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Observation

LEAD TOXICITY IN A FAMILY AS A RESULT OF OCCUPATIONAL EXPOSURE

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This article describes an entire family manufacturing lead acid batteries who all suffered from lead poisoning. The family of five lived in a house, part of which had been used for various stages of battery production for 14 years. Open space was used for drying batteries. They all drank water from a well located on the premises. Evaluation of biomarkers of lead exposure and/or effect revealed alarming blood lead levels [(3.92±0.94) μmol L^{-1}], 50 % reduction in the activity of δ-aminolevulinic acid dehydratase [(24.67±5.12) U L^{-1}] and an increase in zinc protoporphyrin [(1228±480) μg L^{-1}]. Liver function tests showed an increase in serum alkaline phosphatase [(170.41±41.82) U L^{-1}]. All other liver function test parameters were normal. Renal function tests showed an increase in serum uric acid [(515.81±86.29) μmol L^{-1}] while urea and creatinine were normal. Serum calcium was low [(1.90±0.42) mmol L^{-1} in women and (2.09±0.12) mmol L^{-1} in men], while blood pressure was high in the head of the family and his wife and normal in children. Lead concentration in well water was estimated to 180 μg L^{-1}. The family was referred to the National Referral Centre for Lead Poisoning in India, were they were received treatment and were informed about the hazards of lead poisoning. A follow up three months later showed a slight decrease in blood lead levels and a significant increase in haemoglobin. These findings can be attributed to behavioural changes adopted by the family, even though they continued producing lead batteries.

KEY WORDS: *blood lead, chelation therapy, lead acid battery, lead poisoning ,*

Lead is one of the earliest metals known to man and is a normal constituent of the earth's crust with trace amounts found naturally in soil, plants, and water (1,2). If left undisturbed, it is practically immobile; however, once mined and transformed into useful products, it gets dispersed throughout the environment and becomes highly toxic. It has been widely used by man during the last two thousand years for domestic, industrial, and therapeutic purposes (2, 3).

Lead poisoning was common in Roman times because of the use of lead in water pipes and in wine containers (3). In the 19th and 20th centuries lead poisoning was common in industrial workers. The use of lead as antiknock agent for motor vehicles in gasoline at the beginning of the 20th century resulted in environmental pollution. Most of the paints used before 1978 and some of the Indian paints used even today are known to contain alarming levels of lead, which mainly affects the children due to their hand-to-mouth activities (4, 5).

Lead is not biodegradable, and is dispersed into the air, food, soil and water. Lead can enter the body through ingestion, inhalation and, when it comes to organic lead through skin. Most of the environmental exposure occurs by inhaling air containing lead dust, by drinking water supplied through leaded pipes, and by consuming lead contaminated food. Lead

toxicity in adults results primarily from occupational exposure. Particles of $<1\ \mu$m in size can reach the alveoli and are completely absorbed. Larger particles are deposited in airways and are cleared by the mucociliary activity and are eventually swallowed and absorbed from the gastrointestinal tract. Lead toxicity can also occur by ingestion as a result of poor hygiene in lead-contaminated environments such as eating or smoking in areas of lead work (6). Once lead enters the human body, its absorption and biological fate depend on factors such as nutritional status, health and age of the exposed individual. For humans it is a cumulative poison, and health effects are irreversible. It accumulates in the bones and teeth. More than 95 % of the retained lead is in the bones, which act like a reservoir and stage a continuous exchange between blood and soft tissue. The half-life of lead in blood is 36 days (7), in soft tissues 40 days (8), and in bones 20 to 30 years (9).

Although children are more prone to lead poisoning due to their hand-to-mouth activities, adults are at equal risk of lead poisoning from occupational exposure (10-12).

Wastewater streams from battery industries are a major source of lead contamination in the environment. Lead acid batteries account for almost 50 % of lead consumption in the world. Workers involved in lead acid battery manufacture are exposed to varying degrees of lead in the air in the form of fumes or particulates (13). Lead does not have any known useful physiological functions in the human body and produces harmful effects once it enters the body. It affects major organs and systems such as the nervous system, haematopoietic system, digestive system, cardiovascular system, reproductive system; skeletal system, immunological system, and the kidneys (14-16).

