Lead exposure and poisoning in adults

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INTRODUCTION

Acute lead poisoning can present with severe symptoms of toxicity or with nonspecific signs and symptoms, depending in part on how much lead has been absorbed. In addition, chronic exposure to modest or even low levels of lead may produce no symptoms but increase the risks for long-term development of adverse health outcomes.

The consequences of lead exposure may be reduced by taking an occupational and environmental health history, recognizing the early symptoms of elevated blood lead levels (BLL) and lead poisoning, having a low threshold for suspecting asymptomatic lead exposure based on an occupational and environmental history or medical findings, and checking BLL in such cases to verify the diagnosis and provide appropriate advice and treatment. (See "Overview of occupational and environmental health", section on 'Occupational and environmental history'.)

This topic will focus on lead exposure and poisoning in non-pregnant adults.

Lead exposure in pregnant adults and during breast feeding are described separately:

- (See "Occupational and environmental risks to reproduction in females: Specific exposures and impact", section on 'Lead'.)
- (See "Childhood lead poisoning: Exposure and prevention", section on 'Breastfeeding'.)

Lead poisoning in children is described separately:

- (See "Childhood lead poisoning: Exposure and prevention".)
- (See "Childhood lead poisoning: Clinical manifestations and diagnosis".)
- (See "Childhood lead poisoning: Management".)

DEFINITIONS

A blood lead level (BLL) remains the mainstay for assessing an individual's exposure to lead. However, ascribing a specific numeric BLL as a definition of adult lead toxicity is evolving, as research continues to identify adverse health effects in association with lower levels of adult lead exposure.

In keeping with current practice by the US Centers for Disease Control and Prevention (CDC) [1], we use these terms:

- **Adult lead toxicity** – Mean BLL ≥10 mcg/dL, although there is evidence that chronic lead exposure below 10 mcg/dL may carry risks.
- **Adult lead poisoning** – Adult lead toxicity accompanied by symptoms or signs. In pregnant women, some experts might identify lead poisoning even in the absence of symptoms or signs. (See "Occupational and environmental risks to reproduction in females: Specific exposures and impact", section on 'Lead'.)
- **Elevated BLL** – The case definition for an elevated BLL for an adult is now defined as ≥5 mcg/dL by the National Institute for Occupational Safety and Health (NIOSH)/CDC's Adult Blood Lead Epidemiology and Surveillance (ABLES) program [1].

  The reference BLL was lowered from the previous level of >10 mcg/dL (0.48 micromol/L), and, prior to that, ≥25 mcg/dL (1.21 micromol/L), based upon declining population BLLs to a mean adult population level of 0.92 mcg per deciliter (years 2015 to 2016) [2].
- **Goal BLL** – The US Department of Health and Human Services recommends that BLLs among all adults be reduced to <10 mcg/dL, which is consistent with the current lower levels in the population as well as research concerning long-term effects of low level exposures [1,3]. The US Occupational Health and Safety Administration's (OSHA) standard for lead exposure, which allows workers to continue working in a leaded environment with BLL of 40 mcg/dL, is widely recognized as out of date and not adequately protective of health [4]. (See 'OSHA and other governmental lead regulations' below.)

EPIDEMIOLOGY

The full extent of adult lead poisoning and toxicity is difficult to ascertain because of limited data; existing data and research findings suggest that it remains an important environmental and public health problem even if population levels are decreasing [3,5-7]. In 2016, the estimated prevalence of BLL ≥10 mcg/dL was 16 per 100,000 employed adults according to the US Centers for Disease Control and Prevention (CDC) Adult Blood Lead Epidemiology and Surveillance (ABLES)

program, which monitors laboratory-reported elevated BLL among employed adults in 26 states [8].

The prevalence of elevated lead levels is decreasing in the United States [8,9]. The prevalence of BLL ≥25 mcg/dL decreased from 14 to 2.8 per 100,000 employed adults from 1994 to 2016 [8]. There were also decreases in the percentage of adults with BLL ≥10 mcg/dL, from 3.1 to 0.7 percent for ages 20 to 59 years and from 6.5 to 0.7 percent for ages >60 years between 1991 and 1994 and between 1999 and 2002 [10].

The background mean BLL in the adult population is now <2 mcg/dL. Available data from the United States National Health and Nutrition Examination Survey (NHANES) showed that, from 2015 to 2016, average adult BLL was 0.92 mcg/dL and the 95th percentile BLL was 2.89 mcg/dL, with higher levels among adult males than females [2].

LEAD SOURCES AND ABSORPTION

Sources of exposure — Among adults, the majority of lead exposure occurs in the workplace [9,11]. However, there are many other sources of exposure, including the home environment, hobbies, environmental exposure, and unintentional oral ingestion of material contaminated with lead (table 1).

Sources of exposure to lead include:

- **Workplace exposure** – Workplace exposure to lead can occur in numerous settings, including work that involves batteries, pigments or paint, paper-hanging, lead and ore mining, smelting and refining, welding, soldering, ammunitions, car radiators, cable and wires, construction and demolition, some cosmetics, ceramics with lead glazes, plumbing, and tin cans [11].

- **Paint** – Lead paint exposure can occur occupationally or in the residence [12]. The lead content of paint was unregulated in the United States until 1977, so lead paint is widely dispersed in homes as well as on five billion square feet of nonresidential surfaces in the United States (eg, most steel bridges) [13]. Construction workers, residents (especially children), and do-it-yourself home renovators in lead-painted homes can also sustain heavy exposure to lead [13,14]. There are also rare situations of lead poisoning occurring with adults and autistic older children with pica, who eat lead paint or soil [15,16]. Lead from paint also increases soil lead levels when natural disasters (eg, hurricanes) destroy homes [17].

- **Gasoline** – Formerly, most lead in the air originated from automobile exhaust. The introduction of lead-free gasoline in the 1980s contributed to a 99 percent decrease in air lead levels in the United States and consequently a decrease in average blood lead levels (BLL) [18,19]. Use of leaded gasoline has declined worldwide, particularly in industrialized

countries, but it is still used in aviation, racing cars, and, in some countries, conventional automobiles.

- **Bullets** – Leaded bullets can lead to lead toxicity through a variety of mechanisms. At firing ranges, exposure occurs due to dust generated from use of leaded bullets [20-22]. Leaching from bullets also raises lead levels in those who consume wild game hunted using lead bullets [23] and in people who have ongoing lead exposure due to retained bullet fragments [24,25].

- **Drinking water** – Water can be contaminated with lead during its passage through lead or lead-soldered pipes. For most adults, drinking water with mild elevations above the United States Environmental Protection Agency (EPA) action level of 15 parts per billion (15 mcg/L) for lead may not contribute much to their overall BLL [26]. However, adults who repair or remove older leaded pipes (eg, plumbers, construction workers) may encounter considerable lead exposure. Additional information about lead in drinking water is described separately. (See "Childhood lead poisoning: Exposure and prevention", section on 'Water'.)

- **Cosmetics and personal care products** – These sometimes contain lead that can cause toxicity. As an example, litargirio (also known as litharge or lead monoxide), a lead-based powder used particularly by people in some communities as an antiperspirant/deodorant, foot fungicide, burn/wound healing treatment, or for other purposes as a traditional remedy [27]; and tiro, an eye cosmetic from Nigeria [28], have caused lead toxicity.

- **Illegally distilled alcohol ("moonshine")** – Sometimes made in stills with lead-containing solder, moonshine liquor can expose drinkers to lead. In one study among drinkers of moonshine compared with nondrinkers, the median BLL was higher (11.0 versus 2.5 mcg/dL [0.53 versus 0.12 micromol/L]), and the percentage of patients with BLL ≥25 mcg/dL (1.21 micromol/L) was higher (26 versus 0 percent) [29].

- **Herbal supplements** – In one study, BLL was 10 percent higher among women who used herbal supplements than among those who were non-users, although mean BLL was low in both men and women users (<2.0 mcg/dL [0.97 micromol/L]) [30]. BLL was also found to be higher among women reporting use of Ayurvedic [31] and/or traditional Chinese medicine herbs, as well as St. John's wort, compared with non-users [32-34].

