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Neither EPA nor ATSDR endorse the purchase of any commercial products or services mentioned in PEHSU publications.

Objectives

1. Characterize the hazards of lead
2. Review the epidemiology of lead poisoning
3. Describe the basic toxic mechanisms of lead exposure
4. Provide resources on prevention and treatment of lead poisoning
Review and Updates in Lead Poisoning / **Timur Durrani, MD, MPH, MBA**

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**Agenda**

- **Case #1** – A 37 year old father who works as a construction laborer
  - Brief history of lead
- **Case #2** - A 32 year old woman attempting first pregnancy
  - Pathophysiology of lead poisoning
- **Case #3** - A 3 year old Afghan boy
  - Prevention and Treatment Strategies
- **Special Populations:**
  - A 40 year old female s/p GSW with embedded lead fragments
  - A 52 dialysis dependent male

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**Dr. Alice Hamilton**

“Lead is... a race poison. In the case of the man a poison can act only on the germ cell line, but in the case of the woman the toxic action can continue throughout the nine months of pregnancy.”

Case #1

A construction worker…

A 37-year-old male employed as a laborer for a residential construction company notes fatigue, insomnia, difficulty concentrating, abdominal cramps, weight loss, muscle and joint aching, and tremor for several months.

He saw pamphlets noting the risk of lead poisoning from remodeling activities and requested a blood lead level, that returned at 51 µg/dL.
And his daughter

His 14-month-old daughter is immediately tested and found to have a blood lead level of 45 µg/dl, hemoglobin of 8.6 µg/dl and normal liver and renal function.

The child is seen in the ED for increased drowsiness, diarrhea and abdominal pain.

The child is admitted to ZSFG to remove her from exposure and possible chelation.

Child developmental score and maternal whole blood lead levels in the first trimester

Mohsen Vigeh et al. J Child Neurol 2014;29:1305-1311
Blood Lead and IQ scores in 1,333 children followed from birth to age 10.


Small Effects Can Have Large Significance

8.0 million: "Intellectual Disability"
8.0 million: "gifted"

Adapted from Weiss B. Neurotoxicology.
Small Effects Can Have Large Significance (continued)

57% increase in “intellectual disability” population

60% decrease in “gifted” population

12.5 million: “intellectual disability”

3.2 million: “gifted”

Adapted from Weiss B. Neurotoxicology. 1997.

Societal Costs

The costs of lead hazard control range from $1.2-$11.0 billion/yr.

The benefits range from $192-$270 billion/yr, this includes the sum of the costs for medical treatment, lost earnings, tax revenue, special education, lead-linked ADHD cases, and criminal activity.


Flint, Michigan

April 25, 2014: Michigan state officials changed the water source for the City of Flint from Detroit’s municipal system to the Flint River. Anti-corrosives weren’t used, lead began to leach from aging water lines.

How lead gets into home water

https://www.epa.gov/sites/production/files/2015-10/lead-service-line-scenario1.png
Result of change in water source

Drinking Water
- Troy water: 1.1
- Detroit water: 2.3
- Cause for concern: 5

Blood Lead Levels
February 2016: Incidence of elevated blood lead level (> 5 mcg/dL) increased from 2.4% to 4.9%.


San Francisco Homes Built in 1979 or Before

Percentage of Homes Built in 1979 or Before
- 30% or Less
- 30.1% - 60%
- Greater than 60%

Source: U.S. Census Bureau, 2011 American Community Survey (5-year estimates)
San Francisco Department Of Public Health, Environmental Health, 2013
Age of Housing and Detectable Blood Lead Level Cases (2008-2012)

Number of Cases with Detectable Blood Lead Levels:
- 1-20
- 21-40
- 41-70
- 71-100
- 100+

Proportion of Dwellings Built Before 1950:
- 0-3% - 22%
- 23% - 42%
- 43% - 62%
- 63% - 82%
- 83% - 100%

Children's Environmental Health Promotion Program, Environmental Health Branch, Population Health Division, San Francisco Department of Public Health

Environmental Sources of Lead identified during investigations 2013-2015

- Damaged Paint
- Dust Wipe, CDPH
- Soil, CDPH
- Paint (WIP), CDPH

781 sites investigated, 1,313 hazards identified

Paint Hazards identified:
- Interior 38%
- Exterior 62%

Source: SFCLPP Nuisance Database
Brief history of lead

Inorganic lead is a malleable, blue-gray, heavy metal that occurs naturally in the Earth’s crust. It has a low melting point, high density and corrosion resistant. These properties allow it to be used in a variety of products with minimal technical equipment or expertise.

Lead was one of the first metals used by humans and consequently, the cause of the first recorded occupational disease (lead colic in a 4th century BC metal worker).

In 2012, U.S. production of lead was estimated at 1.6 million metric tons; primarily from secondary refining of scrap metal.

U.S. mines produced 342,000 metric tons, ranking third in the world behind China and Australia.
Where is lead?

Damaged paint in homes built pre-1978
Cracked or peeling paint means paint chips and lead dust that can be accessible to children in the home and through contact with bare soil.

