What You Always Wanted to Know About Childhood Lead Poisoning but Were Afraid to Ask

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Objectives

- Recognize effects of lead even at low levels
- Recognize more common sources of lead exposures
- Recognize major risk factors for lead exposure
- Know when to obtain a blood lead level
- Learn about the latest CDC recommendations for pregnant mothers and breastfeeding
I do not have any relevant financial relationships with any commercial interests.
Overview

- Lead poisoning is the most common environmental disease affecting children\(^1\)
- Blood lead level is a short-term measurement reflecting:
  - Exposure from current exogenous sources
  - Release of endogenous lead from bone & soft tissue stores
- Blood lead level is measured on whole blood and expressed in micrograms per deciliter (mcg/dL)
  - Venous blood sample is the gold standard
    - Capillary draw acceptable

\(^1\) MMWR 5/27/2005
Blood Lead Level (BLL)

- Most children have BLL below 2 mcg/dL
  - No known safe levels¹,²
- CDC recommends monitoring children with levels in top 2.5% above mean in most recent NHANES³,⁴
  - Currently 5 mcg/dL
  - Guidance reevaluated every 4 years
- Earliest effects of elevated lead are sub-clinical
  - Screening is best for early diagnosis of exposure
  - Prevention of exposure is best approach

¹ Koller et al. EHP, Jun 2004
² Bellinger, Current Opinions in Pediatrics, 2008, 20:172-177
⁴ National Health and Nutrition Examination Survey
Approximately 727,000 children under 21 received blood lead tests

1 in 317 had results reflecting BLL of 10mcg/dl or more

1 in 34 had BLLs equal or greater than 5 mcg/dL

1 Response & Surveillance System for Childhood Lead Exposure
2 California rounds up results from 4.5 and 9.5 mcg/dL
3 Jusko, et al, Environmental Health Perspectives, Feb. 2008: Intellectual functioning @ 6yo impaired by BLL under 10mcg/dL
4 Bellinger, Current Opinions in Pediatrics, 2008: Very low lead exposures and children’s neurodevelopment
How Much Lead is Hazardous?

- 1 gram packet of lead dust spread over 10,000 square feet gives lead level of 100 mcg/square foot
- Current EPA acceptable level: 40 mcg/square foot
- FDA recommended maximum consumption: 6 mcg per day
Metabolism of Lead

- Main absorption in children is gastrointestinal
  - More bioavailable when fasting
- Similar to iron and calcium
- 70% total body lead is stored in bone\(^1\)
  - Half-life in blood is weeks
  - Half-life in bone is decades

\(^1\) Environmental Health Perspectives 1993, 101:598-616
Sub-clinical Effects of Lead

- Iron deficiency often associated with elevated blood lead level\(^1\)
  - Fe insufficiency allows more lead absorption
- Interferes with hemoglobin synthesis
  - Free erythrocyte protoporphyrin
  - Basophilic stippling
- Neuro-developmental toxin

\(^1\) Wright, et al, J Pediatr, 2003; 142: 9-14
Earliest Clinical Symptoms

- Anemia
- Anorexia
- Abdominal pain
- Constipation

- Abdominal x-ray if BLL over 20mcg/dL

Case reports:
2. Clinical Pediatrics Jan 2007: *Constipation*
Rare Clinical Symptoms

- Blood lead over 70 mcg/dL
  - Changes in mentation (encephalopathy)
  - Ataxia
  - Seizures
  - Coma
  - Death

- Feb 2006: 4 year old dies in Minnesota of undiagnosed lead poisoning (BLL 180)
- Reebok recall
- Pediatrics, Dec 2006, 2548-51
Most Common Clinical Finding

- Neuro-developmental compromise
  - After early childhood exposure
- Clear reduction in IQ inversely correlated with rising lead levels
  - IQ can drop 5-8 points
  - Multiple studies\(^1,2,3\)
- Even at very low levels\(^4\)

\(^1\) Bellinger, 1992, decrease of 5.8 IQ points
\(^2\) Pocock & Smith, 1994, Review
\(^3\) Needleman, 2004, Lead Poisoning
\(^4\) Bellinger, Current Opinions in Pediatrics, 2008
Illustrating the Inverse Relationship Between IQ and Blood Lead Level

Blood Lead Level at 24 Months of Age (mcg/dL)

What is the impact of an average drop of 5 IQ points?
Effects of Small Shift in IQ Distribution in Normal Population

Adapted from Pediatric Environmental Toolkit
Why Is Even Under 10 mcg/dL of Concern?