- **Others** – Lead exposure can occur with other exposures as well [35,36]. These include use of lead-glazed tableware or cookware to cook or when consuming food [35,37] and use of oral radiographic film that was stored in lead-lined boxes, where lead dust deposited on the film resulted in lead exposure during a dental radiograph [38]. Lead has also been found as an adulterant in marijuana [39], candy [40], lipstick [41], contaminated opium [42], and other consumer products.

Living near a major source of occupational lead exposure can cause lead toxicity. For example, mass lead intoxication has been reported among people living around lead battery manufacturing and recycling plants or artisanal gold mines, particularly in low-income countries [43-47].

The Agency for Toxic Substances and Disease Registry and the United States EPA maintain lists of sources of lead exposure (including the home environment).

Lead absorption and distribution — Lead is absorbed into the body through the lungs, gastrointestinal tract, and to a lesser extent, the skin (figure 1).

- The respiratory tract is the most significant route of lead absorption in adults, with an average absorption rate of approximately 50 percent [20]. Respiratory exposures can occur with activities such as scraping, sanding, or burning leaded paint from surfaces as well as with various smelting/burning/welding processes.

- The gastrointestinal (GI) tract is not the major route of absorption for adults, but can be a significant contributor, particularly for those working or eating in a lead-contaminated environment. GI absorption of lead in adults is typically <8 to 10 percent, however absorption increases during fasting and with diets deficient in calcium, iron, phosphorous, or zinc. In contrast to adults, the GI tract is the predominant absorption route in children with absorption of about 50 percent [20] (see "Childhood lead poisoning: Exposure and prevention", section on 'Exposure')

- Skin absorption is not a common route of absorption among adults and typically occurs only with exposure to organic lead in the workplace (eg, organic tetraethyl lead in gasoline).

After absorption, lead is distributed to the blood, soft tissues, and bones (figure 1). One percent of blood lead is free in plasma to exchange with soft tissues (eg, kidney, brain, liver, bone marrow) and cross the placenta. In blood, 99 percent of lead is bound to heme in the erythrocyte.

Lead in blood is excreted via the kidneys and cleared fairly quickly, with a mean half-life of about 30 days if renal function is normal [48]. However, blood clearance can be slower in people with a long history of lead exposure that results in large bone stores of lead that serve as a reservoir that leaches lead into the blood over time [49].

Bones contain up to 95 percent of the body burden of lead, with a half-life of decades [48]. However, lead can be released from the bone reservoir more quickly during times of accelerated bone turnover that occur, for example, with hyperthyroidism [50], bone fracture, immobilization, menopause, pregnancy [51,52], or breast feeding [53].

CLINICAL MANIFESTATIONS

Lead is a toxic metal that adversely affects many physiologic functions and organ systems through multiple biochemical mechanisms [3,4,11,20,54]. Exposure produces adverse effects over a few weeks of exposure as well as over an extended duration. Some of the toxic effects of lead (such as lead colic and anemia) are reversible if lead poisoning is identified early and managed effectively. However, high levels of lead or moderate levels over long periods can result in irreversible damage to the central and peripheral nervous systems, kidneys, and other organs [4,11,20,55].

These exposure effects are summarized in the table (table 2) and discussed in the sections below.

Acute and subacate exposure symptoms — Symptoms of lead poisoning can occur with days to weeks of sustained high lead exposure. There is a general correlation between health effects and blood lead levels (BLL), as show in the table (table 2). However, manifestations of lead toxicity vary from individual to individual. Also, symptoms are often nonspecific, making it difficult to identify lead as the etiology and emphasizing the importance of history taking to identify potential sources of lead exposure (table 1). (See 'Sources of exposure' above.)

Symptoms are most likely to occur with BLL >80 mcg/dL (3.86 micromol/L). With BLL 40 to 80 mcg/dL, the symptoms are less severe and present to a more variable degree. Adults with BLL <40 mcg/dL are usually asymptomatic and other explanations for symptoms should be sought.

Symptoms and signs of acute lead toxicity in adults include the following [4,11,54,56-59]:

- **Gastrointestinal** – Abdominal pain ("lead colic"), constipation, anorexia.
- **Musculoskeletal** – Joint pain/arthralgia, muscle ache/myalgia.
- **General** – Excessive fatigue, sleep disturbance, decreased libido.
- **Neuropsychiatric** – Headache, difficulty concentrating, deficits in short-term memory, irritability, depression.

  Extremely high BLL (>100 mcg/dL [and more commonly >150 mcg/dL]) presents risks for more serious central nervous system effects such as encephalopathy (coma, seizures, delirium) as well as persistent cognitive impairment after recovery.
- **Hematological effects** – Anemia can occur as a subacute effect that usually reflects several months of lead exposures. While lead levels greater than 30 mcg/dL over preceding months can result in inhibition of some of the enzymes of hemoglobin synthesis, frank anemia generally develops when BLL exceed 80 mcg/dL [11,16,20,59-61]. When BLLs decline and return to normal, the hematological abnormalities typically correct. Anemia can also occur as a chronic exposure effect as discussed below.

Effects of elevated BLL on pregnancy are discussed separately. (See "Occupational and environmental risks to reproduction in females: Specific exposures and impact", section on 'Lead'.)

Chronic exposure effects — In addition to the manifestations of symptomatic acute lead poisoning, chronic prolonged elevated BLL, possibly as low as 5 to 10 mcg/dL, may have long-term effects on renal, cardiovascular [7], cognitive [62], and other functions [3,4,20]. These effects, summarized in a table (table 2), may not be reversible with lowering of lead levels.

- **Mortality** – Elevated lead levels in blood have been linked to increased mortality risk [7,63-65]. In one United States study, a BLL >10 mcg/dL was associated with increased risks of all-cause mortality (relative risk [RR] 1.59, 95% CI 1.28-1.98), death due to cardiovascular disease (RR 1.55, 95% CI 1.16-2.07), and death due to cancer (RR 1.69, 95% CI 1.14-2.52) [66]. Similar increase in cardiovascular mortality was found after correcting for hemoglobin and adjusting for other factors [67]. There is no clear threshold BLL that identifies risk; even levels >2 to 5 mcg/dL have been associated with increased mortality [7,64].

  Bone lead levels may be more closely associated with mortality risk. In a study of 868 lead-exposed men followed over nine years, a bone lead concentration in the highest tertile was associated with a higher risk of all-cause mortality (hazard ratio [HR] 2.5, 95% CI 1.2-5.4) and cardiovascular mortality (HR 5.63, 95% CI 1.7-18.3) [65].

  The increased mortality due to lead may be mediated by its effects on deoxyribonucleic acid (DNA) and ribonucleic acid (RNA) [68]. Some studies indicate that lead exposure may alter global DNA methylation [69,70]. Observational studies demonstrated an association between high lead exposure and telomere length shortening in Chinese battery manufacturing plant workers [71] and children [72]. A shortened telomere can result in genomic instability, which epidemiological investigations have linked to adverse outcomes such as decreased life expectancy, increased cancer risk, and cardiovascular diseases.

- **Neurologic/psychiatric** – Chronic (cumulative) lead exposure at a level as low as BLL 5 mcg/dL has been associated with neuropsychiatric effects. These include:

  - Declines in neurocognitive functioning [62,73-75]
  - Psychiatric symptoms (phobic anxiety, depression, and hostility) [76,77]
  - Distal motor and less commonly sensorimotor neuropathy after many years, usually of very high exposure [55]
  - Decreases in hearing acuity [78]
  - Tremor [3]
  - Brain structural changes including white matter lesions, loss of brain volume [79], and increased brain gliosis [80]

  Bone lead, which remains for decades, has been shown to be a better predictor than BLL of long-term effects on cognitive function [73,81]. In a cohort of workers followed over a 22-year period, bone lead level predicted lower cognitive performance, particularly in workers older than age 55, whereas BLL showed no association [73].