Lead dust from work and hobbies
Working in construction, painting, gardening or recycling common as well as doing activities like fishing or making jewelry, pottery or stained glass can suck lead dust back into the homes. Most of us aren’t even getting homes.

Unsafe Work Practices
Homes can become contaminated with lead due to improper remodeling. Always hire a lead-certified contractor to do home repairs. Require lead safe work practices in your home will protect children, pets and the environment.

Activities associated with lead exposure

General
- Battery manufacturing or recycling
- Metal radiator repair
- Scrap metal handling
- Recycling of lead-sheathed cables
- Lead soldering
- Firing ranges
- Ceramics manufacturing
- Machining or grinding metal alloys containing lead
- Plastics manufacturing

Construction Specific
- Sanding, scraping, burning, or disturbing lead paint
- Demolition of old structures
- Welding or torch cutting lead-painted metal
- Abrasive blasting
- Construction or repair of bridges, water towers, tanks, roofing
- Lead abatement
- Painting—residential or commercial
- Renovation or remodeling structures built before 1978
- Welding on metal structures
Occupational or Environmental Lead Poisoning?

**OCCUPATIONAL LEAD POISONING PREVENTION**

**CHILDHOOD LEAD POISONING PREVENTION**
Blood Lead Levels

1978 Science and Regulation
Cal/OSHA lead standards

There are two lead standards in California:

<table>
<thead>
<tr>
<th>General Industry*, 1978</th>
<th>Lead in Construction§ (LIC), 1993</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requires employers to provide health and safety services to employees exposed to lead</td>
<td>Requires medical surveillance and follow-up based on toxicity data from 1978</td>
</tr>
</tbody>
</table>

* Covers "fixed-site" jobs such as manufacturing and non-construction services. See https://www.dir.ca.gov/title8/5198.html
§ See https://www.dir.ca.gov/title8/1532_1.html

Both lead standards:

- Require employers to provide health and safety services to employees exposed to lead
- Require medical surveillance and follow-up based on toxicity data from 1978

The Cal/OSHA lead standards are no longer sufficiently protective and there is a current effort in California to revise them.

Comparison of current and proposed changes in occupational lead standards

<table>
<thead>
<tr>
<th>Current Cal/OSHA</th>
<th>Proposed CA DPH</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Medical Surveillance:</strong></td>
<td><strong>Provided to ALL employees with potential for lead exposure</strong></td>
</tr>
<tr>
<td>Only for exposed workers only if personal airborne lead level measurements exceed 30 µg/m³ on 30 or more days per year</td>
<td></td>
</tr>
<tr>
<td><strong>Mandatory Removal Level</strong></td>
<td>50 µg/dL¶</td>
</tr>
<tr>
<td><strong>Permissible Exposure Limit</strong></td>
<td>50 µg/m² averaged over an 8-hour period.</td>
</tr>
</tbody>
</table>

¶Selected with a goal of achieving a mean and maximum BLL of 40 µg/100g and 60 µg/100g, respectively
Responsibilities under Cal/OSHA for Lead

**Employer**
- Monitor the air for lead
- Provide a respirator
- Provide medical monitoring for employees
- Provide protective clothing, separate eating area, and washing facility for employees
- Pay employee’s full salary during medical removal
- Provide physicians with information on each employee’s duties, exposure levels, and personal protective equipment; as well as prior BLLs and medical opinions

**Physician**
- Provide required biological monitoring and medical evaluations of employees
- Determine employee fitness for work with lead
- Make written recommendations to employer
- Provide employer with results relating only to employee’s occupational exposure to lead
- File Doctor’s First Report of Injury or Illness within 5 days

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Case #2

A Case…

- A 32 year old female, with a 7 year history of chronic abdominal pain, is admitted to UCSF internal medicine service for intractable abdominal pain.
- CC: “Squeezing my guts from the inside”.
- ROS: Associated with nausea, anorexia, and 15 lbs weight loss.
  - Mild constipation. Not associated with food or reflux.
  - Menses regular. No abnl discharge, no recent sex.
  - No dysuria or a change in urination.
  - Occasional headaches.

Role of Delta-aminolevulinic Acid in the Symptoms of Acute Porphyria. Montgomery Bissell, MD, Jennifer C. Lai, MD, Raymond K. Meister, MD, MPH, Paul D. Blanc, MD, MSPH
## Medical History

**Past Medical History:**
- Chronic abdominal pain
  - IBS
  - Fibromyalgia
  - Endometriosis
  - PCOS
- Appendectomy (5/2012)
- Surgical repair of torn labrum right hip

**Meds:**
- Dicyclomine 10mg tid
- Zofran prn
- Oxycodone prn
- Hydromorphone prn

**Family History:**
- Occasional abdominal sx in sister. Brother and parents are well

**Social History:**
- Single, no children.
- Parents from India
- Grew up in Houston, moved to New York in 2004, then to the Bay Area in 2008
- Hasn’t worked outside the home since 2006, as she has been on disability. Previously was trained as an accountant, has recently been licensed a residential realtor
- She has never used tobacco. 2 drinks/week. Occasional medical marijuana, no other elicits. No noted change in her symptoms with marijuana use
- Not sexually active

