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THE DETECTION OF CHILDREN ABNORMALLY EXPOSED TO LEAD

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Childhood lead poisoning usually results from chronic exposure although the presenting features may be acute. Recently lead has been recognised to be a major environmental hazard for children in many cities but no effective preventative measures have yet been agreed. Previous programmes have attempted to detect children with frank or incipient lead poisoning and have been based on 1) the presence of characteristic clinical features, 2) the demonstration of disturbed metabolic processes, 3) the determination of lead in blood and urine. It is suggested that measurement of the potential hazard to which children are exposed would be preferable to screening techniques that require a considerable increase in the body burden of lead before a positive result is registered. The major principle source of lead for children is lead-containing paint applied to objects and surfaces in the home. However, the age of the dwelling and the socio-economic status of the family are poor indices of the lead hazard for an individual child. Measurement of the lead content of paints in the home by conventional methods is time-consuming and costly, but studies with a portable isotope fluorescence analyser have suggested an acceptable alternative for screening. Faecal lead determination is the most sensitive available index of the actual, as opposed to the potential lead hazard for children.

Lead poisoning has hitherto been excluded from the sphere of the Poisons Control Centre. There have been many reasons for this, but perhaps the most telling has been the cumulative nature of lead intoxication. Thus there is not the abrupt and dramatic ingestion of a known or suspected toxin but chronic, long-term, repetitive ingestion of small amounts of lead resulting in an almost imperceptable progression to the poisoned state. The size of this problem is difficult to assess, but in New York City 700 childhood cases of lead poisoning are now being detected per annum and this number is apparently increasing each year. In the United Kingdom only 200 cases per annum are recognised, and this is almost certainly an underestimate. Our own experience in a small part of London is remarkably similar to that in New York and suggests, on a population basis, that about 2000 cases per annum should be detected among children in the United Kingdom (1).

Historically, lead poisoning in adults was probably known to Hippocrates, and the sweet taste of lead acetate ensured that sporadic outbreaks occured in Europe throughout the Middle Ages, as a sequel to the adulteration of poor wine. Lead in distilling apparatus resulted in such high concentrations of lead in rum in the eighteenth century that the entire British garrison in Jamaica at that time was incapacitated with 'epidemic colic' (2) and many similar instances have been recorded. The first good description of the disease was by *Tanquerel des Planches* in his treatise published in 1839, in which he recorded 1,217 cases seen by him in Paris during one year, almost entirely among workers in the textile industry in which lead compounds were at that time used as pigments (3). It is salutary to note that his cases included a number of young children.

It was not until the beginning of this century that a number of childhood cases began to be reported. Initially the number were few and the reported origins of the lead have been bizarre, including oriental dusting powders of white-lead (4) and lead nipple shields used by nursing mothers (5). Subsequently other sources were recognised, including lead pipes in soft water areas and the inhalation of fumes from burning of batteries as scrap or fuel (6), and from industrial undertakings (7). Such episodes are of interest in that adults were often exposed simultaneously to the same source and yet the fatalities often appeared to occur more readily among exposed children. The most common source of lead is domestic paint. This was especially recognised in Queensland (8) where the local climatic conditions and the extensive use of timber and corrugated iron required liberal application of paint. Increasingly, it has been recognised in many countries that this is the principal lead hazard for young children and paint probably exceeds all other sources as a cause of lead poisoning in this age group. In the majority of cases indoor paint is responsible (9).

The situation is thus analogous to that for the more familiar poisonous agents with which we are usually concerned, in which child and toxic agent are physically confined within a limited area. Legislation introduced by some countries intended to limit the lead content of domestic paints has done little to improve the situation for most children, since succesive layers of paint applied to a windowsill for example, may only preserve intact the deep layers of paint with high lead concentration. Typically, lead poisoning occurs in children aged 1–5 years who inhabit old, poorly maintained dwellings. There is no marked sex difference in incidence, but a remarkable seasonal variation occurs in which most cases are seen in the summer months (10). This has never been adequately explained although it has been suggested that the Vitamin D status of the child might be related to it. All affected children must actively ingest lead and they commonly have pica (a tendency to ingest materials not normally regarded as food), although this is so common in childhood that it is not of value for the detection of cases (11). Other

features also include anaemia and irritability, but these are non-specific. The constipation, colic and blue line at the gingival margin of adult plumbism are rare, and peripheral nerve palsies practically never occur.