- There is a steeper drop at lower levels\(^1\)
- There are no known safe levels\(^2\)

\(^1\)Meta-analysis by Lanphear et al. Environ Health Perspect 2005
\(^2\)Confirmed by meta-analysis by Koller et al. EHP, Jun 2004
In Economic Terms

- Estimated savings to society for the decrease of lead from 17.1ug/dL to 2ug/dL based on productivity
- For the year 2000 US birth cohort of 3.8 million individuals
- Approximates $100-300 billion

¹Grosse et al, Environmental Health Perspectives, June 2002, 110:563-569
Other Disorders Associated with Lead Exposure

- Developmental Disorders
  - Fetal Growth, IUGR\(^1\)
  - Reproductive Disorders
  - Delayed Sexual Maturation

- Learning Issues
  - Associated with ADHD\(^2\)

- Cardiovascular Disorders
  - Link to childhood\(^3\) and adult hypertension\(^4\)

- Behavioral Disorders
  - Violence and Aggressive Behavior\(^5,\,6\)
  - Juvenile delinquency\(^7,\,8\)
  - Elevated school drop-out rate\(^9\)
  - Direct effect on behavior\(^10\)
  - Potential link to criminal behavior\(^11\)

\(^1\) Hernandez-Avila, M, et al, Arch. Env. Health 2002; 57, 482-48
\(^5\) Gould E Environ Health Perspective 2009; 117(7): 1162-7
\(^6\) Mielke, HW, Zahran, S, Environment International 2012; 43:48-55
\(^7\) Dietrich KN, et al. Neurotoxicol Teratol 2001; 23(6):511-8
\(^8\) Needleman, HL. Neurotoxicol Teratol 2002; 24(6):711-717
What are the Common Sources of Lead?

- Deteriorated lead-based paint
  - Cracking, flaking, peeling
- Lead-contaminated dust
- Lead-contaminated soil
• Pica
• Chipping paint
• Dust
Top Ten States with Pre-1950 Housing

Based on 1990 Census Data

Millions of Units

NY, PA, CA, IL, OH, MI, MA, NJ, TX, WI

1 Based on 1990 Census Data
Top Ten States with Pre-1980 Housing\(^1\)

1 Based on 2010 Census Data

<table>
<thead>
<tr>
<th>State</th>
<th>Millions of Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>8</td>
</tr>
<tr>
<td>New York</td>
<td>6</td>
</tr>
<tr>
<td>Texas</td>
<td>4</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>4</td>
</tr>
<tr>
<td>Illinois</td>
<td>3</td>
</tr>
<tr>
<td>Florida</td>
<td>3</td>
</tr>
<tr>
<td>Ohio</td>
<td>3</td>
</tr>
<tr>
<td>Michigan</td>
<td>2</td>
</tr>
<tr>
<td>New Jersey</td>
<td>2</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>1</td>
</tr>
</tbody>
</table>

\(^1\) Based on 2010 Census Data
Percent of homes built before 1980 in California by County (2000 Census data)

- 75.8 – 91.0%
- 60.6 – 75.8%
- 45.4 – 60.6%
- 25.0 – 45.4%

Map showing the distribution of the percentage of homes built before 1980 across California counties.
Bright! Shiny! Durable!

- Pre-1955: All white paint is 50% lead
- 1955: Optional industrial voluntary reduction to 1%
- 1971: Federal mandatory maximum of 1%
- 1977: Federal maximum of 0.06%
- 2009: Federal maximum is 0.009% (90 ppm)
Leaded Gasoline

• Used since 1930’s
• Increasingly restricted until banned mid-1990’s
Change in Blood Lead Levels in Relation to Decline in Use of Leaded Gasoline 1976-1980

Source: Annest JL, 1983
Lead in Soil Remains
...And Gets Blown Around\textsuperscript{1}

Lead in Tap Water

- EPA regulatory level is 15 ppb
  - 1991 Safe Drinking Water Act prohibited lead pipe for residential use
  - Pre-1986 housing more likely to have lead in pipes, fittings, solder, fixtures, faucets