## Course

**2006:** Diagnosed with Abdominal pain, Rx: Opioid Meds, little relief

**2008:** Abdominal pain gradually worse.

**5/2012:** Seen at an OSH ED → appendectomy.

**12/2012:** Evaluated for pelvic pain → dx with endometriosis and PCOS.

**2/2013:** Hospitalized for exacerbation of her abdominal pain, with vomiting and constipation and 15 lbs weight loss
Exam
Vitals: T: 36.4 HR: 122 BP: 90/58 R: 16, 100% RA, BMI 21
Gen: Alert, uncomfortable.
HEENT: NC/AT. No icterus. PERRL.
Neck: Supple, no LAD, nl thyroid. No JVD.
Chest: Breathing comfortably. CTAB.
CVR: RRR. NI S1, S2. No m/r/g. No LE edema.
Abd: NABS. Soft, diffuse ttp w/o rebound, guarding. No masses. No HSM.
Extrem: Warm, no cyanosis or clubbing. No joint deformities, effusions or warm
Skin: No rash.
Psych: NI mood and affect. Her behavior is normal. Judgment and thought

Laboratories
WBC 6.4
Hgb 9.9, MCV 84
Platelets 379
Lipase 16
Urinalysis neg
Pregnancy test neg
Total Bilirubin 0.8
AST 39
ALT 63
Gallbladder and biliary
tree normal on ultrasound
Alk Phos 62
Albumin 4.3
Differential Diagnosis?

Chronic Abdominal Pain? – Very Broad
- Gallstones
- Appendicitis
- Endometriosis

Anemia
- Iron Deficiency

Abdominal Pain + Anemia
- Porphyria

A diagnostic test returned…

Fractionated urinary porphyrins:
- Uroporphyrin 32 (ref <22)
- Coproporphyrin 2070 (ref 23-130)
- Porphobilinogen 2 (ref <2)
Another diagnostic test returned(!)

Lead level: 83 mcg/dL
Arsenic and mercury levels were negative
Repeat lead level 91 mcg/dL

Environmental History Obtained:
• Condo in Milbrae that was built in 1977
• Copper pipes
• Water from a municipal source
• Glass dishes; no pottery or ceramics
• No jewelry making, stained glass, painting, or exposure to battery or radiator recycling.

20 Ayurvedic preparations
### Lead Levels

<table>
<thead>
<tr>
<th>BLL (mcg/dL)</th>
<th>Hgb (g/dL)</th>
<th>Date</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>83</td>
<td>91.8</td>
<td>3/23/13</td>
<td></td>
</tr>
<tr>
<td>91.8</td>
<td>70</td>
<td>4/2/13</td>
<td>Start IV Ca EDTA</td>
</tr>
<tr>
<td>70</td>
<td>50</td>
<td>4/5/13</td>
<td>Completed Ca EDTA</td>
</tr>
<tr>
<td>68</td>
<td>4/8/13</td>
<td></td>
<td>Completed Ca EDTA</td>
</tr>
<tr>
<td>22</td>
<td>4/9/13</td>
<td></td>
<td>Started Succimer 1st round</td>
</tr>
<tr>
<td>10</td>
<td>4/15/13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>14.5</td>
<td>4/29/13</td>
<td>Completed 1st Round</td>
</tr>
<tr>
<td>29</td>
<td>6/10/13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>6/24/13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>7/8/13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>8/5/13</td>
<td></td>
<td>Completed 2nd Round</td>
</tr>
<tr>
<td>18</td>
<td>9/5/13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>9/23/13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>10/23/13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>11/4/13</td>
<td></td>
<td>Completed 3rd Round</td>
</tr>
<tr>
<td>12</td>
<td>11/23/13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>1/6/14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>2/13/14</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>3/7/13</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>4/1/14</td>
<td></td>
<td>Completed 4th Round</td>
</tr>
</tbody>
</table>

### OSH KUB

![Radiographic Image](image-url)
## Ayurvedic Preparations Taken by the Patient: Analysis for Lead

<table>
<thead>
<tr>
<th>Name</th>
<th>Appearance</th>
<th>Lead (Limit 0.25 μg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Proprietary) Purple-grey powder</td>
<td>37 mg/g</td>
<td></td>
</tr>
<tr>
<td>(Proprietary) Tan powder</td>
<td>0.88</td>
<td></td>
</tr>
<tr>
<td>(Proprietary) Brown powder</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>(Custom tablet) Black pill</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Vatchintamani Ras (Baidyanath)</td>
<td>Pink pill</td>
<td>37</td>
</tr>
<tr>
<td>Vatchintamani Rasa (Brihat)</td>
<td>Brown pill</td>
<td>36</td>
</tr>
<tr>
<td>Muktashukti Bhasma (Baidyanath)</td>
<td>White powder</td>
<td>48</td>
</tr>
<tr>
<td>(Proprietary) Tan powder</td>
<td>0.88</td>
<td></td>
</tr>
</tbody>
</table>

