Lead Exposure Risk and Testing for Pregnant People in Milwaukee

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ABSTRACT

Background: Despite established lead exposure risks in Milwaukee from leaded water service lines and lead dust exposure with aged housing stock, most pregnant people do not have lead levels tested. We aimed to assess the prevalence of elevated lead levels among pregnant people and assess for differences in maternal and neonatal outcomes by lead detection.

Methods: We conducted a prospective, longitudinal study. English-speaking pregnant people ≥18 years of age receiving prenatal care were consented to receive a point-of-care (POC) lead test from June 2019 through July 2021. POC lead testing was not offered outside of the study. Venous lead labs were ordered to confirm elevated POC results (≥5 mcg/dL).

Results: Overall (n=233), 42.1% had an exposure risk given lead service line to their homes. Nine (3.9%) had an elevated POC lead test; half completed venous lead tests, and none were elevated. Twenty-two (9.4%) had detectable lead (≥3.3 mcg/dL).

Discussion: Venous lead testing should be considered in high-risk areas with standard prenatal labs to facilitate effective lead screening given the study population's risk of lead exposure.

BACKGROUND

Elevated blood lead levels during the prenatal period are associated with adverse neonatal and maternal outcomes. Studies demonstrate that lead exposure during pregnancy affects fetal growth and neurodevelopment,[1,2] as well as gestational hypertension and preterm delivery—even with very low blood lead levels.[3] The Centers for Disease Control and Prevention (CDC) published recommendations in 2010 (reaffirmed by the American College of Obstetricians and Gynecologists in 2018) to screen all pregnant people for risk of lead exposure and to test all with identified risk factors.[4] Risk factors for exposure include lead-contaminated drinking water, household member(s) with an elevated lead level, recent immigration from areas with high ambient lead contamination, and a personal history of previous lead exposure.[4] Risk factors also include housing built before 1978 with renovations or peeling paint, which can lead to lead exposure through dust.[5]

Currently, there is high risk for lead exposure in the city of Milwaukee, Wisconsin, with 74% of homes built before 1960 and an additional 18% built between 1960 and 1979.[6] Additionally, Milwaukee's water system is laden with lead service lines, with efforts to replace 65 000 residential leaded water service lines currently underway.[7] Lead poisoning rates for children in Milwaukee have been and continue to be disproportionately high. In 2016, the rate of elevated blood lead levels (≥5mcg/ dL) in children <6 years old was 10.8% in the city of Milwaukee, compared to a state prevalence of 5.0% and national prevalence of 4.0%.[8] In the most impoverished areas of Milwaukee, the prevalence rate has ranged from 25% to 31%.[9]

Personal history of childhood lead exposure is a risk factor that could contribute to increased prevalence of elevated lead levels during pregnancy in Milwaukee. Lead is deposited in the bones, with 90% of lead burden stored in the bones as adults. During pregnancy, bone lead stores are mobilized into the serum.[4] Studies suggest that serum lead levels may be affected equally by bone stores as by contemporaneous environmental Disease Control and

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While childhood rates of elevated lead levels are readily available, data on the prevalence of elevated lead levels in pregnant people are limited. The rate of blood lead level elevation in pregnant people in the National Health and Nutrition Examination Survey (NHANES) was so low that the study could not reliably report prevalence of elevation nationally (0.5% with relative standard errors >50%, total sample n = 732).[11] A recent study examining 40 years of NHANES data (1976-2016) demonstrated dramatic declines of blood lead levels in people of reproductive age, yet identified lead exposure risks continue, and there are increasing reports of subgroups at high risk of lead exposure requiring further study.[12] While the CDC and ACOG recommend to test all those with identified risk factors,[4] adherence to these guidelines may be low within our local health system in

Table 1. Maternal Demographics and Risk Factors at Time of Point-of-Care Lead Test, N = 233

