

Placental transfer of lead and its effects on the newborns

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Summary

Following delivery, blood was taken from 122 mothers and their infants' cords for estimation of lead, haemoglobin, packed cell volume and mean corpuscular haemoglobin concentration. All were resident in Kasanda, a township within a radius of 3000 metres of Broken Hill Lead Mine and Smelter, Zambia, where the annual mean atmospheric lead concentration was $9.6 \mu\text{g}/\text{m}^3$ and the soil lead concentration $100-9400 \text{ p.p.m.}$ Their mean blood levels were high, being $41.2 \mu\text{g}$ and $37 \mu\text{g}/\text{dl}$ for mothers and infants respectively, with a significant correlation ($r=0.77$, $P<0.001$). Thus an infant's blood lead at birth closely follows that of its mother even at high values. The increased lead level transfer, however, did not appear adversely to affect the birth weight or red cell values of the newborn. Cord blood lead levels are being used in Broken Hill to monitor a community's exposure to lead.

tration in the mother's blood and infant's cord blood is obtained (Barltrop, 1969; Harris and Holley, 1972; Haas *et al.*, 1972).

Investigations have shown that for communities exposed to urban environments, the mean blood lead concentration in mothers lies between $13.2 \mu\text{g}$ and $16.9 \mu\text{g}/\text{dl}$ and in full-term infants the cord blood level lies between 10.8 and $14.9 \mu\text{g}/\text{dl}$ (Table 1).

This investigation was undertaken to determine if a significant correlation of lead concentration between the mother's blood and infant's cord blood was maintained in the presence of a high maternal blood lead level, and also to determine if the transferred lead adversely affected birth weight and red cell values of the newborn. This involved a community living to the west within a radius of 3000 metres of Broken Hill Lead Mine, Kabwe, Zambia, which was subject to a high atmospheric as well as high ground lead concentrations.

TABLE 1. blood lead ($\mu\text{g}/\text{dl}$)

	No. examined	Mothers' blood (mean value)	Infants' cord (mean value)	Cord range	
Scanlon (1971)	13*	— —	22.1 ± 8.7	10-39	
	15†	— —	18.3 ± 4.0	13-26	
Barltrop (1968) U.K.	29	13.9	10.8	4-24	
Harris (1972) U.S.A.	24	13.2 ± 4.2	12.3 ± 3.3	10-20	
Haas (1972) Germany	294	16.9 ± 8.7	14.9 ± 8.6	2-47	
This report	{ control group	31	14.7 ± 7.5	11.8 ± 5.6	3-29
	{ mine group	122	41.2 ± 14.4	37.0 ± 15.3	10-84

Values \pm s.d. * Urban, † Suburban.

Introduction

Lead is known to cross the placenta from mother to fetus. This was first demonstrated by Bauman (1933) in experiments on the rat. Later Barltrop (1968) showed that in the human such lead transfer began about the twelfth to fourteenth week of gestation. Lead transfer continues thereafter throughout fetal life and at the time of delivery a significant correlation between the lead concen-

Method

The study was conducted over a complete year to obviate gross seasonal differences and involved 122 mothers and their newborn infants representing a 1-in-5 presenting sample of deliveries at the clinic of the lead-affected community. Over the same period a control group of thirty-one mothers and their infants resident in a neighbouring district relatively 'unaffected by atmospheric lead' were studied.

Blood samples, each of 5 ml were collected in a

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lithium heparin tube from an antecubital vein of the mother at delivery and from the umbilical cord of the infant. The lead content was determined using an atomic absorption spectrophotometer following extraction with ammonium pyrrolidine dithiocarbamate and *N*-butyl acetate. During each batch of lead estimations the spectrophotometer was checked against known standard blood samples.

Results

The control group, despite a fairly wide scatter (Fig. 1), showed a significant correlation ($r=0.56$, $P<0.001$) between lead concentration in the blood of mothers' and infants' cords. The blood leads ranged from 3 to 29 μg with mean levels of 14.7 $\mu\text{g}/\text{dl}$ and 11.8 $\mu\text{g}/\text{dl}$ for mothers and infants respectively. They were resident in an area within 3300 metres of the mine and smelter but to its north and north-east. There the ground lead concentrations were similar to the mine area but the atmospheric lead concentrations were much less. (It was not swept

