Lead Poisoning in Children

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The prevalence and severity of childhood lead poisoning have been greatly reduced since the removal of lead from paint and gasoline in the 1970s. Despite these efforts, approximately 310,000 U.S. children younger than five years have elevated blood lead levels. Health care professionals should perform targeted screening for lead poisoning in children who are Medicaid-enrolled or -eligible, foreign born, or identified as high risk by the Centers for Disease Control and Prevention (CDC) location-specific recommendations or by a personal risk questionnaire. Venous sampling is the preferred method for measuring blood lead levels, but a carefully collected finger-stick sample is an acceptable alternative. Capillary samples of elevated levels should be confirmed by a venous sample. The CDC recommends that the threshold for follow-up and intervention of lead poisoning be a blood lead level of 10 µg per dL or higher. Recommendations for treatment of elevated blood levels include a thorough environmental investigation, laboratory testing when appropriate, iron supplementation for iron-deficient children, and chelation therapy for blood lead levels of 45 µg per dL or more. Prevention consists of education and avoidance of lead-contaminated products. (*Am Fam Physician*. 2010;81(6):751-757, 759-760. Copyright © 2010 American Academy of Family Physicians.)

▶ **Patient information:** A handout on lead poisoning in children, written by the authors of this article, is provided on page 759.

Lead is a metal that has been redistributed in the environment as a result of human activities over thousands of years. It has been used in construction, for decoration, and even as a food additive. It also has been a known health risk for centuries. Hippocrates is thought to have written the first case report of lead poisoning in 600 BC. The Romans also were aware of the toxicity of lead, with Pliny, Paulus Aegineta, and Vesuvius all commenting on its effects.[1]

There are no signs and symptoms specific to lead poisoning, making identification based solely on patient history and physical examination difficult. Symptoms that do occur are vague and commonly encountered in daily practice. These can include gastrointestinal issues (e.g., abdominal pain, constipation, nausea, vomiting), decreased growth in height, delayed sexual maturation, increased dental caries, and impaired neurologic development (e.g., behavioral changes, mental impairment, seizures, coma).[2,3]

In the United States, an estimated 310,000 children younger than five years have elevated blood lead levels.[4] Primary preventive strategies such as eliminating lead as an additive from paint and gasoline have resulted in lower blood lead levels among U.S. children.

Definitions

The Centers for Disease Control and Prevention (CDC) currently designates a blood lead level of 10 µg per dL (0.48 µmol per L) or higher as abnormal and requiring follow-up and intervention.[4] Even blood lead levels lower than 10 µg per dL can affect cognitive development.[2,5] Thus, a current dilemma is the nearly impossible task of eliminating all lead exposure in children. For physicians, identifying children at high risk; eliminating exposure to known sources of lead; and ensuring adequate nutrition, including preventing and correcting iron deficiency, are key strategies in the care of all children.

Sources of Lead

Table 1 lists common sources of lead to be avoided.[3,6,7] Lead poisoning in children is usually caused by exposure to dust and paint chips from interior surfaces of homes with deteriorating lead-based paint.[6,8] The U.S. Consumer Product Safety Commission (http://www.cpsc.gov/) and the CDC (http://www.cdc.gov/nceh/lead/Recalls/default.htm) post recalls of products containing lead. Dust and soil have been contaminated by decades of deposition of airborne lead from leaded gasoline and lead-based paint. Children playing on bare

SORT: KEY RECOMMENDATIONS FOR PRACTICE

Clinical recommendation	*Evidence rating*	*References*
Targeted screening for elevated blood lead levels should be performed in children at one and two years of age who are Medicaid-enrolled or -eligible.	C	6, 8
Targeted screening for elevated blood lead levels should be performed in all children deemed to be at risk.	C	6
All foreign-born children, such as recent immigrants, refugees, and international adoptees, should be screened for elevated blood lead levels immediately on arrival in the United States.	C	6, 16-19
Measurement of blood lead level with a carefully collected finger-stick sample is an acceptable alternative to a venous sample.	C	6, 8, 23-25
Elevated blood lead levels from capillary samples should be confirmed by a venous sample.	C	26
Chelation therapy is recommended only for blood lead levels of 45 µg per dL (2.17 µmol per L) or greater.	C	3, 27, 31-33
Iron supplementation improves blood lead levels in anemic, iron-depleted children.	C	41, 42

A = consistent, good-quality patient-oriented evidence; B = inconsistent or limited-quality patient-oriented evidence; C = consensus, disease-oriented evidence, usual practice, expert opinion, or case series. For information about the SORT evidence rating system, go to http://www.aafp.org/afpsort.xml.