	Total	Lead Detected on POC		*P* value
		Yes (n = 22)	No (n = 211)	
Age (years), Median (IQR)	27.0 (22.0–32.0)	29.0 (26.0–33.0)	26.0 (22.0–32.0)	0.09
Gestational age at time of POC lead test weeks), Median (IQR)[a]	10.5 (8.5–13.2)	10.6 (9.9–17.4)	10.4 (8.3–13.1)	0.02
Race/ethnicity, n (%)				
Black, non-Hispanic	149 (63.9)	12 (54.6)	137 (64.9)	0.33
White, non-Hispanic	55 (23.6)	6 (27.3)	49 (23.2)	0.67
Other[b]	29 (12.4)	4 (18.2)	25 (11.8)	0.39
Area deprivation index at state decile, n (%)				
< 5	33 (14.2)	3 (13.6)	30 (14.2)	1.00
5 – 6	22 (9.4)	2 (9.1)	20 (9.5)	1.00
7 – 8	29 (12.4)	3 (13.6)	26 (12.3)	0.74
9 – 10	144 (61.8)	13 (59.1)	131 (62.1)	0.78
Unknown	5 (2.1)	1 (4.5)	4 (1.9)	0.39
Length of time at current address, n (%)				
< 1 year	100 (42.9)	7 (3.2)	93 (4.2)	0.18
>1 year	131 (56.2)	14 (63.6)	117 (55.5)	0.46
Unknown	2 (0.9)	1 (4.5)	1 (0.5)	0.05
First 6 years of life outside the US, n (%)	10 (4.3)	0 (0.0)	10 (4.7)	0.60
County lived in during first 6 years of life, n (%)				
Milwaukee County	165 (70.8)	14 (63.6)	151 (71.6)	0.44
Racine County	7 (3.0)	0 (0.0)	7 (3.3)	1.00
Neither Milwaukee or Racine counties	58 (24.9)	7 (31.8)	51 (24.2)	0.43
Unknown	3 (1.3)	1 (4.5)	2 (0.9)	0.26
Drinking water, n (%)				
Tap	56 (24.0)	5 (22.7)	51 (24.2)	0.88
Filtered	38 (16.3)	5 (22.7)	33 (15.6)	0.37
Bottled	137 (58.8)	11 (50.0)	126 (59.7)	0.38
Unknown	2 (0.9)	1 (4.5)	1 (0.5)	0.18
Cooking water, n (%)				
Tap	185 (79.4)	15 (68.2)	170 (80.6)	0.17
Filtered	30 (12.9)	5 (22.7)	25 (11.8)	0.18
Bottled	16 (6.9)	1 (4.5)	15 (7.1)	1.00
Unknown	2 (0.9)	1 (4.5)	1 (0.5)	0.18
Anyone with history of elevated lead test in home, n	12	0	12	0.61
Had lead service line to current home, n (%)	98 (42.1)	14 (63.6)	84 (39.8)	0.03

Abbreviations: POC, point-of-care; IQR, interquartile range.

[a]Anembryonic pregnancy with unknown last menstrual period. Yes, lead detected on POC (n = 21).

[b]Other includes Hispanic, Asian, other, multirace, and unknown.

Table 2. Report of Characteristics, Risk Factors, and Outcomes of Pregnant People With an Elevated Point-of-Care Lead Test

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Patient 6	Patient 7	Patient 8	Patient 9
Age (years)	29	27	28	34	36	29	40	34	26
Gestational age at time of POC lead test	9w 6d	Unknown[a]	10w 1d	9w 4d	10w 4d	9w 1d	17w 3d	9w 4d	15w 0d
Race/ethnicity	Black non-Hispanic	Hispanic	Black non-Hispanic	White non-Hispanic	White non-Hispanic	White non-Hispanic	Black non-Hispanic	White non-Hispanic	Black non-Hispanic
Area deprivation index at state decile	9	10	9	7	8	3	10	1	9
POC lead test result	5.7	37.2	6.1	6.3	6.4	7.5	15.4	5.7	9.2
First venous lead test result	–	–	2	–	2	2	–	2	2
Second venous lead test result	–	–	2	–	–	–	–	–	–
Length of time at current address	>1 year	>1 year	3–6 months	>1 year	>1 year	>1 year	3-6 months	>1 year	3–6 months
First 6 years of life outside of the US	No	No	No	No	No	No	No	No	No
County lived in during first 6 years of life	Milwaukee	Milwaukee	Milwaukee	Milwaukee	Not Racine or Milwaukee	Not Racine or Milwaukee	Milwaukee	Not Racine or Milwaukee	Milwaukee
Drinking water	Tap	Bottled	Bottled	Filtered	Filtered	Tap	Filtered	Tap	Tap
Cooking water	Tap	Tap	Filtered	Tap	Filtered	Tap	Filtered	Tap	Tap
Anyone w history of elevated lead test in home	No	No	No	No	–	No	No	No	No
Had lead service line to home	Yes	Yes	No	–	–	No	Yes	–	No
Lost to follow-up	Yes	–	No	No	No	No	Yes	No	Yes
Miscarried	No	Yes	No	No	No	No	–	No	–
Gestational hypertension this pregnancy	No	–	No	No	No	No	–	No	–
Preeclampsia this pregnancy	No	–	Yes	No	No	No	–	No	–
Gestational diabetes this pregnancy	No	–	No	No	No	Yes	–	No	–
Gestational age at time of delivery	–	–	40w 5d	39w 5d	39w 2d	39w 0d	–	39w 2d	–
Birth weight (grams)	–	–	3100	3360	3790	3320	–	3800	–
5-minute Apgar	–	–	9	9	9	9	–	9	–
Neonatal death	–	–	No	No	No	No	–	No	–

