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Concentrations of heavy metals in maternal and umbilical cord blood

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Concentrations of lead, cadmium, methylmercury and total mercury were measured in maternal and umbilical cord blood using graphite atomic absorption spectrometry. Two essential metals, copper and zinc, were also determined using ion chromatography. Lead, copper and zinc were found to be lower in the cord blood, whereas methylmercury and total mercury were higher in cord blood than in maternal blood. Little differences were noted for cadmium in maternal and cord blood. Significant positive correlations were observed between the concentrations in maternal and cord blood with regard to lead (correlation coefficient, $r = 0.44$), copper ($r = 0.34$), zinc ($r = 0.29$), methylmercury ($r = 0.44$) and total mercury ($r = 0.58$). These results suggest that, like essential metals, most heavy metals can move rather freely across the human placenta. The potential health effects of heavy metal transfer from mothers to young infants cannot be discounted.

Keywords: heavy metals, maternal blood, umbilical cord blood

Introduction

The toxicology of lead, cadmium and mercury has been well studied. The contention that excessive absorption of heavy metals in pregnant women may pose a danger to the fetus has attracted some concern in recent years. Infants and children are particularly susceptible to the toxicity of these elements because of their developing nervous system. Behavioral and learning disorders have been attributed to various chemical toxicants, particularly mercury and lead (Davis & Svendsgaard 1987). At 1 year of age, children who had higher umbilical cord blood levels appear to perform less well than babies with lower lead levels (Needleman 1988). Lead has also been shown to have a high affinity for fetal hemoglobin (Ong & Lee 1980). Cadmium exposure in rats has been shown to cause congenital abnormalities and fetal death (Ahokas & Ditis 1985).

While mercury is ubiquitous in nature, environmental contamination and subsequent accumulation, particularly in sea foods, has raised public health concerns in recent years. Air and water contamination with both methylmercury and inorganic mercury from industrial affluents and improper use of grain treated with mercury fungicides have also been considered as significant sources of background exposure.

Recent reports suggest that mobilization of trace elements occurs during pregnancy, and several heavy metals such as cadmium and lead may also be mobilized (Barltrop 1989). These observations suggest that the mobilization of minerals in the maternal tissue may pose a health risk to young infants.

The main objective of this study was to examine the transfer of lead, cadmium, methylmercury and total mercury from the mother to the newborn. In addition, two essential elements, copper and zinc, were also determined in this study.

Materials and methods

Subjects

This study was conducted during a 9 month period in 1989 at the Singapore General Hospital. All pregnancies were medically uncomplicated and went to term. Maternal venous blood of 2 ml and umbilical cord blood of 5 ml were collected at the time of delivery.

Fifty seven mothers consented to take part in this study, all of them were residents of Singapore. None of them

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were cigarette smokers. Twelve took multivitamins on a regular basis. None of the occupations of the mothers or fathers put them at special risk of exposure to heavy metals.

Analysis of heavy metals in blood

All reagents used in this study were high purity analytical grade for trace metal analysis. Glassware was soaked in 5% nitric acid overnight and rinsed with double-distilled water before use. Disposable polycarbonate tubes and pipet tips that had been tested for minimum heavy metal concentrations were used throughout the assay.

Inorganic mercury and methylmercury were determined by using the cold vapor atomic absorption spectrophotometry (AAS) technique. The average recovery of this method using undigested blood was over 92%. Quality control for mercury was carried out in collaboration with Centre de Toxicologie du Qubec, Canada. Detailed methods for both inorganic and organic mercury have been described previously (Ngim *et al.* 1989).

Cadmium and lead in blood were determined by using a graphite atomic absorption spectrophotometer (GAAS) with an autosampler. The analyzates were carried out in triplicate. The standard deviation for within run precision for a blood lead concentration of 5 μg 100 ml^{-1} was 0.24. The coefficient of variation seldom exceeded 6%. The methods used for blood lead and blood cadmium studies have been varified in several previous studies (Chia *et al.* 1989, Ng *et al.* 1991). External quality controls for cadmium and lead in blood were carried out with the National External Quality Assurance Scheme in the UK. The mean running variance index scores (MRVIS) for blood lead and blood cadmium at the time of analyses were 24–28 and 32–34, respectively.