Although evidence is inconclusive, other studies found that cumulative lead exposure may increase the risk of Parkinson disease and worsen cognitive function among patients with Parkinson disease [82,83]. Whether lead increases the risk of amyotrophic lateral sclerosis (ALS) is controversial because of limitations and biases in the studies, as well as the possibility of reverse causality, because ALS decreases limb movement, leading to bone demineralization and potential release of lead [20,84]. (See "Etiology and pathogenesis of Parkinson disease", section on 'Risk factors' and "Epidemiology and pathogenesis of amyotrophic lateral sclerosis", section on 'Risk factors'.)

Several biochemical mechanisms may contribute to the neurotoxic effects of lead. Lead may compete with another divalent cation, calcium, in several biologic systems, such as mitochondrial respiration and various nerve functions. Lead's interference with several calcium-dependent processes has been implicated as a contributing mechanism in lead neurotoxicity and other adverse health effects [59,85]. Additionally, lead alters permeability of the blood-brain barrier and accumulates in astroglia cells essential for maintenance of the neuronal environment [86].

- **Anemia/hematologic** – Anemia can develop with subacute exposure to very high BLL, usually >80 mcg/dL as discussed above.

  In addition, other studies, including one modeling study examining the relationship between BLL and hematocrit in Taiwanese factory workers, suggest that more chronic low level exposure may be associated with increased risk of anemia [87-89].

  Lead can cause anemia by a number of processes [16,20]:

  - Lead inhibits enzymes such as delta-aminolevulinic acid dehydratase (delta-ALAD) and ferrochelatase that are critical to hemoglobin synthesis [20,59]. Inhibition of ferrochelatase inhibits the insertion of iron into the porphyrin ring and leads to creation of free erythrocyte protoporphyrin (FEP) as well as zinc protoporphyrin (ZPP) when zinc is inserted instead of iron. An excess of FEP can usually be measured in blood when BLL rises above 30 mcg/dL [59]. Lead poisoning and iron deficiency act synergistically to produce very high FEP and ZPP levels and more severe levels of microcytic anemia [16].
  - Additionally, lead causes increased red cell membrane fragility, which leads to a shorted lifespan and resultant hemolysis [16,20].
  - Some studies have also found lower levels of erythropoietin associated with elevated BLL and low hemoglobin [20] that has been attributed to lead accumulation in the proximal tubule of the kidney where cells produce erythropoietin.
  - Lead also inhibits pyrimidine 5' nucleotidase, causing degradation of ribosomal ribonucleic acid (RNA) in red blood cells that can manifest as basophilic stippling on a

peripheral blood smear. However, basophilic stippling is an inconsistent and nonspecific sign of lead poisoning (picture 1) [90,91]. (See "Evaluation of the peripheral blood smear", section on 'Basophilic stippling'.)

- **Hypertension** – There is an association between elevated lead levels and elevated blood pressure, but the magnitude of this effect is uncertain [92-97]. In a meta-analysis of studies in the general population and in individuals with occupational exposure to lead, a twofold increase in BLL was associated with a small increase in blood pressure (1.0/0.6 mmHg) [92].

  Bone lead, reflecting cumulative lead exposure, may be more closely associated than blood lead with development of hypertension [95,97]. As an example, in the Normative Aging Study, an increase from the lowest to the highest quintile of tibial lead was an independent risk factor for developing hypertension (odds ratio [OR] 1.5); however, BLL was not an independent risk factor [95,98].

  Lead may affect blood pressure by promoting generation of superoxide and hydrogen peroxide in endothelial and vascular smooth muscle cells [99].

- **Lead nephropathy** is a potential complication of prolonged high-level lead exposure. Even chronic low levels of lead exposure (ie, resulting in BLL >10 mcg/dL) have the potential for lead-related nephrotoxicity with decrease in renal function over time. This is discussed in detail separately. (See "Lead nephropathy and lead-related nephrotoxicity".)

- **Effects on sperm** have been seen in some studies of men with chronic lead exposure with BLL between 40 and 70 mcg/dL (1.93 to 3.38 micromol/L). The percent of sperm with abnormal morphology increased and there were decreases in sperm concentration, total sperm count, and total motile sperm count [100-102] as well as alterations of male endocrine function [103].

- **Other effects** – Elevated BLL and lead accumulated in bone from low-level lead exposure typically experienced by United States adults appear to be associated with increased risk of age-related diseases such as cataract formation [104], tooth loss [105], and frailty [106] as well as with nephrolithiasis [107] and gout [108]. Elevated lead levels have been associated with electrocardiographic conduction delays [109].

  Although the data are not conclusive, "lead and lead compounds" are listed as "reasonably anticipated to be human carcinogens" by the National Toxicology Program of the US Department of Health and Human Services [110]. Epidemiological studies have had mixed results regarding whether lead increases the risk of cancer, and the studies lack information about quantitative exposure, contributions from smoking, and exposures to other metals. Some animal studies have found that inorganic lead is carcinogenic, particularly for renal tumors [11,110].

Common genetic polymorphisms may predispose to worse responses to lead exposure, though study results vary. In one study, an allele for hemochromatosis (C282Y or H63D), even in heterozygous carriers not at risk for clinical hemochromatosis, was associated with worse cognitive declines given the same cumulative exposure to lead [111]. However, other studies have shown inconsistent polymorphism relationships [112,113]. Assessment of these genetic polymorphisms is not used in clinical practice.

EVALUATION

Because lead poisoning often presents with nonspecific symptoms and signs, the diagnosis must be suspected based on exposure history and other associated symptoms (eg, nonspecific abdominal pain, headache and difficulty concentrating) and signs (eg, anemia) and then confirmed by laboratory testing.

Assessing lead-related symptoms — For a patient with acute symptoms consistent with lead toxicity or organ system dysfunction that could be due to lead exposure, lead should be considered in the differential diagnosis. Such symptoms include unexplained gastrointestinal, neurologic, psychiatric, or constitutional symptoms. (See 'Acute and subacate exposure symptoms' above and 'Chronic exposure effects' above.)

In such patients, exposure to lead should be assessed during history-taking (see 'Sources of exposure' above). Specifics of any history of lead poisoning during childhood should also be obtained.

When lead poisoning is suspected, certain aspects of the physical examination may identify potential manifestations, although these findings are generally seen only with very high prolonged lead exposure (eg, with blood lead level [BLL] >60 mcg/dL) and are frequently absent even in people with BLL >60 mcg/dL. Such findings include:

- Gastrointestinal – Presence of diffuse abdominal tenderness in the absence of palpable organomegaly or mass.
- Neurologic – Behavioral and psychological disturbances (eg, irritability), memory impairment, abnormal gait and coordination, tremor, muscle weakness especially of extensor muscle groups of all extremities.
- Oral mucosa – Although rarely present, there may be a Burtonian or “lead line” (bluish gingival pigmentation at the gum-tooth line due to reaction of lead with bacteria in dental plaque that causes formation of lead sulfide); however, a lead line may not be present even in severe lead poisoning if good oral hygiene is practiced (picture 2 and picture 3).

When to measure blood lead levels — A BLL should be obtained to follow up on a lead exposure history, particularly if it is ongoing or if there are associated signs or symptoms. BLL is

the key test to determine how much lead a patient has absorbed and reflects recent exposure to exogenous lead sources as well as release of endogenous lead from bone and soft tissue stores.

In many workplaces in the United States, federal or state regulations mandate that lead exposure is documented and, when air concentrations meet a certain threshold, that workers undergo surveillance BLL monitoring. (See 'OSHA and other governmental lead regulations' below.)

Other individuals who are not subject to workplace mandates but who are known to be at risk for lead exposure (eg, painters) should have BLL measured at regular intervals (eg, every one to two months during the time a painter might be scraping off old paint). Surveillance of BLL for patients found to have elevated levels is described below. (See 'Monitoring blood lead levels' below.)

BLL is used to guide management and treatment decisions. In interpreting the results and determining appropriate interventions, it is important to use levels appropriate to adults, rather than to children, which are sometimes the ranges of concern reported by testing laboratories.

For routine monitoring of occupational exposure to lead, venous blood is preferable to capillary blood because even after the skin is cleaned with an alcohol wipe, skin contamination with lead can result in false elevations in BLL measured using capillary blood [114]. Although it is still sometimes used to assess lead in children, it is not used for adults.

