Managing the Child with Elevated Blood Lead Levels, Part II: The Clinical Picture

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Today, the child with an elevated blood level presents a clinical picture very different from what I saw managing children admitted to the inpatient unit at Mount Washington Hospital in the early 1990's. An important change was the definition of an elevated blood level, which was lowered in 2012 by the CDC to 5µg/dl. In addition, several high quality studies have documented neuropsychological impairments, such as lowered IQ and short attention span in children with blood lead levels between 5-10 µg/dL. Finally, several children have recently presented with elevated blood levels due to exposure to a non-lead paint source. To effectively manage children with elevated blood lead levels, it is important to be mindful of these new clinical developments. This section, Part II in a series of three articles discussing managing children with elevated blood lead levels, presents current information about the broad clinical picture caused by lead poisoning.

Exposure

Before lead poisoning takes place there must be exposure or the presence of lead in a child's environment. Deteriorated lead-based paint and lead in dust remain the most frequent sources of lead poisoning in Maryland. Houses and apartments built before 1978 often contain lead-based paint and can present a significant hazard when repaired, renovated or painted. Houses built before 1950 have a 90% risk for the presence of lead-based paint and over 90% risk of the lead-based paint having a concentration of lead of up to 50% (current federal standard 0.009%). In Maryland, 18.5% of the houses were built before 1950, and 39.5% were built between 1950 and 1978, but many have been demolished or remediated and no longer present a lead paint hazard to children.

In the last several years, there have been several cases of children in Maryland with elevated blood lead levels resulting from exposure to lead hazard where lead-based paint was not the source. The lead hazard source for these children has been imported toys, folk remedies and jewelry. The following chart summarizes many of the sources of childhood lead hazards.

Sources of Lead Hazards to Children

	SOURCES	COMMENT	
1.	House paint before 1978		Deteriorated paint releases fine lead dust into the air especially during home renovation
2.	Children's furniture painted before 1976 or imported		Furniture from Puerto Rico recalled in 2012 by the US CPSC (Consumer Product Safety Commission)
3.	Painted toys made outside of the US		Thomas the Train characters made in China recalled in 2007
4.	Lead bullets, fishing sinkers, certain weights		
5.	Plumbing, pipes, and faucets		Lead bend used in plumbing in the 1940's
6.	Soil contaminated by lead	Often in soil near highways and in yards of houses with exterior lead paint	

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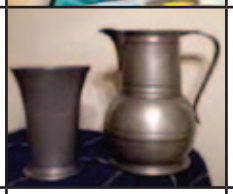
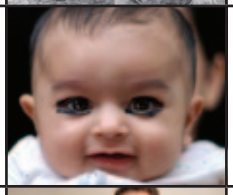
7.	Hobbies involving soldering such as stained glass, jewelry making, pottery glazing, and miniature lead figures		
8.	Children's face paint sets and art supplies		Always check the labels
9.	Pewter pitchers and dinner ware		
10.	Storage batteries.		
11.	Parental Occupation: auto repair, mining, battery manufacturer, pipe fitting and plumbing, welding, firing range instructor, ship building		
12.	In utero exposure; breast milk		Pregnant women can mobilize lead stored in bones from their own childhood exposure
13.	Folk remedies		Bokhoor is used to calm infants; Greta and Azarcon are Hispanic traditional medicines that may contain lead as well.
14.	Moonshine whiskey		Associated with deaths in young adults mostly in the south
15.	Cosmetics		Tiro (also known as Kohl or Surma) is a cosmetic used as eye liner and thought to improve vision
16.	Internationally adopted children		Especially Africa, Asia, and Eastern Europe

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17.	Candy from Mexico		Ingredient tamarind may contain lead
18.	Toy jewelry		Butterfly necklace from China recalled 2006

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Finally, *in utero* exposure to lead can occur when the mother had contemporaneous exposure or had elevated blood levels during her childhood, and her pregnancy causes lead stored in her bones to be released in the blood stream. A recent NHANES (National Health and Nutritional Evaluation Study) study estimated that 1% of women of child bearing age have an elevated blood lead level. The elevated maternal blood lead levels place the fetus at risk for developmental delay, reduced IQ and behavior problems. In addition, the maternal elevated blood lead levels can also be present in her breast milk. Although a lot of basic research still needs to done on maternal elevated blood levels, the CDC did publish some guidelines for clinicians managing women and pregnancy (*Guideline for Identifying and Managing of Lead Exposure in Pregnant and Lactating Women,* CDC 2010).