by the prevailing wind blowing from the direction of the mine.) Mean atmospheric lead concentration was 1.5 $\mu\text{g}/\text{m}^3$ 2 m above ground level on the east and windward side of the mine. The blood results were similar to those obtained by other investigators of urban and suburban communities (Table 1). Scanlon, 1971, examining thirteen infants born of urban mothers and fifteen infants born of suburban mothers showed no significant relationship between umbilical cord blood lead levels and place of residence, the lead in air concentrations being 2 $\mu\text{g}/\text{m}^3$ for the urban and 1 $\mu\text{g}/\text{m}^3$ for the suburban. However, the 122 mothers and infants resident to the west and within 3000 m of the lead mine showed higher blood lead than has previously been reported for such pairs (Table 1). These ranged from 10–84 μg with mean values of 41.2 $\mu\text{g}/\text{dl}$ and 37 $\mu\text{g}/\text{dl}$ for mothers and newborns respectively, with a significant correlation between these values ($r=0.77$, $P<0.001$) (Fig. 2). There was an annual mean atmospheric lead load of 9.6 $\mu\text{g}/\text{m}^3$ measured at a

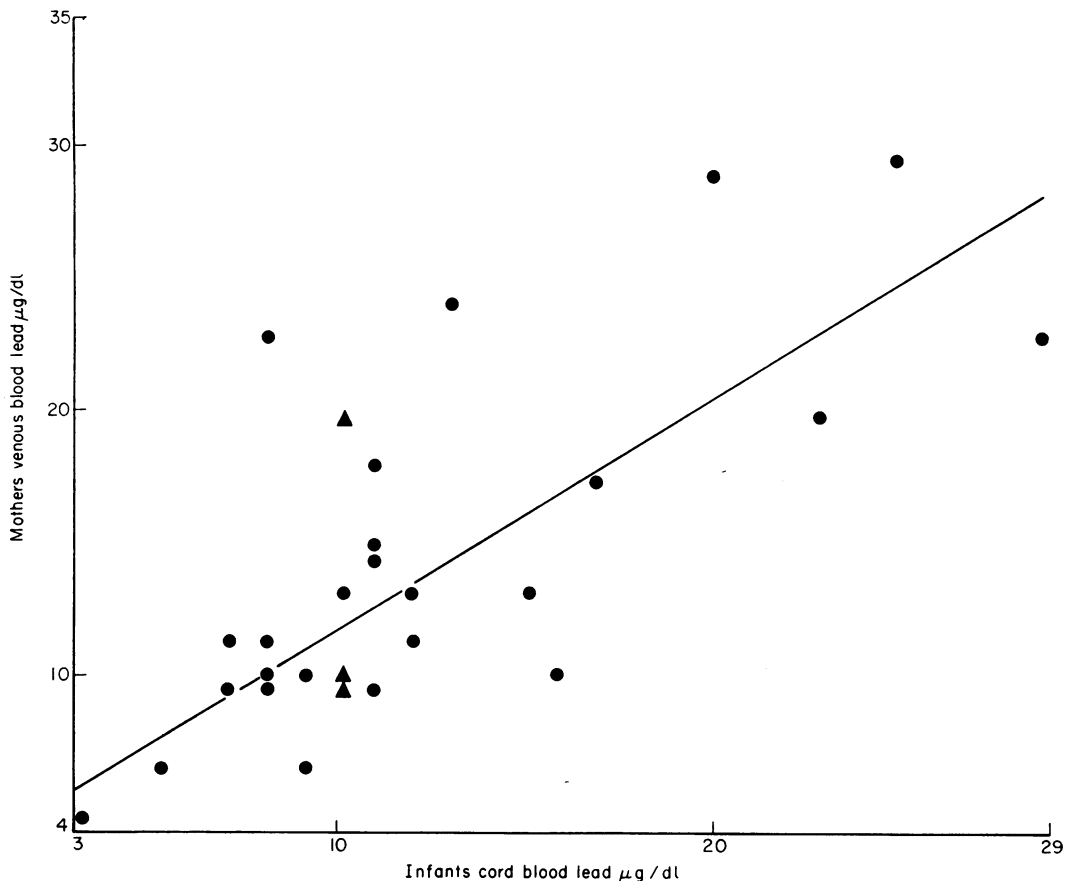


FIG. 1. Relationship between blood lead concentrations of maternal blood and infant cord blood in the control group ($n=31$, $r=0.56$). \blacktriangle = cluster of 2.