## Lead Poisoning in Pregnant Women Who Used Ayurvedic Medications from India — New York City, 2011–2012

**TABLE:** Reported cases of adult lead poisoning related to ayurvedic medications, by state and selected characteristics — United States, 2009–2013

<table>
<thead>
<tr>
<th>State</th>
<th>Year</th>
<th>Age (yr)</th>
<th>Sex</th>
<th>Patient’s country of origin</th>
<th>BLL at presentation (µg/dL)</th>
<th>Type of ayurvedic medications ingested</th>
<th>Lead concentration of medications ingested</th>
<th>Received chelation therapy</th>
</tr>
</thead>
<tbody>
<tr>
<td>New Hampshire</td>
<td>2001</td>
<td>37</td>
<td>Female</td>
<td>India</td>
<td>81</td>
<td>Two powders, three tablets</td>
<td>Powders: 12,000–17,000 Tablets: 60–100</td>
<td>Yes</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>2003</td>
<td>51</td>
<td>Female</td>
<td>India</td>
<td>112</td>
<td>Nine medications, including pills/brew four times daily</td>
<td>15,000; Three others: 21, 65, and 205</td>
<td>Yes</td>
</tr>
<tr>
<td>California</td>
<td>2003</td>
<td>54</td>
<td>Male</td>
<td>India</td>
<td>80</td>
<td>9 powders, tablets, syrup</td>
<td>15000; 17,000; PHE 36</td>
<td>Yes</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>2012</td>
<td>62</td>
<td>Male</td>
<td>India</td>
<td>89</td>
<td>Glycol tablets</td>
<td>14,000</td>
<td>Yes</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>2012</td>
<td>66</td>
<td>Female</td>
<td>India</td>
<td>60</td>
<td>Glycol tablets</td>
<td>14,001</td>
<td>Yes</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>2013</td>
<td>19</td>
<td>Female</td>
<td>Nepal</td>
<td>46</td>
<td>Sandal Karp (pill and liquid)</td>
<td>PHE: 30,000; Liquid: 0</td>
<td>Yes</td>
</tr>
<tr>
<td>New York</td>
<td>2004</td>
<td>26</td>
<td>Female</td>
<td>India</td>
<td>51</td>
<td>Not</td>
<td>Not known</td>
<td>Yes</td>
</tr>
<tr>
<td>New York</td>
<td>2004</td>
<td>52</td>
<td>Male</td>
<td>India</td>
<td>49</td>
<td>Unknown form</td>
<td>Not known</td>
<td>No</td>
</tr>
<tr>
<td>New York</td>
<td>2014</td>
<td>57</td>
<td>Female</td>
<td>India</td>
<td>37</td>
<td>Unknown form</td>
<td>Not known</td>
<td>No</td>
</tr>
<tr>
<td>New York</td>
<td>2014</td>
<td>60</td>
<td>Female</td>
<td>India</td>
<td>52</td>
<td>Jambuloin</td>
<td>44,006</td>
<td>Yes</td>
</tr>
<tr>
<td>New York</td>
<td>2014</td>
<td>56</td>
<td>Male</td>
<td>India</td>
<td>110</td>
<td>Powdier/solid</td>
<td>Not known</td>
<td>Yes</td>
</tr>
<tr>
<td>Texas</td>
<td>2013</td>
<td>30</td>
<td>Not dated</td>
<td>India</td>
<td>52</td>
<td>Jambuloin</td>
<td>25, 50–85, 500</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Blood lead levels.*
Distribution of Blood Lead Levels in U.S. Women of Childbearing Age (15-49 Years)

1982, Johnson Controls barred female employees from working on lead-battery production lines because of the potential damage to a fetus. The company claimed the policy was protecting fetuses from workplace hazards.

1991 UAW, representing 2 women (one who had decided to be sterilized rather than lose her job; the other was transferred from the battery production line to a lower-paying job) and one man (who had been denied a request for a leave of absence so he could lower his blood lead levels before trying to father a child) sues Johnson Controls

March 20, 1991: 9 votes for Automobile Workers, 0 vote(s) against

Ultimately the company was trying to shield itself from liability in potential lawsuits that might be brought on behalf of children born with birth defects possibly attributable to their mothers’ exposure to lead.
Pathophysiology of lead poisoning

Toxicokinetics of lead in children

Absorption –
- Inhaled (30 – 50% complete absorption)
- Ingestion (up to 70% complete absorption), increased with fasting, iron deficiency, and calcium deficiency

Distribution –
T1/2:
- Blood – 28 to 36 days
- Soft tissue – 40 days
- Bone – 25 years

Metabolism – None

Excretion – Renal or Biliary clearance.
- Children <2 retain 50% of absorbed lead, adults retain 1%
**Target Organs**