Abbreviations: POC, point-of care; NICU, neonatal intensive care unit; w, weeks; d, days.
[a]Anembryonic pregnancy with unknown last menstrual period.

southeastern Wisconsin. From 2014 to 2017, a venous lead test was performed for only 0.12% of pregnancy episodes. Given the paucity of local data, low rates of testing for lead levels during pregnancy, and critically high levels of childhood lead poisoning among the Milwaukee community, our study aimed to assess the prevalence of elevated lead levels among pregnant people in Milwaukee and assess for differences in maternal and neonatal outcomes among those with detectable point-of-care (POC) lead levels.

METHODS

The study was designed as a prospective, longitudinal study in order to assess the prevalence of lead elevation among pregnant people in Milwaukee and to identify differences in risk factors for lead exposure. Additionally, we compared maternal and neonatal outcomes between those with and without elevated lead levels. Our study was approved by our Institutional Review Board and funded departmentally.

Pregnant people ≥18 years of age who voluntarily consented to participate were included if they were English speaking, received prenatal care at 1 of 4 clinics in Milwaukee, and if they had an anticipated delivery in our health care system. Recruitment occurred from June 2019 to July 2021. Pregnant people were recruited and consented during their first prenatal care visit, generally occurring in the first trimester. Following consent, pregnant people completed a POC lead test – a finger stick capillary blood test for lead that is resulted in five minutes – by a medical assistant or study research coordinator. Those with a POC lead test ≥ 5 mcg/dL were considered elevated per CDC guidelines at the time of study onset and were referred for management by their obstetric provider with recommended venous lead lab ordered. The obstetric provider received follow-up recommendations for monitoring the patient's lead levels and resources on best practices for management of elevated lead per CDC guidelines. After the completion of study enrollment, the CDC announced the decision to lower the lab reference value for elevated lead level from 5 mcg/dL to 3.5 mcg/dL in October 2021.[13] In addition to the POC lead test, a brief 8-question questionnaire was administered by the study research coordinator. Additional demographic and pregnancy characteristics were collected from the electronic medical record. Public databases were used to collect information on lead service lines to home and the area deprivation index (state decile 1-10 [low to high]). Data on age of housing stock were difficult to obtain via self-

report (highly mobile population, limited knowledge of construction date) and were deferred in this study. Data were collected and stored in REDCap, a secure electronic data capture application.[14]

Categorical variables were presented as frequency with percentage; continuous variables were presented as median (interquartile) due to non-normality. Chi-square and Fisher exact tests were used to assess associations between lead detection and categorical maternal and neonatal outcomes, while Wilcoxon rank sum test was used for continuous variables. *P* values ≤ 0.05 were considered statistically significant. Statistical analyses were carried out using SAS Version 9.4 (SAS Institute, Cary, North Carolina).

Table 3. Maternal Maternal and Neonatal Outcomes Following Point-of-Care Lead Test, N = 233

	Total	Yes (n = 22)	No (n = 211)	*P* value
Participant status following consent, n (%)				
Delivered	185 (79.4)	17 (77.3)	168 (79.6)	0.78
Miscarried	17 (7.3)	2 (9.1)	15 (7.1)	0.67
Lost to follow-up	31 (13.3)	3 (13.6)	28 (13.3)	1.00
Gestational hypertension this pregnancy, n (%)	23 (12.4)	1 (5.9)	22 (13.1)	0.70
Preeclampsia this pregnancy, n (%)	27 (14.6)	3 (17.6)	24 (14.3)	0.72
Gestational diabetes this pregnancy, n (%)	11 (5.9)	1 (5.9)	10 (6.0)	1.00
Gestational age at time of delivery (weeks), median (IQR)[a]	39.1 (38.0 – 39.9)	39.3 (39.0 – 39.7)	39.0 (37.9 – 39.9)	0.26
Birth weight (grams), median (IQR)[a]	3220 (2890 – 3590)	3320 (3030 – 3670)	3210 (2860 – 3570)	0.30
5-minute APGAR, median (IQR)[b]	9.0 (9.0 – 9.0)	9.0 (9.0 – 9.0)	9.0 (9.0 – 9.0)	0.28
Neonatal intensive care unit admission, n (%)[a]	24 (12.8)	3 (17.6)	21 (12.4)	0.71