Analysis of trace elements

Copper and zinc were determined by ion chromatography. The accuracy of this method was checked by certified, commercially available controls. The value obtained was 1.07 ± 0.02 mg l^{-1} for a sample certified to contain 1.11 ± 0.18 mg l^{-1} for blood copper. Detailed procedures for the simultaneous determination of both copper and zinc have been reported elsewhere (Ong *et al.* 1988).

Results

Table 1 summarizes the results of analyses of four heavy metals and two essential elements. Maternal blood concentrations were higher than cord blood concentrations for lead, copper and zinc. Significant differences were noted between copper ($P < 0.005$) and zinc ($P < 0.001$) in mother's blood and umbilical cord blood. The mean blood lead level was also noted to be lower for umbilical cord blood. On the other hand, mercury shows a trend to increase. Both methylmercury and total mercury in cord blood were significantly higher ($P < 0.05$) than in maternal blood.

Figures 1–5 show the relations between maternal and umbilical cord blood for the six metals determined. The scattergrams suggest a direct positive correlation between mother's blood at delivery and cord blood for lead (correlation coefficient $r = 0.44$), copper ($r = 0.34$), zinc ($r = 0.29$), methylmercury ($r = 0.44$) and total mercury ($r = 0.58$). However, there is no significant correlation between maternal and cord blood for cadmium ($r = 0.09$, $P = 0.8$).

Discussion

Lead

The reported range of blood lead concentrations among occupationally unexposed populations varies from 0.4 μmol l^{-1} (5.8 μg 100 ml^{-1}) to 1.2 μmol l^{-1} (25 μg 100 ml^{-1}). The concentrations found in the 36 mothers in this study also fell within this range. As all our subjects were residents of an urban setting with similar water supplies and none had any history of occupational exposure or consumption of liquor

Table 1. Concentrations of lead, cadmium, inorganic mercury, methylmercury, total mercury, copper and zinc for maternal blood and umbilical cord blood

Sample	Pb (μg/l) $N = 36$	Cd (μg/l) $N = 34$	I-Hg (μg/l) $N = 30$	M-Hg (μg/l) $N = 29$	T-Hg (μg/l) $N = 28$	Cu (mg/l) $N = 56$	Zn (mg/l) $N = 56$
Maternal blood	53.0 ± 22.6	0.57 ± 1.53	10.1 ± 5.70	5.46 ± 4.59	15.8 ± 6.85	2.22 ± 0.60	4.97 ± 1.15
(range)	14.0 – 99.0	0.31 – 1.04	3.10 – 25.0	0.80 – 15.4	6.80 – 39.4	0.71 – 4.20	1.89 – 7.77
Cord blood	33.6 ± 12.7	0.58 ± 1.30	10.2 ± 5.80	8.82 ± 5.39	18.8 ± 8.01	1.09 ± 0.31	1.58 ± 0.45
(range)	13.0 – 68.0	0.34 – 0.94	2.40 – 28.0	1.60 – 28.0	6.60 – 49.0	0.48 – 1.95	0.70 – 2.79

I-Hg, inorganic mercury; M-Hg, methylmercury; T-Hg, total mercury.

