Blood Lead Levels in Children: Understanding Sources and Routes of Exposure

Pat McLaine, DrPH, MPH, RN

Understanding Lead Poisoning
In Baltimore and Maryland
October 27, 2016
Routes of lead exposure

- **Typically ingestion**
  - Hand to mouth behaviors
  - Eating/mouthing contaminated products
  - Drinking contaminated water

- **Dermal**
  - Products applied to the skin

- **Inhalation**
  - Tobacco Smoke
  - Organic lead compounds (lead in gasoline, solvents)
Endogenous Lead Exposures

• Lead is stored in bone and teeth for decades
  – 74% of lead in children
  – 95% of lead in adults

• Body mobilizes lead stores from bone to blood during times of stress:
  • Pregnancy
  • Lactation
  • Menopause
  • Physiologic stress
  • Chronic disease
  • Broken bones
  • Hyperthyroidism
  • Kidney disease
  • Old age
Children: reasons for increased susceptibility

- Disproportionately heavier exposures than adults:
  - Drink more water, eat more food and air per weight unit
  - Hand-to-mouth behavior
  - Play close to the ground

- Metabolic pathways, especially in fetal life and first months after birth, are immature
  - Metabolic, detoxification and excretion processes different from adults
  - Blood-brain barrier not fully developed

Landrigan PJ. EHP 2004;112:257-265
FIGURE 2-1
Falling Consumption of White Lead; Rising Consumption of Leaded Gasoline
(Washington: GPO, 1921–90). No statistics for tetraethyl lead were published prior to 1941.
Dramatic changes in lead exposure in the last century

Blood lead levels in NHANES

- 1988 – 1994 ➔ 2.8 µg/dL
- 1999 – 2002 ➔ 1.6 µg/dL

8-fold decline in blood lead

Environmental Sources of Childhood Lead Exposure
The many faces of lead in housing
Older Housing Stock

• Maryland has older housing stock
  – 18.5% built before 1950
  – 39.5% built between 1950-1978
    • Us Census Bureau, 2008-2012 American Community Survey, 5 year estimates.

• Baltimore’s rental stock is older
  – 41,872 properties built before 1950
  – 7,365 properties built 1950-78

• Baltimore’s rental stock is registered with MDE
  – 55,528 pre-1950 units (May 21, 2015)
Maryland Reduction of Lead Risk in Housing Law

• 1996 – registration required of pre-1950 rental property owners
• Full risk reduction certificate required at turn-over [50% by 2001, 100% by 2006]
• Oct 1 2004 – rent court judges and housing registry officials cannot accept cases or applications from pre-1950 owners who cannot present certificate showing compliance
• January 1 2015 – registration and inspection with certificate now required for rental property built between 1950-1978
• Regulation of renovation, repairs and painting in all homes and child care facilities built before 1978
  – Contractors must be trained
  – Workers must use of safe work practices
  – State regulations not yet promulgated
Other sources of lead

- Lead in consumer products
  - Cosmetics – kohl, surma
  - Medicinals
  - Metal charms, jewelry
  - Toys
  - Candy
- Lead in cigarettes
- Occupational exposures of parents
  - Construction
  - Do-it-yourself home repairs
Elevated Blood Lead Levels in Refugee Children

- Newly arrived refugee children are twice as likely as U.S. children to have elevated BLLs.
- Some sub-populations of refugee children are 12-14.5 times more likely to have elevated BLLs.
- Data suggest that refugee children are also at risk for elevated BLLs after resettlement in the U.S.
Herbal Medicine Products

Definition of herbal medicine products:

- Products containing herbs or minerals used for medicinal purposes
- Often used as part of a traditional medical system

Traditional systems used by 65-80% of world’s population*

- Used by 70-80% of India’s population*
- 18% of U.S. prescription medicine users also use herbal medicines±


Lead in Herbal Medicine Products

• **Heavy metals may be present**
  – Intentionally added as part of product for therapeutic effects
  – Contaminated during preparation/manufacturing
  – Lack of protective standards for manufacturers, exporters, importers

• Lead has been found in powders and tablets given for arthritis, infertility, upset stomach, menstrual cramps, colic and other illnesses.