Additional testing — For patients with lead exposure, additional testing may be warranted to assess end-organ effects. (See 'Assessment for clinical exposure effects' below.)

In addition, measurement of erythrocyte protoporphyrin may be warranted if lead toxicity is suspected despite a BLL that is not sufficiently elevated to explain symptoms.

- **Erythrocyte protoporphyrin or zinc protoporphyrin (ZPP)** – Erythrocyte protoporphyrin, typically assayed as zinc protoporphyrin (ZPP), is no longer used for screening for lead exposure. It is sometimes mandated by regulations (eg, US Occupational Health and Safety Administration [OSHA]) or by the workplace.

  ZPP may be used to evaluate suspected lead toxicity in a patient with a BLL that is not high enough to account for the symptoms, particularly if there is suspicion that BLL may have been higher during the preceding three or four months. Lead inhibits enzymes involved in hemoglobin synthesis. With high lead levels (usually at least 30 mcg/dL), erythrocyte protoporphyrin increases because it is a hemoglobin precursor. BLL ≤25 mcg/dL typically do not inhibit the enzymes of hemoglobin synthesis sufficiently to result in much increase in ZPP. Due to the average 120-day lifespan of erythrocytes, ZPP levels can assess lead exposure over the preceding three or four months.

  If ZPP is elevated more than 1.5 above a normal value of 36 mcg/dL, lead exposure in the recent three to four months may have been higher than the current BLL indicates. However, an elevation in ZPP is not diagnostic for lead exposure, because it is also elevated in the

presence of iron deficiency anemia as well as jaundice and sickle cell anemia. If BLL is ≤25 mcg/dL and ZPP is not more than about 1.5 times above normal, the measured BLL is likely representative of the actual BLL over the past few months. Iron deficiency and lead poisoning can act synergistically to cause a very elevated ZPP and more severe microcytic anemia [16].

Other tests to assess for the presence of lead are either not as accurate as BLL or are used primarily in research, not in clinical practice.

- Measurement of lead levels in urine, hair, or other media – Measurement of lead levels in fluids or tissues other than blood is not as accurate or reliable as BLL, and does not correlate as well with adverse health effects.

- X-ray fluorescence – X-ray fluorescence (XRF) measures bone lead concentration, which reflects cumulative lead exposure, because lead has a half-life of up to 30 years in bone [115-117]. XRF is a rapid noninvasive technique and interpretation is increasingly standardized, but XRF equipment is available only in a few research centers and is used primarily for research [118,119]

  Cumulative blood lead index – In research studies, a cumulative blood lead index (CBLI), a time-weighted average of BLL measured regularly over a period of high (eg, occupational) exposure, is sometimes calculated to assess cumulative lead exposure [119]. The test is highly correlated with bone lead concentration, which has been shown to be a better predictor than BLL for the risk for several chronic diseases. CBLI tends not to be used in clinical practice because it does not influence clinical decision-making, but it arguably should be, particularly with known prolonged exposure.

- Provocative chelation – Provocative (also called “challenge”) chelation is a test in which DMSA (2,3-dimercaptosuccinic acid, succimer) or calcium disodium ethylenediaminetetraacetic acid (EDTA) chelation therapy is administered and subsequent urinary excretion of lead is compared with reference ranges calculated from urine specimens from a non-challenged normal population. This mobilization test has been proposed to indirectly measure lead body burden to determine if chelation therapy is indicated, but studies have failed to establish correlations among lead exposure, post-challenge results, and symptoms [120]. The American College of Medical Toxicology (ACMT) does not support provocative chelation [121]. However, some alternative medical practices assess “high body burden” of lead by provocative chelation and then interpret results and offer treatments that are not always based upon scientific evidence.

- Abdominal radiographs – Abdominal radiographs are generally not used to assess lead in adults because exposure is more commonly via inhalation rather than oral intake (except in occasional circumstances) that may be visualized radiographically. However, abdominal radiographs are often useful in children to look for evidence of recent oral lead ingestion and

could be used in the less common situation of suspected oral ingestion of lead by an adult. (See "Childhood lead poisoning: Clinical manifestations and diagnosis".)

INITIAL MANAGEMENT

The goals of management approaches and expert guidelines are to minimize potential short- and long-term adverse health effects of elevated blood lead levels (BLL) [1,4,20,59,122,123]. Even in the absence of symptoms, if BLL is elevated, action is needed to lower the value and to prevent acute or long-term effects of lead toxicity.

Management of patients with elevated BLL includes identification of sources of lead exposure, reduction or removal from lead exposure, and sometimes chelation treatment to reduce BLL [4]. Consultation with an occupational/environmental medicine clinician or toxicologist with experience in lead toxicity can assist in the diagnosis of lead poisoning and ongoing management.

BLL-directed treatment approach — Appropriate interventions are determined by the BLL and whether the exposure is ongoing. Thresholds for intervention may differ in pregnant women and women contemplating pregnancy. (See "Occupational and environmental risks to reproduction in females: Specific exposures and impact", section on 'Lead'.)

Recommendations regarding specific interventions depend on BLL. For nonpregnant adults, we suggest the following initial interventions, summarized below and described in more detail in the sections that follow:

- All patients with elevated BLL (>5 mcg/dL) and/or exposure to lead should undergo education regarding lead-related health risks and exposure reduction. In addition, repeat BLL should be performed for patients with elevated BLL and/or on going exposure to lead.
- For BLL >10 mcg/dL, we suggest education, exposure reduction, repeat BLL within at least three months, and assessment for lead-related health effects if BLL is persistently high.
- For BLL >20 mcg/dL, we suggest education, exposure reduction, assessment for lead-related health effects, repeat BLL in one month, and removal from workplace exposure if BLL is persistently >20 mcg/dL.
- For BLL >30 mcg/dL, we suggest removal from workplace (or other) exposure along with education, assessment for lead-related health effects, and repeat BLL in one month.
- For BLL >40 mcg/dL, we suggest prompt assessment for lead-related health effects, removal from workplace exposure, and specialist referral. Patients with symptoms or signs of lead-related toxicity may benefit from chelation therapy.

- For BLL >80 mcg/dL, we suggest prompt assessment for lead-related health effects, removal from workplace exposure, specialist referral, and chelation therapy.

Ongoing monitoring and subsequent management are described below. (See 'Subsequent management' below.)

Education and exposure reduction — For any BLL >5 mcg/dL or potential exposure, education should be provided about short- and long-term health effects of lead and about how to reduce or eliminate lead exposure. Long-term effects may occur at any chronically elevated BLL, although short-term exposure to lead with BLL <9 mcg/dL is less likely to be a risk to health [3,4,20]. These effects are summarized in a table (table 2) and described in detail above. (See 'Clinical manifestations' above.)

Actions to reduce or prevent excessive exposures include implementing practices that generate less lead dust, using engineering controls to capture the lead dust or fumes, or personal protection (eg, appropriate respirators that fit properly and protective work clothes). Appropriate hand decontamination uses wipes containing isostearamidopropyl morpholine lactate and citric acid, which are more effective at removing lead than washing with soap and water [20]. Contaminated clothing and equipment should not be brought home; such items may expose the worker further as well as pose a risk to children and others at home [124,125]. Contaminated clothing that does come home should be laundered separately. Contaminated shoes should remain outside the home. Individuals should avoid eating or smoking when in a lead environment and thoroughly clean hands prior to eating.

Retained bullet fragments embedded in tissues, particularly bone, can be a source of lead and surgical removal should be considered depending on their location. If there is suspected ingestion of lead fragments or objects (such as paint), and opacities are seen on abdominal radiograph, gastrointestinal decontamination (ingestion of cathartics) can sometimes help to decrease the lead absorption.