contaminated soil have demonstrated elevated blood lead levels.[3] Traditional remedies and certain cultural items, such as folk herbal remedies or cosmetics imported from Asia, the Middle East, Africa, or Mexico, are other common sources.[8] Because lead crosses the placenta, mothers can be a source of exposure for infants in utero.[9] Less common sources include contaminated drinking water, imported food in soldered cans, imported chocolate and candy, ceramic pottery, and blood transfusions.[6,7]

Children at Risk

Effective screening programs for lead poisoning depend on identifying children who are at risk because of their physical and social environment. Race and ethnicity have been linked to higher rates of lead poisoning, with non-Hispanic blacks and Mexican Americans being at higher risk than non-Hispanic whites.[7,10-12] Children from households below the federal poverty level are also more likely to have elevated blood lead levels,

Table 1. Common Sources of Lead

- Dust containing lead from renovations or remodeling
- Folk remedies
  - Ayurvedic medicine (traditional medicine from Tibet)
  - Azarcon (bright orange powder thought to be medicinal)
  - Ba-Baw-San (Chinese herbal medicine used for colic)
  - Bint Al Zahab (Iranian powder mixed with honey and butter for colic)
  - Bint Dahab (Saudi Arabian yellow powder used as a home remedy)
  - Bokhoor (Kuwaiti fumes from wood and lead used to calm infants)
  - Ghasard (brown powder to aid in digestion)
  - Greta (Mexican yellow powder to treat gastrointestinal distress)
  - Jin Bu Huan (Chinese herbal medicinal pain reliever)
  - Pay-loo-ah (Vietnamese red powder to treat fever or rash)
  - Po Ying Tan (Chinese herbal medicine)
  - Santrinj (Saudi Arabian red powder used for teething)
  - Saudi traditional medicine (orange powder for teething)
  - Surma (Indian black powder used for teething)
  - Tibetan herbal vitamin (used for brain health)
- Imported candy
- Imported cosmetics
  - Eye cosmetics from Pakistan
  - Kohl (a type of eyeliner from India, the Middle East, and Africa)
  - Surma (powder applied to the eyes, from India)
- Imported jewelry
- Imported toys
- Paint chips from lead-based paint
- Pottery and ceramics
- Soil contaminated with lead
- Take-home exposures (based on occupation of parents/family members)
  - Battery reclamation workers
  - Ceramics workers
  - Construction workers
  - Furniture refinishers
  - Radiator repair workers
- Tea kettles
- Vinyl mini blinds
- Water contaminated by lead leaching from pipes, solder, valves, fixtures

Information from references 3, 6, and 7.

independent of housing age.[13] Others at risk include those whose home is located in a zip code with a high prevalence of lead poisoning, or areas identified by state or local guidelines.[14] Finally, risk can be identified through a short personal risk questionnaire[8,15] *(Table 2*[6,8,14-19]*)*.

Initial Screening

Most children with elevated blood lead levels are asymptomatic; therefore, the decision for routine screening should not be based on signs or symptoms of lead poisoning. The CDC and the American Academy of Pediatrics (AAP) recommend targeted screening of all Medicaid-enrolled and -eligible children, as well as those who were born outside of the United States[6,8,16-21] *(Table 2*[6,8,14-19]*)*. This is a change from the universal screening used before 1997 because most children with elevated blood lead levels have since been identified by a national survey as Medicaid-enrolled or -eligible.[4,6,20,22] The Advisory Committee on Childhood Lead Poisoning Prevention recommends that all children enrolled in Medicaid be screened for elevated blood lead levels at 12 and 24 months of age or at 36 to 72 months of age if they have not previously been screened.[8,20]

This recommendation also applies to all children deemed to be at risk (as described above), and screening at one year of age should be performed regardless of health insurance status in these children.[6] Screening of blood lead levels should be repeated at two years of age even if the level at one year is not elevated, because a low blood concentration in a one-year-old child does not preclude elevation later.[6] Foreign-born children should be screened as soon as they arrive in the United States, because studies have shown a high prevalence of elevated blood lead levels in immigrants, refugees, and international adoptees.[6,16-21]

The number needed to screen (NNS) depends on the prevalence of elevated blood lead levels. Because the prevalence varies by location, an overall NNS cannot be calculated. Physicians should refer to the CDC Web site (http://www.cdc.gov/nceh/lead/data/state.htm) for state- and county-specific prevalence data and screening policies to guide screening decisions for children who are not eligible for Medicaid.[14]