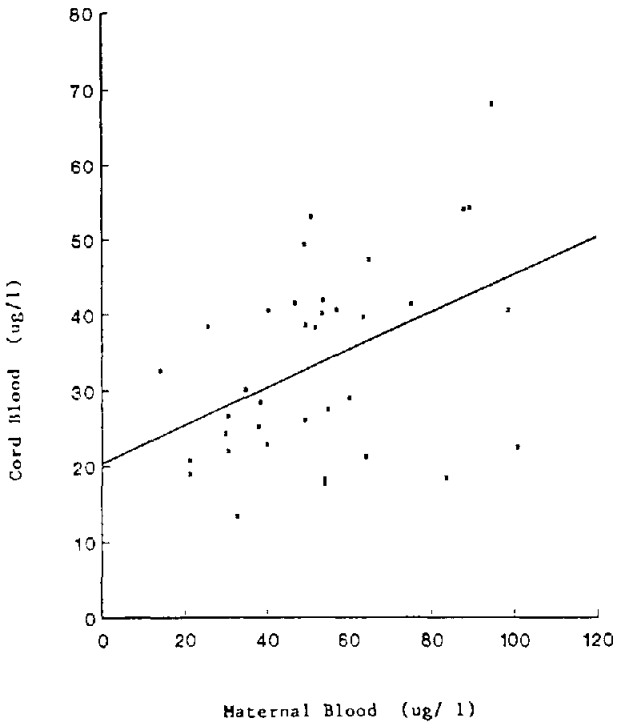

Figure 1. Correlation of lead content between maternal and cord blood, $n = 36$; $r = 0.44$; $P < 0.005$, $Y = 20.47 + 0.25X$.

or cigarettes or both, the blood lead concentrations could be considered to be typical for Singapore.

The mean lead concentration of 35 $\mu g l^{-1}$ in umbilical cord blood that we found was lower than the 0.29 $\mu mol l^{-1}$ (0.58 $\mu g l^{-1}$) observed during winter and 0.34 $\mu mol l^{-1}$ (82 $\mu g l^{-1}$) in summer by Rabinowitz & Needleman (1982) in Boston, and the 0.55 $\mu mol l^{-1}$ (110 $\mu g l^{-1}$) observed in our earlier study in Malaysia (Ong *et al.* 1985). The higher concentrations found among the Malaysians could be due to different levels of exposure, as Malaysia is known to have a high concentration of lead in the city air and Singapore has converted to the use of unleaded petrol.

Table 1 shows that the mean lead content in cord blood was lower than in maternal blood. This finding is similar to our earlier report among Malaysian women (Ong *et al.* 1985). Barltrop (1989) and Tsuchiya *et al.* (1984) also reported the same trend among British and Japanese women. The results here also show that there is a significant correlation between maternal blood lead and the level of lead in cord blood. This is in agreement with our earlier finding on 114 Malaysian women (Ong *et al.* 1985) and the study of Zaemski (1983) among residents in London.

