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Lead Exposure in Children: Failure to Protect the Most Vulnerable

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ABBREVIATIONS BLLs, blood lead levels; CDC, Centers for Disease Control and Prevention; CNS, central nervous system

KEYWORDS chelation; children; lead exposure; neurotoxicity; primary prevention

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Children's exposure to sources of lead contamination continues to be an important public health concern. Lead has no biological role in the body, and any detectable lead level is abnormal. The knowledge that lead exposure results in adverse health effects in children and adults has been well documented, even as early as the late 19th century.[1] Despite this, lead continued to be placed in products for over a century more. In some instances, such as with paint, lead was purposefully added and marketed with this knowledge. Lead has also been known to be a contaminant in many other products including foods marketed to children.[2] The extensive use of lead has resulted in its ubiquitous presence in the environment.

While most children with elevated blood lead levels (BLLs) today are contaminated through exposure to lead-laden dust and paint chips from deteriorating lead paint on interior surfaces, other sources are found that result in the adverse effects from lead. Soil is the second most common source of lead in that lead was used in gasoline, which contaminated the soil. This is important because children spend time outside and may be exposed if playing in bare areas of the lawn. Water continues to be a source of lead exposure as evidenced by the contamination of the drinking water sources in Flint, Michigan. As a result, the incidence of elevated BLLs increased in children younger than 5 years.[3] Other sources that have resulted in elevated BLLs include spices from outside of the United States, lead paint on toys, lead in jewelry, and bullets. A minor source of lead is baby foods wherein the metal has been found in small quantities of root vegetables such as sweet potatoes and carrots.

In both adults and children, lead is primarily absorbed via the lung (inhalation) and gastrointestinal tract (ingestion). While pulmonary absorption is reasonably efficient in both age groups (about 40%), children inhale more air relative to their body size than adults, placing them at a proportionally higher risk. Children generally absorb about 40% to 50% of the lead they ingest, while adults only absorb about 10% to 15%. The gastrointestinal absorption of lead is also higher in those with iron, calcium or zinc deficiency, which is more common in young children than in adults.[4]

Once lead is absorbed, it binds to red blood cells and distributes into 2 major compartments: the bone and the soft tissues. The soft tissue component includes the liver, kidneys, bone marrow, and the brain. Soft tissues are relatively labile compared with bone. In children, 70% of the body burden of lead storage is in bone, whereas in adults, up to 95% is stored in bone. Because 30% is stored in metabolically active sites, children are at greater risk of developing manifestations of lead toxicity.

Even at low BLLs, lead can affect various organ systems, including the central and peripheral nervous system, heme biosynthetic pathway, and the renal system. The primary target organ is the central nervous system (CNS), especially the brain. While the mechanism by which lead results in neurotoxicity has not been fully elucidated, much of the evidence points to ionic mimicry with other divalent cations, namely, iron and calcium.[5,6] Both iron and calcium are critical ions that have multiple functions throughout the body, including the nervous system.

Lead is not metabolized in the body but is excreted unchanged in the urine and bile. Depending on the amount of lead absorbed and length of time of exposure, the time it takes for lead to be removed from the body changes. An acute (one-time) exposure of lead will result in lead binding to red blood cells where the half-life is within 1 to 4 weeks in a child. With continued exposure, the lead will distribute into soft tissues including the brain where it takes months for it to equilibrate back into the bloodstream for removal. Lastly, with prolonged exposure, the lead is deposited into the bone with an elimination half-life of up to 10 years. Thus, children with prolonged exposure (months to years) may have elevated BLLs for years after the exposure has ended.

Unfortunately, the BLL is a poor biomarker for the total body burden of lead. It is a measurement of what the lead level is in the blood at that point in time. It is not a direct correlation with how much lead is in the soft tissues (e.g., brain) or bone. BLLs are obtained by capillary (finger stick) or venous blood draws. The capillary blood draw is a screening test used by clinicians to determine if a child is at risk for lead poisoning. If the BLL is elevated by a capillary draw, the child should be sent for a confirmatory test by a venous stick.