In most highly industrialised countries strict control and improvements in industrial production standards have ensured that occupational lead poisoning is less prevalent than before. In developing countries like India, however, it remains a problem of potentially huge dimensions. This paper describes a case of lead poisoning in a family who was using a part of the house for manufacturing small lead-acid batteries. The poisoning went undetected for a long time, as the family was completely unaware of the necessity to take preventive measures for safe handling of this toxic metal.

SUBJECTS AND METHODS

A man (family head) aged 41 years was referred to the National Referral Center for Lead Poisoning in India (NRCLPI) for blood lead testing. History revealed that he had been running a lead acid battery manufacturing unit (Unit) for 14 years. He was married and had three children: an elder girl and two boys (twins). He and his wife had completed high school. Their daughter was away from home pursuing further education. Both sons were average elementary school students. They were well nourished. Their house was attached to the Unit (Figure 1). The source of drinking water was an open well close to the Unit. Finished batteries were dried on a parapet of the well (Figure 2). In addition, wastewater from the Unit was discharged into the soil close to the well. Both the Unit and the house were located in a residential area. All children played, ate, drank, and slept on the premises of the Unit. The Unit started as a small-scale production with only three workers: the family head, his wife, and a friend. Initially, they would only assemble finished lead plates, but after 10 years they started making batteries on their own, using lead oxide powder. They would make 3 to 5 car batteries a day. After a few years the friend had left for Saudi Arabia, leaving the Unit to the family. The family head used to complain of symptoms such as abdominal pain, joint pain, generalised weakness, and headache, which he treated by consuming a lot of analgesics. Recently his wife and children also began suffering from the same symptoms.

The family was then referred to the National Referral Centre for Lead Poisoning in India (NRCLPI), and their blood was taken to measure lead, δ-aminolevulinic acid dehydratase (ALAD), zinc protoporphyrin (ZPP), and haemoglobin levels (Hb). Examination also included liver and kidney tests and blood pressure. Lead level in the well water was also measured.

Blood lead analysis was carried out using anodic stripping voltammetry on an ESA-3010B lead analyser (17). Haemoglobin was estimated using the Drabkins method (18), ALAD activity was measured using the European standardized method (19), ZPP was estimated using front-face fluorometry on a haematofluorometer (20) and serum aspartate amino transferase (AST), alanine amino transferase (ALT), alkaline phosphatase (ALP), gamma glutamyl transpeptidase (γ-GT), bilirubin, total proteins, urea, uric acid, creatinine, calcium and phosphorous were estimated using fully automated methods on an Excel-300 ERBA auto analyzer. Lead content in sampled

well water was analyzed using graphite furnace atomic absorption spectrometry (GFAAS) with the detection limit under optimal conditions of 0.08 μg L^{-1} (21).

RESULTS AND DISCUSSION

Tables 1-3 show data for relevant parameters in all members of the family exposed to lead. Average (mean±SD) blood lead concentration for all family members was (3.92±0.94) μmol L^{-1}; the allowable safe level for the occupationally exposed according to the Occupational Safety Health Administration (OSHA) standards is 1.93 μmol L^{-1} (400 μg L^{-1}) while maximum allowable level is 2.41 μmol L^{-1} (500 μg L^{-1}) (22). The daughter had the lowest blood lead concentration, as she was away from home pursuing education. ALAD activity was reduced to 50 % of the normal value [(24.67±5.12) U L^{-1}]. (23). ZPP levels increased [(1228±480) μg L^{-1}]. Haemoglobin concentration decreased [(122±5) g L^{-1} in men and (118±12) g L^{-1} in women]. A mild increase in blood pressure was found in the family head (128/84) and his wife (126/84), while in children it remained normal (Table 1). Among the liver function tests, AST, ALT, gamma-GT, cholesterol, and total proteins were normal, but ALP activity ± (Table 2) was high. Kidney function tests showed an increase in uric acid level, while urea and creatinine levels were within the normal range (Table 3).

Additional measurements showed that serum calcium was low, more so in women [(1.90±0.42) mmol L^{-1}] than in men [(2.09±0.12) mmol L^{-1}]. However, serum phosphorous levels were at the upper end of the normal range (Table 3). The most significant finding was high lead concentration in the well water, which was 180 μg L^{-1} (permitted level by the US Environmental Protection Agency is up to 15 μg L^{-1}) (25).