**ADULTS**
- **Brain**
  - Memory loss, lack of concentration, headaches, irritability, depression
- **Body**
  - Fatigue, joint and muscle pain
- **Cardiovascular**
  - High blood pressure
- **Digestive system**
  - Constipation, nausea and poor appetite
- **Nervous system**
  - Damage including numbness and pain in the extremities
- **Reproductive system**
  - Men: Decreased sex drive and sperm count, and sperm abnormalities.
  - Women: Spontaneous miscarriage

**CHILDREN**
- **Brain**
  - Behavior problems, lower IQ, hearing loss, learning disabilities
- **Body**
  - Decreased bone and muscle growth
- **Kidneys**
  - Damage
- **Nervous system**
  - Damage
- **Blood**
  - Anemia

---

**Leads movement through the blood brain barrier**

Substitutes for Ca\(^{2+}\) and passes through ion channels

Interferes with astrocyte and endothelial cell communication

In children <6 (12 – 24 months) have incomplete blood brain barrier that permits the entry


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April 26, 2018 / WOEMA 2018 Webinar Series
Lead mimics calcium

Lead has a higher affinity for calmodulin binding sites than calcium does.

Ionic radius of Ca^{2+} and protein O atoms on calmodulin is 2.3 angstrom (Å)

Ionic radius of Pb^{2+} and protein O atoms vary between 2.0 and 2.7 Å, demonstrating that lead ions have the ability to create shorter and therefore stronger bonds with the protein complex.


Lead’s multiple toxic mechanisms

Pb^{2+} enters through Ca^{2+} channel, and binds with calmodulin with a higher affinity than Ca^{2+}

Pb^{2+} may also be stored in the endoplasmic reticulum, in place of Ca^{2+}, and released when the G-protein activates phospholipase C, leading to abnormal enzyme activity and gene transcription

Protein kinase C binds Pb^{2+} more readily than Ca^{2+} resulting in cellular dysfunction


Lead induced anemia

**Ineffective erythropoiesis**

- <40 µg/dL, likely iron deficiency anemia (same risk factors as lead toxicity)

- 40 µg/dL = anemia 2/2 to hemoglobin precursors:
  - Inhibition of delta aminolevulinate dehydratase and ferrochelatase
  - Results in accumulation of heme intermediates such as free protoporphyrin in erythrocytes

**Hemolysis (>70 µg/dL)**

- Acquired deficiency of erythrocyte pyrimidine 5’-nucleotidase
  or
  - Acquired deficiency of erythrocyte pyrimidine 5’-nucleotidase
  - Inhibits alpha chain synthesis, mimicking alpha thalassemia
  or
  - Inhibition of RBC membrane ATP-ase


Lead lines

**At 30 µg/dL as BLL↑,**

- Vitamin D ↓ affecting tooth/bone maturation

- Bands of increased density at metaphyses of tubular bones (growing bone)

- Metaphyses of growing bones may be dense normally

- Lead lines more apt to be seen in proximal fibula and distal ulna where growth is not as great as other long bones

*Frontal radiograph of both knees of a child with lead poisoning*

*http://www.learningradiology.com/notes/bonenotes/leadpoisonpage.htm#sthash.5lp8J7M4.dpuf*
A Case…

3 year old boy from Afghanistan in the US since 2013, is referred to CHO for iron deficiency anemia and a blood lead level of 72 mcg/dL.

He has constipation and anorexia
What is your next step in the management of this patient?

A) Request a repeat blood lead level
B) Obtain a Zinc Protoporphyrin Level (ZPP)
C) Begin immediate oral and IV chelation
D) Order a KUB
Health System Triad

What Happened Next?

Day 1 0600 – Poison Center is called
0720 - Email to the CHO inpatient team and Alameda County Lead Poisoning Prevention Program
1511 – Alameda County Public Health Nurse meets with family and notes the child lives in a home built in 1923
So happened to our patient?

**Day 1** 1511 – Public health nurse inquires about the use of Surma use.
1755 – Repeat level of 58 µg/dL returns.
2000 – Pt receives first oral dose of chelation therapy.

**Day 2** – Pt receives nutrition assessment and recommendations.

**Day 3** – Environmental assessment of the home reveals the exterior paint is deteriorated and quite high for lead, especially around the apartment unit door & threshold. Lead-containing dust was identified on the window sills and the exterior.

Epidemiology of pediatric lead poisoning

Highest prevalence among among inner-city children who live in deteriorating housing that was built before the 1970s.

Non-Hispanic black children have statistically higher BLL compared with other populations.