- 2010 California further lowered allowable lead content in plumbing fixtures
  - Families should consult with an environmental professional about testing if they have concerns
    http://water.epa.gov/drink/info/lead/index.cfm
  - Well water should be tested before use
    http://safewater.supportportal.com/link/portal/23002/23015/Article Folder/879/Household-Wells
What are other, less common sources of lead?
Occupational Sources Brought Home

- Construction/abatement/remodeling
- Smelting/soldering/painting
- Storage battery production
- Firing ranges

At-Risk Activities

- Furniture painting/refinishing
- Glazing
- Soldering
- Lead fishing weights
- Collectibles
- Firearms
Lead in Imported Ceramics

Cazuela¹

¹Jl Environ Health, May 2008; Lead Leachability from Lead-Glazed Ceramic Cooking Vessels

Jarra²

²Eating Soil: www.cdc.gov/ncidod/eid/vol9no8/pdfs/03-0033.pdf
Lead in Consumer Products

Check for recalls at [www.cpsc.gov](http://www.cpsc.gov) and [www.dtsc.ca.gov/LeadInJewelry.cfm](http://www.dtsc.ca.gov/LeadInJewelry.cfm)
Lead Contamination in Candy and Foods

Chili powder

Turmeric

Chapulines from Oaxaca
AJPH, May 2007
Lead in Traditional Remedies

- Azarcon and Greta
  - Mexican community
  - Bright powders used for gastrointestinal upset (*empacho*)
Lead in Traditional Remedies: Other Communities

- Patent remedies in Chinese community
- Bright colored powders in South Asian community
- Black-powder cosmetics in Middle Eastern community
- Herbal remedies
- Ayurvedic medicines

Sindoor
Who is at Risk for Lead Exposure?

- Children living in older housing
- Toddlers 1-2 years old
  - Hand-mouth behavior
  - Pica
- Children from countries with higher environmental lead exposures
- Children living below poverty line
  - Traditionally those enrolled in government-assisted programs:
    - Medicaid
    - Child Health & Disability Prevention Program (CHDP)
    - Supplemental Nutrition Program for Women, Infant and Children (WIC)
    - Healthy Families
    - Head Start
What You Need to Do:
California’s Statewide Targeted Assessment Policy
1. Anticipatory Guidance

- At each periodic health assessment from six months to 72 months
- Inform parents of risk of lead exposure to young children
  - Especially deteriorating/disturbed lead-based paint and paint dust
  - Particularly after child begins crawling
  - Particularly because of hand-mouth behavior
- Advise reducing soil exposure and dust levels
- Advise about leaded pipes & fixtures if living in older house
- Provide simple written information
2. PREVENTION is the Goal

- General prevention
  - Hand washing
  - Good nutrition
  - Infant stimulation

- Prevent further neuro-developmental compromise
  - Enroll in Head Start/Early Childhood Education
  - Arrange for developmental evaluation and follow-up

- See treatment matrix at:
3. Statewide Targeted Assessment Policy

- Blood test all children who receive services from publicly funded programs
  - Medi-Cal
  - Healthy Families
  - CHDP
  - WIC
  - Head Start
- Blood test children not in publicly funded programs whose family answers “yes” or “don’t know” to the following question:
  - “Does your child live or spend a lot of time in a place built before 1978 that has chipped or peeling paint or has been recently renovated?”
- @ ~12 months & ~24 months of age
- “Catch up” testing between 2 & 6 years of age
Other Indications for a Blood Lead Test

- Any child not appropriately tested
- If parent requests
- If refugee or recent immigrant
  - Because of exposure to unknown risks
    - Especially adopted toddlers from developing countries
- If known lead exposure in family members or close contacts
- If obvious risk factors or exposures are present
- If required as part of special programs
Federal Refugee Guidelines¹

- Blood lead test all refugee children 6 mo.-16 yr. upon entry to U.S.
- Children age 6 mo. - 6 yr. need repeat BLL 3-6 months after placed in permanent residences
  - In older children, repeat if warranted, regardless of initial test results.
- Evaluate child’s iron status
  - Hemoglobin/hematocrit
  - Red blood cell indices