Absorption/Biologic Uptake

Although lead hazard exposure represents a potential harm to a child, it is the actual uptake or absorption that results in serious consequences to the young child. Absorption refers to the amount of lead that actually enters the body. Although small amounts of lead can be absorbed dermally or through the respiratory tract, the gastrointestinal tract represents the main route through which lead enters a child's body. Children up to eight years of age absorb about 50% of GI ingested lead, which is much greater than the 10% that is absorbed by adults. The amount of lead absorbed by children may be increased by iron deficiency and lower dietary zinc levels, and decreased by food in the stomach and dietary calcium levels. Research studies have demonstrated that house dust containing lead is a particularly important hazard for young children because they absorb it so efficiently. One study showed that four month old infants, who were mouthing their fingers, absorbed 4 µg of lead per day, resulting in an elevated blood lead level up to 2.4 µg/dL. A pooled analysis of 12 studies reported that lead-contaminated house dust was the main contributor to a child's elevated blood level.

Toxicokinetics

Toxicokinetics refers to the distribution throughout the body compartments of an individual who has absorbed lead. In children, nearly 70% of body lead burden is located in the bone, while 1% is found in the blood. Lead accumulates in bone undergoing the most active calcification which, in children, is the trabecular bone. The bone lead generally recycles back to the plasma in less than two years. Additional toxicokinetic studies provide important information needed when monitoring children with elevated blood lead levels. For example, the blood lead level has a half-life of about 30 days in children following acute ingestion. In addition, after chronic lead ingestion, it takes approximately 382 days for blood lead levels to fall below 10 µg/dL. Finally, a measurement of an elevated blood level reflects recent as well as past lead ingestion, due to the release of lead from the bone back to the serum.

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Clinical Effects

The Environmental Protection Agency issued a report, *EPA Integrated Science Assessment of Lead 2013* (www.epa.gov), that summarized an expert committee's review of research articles describing the clinical effects of lead poisoning. This review defined a causal association as: "…the pollutant (lead) has been shown to result in health effects in studies in which chance bias and confounding could be ruled out with reasonable confidence." The following health effects were determined to be causally associated with elevated blood lead levels:

1. Neuropsychological impairments including decreased Full Scale IQ scores, academic underachievement, and deficits in executive function in studies of children 4-11 years old with blood lead levels between 2-8 µg/dL. Studies show that an increase in a child's blood lead level from 2.4 to 10 µg/dL resulted in 3.9 Full Scale IQ points lost.
2. Neuro-behavior effects of short attention span, impulsivity, and hyperactivity described in children 7-17 years with blood lead levels of 7-14 µg/dL
3. Hypertension reported in young adults with childhood blood lead levels > 10 µg/dL.
4. Hematologic effects include decreased red blood cell survival time and altered synthesis of heme that resulted in decreased hemoglobin, hematocrit, and mean corpuscular volume.

The EPA report defined a likely causal association as: "…evidence is sufficient to conclude that a causal relationship is likely to exist with relevant pollutant exposure, but important uncertainties remain." An example of an uncertainty would be the presence of multiple high quality animal studies but lack of human studies. The following health effects were determined to be likely a causal association with elevated blood lead levels:

1. Conduct disorders in children and criminal offenses in young adults with mean lead blood levels of 7-14 µg/dL are well documented in high quality epidemiological studies. Uncertainty exists due to lack of consistent evidence in animal studies.
2. Depression and anxiety documented in prospective studies of children 8-13 years who had lifetime average blood lead levels of 14 µg/dL. Uncertainty exists due to lack of control of parental caregiving in the studies.
3. Hearing loss noted at ages 4-19 years associated with blood lead level median of 8 µg/dL, but animal studies have produced some uncertainty.
4. Asthma and allergy in with children 1-5 years is associated with elevated blood lead levels >10 µg/dL, but uncertainty exists, since the studies did not control for confounding factors, such as parental smoking.
5. Fine motor and gross motor deficits reported in children 4-17 years with blood lead levels 4.8-12 µg/dL, but uncertainty exists due to lack of evidence in animal studies.

Finally, an important but uncommon clinical effect of a very high blood lead level is a preventable death. The most recent death of a child due to lead poisoning was reported in the CDC's MMWR March 23, 2006 (http://www.cdc.gov/mmwr/preview/mmwrhtml/mm55d323a1.htm). A 4 year old boy presented to the emergency room with vomiting and "sore tummy" diagnosed as viral gastroenteritis. When he returned two days later with dehydration and listlessness, he was admitted. When his condition worsened and he became combative, a CT of his head showed cerebral edema. An abdominal film showed a metallic object in his abdomen, and a blood lead was drawn that was 180 µg/dL. At autopsy, the metallic object was identified as a heart shaped charm that, on analysis, was 99.1 % lead. He apparently swallowed this while visiting a friend.

In summary, lead poisoning can result in a diverse clinical picture in young children, with significant impairment to the central nervous system as well as effects on other body organs. The potential outcome may range from loss of IQ points, attention deficits, anemia, and, on rare occasions, death. Part III, the final article in this discussion, will outline specific clinical guidelines for managing children with elevated blood levels.

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