Interpretation of BLLs should be done cautiously.[7,8] For the last several decades, the Centers for Disease Control and Prevention (CDC) has updated the information regarding the toxicity of lead. It is currently recognized that there is no known safe lead level as compared with prior to 2012 when the "action level" was 10 mcg/dL. Unfortunately, laboratory recommendations have not changed and continue to use "old" terminology of *lead poisoning* based on elevated BLLs. Rather than using the recommendations of the laboratory reports regarding levels previously considered safe, clinicians should be referred to the American Academy of Pediatrics[9] or the CDC.

Although much less prevalent now, children may present with acute signs and symptoms of lead poisoning. The most serious symptoms are found in the CNS and depend on the acuity and total exposure to lead. Neurotoxicity has long been known to occur at BLLs above 10 mcg/dL. However, recent evidence suggests that lower BLLs (e.g., below 5 to 10 mcg/dL) over a prolonged period can result in subtle effects including decreased IQ, problems with attention and impulsivity, and impairments in verbal processing and nonverbal reasoning.[4,10] Additionally, low BLLs in infancy and toddlerhood have been associated with learning disabilities and behavioral concerns later in childhood and even into adulthood.

At BLLs above 30 mcg/dL, early complaints can include headache, abdominal pain, loss of appetite, or constipation; these symptoms may be misdiagnosed. At BLLs above 70 mcg/dL, the risk for CNS involvement increases and may be, acutely, severe. Usually at BLLs above 100 mcg/dL, more severe symptoms such as clumsiness, agitation, decreased activity, or somnolence may rapidly progress to vomiting, encephalopathy, and seizures. These severe symptoms can rarely occur at BLLs below 100 mcg/dL. Symptomatic lead poisoning, as this implies, should be treated as an emergency.

Treatment of children with elevated BLLs has, largely, been through secondary and tertiary prevention. Secondary prevention is the identification and management of individual children with increased BLLs, after exposure has already resulted in elevated BLLs with potentially harmful impacts on the CNS.[11] Secondary prevention involves obtaining a blood sample from children at high risk for lead exposure. Once lead is found in the child, it is only at that time that the source of lead is determined and properly removed to prevent further exposure. Thus, the child has already been harmed by the lead exposure, and it is only the ongoing exposure that is the focus of this "treatment."

Tertiary prevention prevents further complications in children with known elevated BLLs. It involves removing the source of lead from the child's environment (secondary prevention), but it also includes pharmacologic therapy for those children with higher BLLs (e.g., greater than 45 mcg/dL) or those that are symptomatic. Chelation therapy removes lead from the blood and soft tissues but will not directly remove lead from the bone or CNS (owing to the blood brain barrier). Like secondary prevention, the child has already had harm from lead exposure. Chelation therapy is used to treat the acute symptoms of high BLLs but may not address the neurocognitive effects that occur chronically.

The availability of chelation treatment is imperative in the acute treatment of children with high BLLs. While not encountered as frequently as in the past decades, there are those who present with symptomatic "lead poisoning" who require immediate treatment with chelation therapy. As Whitledge et al[11] have documented, the issue of drug shortages has also affected chelation therapy for these children. Few chelation medications are available in the United States, and concurrent shortages occurred, preventing appropriate emergency care for children.

However, it cannot be emphasized enough that no safe BLL in children has been found. There are no effective treatments to counter the neurodevelopmental toxicity of lead exposure. Thus, primary prevention should be an essential public health imperative. Traditional primary prevention strategies include the removal of lead-based paint from a family's home before the child moves in. It includes planting grass in parks and backyards. It includes testing water before it is used to make bottles for babies.

By far, most children who are exposed to lead are asymptomatic acutely but are at risk for the adverse neurodevelopmental effects as they age into adolescence and adulthood. This occurs at BLLs much lower than what was considered safe decades ago. While the reliance of chelation therapy is necessary for the treatment of elevated BLLs, the focus should not be on treatment after the exposure. Primary prevention of lead exposure is imperative in eliminating the harm that lead has on children's brains.

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