¹[www.cdc.gov/immigrantrefugeehealth/guidelines/lead-guidelines.html](http://www.cdc.gov/immigrantrefugeehealth/guidelines/lead-guidelines.html)
Confirmatory Testing and Follow-up

● The higher the BLL is on screening, more urgent the need for confirmatory testing/follow-up
  ● Elevated capillary BLLs must ALWAYS be confirmed with a venous level

<table>
<thead>
<tr>
<th>Screening test result (mcg/dL)</th>
<th>Confirm within</th>
<th>Follow-up BLLs</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.5-9.4</td>
<td>6 months</td>
<td></td>
</tr>
<tr>
<td>9.5-19.4</td>
<td>3 months</td>
<td></td>
</tr>
<tr>
<td>19.5-44.4</td>
<td>1 week-1 month</td>
<td></td>
</tr>
<tr>
<td>44.5-59.4</td>
<td>48 hours</td>
<td>Every 2 wks-1 mo until trends downwards</td>
</tr>
<tr>
<td>59.5-69.4</td>
<td>24 hours</td>
<td></td>
</tr>
<tr>
<td>69.5 &amp; over</td>
<td>Immediately</td>
<td></td>
</tr>
</tbody>
</table>

● Always refer to latest online CDPH recommendations:

● Responsibility rests with provider to test & ensure appropriate follow-up
  ● Contact local health jurisdiction
    ● http://www.cdph.ca.gov/programs/CLPPB/Pages/CLPPPIIndex.aspx
What About Pregnancy and Breastfeeding?
Consider Ordering Blood Lead Level for Pregnant Women

- Particularly if previous history of lead poisoning
  - Most gravidas had previous exposure to leaded gasoline
  - Any lead stored in bones can be remobilized\(^1\)
- Exhibits pica/other risks
  - Remodeling older house
- Refugee or new immigrant
- Household member works in occupation with significant risk of lead exposure
- Lead-poisoned child living in household

\(^1\)Manton, et al, Environmental Research 2003
Elevated Lead Levels During Pregnancy

- Associated with
  - Maternal hypertension
  - Spontaneous abortion
  - Decreased fetal growth
  - Premature birth
  - Adverse neurodevelopmental effects
  - May adversely impact sexual maturation in the developing female

- Crosses the placenta
  - Infant’s BLL correlates with mother’s

- If elevated requires more frequent testing

CDC Breastfeeding Recommendations if Maternal Blood Lead Levels are Increased

- Measurement of levels of lead in breast milk is not recommended
  - Breast milk lead concentration is ~3% of mother’s blood lead concentration
  - At 1 month infant’s BLL is ~12% of maternal BLL
- Breast feeding reasonable if maternal BLL under 40 mcg/dL
- Breastfeeding not recommended if maternal BLL over 40 mcg/dL
  - Mother may pump and discard until maternal BLL is <40 mcg/dL
What are the services provided by the county childhood lead poisoning prevention program?
County Childhood Lead Poisoning Prevention Program (CLPPP)

- Automatic referral when there is:
  - BLL greater than 20 mcg/dL
  - Persistent BLL from 15 – 19 mcg/dL
  - As resources allow, some services for BLL below 14.5 mcg/dL

- Provide:
  - Home environmental investigation to identify lead sources
  - Case management services

- Most counties have state contract to provide services
  - If not then state provides
Case Management Services

- Public health nursing services
- Risk/exposure queries
- Further environmental interventions
- Identify other affected children/family members
- Tailored education
- Referral to WIC, Head Start, Special education
- Surveillance and follow-up
How should the clinician manage elevated lead levels?
Urgent Response to Very High Levels

- Rapidly retest and contact local county CLPPP
- Always confirm initial elevated BLL with another stat venous sample
  - Urgent attention
- Always evaluate the child’s environment
- Follow the California Management Guidelines
What is Chelation Therapy?