Prevalence of lead poisoning is increasing among refugee children who have arrived recently in the United States and among children entering foster care.
Pediatric and Maternal Health Report

Childhood Lead Exposure Associated with the Use of Kajal, an Eye Cosmetic from Afghanistan — Albuquerque, New Mexico, 2013

Lead is a toxic metal that damages blood cells, the bone marrow, the nervous system, and the developing nervous system of infants and children. Children are at high risk for lead poisoning because of their hand-to-mouth activities and their higher proportion of ingestional exposure compared with adults (1). By January, 2013, the New Mexico Department of Health had received reports of 37 children with elevated blood lead levels (BLLs) ≥ 25 μg/dL, with a range of 25–166 μg/dL. Two of these children had BLLs > 50 μg/dL, while 29 children had BLLs > 25 μg/dL but < 50 μg/dL. The New Mexico Department of Health conducted an investigation to determine the source of the lead exposure among children with elevated BLLs. The investigation identified the use of black kohl (kajal) eye pencil with a high lead content, as the source of lead exposure for these children. The New Mexico Department of Health conducted a questionnaire and blood lead testing among children using kohl and their parents. The results showed that children using kohl had significantly higher BLLs compared with those who did not use kohl. The questionnaire also revealed that children using kohl had a higher prevalence of symptoms consistent with lead poisoning, such as irritability, anemia, and neuropathy. The study also highlighted the potential for lead poisoning among children and the need for education and awareness among caregivers. The investigation led to a ban on the importation and sale of kohl in New Mexico and a recall of the affected products. The study also emphasized the importance of public health interventions to prevent lead poisoning, especially in vulnerable populations. The study recommended education and awareness campaigns for caregivers and healthcare providers to prevent lead poisoning among children using kohl.

Keywords: Lead poisoning, Childhood exposure, Kajal, Eye cosmetic, New Mexico.
Prevention and Treatment Strategies

Hierarchy of Controls

- **Elimination**: Physically remove the hazard
- **Substitution**: Replace the hazard
- **Engineering Controls**: Isolate people from the hazard
- **Administrative Controls**: Change the way people work
- **PPE**: Protect the worker with Personal Protective Equipment

Most effective

Least effective
Levels of Prevention

<table>
<thead>
<tr>
<th></th>
<th>Primary Prevention</th>
<th>Secondary Prevention</th>
<th>Tertiary Prevention</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Definition</strong></td>
<td>Intervention implemented before there is evidence of injury</td>
<td>Intervention implemented after a disease has begun, but before it is symptomatic</td>
<td>Intervention implemented after a disease is established</td>
</tr>
<tr>
<td><strong>Intent</strong></td>
<td>Eliminate causative factor</td>
<td>Early identification and treatment</td>
<td>Prevent sequelae</td>
</tr>
<tr>
<td><strong>Example</strong></td>
<td>Eliminate lead Exposure</td>
<td>Screen for lead exposure</td>
<td>Prevent anemia, encephalopathy, and renal failure</td>
</tr>
</tbody>
</table>
PRIMARY PREVENTION:

- Hygiene Guidance
  - Change out of work clothes and shoes before going inside the home.
  - Take off shoes or wipe them on a doormat before going inside the home.
  - Keep the home clean and dust-free.
  - Keep furniture away from paint that is chipped or peeling.
  - Never sand, dry scrape, power wash or sandblast paint.
  - Always wash hands before eating and sleeping.
- Nutrition Guidance
  - Balanced diet two daily servings of dairy or other calcium rich foods and two servings of fruit or fruit juice provide sufficient calcium and vitamin C in the diet.
  - Avoid giving your child sweets. Some sweets contain lead.
  - Do not use dishes or pots made outside the U.S. for food or drinks.
- Provide families guidance on their right to habitable housing.

California Rental Laws

The landlord must disclose the presence of known lead-based paint and lead-based paint.

The landlord is not required to conduct any evaluation of the lead-based paint, or to remove it.

the landlord must repair problems that make the rental unit unfit to live in, or uninhabitable.
Secondary Prevention - Child

AAP*
A risk assessment and anticipatory guidance to parents of children particularly 6 months to 6 years
BLL's ideally at 1 and 2 years of age, unless lead exposure can be confidently excluded.

USPSTF (2006)
- There is INSUFFICIENT evidence to recommend for or against routine screening for elevated blood lead levels in asymptomatic children aged 1 to 5 who are at increased risk.
- Recommends AGAINST routine screening for elevated blood lead levels in asymptomatic children aged 1 to 5 years who are at average risk.

CA DPH
Screen:
Children in publicly supported programs at both 12 months and 24 months.
Children age 24 months to 6 years in publicly supported programs who were not tested at 24 months or later.
Lives in a place built before 1978 that has peeling or chipped paint or that has been recently remodeled.
### Secondary Prevention - Occupational

<table>
<thead>
<tr>
<th>Medical Surveillance:</th>
<th>Current Cal/OSHA</th>
<th>Proposed CA DPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only for exposed workers only if personal airborne lead level measurements exceed 30 µg/m³ on 30 or more days per year</td>
<td>Provided to ALL employees with potential for lead exposure</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Frequency of Blood Lead Levels:</th>
<th>Current Cal/OSHA</th>
<th>Proposed CA DPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveillance: at least every 2 months for the first 6 months and every 6 months thereafter</td>
<td>Surveillance: at least every 1 month for the first 3 months or upon change in task to a higher exposure, then every 6 months thereafter.</td>
<td></td>
</tr>
<tr>
<td>≥ 40 µg/dL follow-up testing within two weeks</td>
<td>≥10 µg/dL - tested at least every 3 months</td>
<td></td>
</tr>
<tr>
<td>≥ 50 µg/dL testing monthly during the removal period.</td>
<td>≥20 µg/dL - tested at least every month.</td>
<td></td>
</tr>
<tr>
<td>≥ 30 µg/dL - tested monthly during the removal period.</td>
<td>≥ 30 µg/dL - tested monthly during the removal period</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical Exam</th>
<th>Current Cal/OSHA</th>
<th>Proposed CA DPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Comprehensive Pre-placement PE Teeth and Gum Exam</td>
<td>Comprehensive Pre-placement PE Blood pressure Questionnaire on Medical Conditions including Renal Insufficiency</td>
<td></td>
</tr>
</tbody>
</table>