Table 2. Lead Poisoning Screening Criteria

Screen children who meet any of the following criteria:
All Medicaid-enrolled or -eligible children at one and two years of age
All children who are identified as high risk based on results of a personal risk questionnaire (if one of the following questions is answered "Yes" or "Don't know"):
Does your child live in or regularly visit a house that was built before 1950 (this could apply to a home day care center or the home of a babysitter or relative)?
Does your child live in or regularly visit a house built before 1978 with recent or ongoing renovations or remodeling (i.e., within the past six months)?
Does your child have a sibling or playmate who has or has had lead poisoning?
All refugees, recent immigrants, and international adoptees on arrival in the United States; repeat screening three to six months later for children six months to six years of age
All children who are identified to be at increased risk by the CDC's state or local screening recommendations (i.e., high-risk zip codes)
In the absence of recommendations from the CDC, screen all children at one and two years of age, and screen children 36 to 72 months of age who have not been previously screened

CDC = Centers for Disease Control and Prevention.

Information from references 6, 8, and 14 through 19.

Diagnosis

Venous sampling is the best method for assessing the level of lead in the blood because it limits cutaneous contamination; a carefully collected finger-stick sample is an acceptable alternative.[6,8,23-25] If finger-stick screening is used, any elevated blood lead level should be confirmed by a venous sample.[26] Laboratories that perform blood lead testing are required to meet federal proficiency standards with an error range of ± 4 μg per dL (0.19 μmol per L) or ± 10 percent, whichever is greater.[8,26] As a result, a blood lead level of 8 μg per dL (0.39 μmol per L) could be reported as any value ranging from 4 to 12 μg per dL (0.19 to 0.58 μmol per L) and remain within the range of the proficiency standards.

Management of Elevated Blood Lead Levels

HIGH LEVELS

Chelation therapy is recommended by the CDC for blood lead levels of 45 μg per dL (2.17 μmol per L) or greater.[3,27] The CDC recommends consulting an expert such as a toxicologist before starting chelation therapy.[3] A complete blood count; reticulocyte count; urinalysis; and testing of electrolytes, blood urea nitrogen, creatinine, and liver function should be performed and any iron deficiency should be identified.[3,28] Abdominal radiography can identify any materials containing lead that remain in the gut.[3,28] Enemas such as mineral oil, polyelectrolyte solutions, milk and molasses, and hypertonic

Table 3. Summary of Recommendations for Children with Confirmed (Venous) Elevated Blood Lead Levels

	Blood lead level (µg per dL [µmol per L])		
Intervention	*10 to 14 (0.48 to 0.68)*	*15 to 19 (0.72 to 0.92)*	*20 to 44 (0.97 to 2.13)*
Education	Diet, environment	Diet, environment	Diet, environment
Actions and interventions	Education only	Repeat measurement of blood lead levels in three months If repeat levels are still in this range or higher, proceed to actions and interventions for 20 to 44 µg per dL If repeat levels are less than 15 µg per dL, perform education only at this time	Complete history and physical examination Laboratory testing (hemoglobin, hematocrit, iron status) Abdominal radiography (if particulate ingestion is suspected) with bowel decontamination (if indicated) Environmental investigation Lead hazard reduction
Initial follow-up blood lead monitoring (first two to four tests after first high level)	Three months	One to three months	Two weeks to one month
Late follow-up blood lead monitoring (after levels begin to decline)	Six to nine months	Three to six months	One month
Additional monitoring	—	—	Developmental monitoring

Adapted from Centers for Disease Control and Prevention. Managing Elevated Blood Lead Levels Among Young Children: Recommendations from the Advisory Committee on Childhood Lead Poisoning Prevention. Atlanta, Ga.: CDC; March 2002. http://www.cdc.gov/nceh/lead/CaseManagement/caseManage_main.htm. Accessed January 13, 2009.

phosphate can then be used to eliminate these sources of additional lead absorption.[28]

Chelation therapy is usually done with succimer (Chemet), but dimercaprol (Bal in oil) can also be used. Succimer is preferred because it can be administered orally and is better tolerated. Children treated with chelating agents should be monitored closely during and after treatment.[3] Further information on dosing, side effects, and monitoring can be found in resources such as *The Harriet Lane Handbook*[28] or a pharmacopeia.[29,30] Additionally, an environmental investigation to identify and remediate the source of the lead should be performed in collaboration with the local health department.[3,28] Remediation measures include removing the child from the source of lead, correcting the source of lead by home renovation or cleaning, and avoiding any sources of lead such as contaminated soil or products.