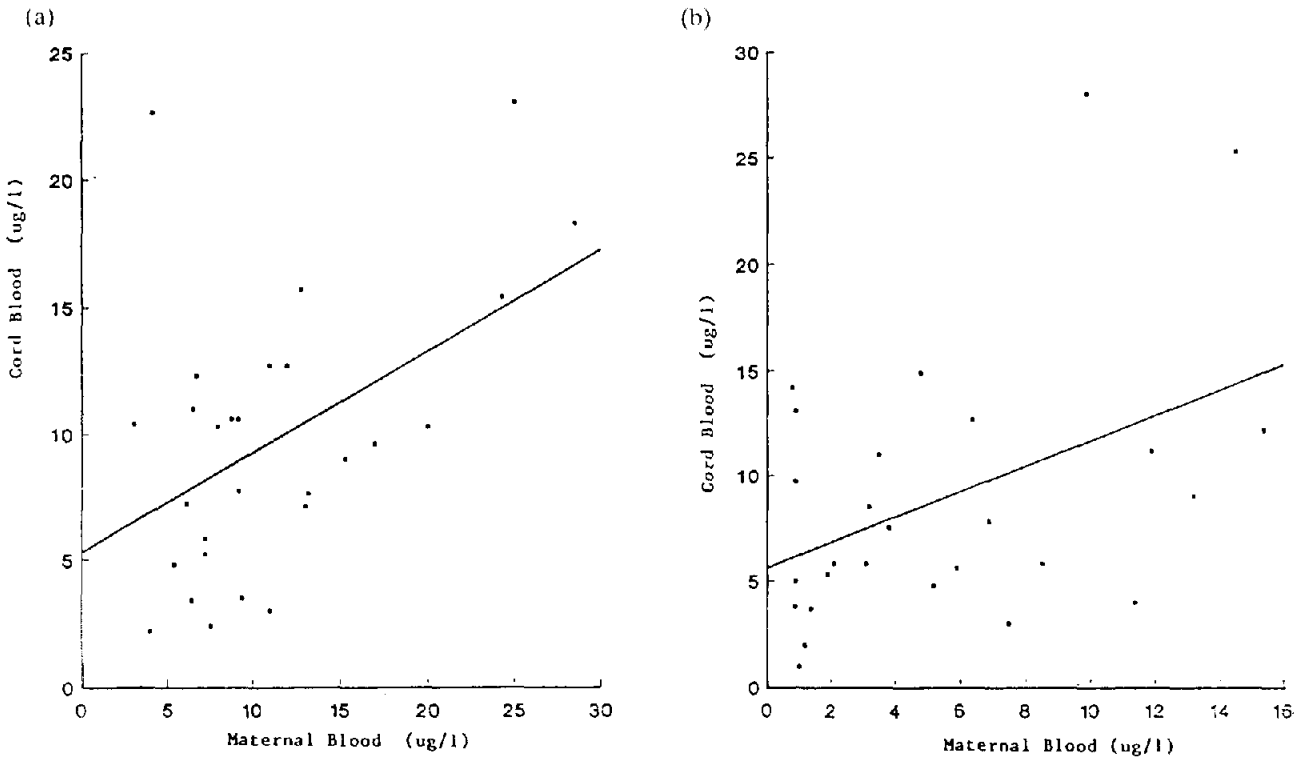

Figure 2. Correlation of (**a**) inorganic mercury content between maternal and cord blood, $n = 30$; $r = 0.38$; $P < 0.05$; $Y = 5.36 + 0.36X$; and (**b**) methylmercury content between maternal and cord blood, $n = 29$; $r = 0.44$; $P < 0.01$; $Y = 5.64 + 0.59X$.

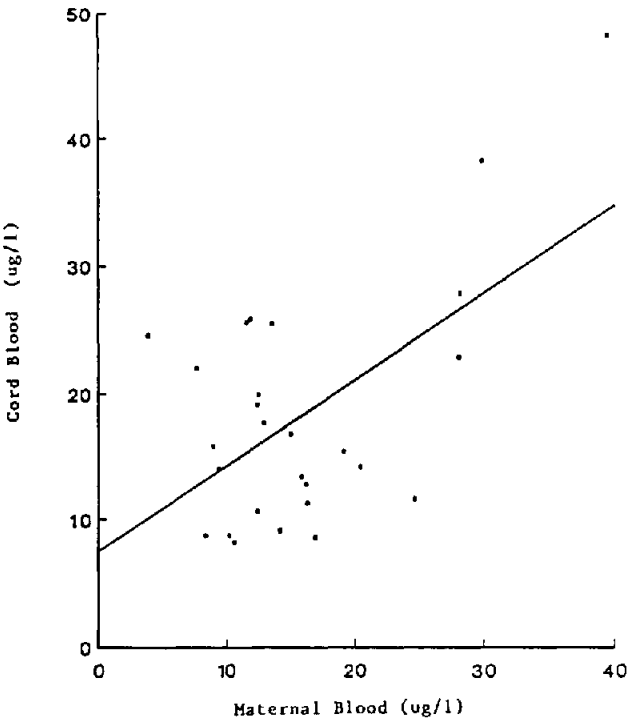

Figure 3. Correlation of total mercury content between maternal and cord blood, $n = 28$; $r = 0.58$; $P < 0.005$, $Y = 7.18 + 0.69X$.