The stages of lead exposure may be divided into four groups: Grade one, normal exposure; grade two, asymptomatic; grade three, symptomatic; grade four, encephalopathy (12). These stages are traversed at an accelerating rate, so that the initial asymptomatic phase may last for several months and the last and most severe stage for only a few days before death may supervene. The significance of any individual stage in terms of prognosis is not known since the true prevalence has never been determined. However, 23.5 per cent of children with encephalopathy in one series died (13) and 30 per cent of the survivors in another study had permanent cerebral damage in spite of treatment (14). Clearly early detection is desirable before the symptomatic stage has been reached, especially since the value of therapy is limited. *Kehoe* (1961) conducted a series of long-term studies with adult human volunteers. He showed that widely differing rates of ingestion of lead resulted in evidence of toxicity at intervals which were proportional to the rate of ingestion (15). It follows that a single blood lead determination is of limited value in a given individual, since it gives no information concerning the slope of the curve on which it lies (16). This might be zero or even negative although the blood lead concentration was considerably above the upper limit of the 'normal' range.

The concept of 'normality' is one that has frequently been neglected in the search for tests that will discriminate between normally and abnormally exposed children. Coupled with the failure to distinguish between poisoning and abnormal exposure this has resulted in much confusion. It is suggested that there are two groups of tests which should be considered separately.

Tests for frank or latent poisoning must, by definition, rely on the demonstration of a metabolic disturbance which is specifically due to the presence of lead in the organism. If such tests are to meet the requirements of screening programmes they must also be capable of large-scale application, require easily obtained samples for analysis and not be too expensive in apparatus or personnel.

Much attention has been paid to disturbances of porphyrin synthesis and the measurement of 5-aminolaevulinic acid and coproporphyrin III in the urine (17) and even free erythrocyte protoporphyrin have been advocated. Our own experience with some of these measurements suggests that although they may be of value in the diagnosis of frank poisoning, the range of normal values is such that false negative results may be obtained in early cases so that they have little value for screening (18).

The enzyme ALA dehydratase has been found to be a sensitive index of exposure to lead; in fact it would appear to be too sensitive as a poisoning screening test since almost complete inhibition has been report-

ed at blood lead concentrations which are at present regarded as lying within normal limits. Basophilic stippling of the erythrocytes certainly occurs in children, and it is best demonstrated by dark ground microscopy. Unfortunately this appears to be a less sensitive test for childhood plumbism than for the adult disease; it is not specific and again there is a wide range of normal values. Similarly the possibility that symptoms alone might be a useful index of lead poisoning has not proved reliable in practice (18). Other disturbances of metabolism that have been studied include those resulting from impaired function of the renal tubular cells with a resultant aminoaciduria, phosphaturia and glycosuria. Clinically, glycosuria in the presence of a normal blood sugar in an at-risk child should always raise the suspicion of lead intoxication.

The alternative possibility is, therefore, to detect exposed children and this concept has much to commend it since it implies that possibility of preventative measures before disturbances of metabolism occur. The first approach to this problem, the application of an 'exposure score' based on the age of the child's dwelling, the state of the paintwork and proximity to industry did not, however, give reliable results. The second approach was the identification of those children with pica. *Bradley* et al. (1958) claimed that pica alone was the best index of an increased blood lead concentration and advocated that a history of this was the best possible screening test for poisoned children (19). This hypothesis was examined, however, and it was shown that pica is a normal phase of maturation that seldom involves lead containing materials. It can be calculated that approximately 30 per cent of all children aged 1–5 years exhibit this activity at any one time and it involves almost all children during this period at some time (11).

The determination of blood and urine lead does provide a direct measure of the exposure of the individual within the limits previously discussed. Blood lead determinations can now be made in a large-scale manner on small samples. However, examination of the normal distribution of blood lead values again demonstrates the difficulty in interpretation of an individual value, especially at low and intermediate concentrations. Our own experience has also indicated that there is an age-dependent variation in blood lead concentration when this is determined in a large number of children. The significance of this is not known and it may merely reflect increased lead ingestion in the 2–4 age groups. The urine lead has similar difficulties in interpretation. The large-scale collections of 24-hour urine samples is difficult in children and the results obtained are rather poor indices of exposure.

Radiological studies are mentioned only to be dismissed. Opaque material in the gut may represent flakes of paint ingested by the child, but this is not necessarily lead-containing, and conversely lead paints may become finely divided in the gut and thus be invisible radiologically. X-ray studies of the growing end of the bone, usually the wrist, may reveal a 'lead-line'. However, while this provides evidence of previous

exposure it gives little information about current exposure. After a known single massive inhalational exposure, it has been found that the 'lead-line' may take as long a three months to become apparent (6). This is not suprising since the 'lead-line' probably indicates altered bone trabeculation rather than local deposition of lead.