Table 1 *Individual and mean±SD values for relevant parameters in all members of the family exposed to lead*

	Age / years	Blood Pressure / mm Hg		Blood lead / μmol L^{-1}	ALAD / U L^{-1}	ZPP / μg L^{-1}	Hb / g L^{-1}
		Systolic	Diastolic				
Normal levels		<120	<80	<1.93	52.7-56.4	<350	M: 132-173 F: 117-155
Husband	42	128	84	4.71	21.3	1820	118
Wife	38	126	84	4.42	20.0	1560	109
Daughter	18	110	76	2.32	32.0	580	126
Son-1	14	112	78	3.96	22.1	1120	127
Son-2	14	116	78	4.17	28.0	1060	122
Mean±SD	25±14	118±8	80±4	3.92±0.94	24.7±5.1	1228±480	120±7

Table 2 *Individual and mean±SD values of the liver function tests in all members of the family exposed to lead*

	AST / U L-1	ALT / U L-1	ALP / U L-1	γ-GT / U L^{-1}	Bilirubin / μmol L^{-1}			Total protein / g L^{-1}	Albumin / g L^{-1}	Globulin / g L^{-1}	Cholesterol / mmol L^{-1}
					total	direct	indirect				
Normal levels	15-40	13-40	45-160	0-40	5-21	<5.0	<19	60-80	35-50	15-30	32.4-62.3
Husband	36	36	222	18	20	5.1	14	88	44	44	61
Wife	19	13	168	8	19	5.5	14	78	39	39	57
Daughter	14	11	108	9	11	2.4	9	74	40	34	60
Son-1	25	9	190	4	14	4.4	10	75	42	33	45
Son-2	28	14	162	4	15	3.8	11	82	43	39	54
Mean±SD	25±9	17±11	170±42	9±6	15.7±3.5	4.2±1.2	11±2	79±6	42±2	38±5	55±6

Table 3 *Individual and mean±SD values of the kidney function tests (urea, uric acid and creatinine) and calcium and phosphorus in serum in all members of the family exposed to lead*

	Urea / mmol L^{-1}	Uric acid / μmol L^{-1}	Creatinine / μmol L^{-1}	Calcium / mmol L^{-1}	Phosphorus / mmol L^{-1}
Normal levels	2.3-8.3	M: 262-452 F: 137-393	M: 80-115 F: 53-97	2.10-2.50	0.87-1.45
Husband	6.0	607	106	1.97	1.32
Wife	3.6	588	92	1.60	1.44
Daughter	2.2	392	81	2.19	1.25
Son-1	6.2	505	80	2.08	1.44
Son-2	5.0	487	74	2.22	1.51
Mean±SD	4.6±1.7	516±86	87±13	2.01±0.25	1.39±0.11

The family was totally unaware of the toxic effects of lead, and they had lived in a lead contaminated environment for over 14 years. Lead entered into their body through all routes, inhalation and ingestion being the most significant. Blood lead levels were at alarming levels because of continuous exposure. Since they were well nourished, there may have been a delay in toxic effects.

Lead poisoning is known to cause anaemia, which is believed to be due to both shorter erythrocyte survival and lower haemoglobin synthesis (26). Lead is known to decrease the life span of erythrocytes by inhibiting sodium-potassium ATPase and pyrimidine-5' nucleotidase, which impairs erythrocyte membrane stability by altering energy metabolism (27) and decreases haem synthesis by inhibiting some of the enzymes of the biosynthetic pathway such as ALAD, ferrochelatase, and coproporphyrinogen oxidase (28). Inhibition of ferrochelatase results in decreased haem production and increase in the concentration of erythrocyte protoporphyrin. These erythrocyte protoporphyrin complexes with zinc at the site normally occupied by iron form ZPP (29, 30). Increased blood pressure is probably the most sensitive adverse health effect observed in lead poisoning. Several epidemiological studies have found a significant association between increased blood pressure and body lead burden (31, 32). A slight decrease in calcium level was observed, indicating the effect of lead on vitamin D and calcium metabolism (33). Uric acid levels were increased due lower excretion rate through the kidneys caused by lead (34).

Lead poisoning may go undetected because there are no obvious signs or symptoms. By removing or avoiding lead sources or with early detection and treatment the adverse effects of lead can be limited or prevented.