Assessment for clinical exposure effects — In patients with lead toxicity, further testing is useful to evaluate for end-organ effects which may suggest a more aggressive approach to management. This testing supplements findings from the history and examination as outlined above (see 'Assessing lead-related symptoms' above) and should be performed urgently in patients with BLL >40 mcg/dL. These tests are sometimes also required for baseline or surveillance for lead-exposed workers. The tests include:

- CBC to assess for anemia. If anemia is present, blood smear morphology should be assessed; lead poisoning is often associated with microcytosis and sometimes basophilic stippling. In the absence of anemia, blood smear analysis is not necessary because morphologic abnormalities associated with a high BLL are non-specific.

- Serum BUN/creatinine and urinalysis to assess for renal effects of lead. However, serum creatinine is not a sensitive indicator of renal damage, because if baseline values are normal, it does not rise substantially until kidney function is reduced >50 percent. (See "Assessment of kidney function" and "Lead nephropathy and lead-related nephrotoxicity".)

If certain neurologic symptoms are present, the following may also be indicated:

- Neuropsychological testing – While not a routine aspect of the evaluation of patients with cognitive impairment, neuropsychological testing may be appropriate for such patients in the setting of elevated BLL, as it may be more sensitive than routine bedside cognitive assessment. Neuropsychological testing may also be helpful in distinguishing adverse effects of lead exposure from other causes of cognitive dysfunction [74,126]. Neuropsychological testing can demonstrate changes in manual dexterity, perceptual motor speed, and memory deficits characteristic of lead poisoning. The evaluation of cognitive impairment is discussed separately. (See "Evaluation of cognitive impairment and dementia".)

- Nerve conduction velocity testing – Nerve conduction velocity testing may be indicated for patients with symptoms or clinical findings suggestive of peripheral neuropathy in the setting of lead exposure and may reveal suggestive findings of a lead-associated neuropathy. (See "Overview of acquired peripheral neuropathies in children", section on 'Lead'.)

Removal from workplace exposure — If BLL remains >20 mcg/dL despite efforts to improve exposure controls, the patient should be removed from working with or around lead. In addition, when BLL >30 mcg/dL, the patient should be removed from working with or around lead [4,123]. Although US Occupational Health and Safety Administration (OSHA) regulations specify a higher threshold BLL (50 mcg/dL) for removal from work exposure, OSHA also allows for medical removal at a lower level if the examining clinician believes removal is medically indicated. (See 'OSHA and other governmental lead regulations' below.)

Removal from lead exposure may be accomplished by transfer to another job in a lead-free area or, if not possible, by removal from work while receiving salary under the "medical removal protection" provision of OSHA's medical surveillance guidelines [127]. Medical removal protection provides protection of earnings and seniority for 18 months. (See 'OSHA and other governmental lead regulations' below.)

Leaving a workplace that is causing lead exposure may result in financial hardship for the worker, even with an application for medical removal protection. Clinicians need to address each patient's situation, including medical history, risk factors, length of time expected to work with lead, and the patient's perspectives on financial and social impacts of removal from work.

Specialty referral — Prompt consultation or advice with an experienced specialist in occupational and environmental medicine or medical toxicology is advised for all patients with a BLL >40 mcg/dL. Referral for urgent evaluation and treatment is warranted for a patient with BLL ≥80

mcg/dL [4]. Those who may need chelation therapy for BLL 50 to 79 mcg/dL should also be referred.

Clinicians may also find it advisable to refer a patient with BLL >20 mcg/dL (0.97 micromol/L) to an occupational/environmental medicine clinician with experience in lead toxicity to assist in the assessment of lead exposure sources and lead toxicity, help with arrangement of environmental site evaluations, suggest preventive measures to avoid short-term poisoning and long-term health effects, and advise about methods to reduce lead exposure. The specialist may also assist in various worker compensation and regulatory issues that arise with cases of work-related lead poisoning and may be able to help set up a lead surveillance program that is in compliance with national and local regulations to prevent future lead poisoning.

The Association of Occupational and Environmental Clinics (AOEC) is an organization of occupational medicine clinics (frequently academically affiliated). Their website includes information about finding board-certified occupational medicine clinicians.

Chelation therapy — We suggest chelation therapy for most patients with a BLL >80 mcg/dL and all patients with a BLL >100 mcg/dL [4,59,122]. We also suggest chelation therapy for BLL >50 mcg/dL if the patient has significant symptoms or signs of lead toxicity (eg, abdominal pain, constipation, headache, cognitive impairment, or anemia). Chelation therapy may also be appropriate for patients with BLL >50 mcg/dL with milder symptoms if there has been a longer duration of excessive lead exposure or underlying medical problems [13,128]. We generally do not advise chelation therapy for patients with BLL <50 mcg/dL.

Chelation should not be undertaken unless exposure has been definitively curtailed because in the presence of continuing lead exposure, chelation may result in enhanced absorption of lead and worsening, rather than amelioration, of lead toxicity.

No clinical trials exist in adults to support these recommendations. Chelation therapy may accelerate decreases in BLL and relieve acute lead-related symptoms (eg, lead colic). Some studies have suggested improvement in central nervous system (CNS) symptoms [129] and creatinine clearance [130] with chelation. However, some observational data suggest that naturally declining lead levels are also associated with neurologic improvement [131-133]. There are no data from randomized trials that provide information on long-term health outcomes with and without chelation therapy [59].

The two most commonly used chelating agents for adults are DMSA (2,3-dimercaptosuccinic acid, succimer) and calcium disodium ethylenediaminetetraacetic acid (EDTA). Dimercaprol is used for some patients. The selection of the agent depends on the severity of symptoms and the BLL as well as the presence or absence of important contraindications such as renal insufficiency or liver failure and whether treatment is given as an inpatient or in the outpatient setting.

Specific recommendations regarding choice of agent, and the dosing and administration of these agents, are beyond the scope of this topic and should be done under the supervision of an experienced specialist in occupational and environmental medicine and/or a medical toxicologist.

The Trial to Assess Chelation Therapy (TACT) investigated the role of chelation therapy as a possible treatment for cardiovascular disease; however, participants were not selected based on known lead exposure or elevated BLL. This trial is discussed separately. (See "Overview of the prevention of cardiovascular disease events in those with established disease (secondary prevention) or at high risk", section on 'Therapies with uncertain or no benefit'.)

SUBSEQUENT MANAGEMENT

Monitoring blood lead levels — How often to monitor blood lead levels (BLL) after an elevated level has been detected depends on how high the level is, whether or not the exposure is ongoing, and if there have been interventions to lower BLL. In addition, whether the exposure has been short- or long-term will influence the expected trajectory of BLL decline and the frequency of monitoring. A long history of lead exposure that resulted in large bone stores of lead means that bone lead will leach slowly into blood over many years, even decades, and thus, the BLL will decline slowly [4].

Any increase in lead exposure or development of symptoms suggestive of lead toxicity should prompt BLL retesting. (See 'Clinical manifestations' above.)

At a minimum, we suggest that for a patient with BLL <10 mcg/dL, surveillance with repeat BLL testing should be done at least annually as long as lead exposure continues. For BLL 10 to 29 mcg/dL, a repeat BLL should be obtained every three months until BLL is reduced to <10 mcg/dL, then BLL should be tested annually as long as lead exposure continues. For BLL >30 mcg/dL, BLL should be repeated every month.

When an elevated BLL is reduced to <15 mcg/dL, BLL may be monitored every three months as long as lead exposure continues; for BLL <10 mcg/dL, every six month testing is likely sufficient. If exposures and BLLs are stable, the frequency of monitoring can be extended.

Return to work — When two BLL results obtained one month apart show BLL <15 mcg/dL, and all of the patient's symptoms of lead poisoning have resolved (eg, the patient has regained neurocognitive function), the patient may return to working with or around lead with proper control measures. If the patient had chelation therapy, both BLLs must have been obtained at least one and two months after chelation therapy ended.

Prior to returning to work, conditions that caused lead poisoning must have been remediated. Exposure controls should be re-examined and improved. (See 'Education and exposure reduction' above.)

After returning to working with or around lead, BLL should be repeated in one month. If that BLL is <15 mcg/dL, then BLL should be tested every three months as long as lead exposure continues. If both BLLs and exposures are stable, then repeat testing may be done less frequently. (See 'Monitoring blood lead levels' above.)