Ingested lead is largely unabsorbed (90 per cent) and is, therefore, excreted in the faeces. Using animals, it has been shown that a single oral dose of lead can be detected in faecal collections with great precision, even though the blood and urine lead concentrations remain unchanged (Fig. 1). The determination of faecal lead was therefore applied

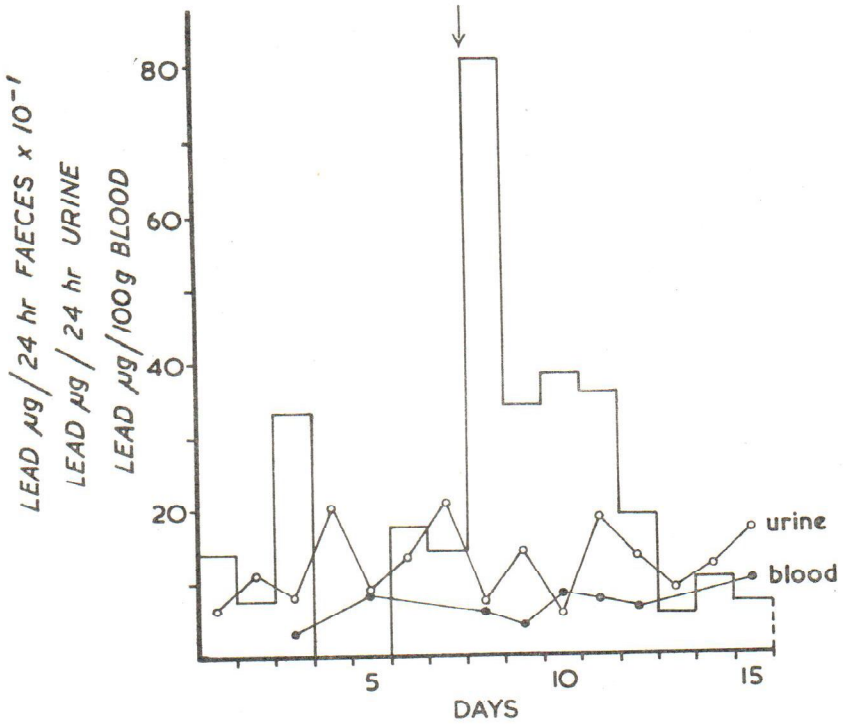

Fig. 1. *The blood, urine and faecal lead concentration in a 20 kg dog before and after the oral administration of lead, 1.0 mg as the acetate (arrow)*

to children in the at-risk age group and the upper limit of normal found to be 180 μg per day (20). This was shown to be valid for both hospital in-patient and normal healthy children attending an infant welfare clinic. The latter had similar lead excretions in both pica and non-pica groups, although one child ingesting lead was detected in this way. The results contrast with the faecal lead excretion by children with lead

poisoning in whom a marked dissociation between the faecal lead excretion and the blood lead concentration becomes apparent within a few days after admission to hospital. The blood lead thus provides an integrated index of the exposure experience for the previous few weeks or months, whereas the faecal lead provides an index of ingested lead during the previous few days. The findings together with the histories obtained allowed computation of the toxic dose of lead for children in this age group. In these cases reported a total of 200 mg of lead had been ingested during a six month period, or approximately 1–2 mg of lead per day. In terms of paint concentrations this is an extremely small amount which may be contained in a flake of paint weighing only a few milligrams.

It would be preferable to identify the lead at source before the ingestion had started. The American literature frequently refers to 'lead belts' in their cities in which families of low socio-economic status inhabit old, poorly-maintained dwellings. It seemed, therefore, a simple matter to identify the children at risk by restricting attention to families that