• **Greta** and **Azarcon** (also known as alarcon, coral, luiga, maria luisa, or rueda) are Hispanic traditional remedies taken for an upset stomach (empacho), constipation, diarrhea, vomiting, and used on teething babies. Greta and Azarcon are both fine orange powders that have a lead content as high as 90%.
Routes of Exposure in Maryland
Herbal Medicine Products and Kohl
MDE Case Investigation

Kum Kum and Orange Powder

Kohl
More recent sources of childhood lead exposure
## New Cases of BLLs $\geq 10\mu g/dL$
### 2014 and 2015

<table>
<thead>
<tr>
<th>Jurisdiction</th>
<th>2014</th>
<th>2015</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baltimore City</td>
<td>119</td>
<td>140</td>
</tr>
<tr>
<td>Prince George’s County</td>
<td>42</td>
<td>37*</td>
</tr>
<tr>
<td>Montgomery County</td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>Baltimore County</td>
<td>20</td>
<td>25</td>
</tr>
<tr>
<td>Maryland TOTAL</td>
<td>233</td>
<td>261</td>
</tr>
</tbody>
</table>

- 17 cases were in children of refugee families who had relocated to the US from Afghanistan. High usage of cultural remedies, herbs and make-up was identified among these families.

MDE Childhood Blood Lead Surveillance in Maryland, Annual Report, 2014 and 2015
Housing of New Cases (BLL 10+ µg/dL), Baltimore Children, 2013-2015**

<table>
<thead>
<tr>
<th>YEAR</th>
<th>Pre-1950 rental</th>
<th>Post-1950 Rental</th>
<th>Owner-occupied</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BALTIMORE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>52%</td>
<td>3%</td>
<td>45%</td>
</tr>
<tr>
<td>2014</td>
<td>60%</td>
<td>2%</td>
<td>38%</td>
</tr>
<tr>
<td>2015</td>
<td>59%</td>
<td>3%</td>
<td>38%</td>
</tr>
<tr>
<td></td>
<td>MD COUNTIES</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>25%</td>
<td>38%</td>
<td>37%</td>
</tr>
<tr>
<td>2014</td>
<td>17%</td>
<td>50%</td>
<td>33%</td>
</tr>
<tr>
<td>2015</td>
<td>13%</td>
<td>42%</td>
<td>45%</td>
</tr>
</tbody>
</table>
What we know about Maryland Lead Exposures

• Case management for children with BLLs of 10µg/dL
  – Environmental investigation
  – Home visit with interview
  – Federal Guidelines: HUD Chapter 16

• Many cases now have multiple exposure sources:
  – paint,
  – dust,
  – soil

• In 2015, 17 cases of lead poisoning were identified among Afghani refugee children, exposed to cultural remedies, herbs and make up

• We only know about exposures if we test for them.
  – Housing is a major source – what is the contribution of soil?
  – Is water an issue, particularly for older homes on wells

• In the future: more cases with multiple or “other” sources
Maryland and CDC’s New Lead Reference Value: 5µg/dL

- No threshold and no safe level
- $5\mu g/dL = 0.5\%$ of US population of children
- In Baltimore, 3.9% of children tested in 2014 had new BLL of 5-9µg/dL ($N = 708$)
- In Maryland counties, 1.0% of children tested in 2014 had new BLL of 5-9µg/dL ($N = 899$)
Lead & Cognitive Effects in Children

- Decreased IQ
- Decreases in visual-spatial skills, cognitive flexibility, working memory
- Poor school performance
  - Lower scores on end of grade exams (reading, math)
  - Failure to graduate from high school
- Reading disability
- Increased attentional dysfunction
- Increased aggression
- Increased delinquency