### Tertiary Prevention - Child

Any level = **REMOVAL FROM EXPOSURE!**

- **>45 µg/dL**
  - Gut Decontamination
  - Hospitalization or other Lead free environment
  - Oral Chelation (Succimer/DMSA)
- **>70 µg/dL**
  - Oral + IV (Succimer + Ca EDTA)
- **>100 µg/dL**
  - IV + IM (Ca EDTA + Dimercaprol/BAL)
### Tertiary Prevention - Adult

<table>
<thead>
<tr>
<th>Blood lead level (μg/dL)</th>
<th>Management recommendations and requirements for adults</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5</td>
<td>No action needed</td>
</tr>
<tr>
<td>5–9</td>
<td>Discuss health risks</td>
</tr>
<tr>
<td></td>
<td>Reduce exposure for pregnancy</td>
</tr>
<tr>
<td>10–19</td>
<td>Discuss health risks. Decrease exposure. Monitor BLL</td>
</tr>
<tr>
<td></td>
<td>Remove from exposure for pregnancy, certain medical</td>
</tr>
<tr>
<td></td>
<td>conditions, long-term risks</td>
</tr>
<tr>
<td>20–29</td>
<td>Remove from exposure if repeat BLL in 4 weeks remains ≥20 μg/dL</td>
</tr>
<tr>
<td>30–79</td>
<td>Remove from exposure. Prompt medical evaluation and</td>
</tr>
<tr>
<td></td>
<td>consultation advised for BLL &gt; 40 μg/dL</td>
</tr>
<tr>
<td>≥80</td>
<td>Urgent medical evaluation and consultation indicated</td>
</tr>
<tr>
<td></td>
<td>Chelation may be indicated if symptomatic and/or BLL ≥100 μg/dL</td>
</tr>
</tbody>
</table>

### Calcium EDTA

![Calcium EDTA](https://sites.google.com/a/umn.edu/phar6157s13/home/calcium-disodium-edta)

Calcium disodium edetate (EDTA) is used to chelate lead and other heavy metals. It forms a stable complex with lead, facilitating its removal from the body. EDTA can be administered orally or intravenously.

Sources:
- [Calcium disodium edetate](http://intranet.tdmu.edu.ua/data/kafedra/internal/pharmakologia/classes_sp/sen/pharm/prov_pharm/ytn/Pharmacology/3%20year/24%20Pharmacotherapy%2020%20Drug%20Poisoning%20and%20Emergency%20States.htm)
- [Calcium EDTA](https://sites.google.com/a/umn.edu/phar6157s13/home/calcium-disodium-edta)
Dimercaptosuccinic acid (DMSA) aka Succimer

**Mechanism:** Two sulphydryl groups bind divalent metal ions, thought to occur in the kidney.  
**Side effects** are generally mild and may include headache, nausea, anorexia, diarrhea, rash and renal dysfunction. Uncommon, but potentially severe adverse events include hypersensitivity reactions.  
**Efficacy:** Succimer achieves a 20-30% mean reduction in blood lead  
**Contraindications:** Hepatic insufficiency
Dosing of Succimer

10mg/kg/day TID x 5 days, then BID for 12 days, recheck in 1 month.

Don’t check during or immediately after chelation.

Continue blood lead level checks q 1 month,

Generally lead testing has a margin of error of +/- 4mcg/dL, so if it goes up beyond that in subsequent months, consider re-exposure.

Wholesale Prices for Calcium Disodium Edetate (Calcium EDTA) – 5 ml ampules (200mg/ml)

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Package Size (# of ampules)</th>
<th>Effective Date</th>
<th>Wholesale Acquisition Cost Package</th>
<th>Average Wholesale Price – Package</th>
<th>Average Wholesale Price per ml</th>
<th>Percent Increase per ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graceway Pharmaceuticals</td>
<td>6</td>
<td>10/02/2008</td>
<td>$464.24</td>
<td>$557.09</td>
<td>$18.57</td>
<td></td>
</tr>
<tr>
<td>Valeant Pharmaceuticals North America</td>
<td>5</td>
<td>12/22/2014</td>
<td>$26,927.33</td>
<td>$33,659.16</td>
<td>$1346.37</td>
<td>7.150 %</td>
</tr>
</tbody>
</table>