- Very rare to use
  - Not indicated below 45 mcg/dL
- Chemical that preferentially binds lead into a complex that can be excreted
  - Reduces lead in blood and soft tissue
  - Dropped mortality rate of severe acute encephalopathy from 66% to less than 2% ¹

- Chelating agents
  - Ca-Versenate (EDTA)
    - Always verify calcium salt!²
  - Dimercaprol (BAL in oil)
    - Very painful injection; given before CaEDTA
  - Succimer / DMSA / Chemet
    - Oral agent, FDA approved 1991
    - ~3 week course of treatment

¹ Chisolm JJ Jr. Environ Health Perspect. 1990; 89:67-74
² Use of wrong salt causes death!!
# Suggested Chelation Matrix

<table>
<thead>
<tr>
<th>BLL</th>
<th>Clinical status</th>
<th>Medication</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 45 mcg/dL</td>
<td>Chelation not indicated</td>
<td></td>
</tr>
<tr>
<td>45-69 mcg/dL</td>
<td>Asymptomatic</td>
<td>PO Succimer</td>
</tr>
<tr>
<td>45-69 mcg/dL</td>
<td>Symptomatic</td>
<td>IM BAL, IV CaNa₂EDTA²</td>
</tr>
<tr>
<td>70+ mcg/dL</td>
<td>No Encephalopathy</td>
<td>IM BAL, IV CaNa₂EDTA²</td>
</tr>
<tr>
<td>Medical emergency</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70+ mcg/dL</td>
<td>Encephalopathy</td>
<td>IM BAL, IM CaNa₂EDTA²</td>
</tr>
<tr>
<td>Medical emergency</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Often need bowel cleansing before initiating treatment
- Always consult with provider experienced in managing chelation

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2 Use of wrong salt causes death!
Today’s Take-home Messages

1) Lead can cause developmental delay even at very low levels
2) Most at risk are toddlers (hand-mouth activity) and children in federally funded programs
3) Most common lead exposure for children is from lead-contaminated paint, dust, or soil
4) Other sources need to be considered
   - Exposure is often multifactorial
   - Exposure is cumulative
5) Prevention best approach to lead exposure
6) Blood-testing of at-risk groups best method of early detection
7) Local county CLPPPs can provide various resources for the primary care provider
Thank You!!

Questions?
Complying with Current Standards of Care\textsuperscript{1,2}

- Provide anticipatory guidance about lead hazards to all parents
- Lead test all publicly assisted children
- Ask assessment question of other children
- Identify and eliminate lead sources to prevent further exposure
- Encourage good nutritional practices
- Referral to Head Start/Early Childhood Education
- Consider periodic developmental testing if BLL is 5 mcg/dL or greater
- Request assistance of local county CLPPP when BLL is 10 mcg/dL or greater
- Refer family members for blood lead test when appropriate
- Ask if pregnant family members tested for lead

\textsuperscript{1} California Recommendations
\textsuperscript{2} AAP Current Management: http://aappolicy.aappublications.org/cgi/reprint/pediatrics;116/4/1036.pdf
<table>
<thead>
<tr>
<th>Blood Lead</th>
<th>Suggested Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5 mcg/dL</td>
<td>Anticipatory guidance and assess lead exposure, nutrition, anemia, development. Screening at risk and when suspect exposure.</td>
</tr>
<tr>
<td>5-9</td>
<td>As above + more attention to development. Test young children &amp; pregnant nursing women. Add lead poisoning to diagnosis. Retest within 6 mo.</td>
</tr>
<tr>
<td>10-14</td>
<td>As above + consider early intervention programs. Refer to CLPPP for information &amp; some services. Venous retest in 3 months.</td>
</tr>
<tr>
<td>15-19</td>
<td>As above + order hemoglobin/hematocrit. Venous retest in 1-2 months. If persists 15-19 µg/dL treat as for 20-44 µg/dL.</td>
</tr>
<tr>
<td>20-44</td>
<td>As above. Depending on BLL, retest in 1 week to 1 month. Order abdominal x-rays and if positive, bowel decontamination. CLPPP public health referral for case management &amp; environmental investigation.</td>
</tr>
<tr>
<td>45-69</td>
<td>URGENT. Venous retest 48 hours; in 24 hours if over 60 µg/dL. If confirmed, consider oral chelation. Bowel decontamination before chelation. Everything as above.</td>
</tr>
<tr>
<td>70 and above</td>
<td>MEDICAL EMERGENCY. Immediately venous retest. If confirmed admit for IV chelation. Bowel decontamination and everything else as above.</td>
</tr>
</tbody>
</table>

Adapted from http://www.cdph.ca.gov/programs/CLPPB/Documents/Provider%20mgmt%20guides.pdf