Early deficits may persist
No threshold
Association Between IQ Scores & Blood Lead Levels in Children

- Fulton et al. (1987)
- WHO/CEC (Winneke et al., 1990)
- Lansdown et al. (1986), manual occupation
- Lansdown et al. (1986), non-manual occupation
- Yule et al. (1981)
- Schroeder et al. (1985)
- Hawk et al. (1986)
Significance of IQ Deficit

IQ Score

6 pt. shift in mean

Subjects (x100,000)

“Impaired”

“Genius”
Estimated IQ decrements estimated with increases in blood lead from:

- 2.4 to 10 µg/dL: 3.9
- 10 to 20 µg/dL: 1.9
- 20 to 30 µg/dL: 1.1

Steepest declines were at blood lead levels <10 µg/dL
Low Level Exposure and Cognitive Function

WISC-R Full Scale I.Q. Scores

Adjusted Score

Blood lead (µg/dL) at 24 months

Lead and Reading Scores
~8,600 children

Miranda et al. EHP 2007;115(8):1242-1247
Differences in Mean Fall PALS-K Scores between Refined GM BLL Category & Reference Category

<table>
<thead>
<tr>
<th>GM BLL Category</th>
<th>Difference in Adjusted Mean Fall PALS-K Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ref. -2.7</td>
</tr>
<tr>
<td>2</td>
<td>-3.3</td>
</tr>
<tr>
<td>3</td>
<td>-2.7</td>
</tr>
<tr>
<td>4</td>
<td>-5</td>
</tr>
<tr>
<td>5</td>
<td>-8.1</td>
</tr>
<tr>
<td>6</td>
<td>-8.2</td>
</tr>
<tr>
<td>7</td>
<td>-9.3</td>
</tr>
<tr>
<td>8</td>
<td>-7</td>
</tr>
<tr>
<td>9</td>
<td>-13</td>
</tr>
<tr>
<td>10+</td>
<td></td>
</tr>
</tbody>
</table>

Prevalence of BLLs $\geq 10\mu$g/dL in Providence kindergarten students

- 20% - one in five - had at least one BLL $\geq 10\mu$g/dL.
- NHANES 1999-2004: 1.4% of 1-5 year olds had BLL $\geq 10\mu$g/dL.

Urban School Districts: Challenges Underestimated

- The extent of lead exposure risks for urban children is not well understood.
- Urban children from higher income families are more likely to attend private/parochial/charter schools.
- Population of children remaining in public schools is at higher risk for poor educational outcomes:
  - Lower income
    - Poor housing
  - Higher proportion of children with lead exposure history
Children Affected by Lead in Maryland

- Since 1998, nearly 60% of Maryland children with new BLL of 10+ μg/dL have lived in Baltimore.
- Annual estimates of BLL of 10+ μg/dL in Baltimore have declined tremendously:
  - 1,979 in 1998 (11.4% of children tested)
  - 129 in 2014 (0.7% of children tested)
- But, in 2016, the burden of lead exposure (BLL of 10μg/dL or higher) among school aged children, 18 and younger, remains high:
  - about 10,440 children living in Baltimore City
  - about 5,000 children living in Maryland counties,

Overall Conclusions

• Lead exposure contributes to many disparities observed in educational settings.
• Data support that there is no “safe” lead level.
• Data linkage approaches would benefit public schools and public health.
• Advocacy for resources and approaches that work will be critical.
• Targeting children with elevated BLLS for early educational opportunities may help
Clinician Testing

Keep it simple - BLL testing as part of routine check ups

Consider Point of Care testing for lead
Why Point of Care Testing?

