONS IN LONG BONE (TIBIA) - NON-OCCUPATIONAL EXPOSURE (95% CONFIDENCE LIMITS) FEMALES. (36 SUBJECTS)



LEAD CONCENTRATIONS IN LONG BONE (TIBIA) - NON-OCCUPATIONAL EXPOSURE (95% CONFIDENCE LIMITS) MALE - (58 SUBJECTS)