Other measures — Men should be advised to avoid conception until three months after BLL falls below 30 mcg/dL because lead can cause sperm abnormalities.

PREGNANCY AND BREASTFEEDING

- **Pregnancy** – Elevated blood lead levels (BLL) are associated with pregnancy complications. Additionally, lead readily crosses the placenta; thus, even slight elevations in BLL during pregnancy are of high concern because the developing fetus is more susceptible to lead's toxic effects.

  Whether to screen a pregnant patient (or a woman contemplating pregnancy) for elevated BLL; follow-up testing; management of lead exposure during pregnancy; and effects of lead on reproduction and development are described separately [134]. (See "Occupational and environmental risks to reproduction in females: Specific exposures and impact", section on 'Lead'.)

- **Breastfeeding** – During breastfeeding, lead is transmitted in breast milk. In general, however, breastfeeding may be encouraged if BLL is in a certain range. Information about neonate and infant BLL and childhood lead poisoning is described separately. (See "Childhood lead poisoning: Management", section on 'Breastfeeding'.)

OSHA AND OTHER GOVERNMENTAL LEAD REGULATIONS

In the United States, there are federal regulations as well as regulations in some states for workers exposed to lead. Regulations and requirements may vary among governmental agencies (eg, federal and state agencies) and the military. The United States Occupational Safety and Health Administration (OSHA) provides medical surveillance guidelines for medical surveillance as well as guidance about removal from all lead exposure. However, OSHA standards were last updated in the early 1980s, and we as well as many experts and other agencies [123] use newer lower blood lead levels (BLL) than OSHA specifies for removal from lead exposure and for return to working with lead [4,122,135].

According to the OSHA regulations, workers exposed to lead in the air (30 mcg/m^3 time-weighted average [TWA] for more than 30 days per year) are evaluated with a physical examination, BLL, complete blood count with smear, blood urea nitrogen, serum creatinine, urinalysis, and zinc protoporphyrin. OSHA requires ongoing medical surveillance that includes BLL and zinc

protoporphyrin (ZPP) testing at least every six months whether or not the patient is symptomatic. Removal from work is mandated for a BLL ≥60 mcg/dL confirmed on repeat testing within two weeks or a BLL ≥50 mcg/dL averaged over the three most recent BLL within six months, unless the most recent BLL is <40 mcg/dL. OSHA also allows for medical removal at a lower level if the examining clinician believes removal is medically indicated. A worker may return to work when two consecutive BLL are <40 mcg/dL.

By contrast, other organizations including the Council of State and Territorial Epidemiologists (CSTE), the US Department of Defense, and other professional organizations recommend removing workers from lead exposure with a BLL >30 mcg/dL, or 20 mcg/dL if persistent over one month despite actions to control exposures [4,122]. For example, the US Department of Defense updated its recommendations for medical surveillance, specifying that service personnel who may be exposed to lead (eg, at shooting ranges) should have a BLL at least yearly or more frequently if needed, as long as their BLL is <10 mcg/dL and they are working in an environment with air levels of 30 mcg/m^3. For BLL 10 to 19 mcg/dL, a repeat BLL is to be done every three months, with removal from work around lead if two tests are ≥20 mcg/dL, and return to work after two BLL are <15 mcg/dL one month apart [20,123,136].

SOCIETY GUIDELINE LINKS

Links to society and government-sponsored guidelines from selected countries and regions around the world are provided separately. (See "Society guideline links: Lead and other heavy metal poisoning".)

INFORMATION FOR PATIENTS

UpToDate offers two types of patient education materials, "The Basics" and "Beyond the Basics." The Basics patient education pieces are written in plain language, at the 5^{th} to 6^{th} grade reading level, and they answer the four or five key questions a patient might have about a given condition. These articles are best for patients who want a general overview and who prefer short, easy-to-read materials. Beyond the Basics patient education pieces are longer, more sophisticated, and more detailed. These articles are written at the 10^{th} to 12^{th} grade reading level and are best for patients who want in-depth information and are comfortable with some medical jargon.

Here are the patient education articles that are relevant to this topic. We encourage you to print or e-mail these topics to your patients. (You can also locate patient education articles on a variety of subjects by searching on "patient info" and the keyword(s) of interest.)

- Basics topics (see "Patient education: Lead poisoning (The Basics)")

SUMMARY AND RECOMMENDATIONS

- Lead exposure and toxicity remains an important environmental health problem, particularly as the adverse health effects of even low levels of toxicity have been demonstrated. (See 'Epidemiology' above and 'Chronic exposure effects' above.)
- Among adults, the majority of lead exposure occurs in the workplace. Other sources include hobbies, environmental exposure, and unintentional oral ingestion of material contaminated with lead. (See 'Sources of exposure' above.)
- Clinical manifestations of lead toxicity are varied and may be nonspecific. (See 'Clinical manifestations' above.)
    - Manifestation of acute toxicity may include abdominal pain ("lead colic"), joint/muscle aches, fatigue, decreased libido, headaches, difficulty concentrating, short-term memory deficits, and irritability. These symptoms may also occur with long-term exposure of over one year. (See 'Acute and subacate exposure symptoms' above.)
    - Additionally, long-term exposure may produce anemia, decline in neurocognitive function, lead nephropathy, tremor, and hypertension. (See 'Chronic exposure effects' above.)
- A blood lead level (BLL) is used to assess an individual's exposure to lead. The BLL reflects recent exposure to exogenous lead sources as well as release of endogenous lead from bone and soft tissue stores. (See 'When to measure blood lead levels' above.)
- Interventions in patients with elevated blood lead levels (BLL >5 mcg/dL) and ongoing exposure, regardless of symptoms, are indicated in order to minimize potential short- and long-term adverse health effects. All patients with elevated BLL or exposure to lead should undergo education and exposure reduction. (See 'Education and exposure reduction' above.)
- Other interventions are based upon BLL level (see 'BLL-directed treatment approach' above):
    - We suggest chelation therapy for adult patients with a BLL >80 mcg/dL and also for patients with BLL >50 mcg/dL who have significant symptoms or signs of lead toxicity (eg, abdominal pain, constipation, headache, or anemia) (**Grade 2C**). In some circumstances, chelation therapy may also be appropriate for patients with BLL >50 mcg/dL with milder symptoms. (See 'Chelation therapy' above.)
    - For rare adult patients with BLL >100 mcg/dL and life-threatening symptoms, including encephalopathy, we recommend chelation therapy (**Grade 1C**); as experience in children suggests that it may be life-saving. (See 'Chelation therapy' above.)

Consultation with an occupational/ environmental medicine clinician with experience in lead toxicity can assist in the assessment of lead toxicity, advice about exposure controls, and

ongoing management. (See 'Specialty referral' above.)

- Ongoing surveillance is recommended for patients with continued occupational or other sources of recurrent lead exposure. (See 'Subsequent management' above.)
- For pregnant patients, elevated BLL is associated with pregnancy complications. Lead readily crosses the placenta, and the developing fetus is more susceptible to lead's toxic effects. Specifics are described separately. (See "Occupational and environmental risks to reproduction in females: Specific exposures and impact", section on 'Lead'.)
- Information about breastfeeding, neonate and infant BLL and childhood lead poisoning is described separately. (See "Childhood lead poisoning: Management", section on 'Breastfeeding'.)

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Topic 2773 Version 45.0

GRAPHICS

Sources of lead exposure

Occupational
Plumbers, pipe fitters
Lead miners
Lead smelters and refiners
Painters
Auto repairers
Glass manufacturers
Shipbuilders
Printers
Plastic manufacturers
Police officers
Steel welders or cutters
Construction workers (especially renovation and rehabilitation)
Rubber product manufacturers
Gas station attendants (past exposure)
Battery manufacturers
Battery recyclers
Bridge reconstruction workers
Firing range instructors

Homes/Buildings
Lead-containing paint/pigment
Soil/dust near lead industries, roadways, lead-painted homes
Plumbing leachate
Ceramic ware (especially imported)
Leaded gasoline
Vinyl miniblinds*
Hobbies and related activities
Glazed pottery making
Target shooting at firing ranges
Lead soldering (eg, electronics)
Painting
Preparing lead shot, fishing sinkers
Stained-glass making
Car or boat repair
Home remodeling
Other sources
Folk remedies (Mexican: azarcon, greta; Asian: ba-baw-san, bali goli)
Tobacco smoking
Cosmetics
Moonshine whiskey
Gasoline "huffing"
Ayurvedic medications

* Made outside the United States and purchased before 1997.