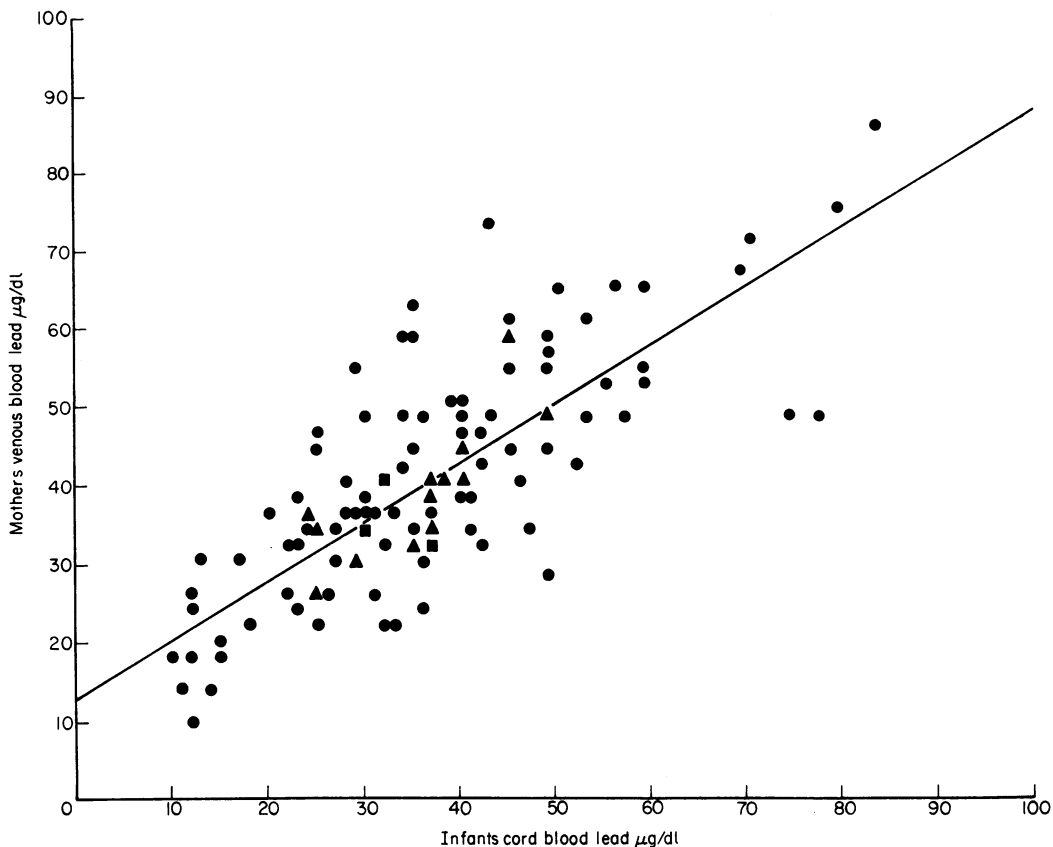


FIG. 2. Relationship between blood level concentrations of maternal venous blood and infant cord blood in the Kasanda township ($n=122$, $r=0.77$). ▲ = cluster of 2, ■ = cluster of 3.

height of two storeys and ground lead concentration between 100–9400 p.p.m. similar to concentrations around lead mines and smelters in other parts of the world (Waldron and Stofen, 1974; Barltrop *et al.*, 1975).

This investigation confirms that, even at raised levels, the infant's blood lead concentration at birth closely matches that of its mother. All workers have shown that cord blood leads, with few exceptions, are lower than their respective maternal levels, suggesting that the placenta may 'protect' the fetus in some way. Of the mine group, thirty-three cord blood leads were higher than the mothers' and of the control group, ten were higher. Furthermore, the difference in means between maternal and cord blood lead was shown to be significant in the large mine group where $P < 0.05$.

Ninety-five per cent of the lead in blood is carried by the red cell, the remainder being in the plasma,

and this is in equilibrium with lead in neighbouring soft tissue (Barry, 1972). Lead concentration varies with the nature of the tissue and is related to the lead supply from the external environment. Thus an equilibrium exists (not always truly obtained, possibly due to some placental dysfunction) between lead in the fetus and the lead in the mother and her external environment which, in this investigation, was abnormal in the atmospheric concentration.

The accepted upper blood lead limit of normal for children aged one year is 36 µg/dl (Barltrop, 1969). In this investigation the mean value for infants beginning an independent existence was 37 µg/dl. The significance of this and the lead level at which adverse effects can be expected in the fetus requires careful consideration, especially in those industrial areas where atmospheric lead is high.

In the present investigations the lead concentrations in the mothers' blood and infants' blood

TABLE 2.