Abbreviations: POC, point-of-care; IQR, interquartile range.
[a]Total number of babies delivered, N = 188.
[b]Total number of babies delivered, N=187.

RESULTS

A total of 249 pregnant people were enrolled; 16 were excluded due to POC lead test recall. Overall (n = 233, Table 1), a majority lived in Milwaukee during their first 6 years of life (70.8%), with 2 (<1.0%) identifying a personal history of lead exposure. Nearly half (42.1%, n = 98) had a lead service line to their current home, of which 27.6% used tap water (as opposed to filtered or bottled water) for drinking and 77.6% used tap water for cooking.

POC lead tests were ≥ 5 mcg/dL in 9 (3.9%) pregnant people, but only 5 of the 9 completed additional venous lead tests – none of which had a detectable lead level (Table 2). Overall, 22 (9.4%) pregnant people had lead detectable on POC ≥ 3.3 mcg/dL (POC 3.4 – 4.9 mcg/dL, n = 13; POC ≥ 5 mcg/dL, n = 9). Those with detectable POC lead levels were significantly more likely to have a lead service line to their home (63.6% vs 39.8%; *P* = 0.03). All 17 pregnant people who delivered in our system with detectable POC lead levels had a normal birth weight; 1 delivered preterm. Maternal and neonatal outcomes did not differ between groups (Table 3); there were no neonatal deaths.

DISCUSSION

Our study results highlight concerns for increased risk of lead exposure for pregnant people in Milwaukee through various potential routes. In the context of the lead poisoning crisis that was even worse 20 years ago than today, it is notable that the majority of pregnant people (70.8%) lived in Milwaukee County during their first 6 years of life, when the rates of lead poisoning ranged from 25% to as high as 80%, depending on year and location in the city. While <1.0% of participants self-identified a personal history of lead exposure, these data raise the question if participants could have a personal history of lead exposure and be unaware. Regarding contemporaneous lead exposure, nearly half of the participants had leaded water service lines to their current home address. While not assessed through the study, local city data demonstrate a preponderance of old homes constituting housing stock in Milwaukee. Furthermore, following updated guidance from the CDC identifying lead levels as elevated at and above 3.5 mcg/dl,[13] an additional 13 participants (5.6%) would have indication for venous testing.

Our study is limited by enrollment of English-speaking pregnant people only, which is not necessarily reflective of the diversity of people seen within our hospital. The study is also limited by a prolonged enrollment period due to the onset of the COVID-19 pandemic. Enrollment numbers and further recruitment also were disrupted by a POC lead test recall for lots distributed in December 2020, with no new POC lead tests immediately available following the recall. Pregnant people affected by the POC recall were withdrawn and asked to contact their prenatal provider to discuss their personal risk of an elevated lead level, next steps (which may include repeat venous lead level screening), and any questions they may have. Notably, obtaining indicated venous sample confirmation for elevated lead level on POC testing as indicated posed a challenge, with 4 pregnant people not completing the recommended venous test. While our study is not without limitations, it is strengthened by a fairly large sample size.

Considering the limited literature available on the prevalence of elevated lead levels among pregnant people, the high frequency of risk factors identified in the study population, and challenges to follow-up for venous lead testing for elevated POC, we recommend adding venous lead testing to the routine first trimester prenatal labs. Adding to routine prenatal labs limits addi-

tional finger sticks and provides gold standard lead testing in a community that has been and continues to be adversely affected by the presence of lead exposure. While POC testing allows for immediate office visit results, it may be more cost effective to do venous testing first, as positive POC testing has demonstrated positivity bias[15] and requires confirmatory venous testing with elevated POC results, thus duplicating tests and costs. Currently, there is no cost difference between POC and venous lead testing within our system.

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