• Easy and convenient
  – No loss in opportunity as seen with outside labs
  – Fingerstick – 2 drops of blood

• Results available immediately – 3 minutes

• Test, educate and take action in one visit
  – If < 5 µg/dL - prevention education
  – If ≥ 5 µg/dL must be confirmed (venous)
    • Also assess for lead exposures
      – Housing
      – Other

Hand Held Analyzer – Lead Care II
Increased BLL Reporting – Point of Care

<table>
<thead>
<tr>
<th>Year</th>
<th># entities</th>
<th># BLL Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>32</td>
<td>11,041</td>
</tr>
<tr>
<td>2013</td>
<td>35</td>
<td>12,908</td>
</tr>
<tr>
<td>2014</td>
<td>47</td>
<td>16,758</td>
</tr>
<tr>
<td>2015</td>
<td>66</td>
<td>22,360</td>
</tr>
</tbody>
</table>

MDE Childhood Blood Lead Surveillance in Maryland, Annual Report 2015
How are we doing?
Blood lead testing at 12 and 24 months in 2015

- Alleghany County – 68.2%
- Somerset County – 59.8%
- Baltimore City – 54.8%
- Talbot County – 54.3%
- Caroline County – 50.4%
- Baltimore County – 49.2%
- Charles County – 48.9%
- Dorchester County – 48.9%
- Worcester County – 49.2%
- Wicomico County – 48.2%
- State of Maryland – 39.8%

MDE Childhood Blood Lead Surveillance in Maryland, Annual Report 2015
Information and Reporting

- Maryland Department of the Environment – Childhood Lead Poisoning Prevention Program
  - Annual reports on lead testing since 1998
  - Materials for health care providers, parents, tenants, home owners, rental owners, contractors
  - Look-up available for rental housing built before 1978
- [http://www.mde.state.md.us/programs/Land/LeadPoisoningPrevention/Pages/index.aspx](http://www.mde.state.md.us/programs/Land/LeadPoisoningPrevention/Pages/index.aspx)
Questions?
Adult Lead Exposure: Time for Change

Brian S. Schwartz¹,² and Howard Hu³

¹Departments of Environmental Health Sciences and Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA; ²Department of Medicine, Johns Hopkins School of Medicine, Baltimore, Maryland, USA; ³Department of Environmental Health Sciences, University of Michigan School of Public Health, Ann Arbor, Michigan, USA

Blood lead levels defined as lead poisoning (mg/dL)


0 10 20 30 40 50 60 70

60 µg/dL
40 µg/dL
30 µg/dL
25 µg/dL
10 µg/dL
5 µg/dL

1976-1980 geo. mean = 15 µg/dL (children)
2002 geo. mean = 2.2 µg/dL (children)

OSHA criteria for workers

CDC criteria for children

5 µg/dL
Lead biomarkers – Blood vs. bone lead

- **Bone (cortical, trabecular)**
- **Whole blood**

- **Half-life** Decades
- **~35 days**

- **Reflect** Cumulative exposure Recent external and internal exposure

- **Analysis** K X-ray fluorescence AAS / ICPMS

- **Monitoring** No
- **Yes**

- **Criterion** No
- **5 µg/dL children**
- **40 µg/dL workers**

AAS: atomic absorption spectometry / ICPMS: inductively coupled plasma mass spectometry

Other lead biomarkers not usually used (hair, toenails, urine, plasma, serum)

Barbosa et al. EHP 2005;113:1669-74  
Hu et al. EHP 2007;115:455-63
The Decline in Blood Lead Levels in the United States

The National Health and Nutrition Examination Surveys (NHANES)

James L. Pirkle, MD, PhD; Debra J. Brody, MPH; Elaine W. Gunter; Rachel A. Kramer, ScD; Daniel C. Paschal, PhD; Katherine M. Flegal, PhD, MPH; Thomas D. Matte, MD, MPH

NHANES II (1976 to 1980)

NHANES III Phase 1 (1988 to 1991)

78% drop

Fig 1.—Blood lead levels for persons aged 1 to 74 years: United States, second National Health and Nutrition Examination Survey (1976 to 1980, top) and phase 1 of the third National Health and Nutrition Examination Survey (1988 to 1991, bottom).