	Mine (n=122)		Kabwe		Control (n=31)	Lusaka (n=75)
	Mothers	Infants	Mothers	Infants	Infants	Infants
Blood lead (μ /dl)	41.2 \pm 14.4	37.9 \pm 15.3	14.7 \pm 7.5	11.8 \pm 5.6		
Hb (g/dl)	13.6 \pm 1.4	15.2 \pm 1.8	12.4 \pm 1.9	15.7 \pm 1.7		15.6 \pm 1.9
Packed cell volume	41.6 \pm 3.5	47.9 \pm 5.6	40.3 \pm 4.5	49.8 \pm 5.2		49.3 \pm 6.2
M.C.H.C. %	32.5 \pm 1.9	31.7 \pm 1.7	30.8 \pm 2.2	31.5 \pm 1.6		31.6 \pm 2.7
Birth weight (kg)		3.2 \pm 0.5		3.1 \pm 0.5		

Values \pm s.d.

were above normal yet still maintained a significant correlation between the two. Thereby the infants were exposed to an unusually raised lead concentration for most of their fetal lives. This finding stimulated an enquiry into likely adverse effects of such a raised lead on the fetus in respect of the birth weight and the red cell values of the newborn.

Results

The results obtained from the two groups are given in Table 2 in addition to Ezeilo's (1972) data for seventy-five Lusaka urban infants. These latter figures are the only ones so far published for Zambian cord bloods. They, and the Kabwe control group, showed very similar values for the red cells and, therefore, form an important base line for comparison with the mine group. The lead level of the Lusaka infants was not known but assumed to be within the range of 'normal' for urban and suburban communities. This range of 10.8–22.1 μ g/dl has been established by various investigators (Barltrop, 1968; Harris and Holley, 1972; Haas *et al.*, 1972; Rajegowda, Glass and Evans, 1972; Scanlon, 1971) and the Kabwe control group fell within this range.

Birth weight

Lead was said to cause abortion in women who worked in the potteries in the days before protective measures were in operation (Hunter, 1969). Amongst the women resident in the mine township lead did not appear to be a contributory factor to abortion, possibly because their mean blood lead level of 41.2 μ g/dl was not sufficiently raised. In this investigation there was no significant difference in birth weight between infants of the mine group compared with the controls, their mean values were 3.2 and 3.1 kg. respectively (Table 2). Five of the mine infants weighed between 2.0 and 2.5 kg and three from the control group weighed between 2.2 and 2.5 kg.

Rajegowda *et al.*, 1972, examined 100 infants in New York with a mean cord blood lead of 20 μ g/dl. Their mean birth weight was 3.2 kg and did not differ significantly from the Zambian newborn

infants; fourteen of them had weighed less than 2.5 kg. The birth weights of these Zambian infants compare favourably with European infants. Not so long ago a 2.5 kg birth weight amongst Zambian infants was the exception rather than the rule. Their improved birth weights are perhaps due to the better nutrition of the mothers, probably a consequence of a higher family income and improved education during the past few years.

Red cell values

Despite the better haemoglobin levels in the mine mothers, their infants were born with lower haemoglobin levels than the control groups. Twenty (16%) of the mine infants were born with haemoglobins below 13.7 g, the minimum level of normal (Nelson) and two (6%) of the control group were below this figure (Fig. 3). The low haemoglobin however was not due to lead; no correlation existed between lead concentration and haemoglobin level. These differences were not statistically different, nor was there any significant difference between the mean haemoglobins and packed cell volumes of mine and control groups. The mean values for other measurements of the red cells were also remarkably similar in the mine, control and Lusaka infants (Table 2).

The literature is deficient regarding the relationship of raised lead to red cell values in cord blood. Lead in excess is known to depress the action of various enzymes necessary for haem synthesis. Levels of 40 μ g/dl have been shown to depress δ -aminolaevulinic acid dehydrogenase but without affecting the haemoglobin concentration (Hernberg and Nikkanen, 1970; Miller *et al.*, 1970). In addition, it has been shown that a raised blood lead concentration reduces the life span of red cells (De Bruin, 1971).

Conclusion

It would seem that infants can tolerate blood lead levels *in utero* of 37 μ g/dl without adverse effects on their birth weights, haemoglobin concentrations.

or packed cell volumes, as no significant differences were shown in these values compared with the controls. On the other hand, twenty (16%) mine infants were born with haemoglobins below 13.7 g/dl and might be considered anaemic. As there are so few published figures available for Zambian cord bloods it is possible that the values for haemoglobins obtained in the mine infants are, in fact, within the normal range for this ethnic group.

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