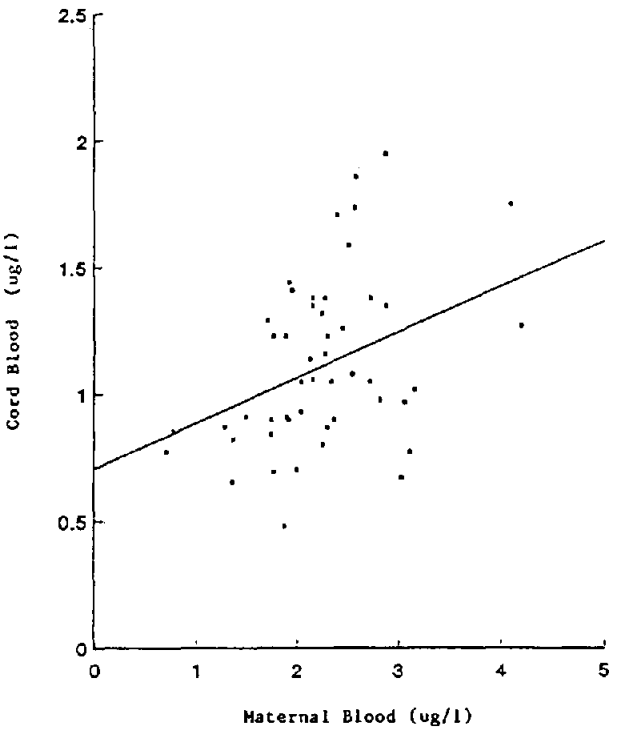

Figure 4. Correlation of copper content between maternal and cord blood, $n = 56$; $r = 0.34$; $P < 0.05$, $Y = 0.70 + 0.18X$.

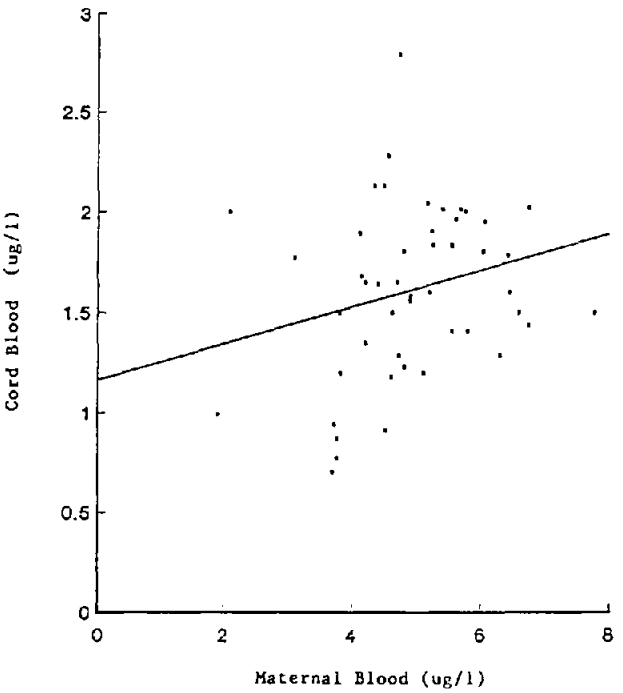

Figure 5. Correlation of zinc content between maternal and cord blood, $n = 49$; $r = 0.29$; $P < 0.05$, $Y = 1.17 + 0.09X$.

Cadmium

Compared with lead, relatively few studies have been conducted on cadmium. Reported cadmium levels in blood, however, encompass a relatively narrow range, with concentrations from 0.1 to 1.7 $\mu g l^{-1}$ (Commision of the European Communities 1990). The mean values for both maternal and cord blood from the present investigation also fell within this range. However, it is important to point out that although there is little difference between the mean concentrations of cadmium in maternal and cord blood (Table 1), no correlation between the two variables was noted ($r = 0.09$, $P > 0.1$).