Adapted from:

1. *Environmental Health and Medicine Education. Lead Toxicity: Who Is at Risk of Lead Exposure? Agency for Toxic Substances & Disease Registry. Available at: https://www.atsdr.cdc.gov/csem/csem.asp?csem=34&po=7.*
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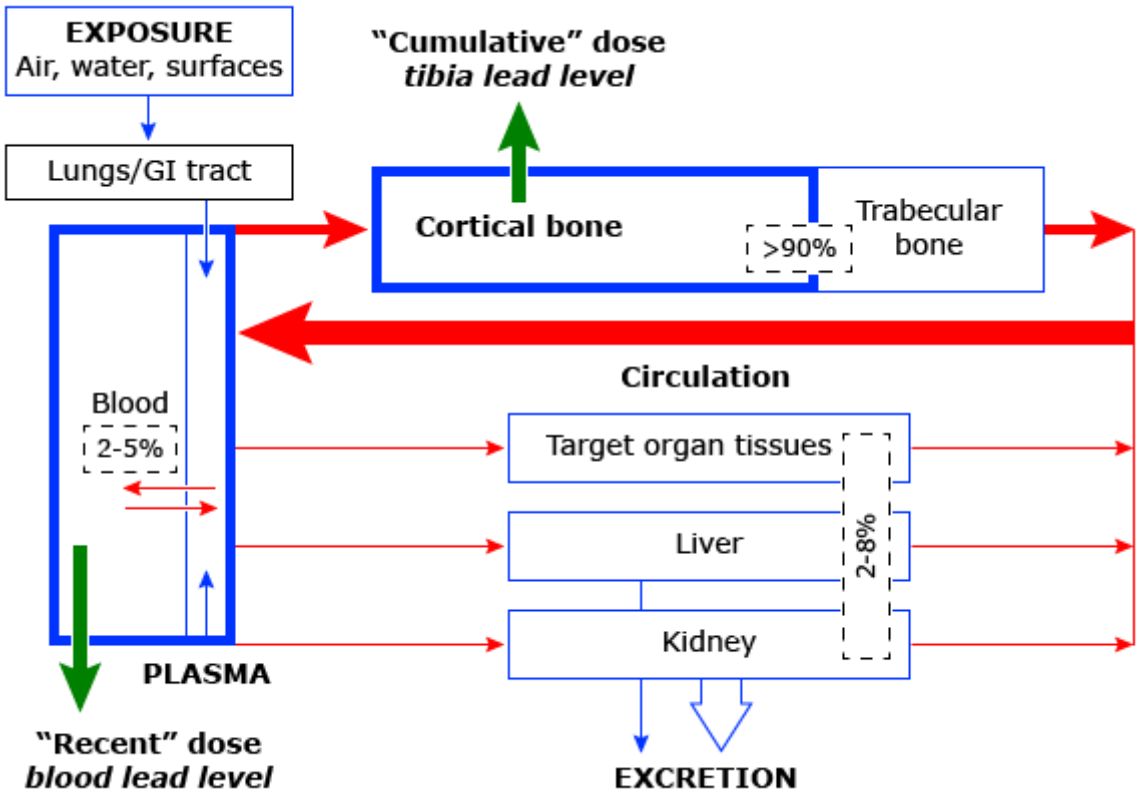
Graphic 53953 Version 5.0

Compartmental model for lead



Compartmental model for lead (modified from O'Flaherty 1993). The percentages shown represent the fractions of lead found in different tissue compartments.

GI: gastrointestinal.

From: Committee on Potential Health Risks from Recurrent Lead Exposure of DOD Firing-Range Personnel, Committee on Toxicology, Board on Environmental Studies and Toxicology, et al. Potential Health Risks to DOD Firing-Range Personnel from Recurrent Lead Exposure, The National Academies Press, Washington, DC, 2013; 49. Copyright © 2013 Brian S. Schwartz, MD, MS. Reproduced with permission.

Graphic 99977 Version 3.0

Risks associated with lead exposure in adults

Blood lead level (mcg/dL)	Short-term risks (lead exposure <1 year)	Long-term risks (lead exposure ≥1 year)
<5	▪ None documented	▪ None documented
5 to 9	▪ Possible spontaneous abortion ▪ Possible postnatal developmental delay ▪ Preeclampsia*[1]	▪ Possible spontaneous abortion ▪ Possible postnatal developmental delay ▪ Possible hypertension and kidney dysfunction ▪ Essential tremor*[2]
10 to 19	▪ Possible spontaneous abortion ▪ Possible postnatal developmental delay ▪ Reduced birth weight	▪ Possible spontaneous abortion ▪ Reduced birth weight ▪ Possible postnatal developmental delay ▪ Hypertension and kidney dysfunction ▪ Possible subclinical neurocognitive deficits ▪ Essential tremor*[2] ▪ Increased cardiovascular mortality*[3]
20 to 29	▪ Possible spontaneous abortion ▪ Possible postnatal developmental delay ▪ Reduced birth weight	▪ Possible spontaneous abortion ▪ Possible postnatal developmental delay ▪ Reduced birth weight ▪ Hypertension and kidney dysfunction ▪ Possible subclinical neurocognitive deficits
30 to 39	▪ Spontaneous abortion ▪ Possible postnatal developmental delay ▪ Reduced birth weight ▪ Adverse effects on sperm or semen*[3]	▪ Spontaneous abortion ▪ Reduced birth weight ▪ Possible postnatal developmental delay ▪ Hypertension and kidney dysfunction ▪ Possible neurocognitive deficits ▪ Possible nonspecific symptoms¶
40 to 79	▪ Spontaneous abortion ▪ Reduced birth weight ▪ Possible postnatal developmental delay ▪ Nonspecific symptoms¶ ▪ Neurocognitive deficits ▪ Sperm abnormalities	▪ Spontaneous abortion ▪ Reduced birth weight ▪ Possible postnatal developmental delay ▪ Nonspecific symptoms¶ ▪ Hypertension ▪ Kidney dysfunction/nephropathy ▪ Subclinical peripheral neuropathy ▪ Neurocognitive deficits ▪ Sperm abnormalities ▪ Anemia ▪ Colic ▪ Possible gout
≥80	▪ Spontaneous abortion ▪ Reduced birth weight ▪ Possible postnatal developmental delay ▪ Nonspecific symptoms¶ ▪ Neurocognitive deficits ▪ Encephalopathy ▪ Sperm abnormalities ▪ Anemia ▪ Colic	▪ Spontaneous abortion ▪ Reduced birth weight ▪ Possible postnatal developmental delay ▪ Nonspecific symptoms¶ ▪ Hypertension ▪ Nephropathy ▪ Peripheral neuropathy ▪ Neurocognitive deficits ▪ Sperm abnormalities ▪ Anemia ▪ Colic ▪ Gout

BLL: blood lead level.
* This is an UpToDate clinical suggestion.
¶ Nonspecific symptoms may include headache, fatigue, sleep disturbance, anorexia, constipation, arthralgia, myalgia, and decreased libido.

Adapted from Environmental Health Perspectives with permission from the authors: Kosnett MJ, Wedeen RP, Rothenberg SJ, et al. Recommendations for medical management of adult lead exposure. Environ Health Perspect 2007; 115:463.