Children with levels higher than 70 µg per dL (3.38 µmol per L) should be hospitalized immediately for treatment under direct medical supervision.[3]

MODERATE LEVELS

If a child's blood lead level is measured as greater than 20 µg per dL (0.97 µmol per L) once, or greater than 15 µg per dL (0.72 µmol per L) twice, environmental investigation, including a home inspection, should be conducted.[3] Children with levels below 45 µg per dL who are treated with chelation do not demonstrate measurable differences in neurologic, behavioral, and cognitive developmental outcomes.[3,31,32] In addition, succimer chelation may actually be harmful in these children. The Treatment of Lead-Exposed Children trial demonstrated a decrease in the rate of growth in height between children treated with succimer and those who received placebo.[33] Thus, chelation is not recommended for this group of children.

As in the group with high levels of blood lead, children with moderate levels should have confirmatory venous sampling and abdominal radiography to identify lead-containing particles. Additional laboratory testing includes hemoglobin, hematocrit, and iron studies. *Table 3* outlines education and follow-up measures.[3]

LOW LEVELS

For children with a blood lead level of less than 10 µg per dL, providing basic nutritional and environmental education to parents may be of benefit, although the true effectiveness is unknown.[6] Identifying and treating iron deficiency are important in decreasing a child's vulnerability to lead (see Iron Supplementation). The ultimate goal is to maintain the child's blood lead level as low as possible because of evidence that levels of less than 10 µg per dL still pose a risk of damage to the child's neurologic development as mentioned previously.[3,26]

45 to 69 (2.17 to 3.33)	*> 70 (3.38)*
Diet, environment	Diet, environment
Chelation therapy All actions and interventions as indicated for 20 to 44 µg per dL	*Hospitalize immediately* and begin chelation therapy All actions and interventions as indicated for 45 to 69 µg per dL
As soon as possible	As soon as possible
During/after chelation	During/after chelation
Developmental monitoring	Developmental monitoring

Prevention

The goal of the CDC's Healthy People 2010 program is to eliminate elevated blood lead levels in children at national, state, and local levels.[3] Preventive strategies become essential in decreasing the environmental burden of lead and in identifying children with elevated blood lead levels early.

PRIMARY PREVENTION

Primary prevention is defined as interventions that prevent a disease or illness before it occurs. Primary prevention of lead poisoning in children includes strategies such as eliminating lead in gasoline and paint, which have had a positive effect in lowering blood lead levels in U.S. children.[34]

SECONDARY PREVENTION

Because lead is ubiquitous in our environment, secondary prevention focuses on identifying asymptomatic children with high levels of lead in their blood. For children with elevated levels, once the source is identified, the lead hazard should be evaluated, treated, and monitored by a safe-lead authority (often private firms specialize in this and can be identified by the local health department). Follow-up is important to prevent the cycle of inadequately treated housing exposing additional children who subsequently live in the residence.[3]

Other measures of prevention that have been studied include parental education, dust control, and soil abatement. Educating parents and caregivers about the prevention of lead exposure does not have a notable effect on reducing already elevated lead levels in children.[35] Dust control is not effective when performed by parents and families.[35,36] However, if dust control is done by cleaning professionals, there may be the beneficial effect of lowering both environmental and blood lead levels. It is unknown whether this intervention leads to any clinical behavioral or cognitive improvement.[37] Soil abatement, which involves removing contaminated soil and replacing it with fresh soil, has an unknown effect because of high variation among studies.[35]

Iron Supplementation

Several studies published within the past 10 years found an association between low iron levels and elevated blood lead levels in infants and children.[38-40] Recent studies suggest that iron therapy may lower blood lead levels in both anemic and non-anemic children.[41,42] Findings of these studies support the theory that a lack of iron may increase a child's susceptibility to lead poisoning.[43,44] However, other studies have found that iron supplementation did not decrease lead levels in children without iron deficiency.[43] The CDC currently recommends testing all children with elevated blood lead levels for iron deficiency and correcting the deficiency.[3] Based on current evidence, the CDC does not recommend placing all at-risk children on an iron supplementation regimen but does generally recommend an iron-rich diet for all children.[3]

Role of the Family Physician

If a child's screening blood lead level is greater than 10 µg per dL, the family physician is encouraged to perform a detailed interview looking for potential sources of lead exposure.[3] Physicians who do not feel comfortable taking a detailed lead history or providing the family with counseling should contact their local health department for assistance. The quest for sources of exposure must include the home, school, day care facility, or any place where the child spends a large amount of time. Additionally, parents and caregivers should be educated about the risks of lead exposure.[3] For children with moderate to high blood levels, a referral to the local health department to identify a case manager is essential.[3] Physicians may be the primary providers of developmental monitoring for children exposed to lead. The AAP and the Commonwealth Fund have published useful tools for developmental monitoring.[44,45]

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