Mercury

The mercury levels in non-occupationally exposed subjects reflect intake from food and from the environment. Different levels of mercury in blood have been reported in studies of people residing in different parts of the world. Some of the differences have been attributed to the natural abundance of mercury and, as a result, the high levels of mercury in food sources for local people (Kyle & Ghani 1983). The results here show that the total mercury content in maternal blood ($15.4 \pm 5.8\ \mu g l^{-1}$) was much higher than in Europeans ($5.3 \pm 0.9\ \mu g l^{-1}$) (Commission of the European Communities 1990)

but lower than in Japanese women ($19 \pm 3.6\ \mu g l^{-1}$) (Ong *et al.* 1985). Fish and marine products are the main sources of mercury intake through diet in many parts of the world. Data from Japan and our laboratory indicate that dietary fish or marine food consumption is an important factor contributing to the mercury content of local residents (Ong *et al.* 1985, Foo *et al.* 1988). At the moment it is difficult to access whether blood mercury at these levels will have any long-term health effects. Nevertheless, it is interesting to note from the present study that there is a significant positive relationship between maternal blood mercury levels and cord blood (Figure 5), and cord blood has a higher level of blood mercury than maternal blood (Table 1). This finding is similar to two recent studies in Japan and Taiwan (Tsuchiya *et al.* 1984, Soong *et al.* 1991). These authors noted that the mercury contents in umbilical cord blood were much higher than those found in maternal blood. These observations, together with the present investigation, suggest that mercury can readily move across the placenta. This raises the possibility of higher exposure to mercury for the fetus.

It is likely that there is a complex interaction of mercury in infants and their mothers; as noted in these studies, the fetus may act as a 'sink' for the mother's body mercury burden. These observations suggest intriguing possibilities for future work.

Copper and zinc

As shown in Table 1, the copper content in maternal blood was significantly higher than in cord blood ($P < 0.01$). The maternal blood content in this study was higher than that found in normal females ($1.25 \pm 0.12\ mg l^{-1}$) in our earlier study in Singapore. This is attributed to the elevation of blood copper that occurs during pregnancy (Vir *et al.* 1991).

Similar to copper, the zinc content in cord blood ($1.58 \pm 0.45\ mg l^{-1}$) was also significantly lower than in maternal blood ($4.9 \pm 1.2\ mg l^{-1}$). The normal zinc content in whole blood of Singaporeans ranges from 3.8 to 6.1 $mg l^{-1}$ (Ong *et al.* 1988).

For copper and zinc, there were significant positive correlations between the concentrations in maternal blood and cord blood. These findings are in agreement with the recent study of Tsuchiya (1984).

Transfer of heavy metals through the placenta

For a long time, the placenta was considered to present a physiological and anatomical barrier sufficient to mitigate or prevent the transfer of toxic substances. However, recent studies indicate that the placenta is unable to prevent the movement of many substances to which the mother is exposed (Miller 1984).

Transfer to the developing fetus of low levels of toxic metals such as lead and mercury is potentially very important. In general, exposure of the fetus may be considered equivalent in doses to that of the mother. In the present study, most metals were significantly correlated and were generally found to be lower in the cord blood; however, there is clearly a cause for concern, in particular with regard to mercury. Levels of mercury in cord blood were found to be significantly higher ($P < 0.01$) than in the mother's. Furthermore, exposure of the fetus to heavy metals during the course of pregnancy may not be accurately indexed by heavy metals in the blood at parturition. Various studies have indicated that average maternal metal concentrations vary during pregnancy (Davis & Svendsgaard 1987). This suggests the likelihood that the maternal heavy metal pool is subjected both to storage and mobilized during pregnancy.

Conclusion

The findings reported here showed that various heavy metals can move freely across the human placenta. The potential health effect of heavy metal transfer from mother to young infant cannot be discounted. The importance of the quantities transfered to the infant remains unknown. The mercury concentrations in cord blood were noted to be higher than in maternal blood, and the content in both blood samples correlated significantly. This finding suggests that the placenta offers no noticeable barrier to the transfer of mercury.

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