[Source: Red Book Online Database – Micromedex Solutions® accessed 1/23/2016]
Over a 2-month period until in May 2010, nearly 300 children aged <5 years old presented with intractable seizures of unknown etiology, with a mortality of 48%.
Special Populations: Embedded Lead Fragments

Embedded Lead Fragments
Risk of elevated blood lead level and treatment

Change in Blood Lead Concentration up to 1 Year after a Gunshot Wound with a Retained Bullet

THE TREATMENT OF LEAD POISONING FROM GUNSHOT WOUNDS WITH SUCCIMER (DMSA)

William J. Meggs, M.D.,***, R. David Cope, M.D.,****, Robert A. Fields, M.D.,***, Mario Manalo, M.D.,* and Andrew C. Todd, M.D.,***

New York City Poison Control Center, New York, New York; East Carolina University, Greenville, North Carolina; Icahn School of Medicine at Mount Sinai, New York, New York; and University of California, San Diego School of Medicine, San Diego, California

ABSTRACT

Lead poisoning is an unusual complication of gunshot wounds that occur when metallic lead bullets penetrate the body. The mechanism of lead poisoning following gunshot wounds is the result of either gunshot wound to a bone and projectile lodging within the bone, or penetration of the chest by a bullet that may result in airway, lung, or diaphragm injury. The time course and prevalence of elevated blood lead concentrations and associated treatment with oral chelation agents is presented for gunshot wound patients.

Special Populations: Dialysis Dependent Patients
Another Case

A 52-year old male with a history of end-stage renal disease secondary to DM and HTN, on hemodialysis presented to his primary care provider with complaints of 3 months of abdominal pain and hair loss.

Occupational/Environmental History
Unemployed secondary to disability
No known exposure to heavy metals
No family members with similar complaints

Concern for lead exposure was raised

The patient reported using several supplements from Mexico
Patient also noted eating small amounts of Mexican pottery (chronicity was unclear)
**Objective Findings**

**Physical Exam**
- BP 159/89, HR 95, RR 14, T 37.0°C, SpO2 97%
- GEN: Alert, no acute distress, no overt signs of toxic exposure
- HEENT: Moist mucous membranes
- ABD: Soft, minimal lower abdominal tenderness, no guarding or rebound
- NEURO: CN II-XI intact, strength hand sensation in upper and lower extremities grossly intact and symmetric.

**Initial Laboratory Values:**

<p>| | | | |</p>
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<tr>
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<tbody>
<tr>
<td></td>
<td>136</td>
<td>99</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>5.9</td>
<td>29</td>
<td>7.7</td>
</tr>
<tr>
<td></td>
<td>14.6</td>
<td>6.9</td>
<td>46.2</td>
</tr>
</tbody>
</table>

**Whole Blood Lead Level: 100.0 μg/dL**

**Chelation Protocol**

The patient was referred to the Emergency Department, and admitted to facilitate coordination of hemodialysis and intravenous chelation.

**Dosing Regimen**

1 gram Ca Na₂EDTA in 250 mL NS IV given over 1 hour, completed just prior to hemodialysis

HD completed with High Flux dialyzer with F160 membrane

Draw Pre-HD (post EDTA) and Post-HD lead levels

Continue Ca Na₂EDTA dosing UNTIL lead falls below 40 μg/dL OR no longer receiving benefit from therapy
Whole Blood Lead Levels

Hemodialysis following CaNa₂EDTA infusion indicated by red arrows.

Case Discussion

Supplements obtained from Mexico contained no lead.

The source of this patient’s lead toxicity was likely the glazed pottery imported from Mexico the patient reported eating however it was not available for testing.

Traditional Mexican pottery decorated with lead containing paint fired at improper temperature has long been identified as a source of lead toxicity.

The fall in blood lead level from 100.0 μg/dL to 33 μg/dL within 12 days is indicative of an accelerated chelation-induced decline.
Summary

Lead is a potent toxin.
There is no “safe” lead level.
Treatment should focus on removal from exposure, followed by chelation if necessary.
Discussion

Backup Slides
Lead Judgment in California

Sherwin, NL, ConAgra Lose $1.1 Billion Lead Paint Ruling

by Joel Roseblatt and Jack Ewen

December 17, 2013 — 12:01 PM PST

Dec. 17 (Bloomberg) -- Sherwin-Williams Co., NL Industries Inc. and ConAgra Grocery Products LLC were ordered by a judge to pay $1.1 billion to replace or contain lead paint in millions of homes after losing a public-nuisance lawsuit brought by 10 California cities and counties.

X-Ray Fluorescence

$785 at Mt. Sinai
Used for research purposes only
Measures of long-term lead exposure
Useful for people without known exposure
http://research.mssm.edu/xrf/index.html
Lead and breast milk kinetics

Breast milk lead to maternal blood lead ratios of approximately 3% or less; that is, a milk lead concentration of 3 μg/dL (or 30 μg/L) would be associated with a maternal blood lead concentration of 100 μg/dL.

A milk lead concentration of 0.3 μg/dL (3 μg/L) would be associated with a maternal blood lead concentration of 10 μg/dL.