Steps taken by the NRCLPI

As a part of creating awareness, which is the most important aspect of treatment, we educated the entire family during their visit to the NRCLPI, about different pathways through which lead enters the body, the toxic effects on children and adults, and the preventive measures that are to be taken, such as wearing gloves, masks, respirators, protective clothing at workplace, change of work clothes before leaving worksite, modification of personal hygiene habits, prohibition of eating, drinking, and smoking at workplace, avoiding storing food in open cans, reducing soil lead exposure by planting grass and shrubs around the house, dust control, improvement of ventilation at workplace, and the importance of good nutrition in reducing the absorption and effects of lead. We also advised them to shift the factory to an industrial area, and arrange to have safe drinking water. Months later they shifted their factory to an industrial area, stopped drinking the well water, and shifted to tap water. For high blood lead levels we referred them to a clinician who gave them chelation therapy with D-penicillamine 250 mg twice a day over a period of one month.

Three months later, a follow up blood lead estimation showed only a slight decrease in blood lead level [(3.28±0.68 μmol L^{-1})] and a slight increase in Hb [(126.6±5.0) g L^{-1} in men and (124.5±2.1) g L^{-1} in women]. Only a slight decrease in blood lead level was seen because they still lived in a highly lead-contaminated environment, continued battery production, and because of the release of deposited lead from bones.

CONCLUSION

This case is particularly interesting because an entire family had lived in highly lead contaminated environment for over 14 years because most of the symptoms went undiagnosed until blood lead reached an alarming level. This would not have happened if the family was aware of the dangers of lead poisoning , which highlights the importance of proper education about safe handling of this toxic metal to create a "lead safe" environment.

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Sažetak

TOKSIČNI UČINCI OLOVA U PROFESIONALNO IZLOŽENE INDIJSKE OBITELJI

Olovo je sveprisutni metal s mnogo namjena, a čovječanstvo ga rabi već više od 6000 godina. Danas je olovo među najrasprostranjenijim toksinima u okolišu, a drugi je na popisu toksičnih metala, odmah iza arsena. Mnogi još nisu svjesni njegova toksičnoga djelovanja te se i dalje izlažu olovu. Ovdje je opisana obitelj koja proizvodi olovne akumulatore i koja je pretrpjela trovanje olovom zahvaljujući svojoj neobaviještenosti. Ova peteročlana obitelj živjela je u jednome kućanstvu čiji je dio namijenjen različitim fazama proizvodnje akumulatora već 14 godina. Akumulatori su se sušili na otvorenome. Na imanju je bio i bunar s pitkom vodom. Mjerenja biopokazatelja izloženosti olovu i njegova djelovanja u svih pet članova obitelji dovela su do alarmantnoga saznanja o razinama olova u krvi [(3,92±0,94) μmol L^{-1}], 50 %-tnom padu aktivnosti dehidrataze δ-aminolevulinske kiseline [(24,67±5,12) U L^{-1}] te povišenom cinkovu protoporfirinu [(1228±480) μg L^{-1}]. Jetrene probe otkrile su povišene razine alkalne fosfataze u serumu [(170,41±41,82) U L^{-1}]. Ostali su parametri jetrene funkcije bili normalni. Testovi funkcije bubrega otkrili su povišene razine mokraćne kiseline u serumu [(515,81±86,29) μmol L^{-1}], dok su razine ureje i kreatinina bile normalne. Također je zabilježen pad razina kalcija u serumu [(1,90±0,42) mmol L^{-1} u žena te (2,09±0,12) mmol L^{-1} u muškaraca]. Povišeni krvni tlak zamijećen je u glave obitelji i njegove supruge, dok je u djece bio normalan. Koncentracija olova u bunarskoj vodi bila je izrazito visoka, prema procjeni 180 μg L^{-1}. Obitelj je upućena u indijski Državni referalni centar za otrovanje olovom (National Referral Centre for Lead Poisoning) gdje je primila lijekove i bila upoznata s činjenicama vezanim uz otrovanje olovom. Tromjesečno je praćenje pokazalo blagi pad razina olova u krvi te značajan porast hemoglobina. Ovi se nalazi mogu pripisati promjenama u ponašanju obitelji, bez obzira na to što je nastavila proizvoditi akumulatore.

KLJUČNE RIJEČI: *akumulatorska baterija, liječenje kelatima, olovo u krvi, otrovanje olovom*

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