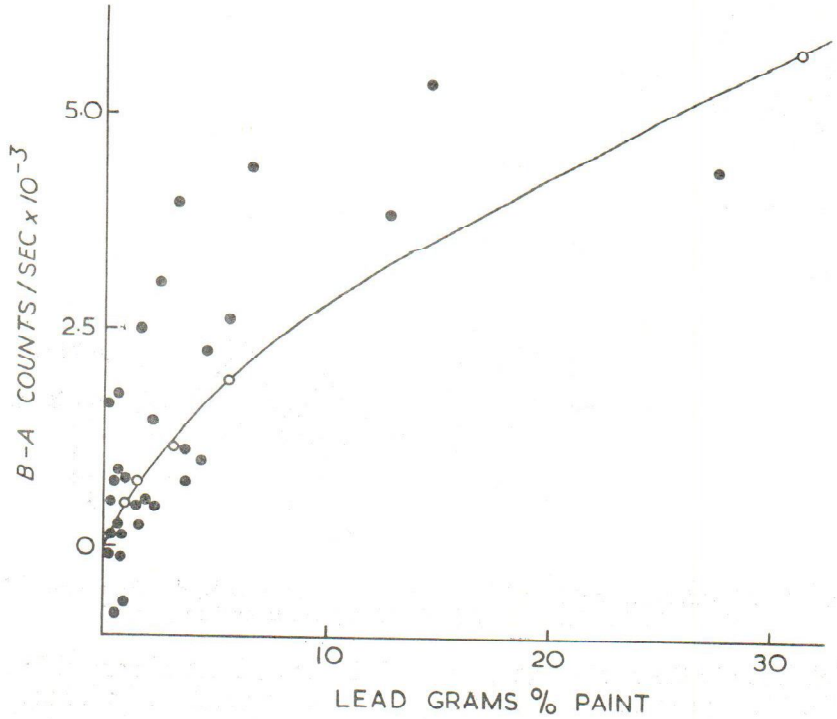

Fig. 2. *The relationship between lead content of a series of domestic paint films determined in situ with a portable isotope fluorescence analyser and the chemical analysis of a representative sample. The line and open circles are a standard curve obtained in the laboratory with a series of uniform paint films to which lead oxide had been added*

fulfilled these criteria. However, in London, although there was a general correlation between these factors and the lead content of the paint to which the local children were exposed, this was by no means absolute (1).

The determination of paint lead concentration by chemical methods is relatively time-consuming and costly; it requires that the surface of the paint is damaged and this is not always welcomed by the family. Recently, we have explored the application of X-ray fluorescence techniques to this problem using a portable device containing Pu-238 30 mCi as the exciting source. Similar devices have long been used by geologists but have not hitherto found application in the public health field. Among the advantages possessed by such an apparatus is that it allows a reading to be obtained by a relatively unskilled operator almost instantaneously and that the painted surface remains intact. The findings suggest that the results are almost specific for lead and that there is a satisfactory correlation with chemical analyses (Fig. 2).

It is therefore suggested that the traditional approaches to the detection of children abnormally exposed to lead should be abandoned as costly and inefficient. The most sensitive index of lead ingestion is the faecal lead content which will identify children at risk from the commencement of ingestion before any appreciable absorption of lead has occured. Direct determination of the lead content in paint films by X-ray fluorescence offers a more logical approach to the problem by screening the child's environment.

ACKNOWLEDGEMENTS

Fig. 2 is based on an illustration that was originally published in the Lancet (20).

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Sažetak

DETEKCIJA DJECE ABNORMALNO IZLOŽENE OLOVU

Otrovanje olovom u djetinjstvu obično je posljedica kronične ekspozicije premda slika otrovanja može biti akutna. Nedavno je potvrđeno da je olovo postalo jedna od glavnih opasnosti okoline za djecu u mnogim gradovima, ali do sada nisu poduzete nikakve efikasne zaštitne mjere. Prethodna istraživanja kojima se pokušalo otkriti početno otrovanje olovom u djece zasnivala su se na 1) karakterističnoj kliničkoj slici, 2) poremećenom metabolizmu, 3) određivanju olova u krvi i urinu. Mjerenje potencijalne opasnosti kojoj su djeca izložena smatra se povoljnijim od »screening« tehnika, koje daju pozitivan rezultat tek kad je količina olova u tijelu znatno povećana. Glavni izvor olova za djecu je boja koja sadrži olovo i kojom su obojeni predmeti i površine u kući. Međutim, starost zgrade i socijalno-ekonomski položaj obitelji slabi su pokazatelji opasnosti koju olovo predstavlja za dijete. Mjerenje sadržaja olova u bojama u kući konvencionalnim metodama sporo je i skupo, ali su zato istraživanja s prenosivim analizatorom fluorescencije izotopa prihvatljiva alternativa za »screening«. Određivanje olova u fecesu je do sada najosjetljiviji raspoloživi indeks stvarne – za razliku od potencijalne – opasnosti od olova za djecu.

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