Additional information from:

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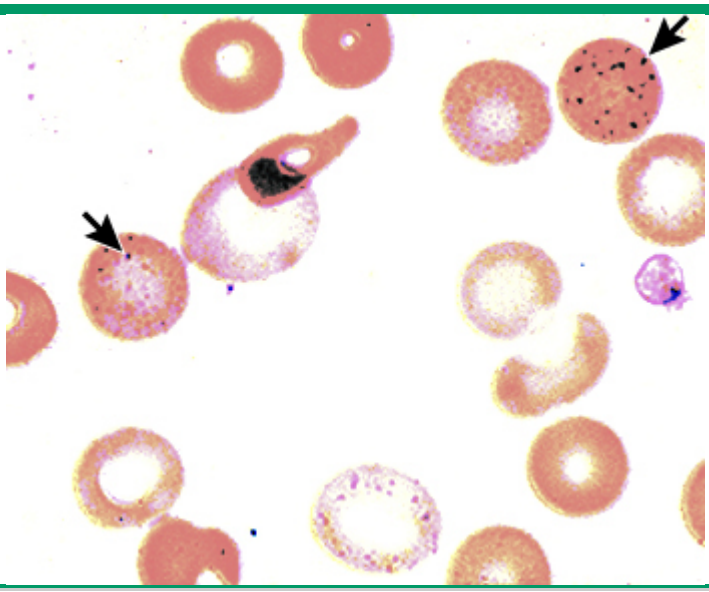
Graphic 126079 Version 1.0

Basophilic stippling of red cells in lead poisoning

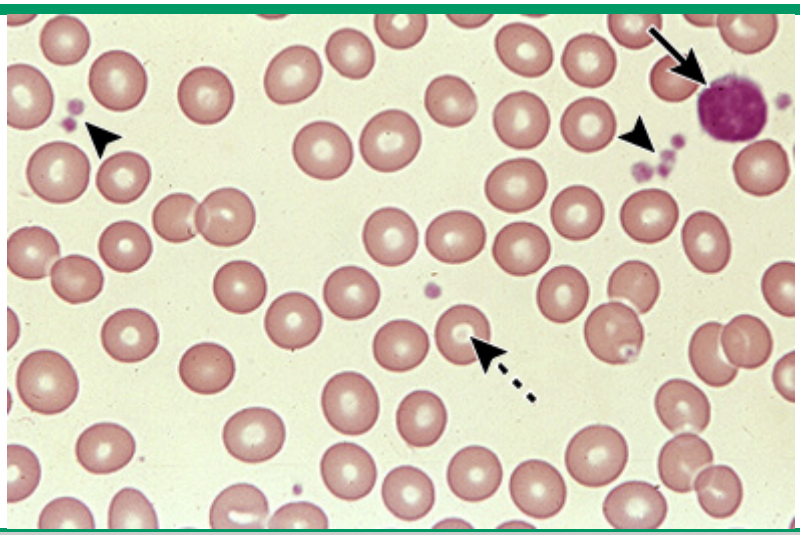


Peripheral blood smear shows basophilic stippling in several red cells from a patient with lead poisoning. The granules represent ribosomal precipitates. A similar picture can be seen in a number of other conditions including thalassemia, megaloblastic anemia, sickle cell anemia, and sideroblastic anemia.

Courtesy of Carola von Kapff, SH (ASCP).

Graphic 71989 Version 4.0

Normal peripheral blood smear

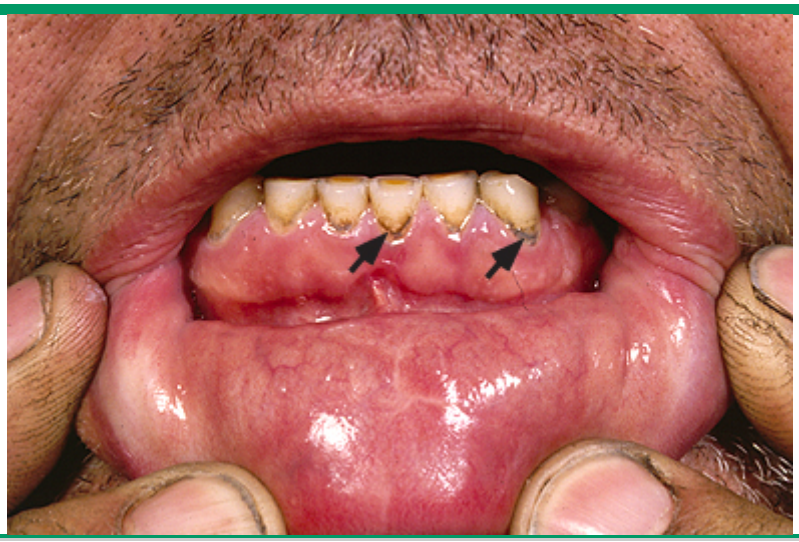


High-power view of a normal peripheral blood smear. Several platelets (arrowheads) and a normal lymphocyte (arrow) can also be seen. The red cells are of relatively uniform size and shape. The diameter of the normal red cell should approximate that of the nucleus of the small lymphocyte; central pallor (dashed arrow) should equal one-third of its diameter.

Courtesy of Carola von Kapff, SH (ASCP).

Graphic 59683 Version 5.0

Lead line in the gums of a patient with occupational lead poisoning

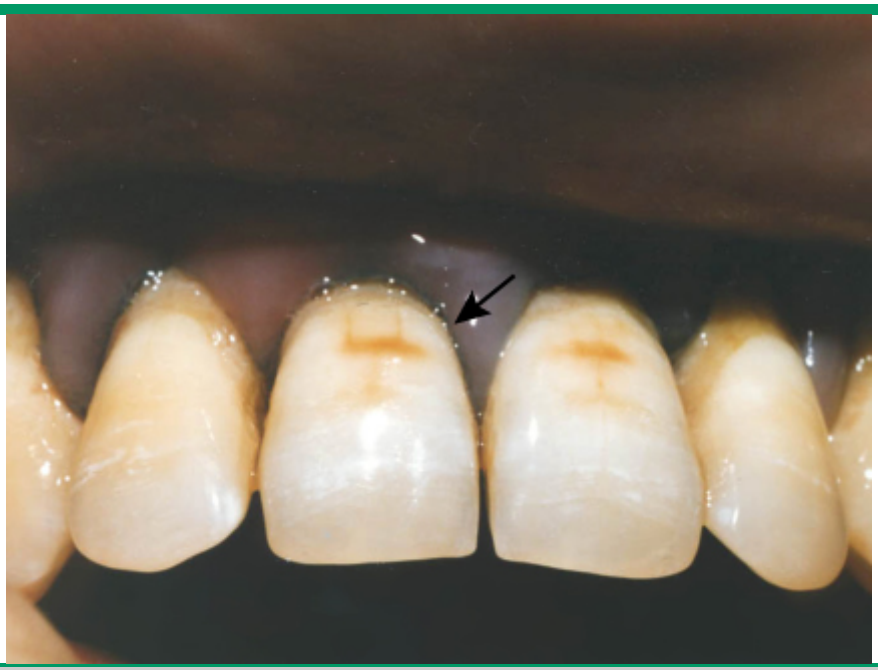


This photograph shows a "lead line" in the region between the teeth and gingiva of a patient with lead poisoning due to occupational exposure (automobile radiator repair). The dark areas (arrows) represent deposition of insoluble lead following interaction with sulfur-containing metabolites produced by bacteria in these gingival pockets.

Photograph provided by Stephen A Landaw, MD, PhD.

Graphic 77682 Version 2.0

Lead line in gingival tooth border



This man with severe lead poisoning has a "lead line," a bluish-gray thin line running along the gingival tooth border, which also has considerable plaque. It is best seen at the location of the arrow. In patients with poor oral hygiene, hydrogen sulfide released by bacteria in the gingival pockets may react with lead in the gingival circulation to produce lead sulfide, a precipitate that appears as a darkly pigmented blue-gray line.

Graphic 68115 Version 3.0

Contributor Disclosures

Rose H Goldman, MD, MPH Other Financial Interest: Expert witness [Workers' compensation and disability cases related to occupational medicine and environmental health]. **Howard Hu, ScD, MD** Other Financial Interest: Expert witness [Worker's compensation, disability, and general causation cases related to occupational medicine and environmental health]. **Joann G Elmore, MD, MPH** Nothing to disclose **Stephen J Traub, MD** Nothing to disclose **Lisa Kunins, MD** Nothing to disclose

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Conflict of interest policy