Sickle Cell Disease and Lead Poisoning in New York City, 2005–2019

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abstract

OBJECTIVES: Previous analyses of New York City (NYC) health department's lead registry indicated that, among children with lead poisoning, an increased prevalence of sickle cell disease (SCD) exists. However, SCD is not considered a risk factor for lead poisoning. We assessed the association between SCD and childhood lead poisoning to determine if specific lead poisoning prevention efforts are needed for children with SCD.

METHODS: We analyzed NYC's lead registry data for children with venous blood lead levels (BLLs) ≥15 mcg/dL during 2005 to 2019. *t* tests and χ^2 tests were performed to compare demographic characteristics, BLLs, and lead exposure risks in non-Hispanic Black children with and without SCD. A *t* test was used to compare observed SCD prevalence among Black children with BLLs ≥15 mcg/dL with an estimated 0.43% SCD prevalence among Black NYC children.

RESULTS: Among 1728 Black children with BLLs ≥15 mcg/dL identified, 37 (2.14%) had SCD. When comparing children with and without SCD, both mean age at peak BLL (62.8 versus 42.7 months; $P = .003$) and peak BLL (42.59 versus 23.06 mcg/dL; $P = .008$) were higher for children with SCD. Among risk factors for lead exposure, children with SCD had higher prevalence of pica. Observed SCD prevalence was 1.71% higher than estimated SCD prevalence among Black NYC children ($P < .001$).

CONCLUSIONS: We found a potential association between SCD and childhood lead poisoning. Pica emerged as a potentially important risk factor. Our findings might have implications for lead poisoning prevention guidelines for children with SCD.

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Lead poisoning is a serious condition with potentially permanent and disabling consequences, particularly for children.[1,2] Although substantial improvements have been made in childhood lead exposure rates in the United States,[3,4] disparities persist, with certain populations having higher rates than others. Children at highest risk for lead exposure include those from low-income households, immigrant families, those living in older or poorly maintained homes, and households with adults whose occupations or hobbies expose them to lead.[5]

Sickle cell disease (SCD) is a group of inherited disorders characterized by abnormal hemoglobin molecules that cause red blood cells to develop a crescent shape, leading to chronic and sometimes debilitating or life-threatening disease.[6] In New York City (NYC), previous analyses of lead registry data have suggested that, among children with blood lead levels (BLLs) ≥45 mcg/dL, an increased prevalence of SCD exists.[7] Although sporadic cases of lead poisoning in children with SCD have been reported previously,[8–12] this association is not widely known and SCD is not typically considered a risk factor for lead poisoning.

This investigation sought to assess the potential association between SCD and lead poisoning in children by analyzing BLL testing data for children aged 0 to 17 years during 2005 to 2019 in the NYC Department of Health and Mental Hygiene (DOHMH) lead registry, which includes case investigation information about NYC children with venous BLLs ≥15 mcg/dL. We asked 2 primary questions:

1. Among children with lead poisoning, do children with SCD have higher BLLs and increased prevalence of known risk factors for lead exposure when compared with children without SCD?
2. Is the prevalence of SCD greater in children with lead poisoning when compared with the prevalence of SCD in the general childhood population?

Our goal was to determine if NYC children with SCD are at higher risk for lead poisoning, compared with NYC children overall, which could indicate a need for tailored prevention efforts to reduce lead poisoning in NYC.

METHODS

We conducted a cross-sectional study assessing children with lead poisoning in NYC during 2005 to 2019. We analyzed data from the NYC DOHMH lead registry, which includes BLL results for all NYC children aged 0 to 17 years tested for lead exposure. All of the NYC laboratories that conduct BLL testing are certified, registered, or permitted by New York State Department of Health's Wadsworth Center.[13] New York state law requires health care providers to conduct a BLL test for all children at ages 1 and 2 years, and interview caregivers to assess children for risk of lead exposure until age 6 years; the BLL testing rate in NYC is ∼80% among children aged <3 years. During 2005 to 2019, DOHMH was required by law to investigate cases of lead poisoning among children aged <18 years with venous BLLs ≥15 mcg/dL. Investigations included home inspections, risk assessment interviews with the child's guardian, and coordination of care with the child's health care providers by public health nurses. Information collected as part of routine surveillance and case investigations was documented in the lead registry.

For this investigation, we abstracted deidentified data from the lead registry for all NYC children aged 0 to 17 years during 2005 to 2019 with venous BLLs ≥15 mcg/dL into SQL Studio. We identified children with SCD by performing a keyword search of the health care provider reports documented by public health nurses. Each child's medical information was then manually reviewed by a DOHMH physician to confirm SCD diagnosis (Hb SS, Hb SC, or Hb S-beta thalassemia disease); no children with sickle cell trait were classified as having SCD. Variables assessed included SCD status, BLLs, demographic characteristics (age, gender, Medicaid enrollment status, race and ethnicity, and maternal and child countries of birth), and lead exposure risk assessment data (mouthing and chewing nonfood items, pica, pervasive developmental delay, travel outside United States, use of imported products, occupations and hobbies of household members, paint inspection results, and housing age).

Although SCD can affect people of all ethnicities, it mainly persists in people with African, Mediterranean, Middle Eastern, and South Asian ancestry,[6] with >90% of people with SCD in the United States identifying as non-Hispanic Black.[14] Similarly, in our data set, the majority of children with SCD ($n = 37$) self-identified as, or were identified by their parents or caregivers as, non-Hispanic Black; the remainder identified as Hispanic ($n = 4$) or were missing race and ethnicity information ($n = 2$). Given that the number of Hispanic children with SCD was too small for meaningful statistical analysis, and that there were no children with SCD from other racial or ethnic backgrounds, we limited our analyses to children who identified as non-Hispanic Black. This was necessary to ensure the most conservative and statistically robust estimates of differences in lead exposure risk factors among children with and without SCD in our data set.

Data analyses were performed using SAS 9.4 (SAS Institute, Cary, NC). Descriptive statistics were calculated for demographic characteristics and SCD status. Two-sample t tests and χ^2 tests were used to compare demographic characteristics, BLLs, and lead exposure risk factors in Black children with and without SCD. A 1-sample t test was used to compare the observed prevalence of children with SCD in Black children with BLLs ≥15 mcg/dL to the expected

prevalence of children with SCD in Black children in the general NYC population.

NYC DOHMH institutional review board approval was obtained for this study. This study was reviewed by the Centers for Disease Control and Prevention and was conducted consistent with federal law and Centers for Disease Control and Prevention policy (45 Code of Federal Regulations, Part 46; 21 Code of Federal Regulations, Part 56; 42 US Code [U.S.C.], Section [Sect.] 241(d); 5 U.S.C., Sect. 552a; 44 U.S.C., Sect. 3501, et seq).

RESULTS

We identified 1728 non-Hispanic Black children in the lead registry with BLLs ≥15 mcg/dL during 2005 to 2019 (Table 1). Thirty-seven (2.14%) children had SCD. Among Black children with BLLs ≥15 mcg/dL, we compared demographic characteristics, BLLs, and lead exposure risk factors of children with SCD with those of children without SCD (Table 2). No significant difference was found in the percentage of children enrolled in Medicaid or living in pre-1960 housing. Notably, the mean age at peak BLL was higher for children with SCD (62.8 months [95% confidence interval (CI) 50.3–75.3] vs 42.7 months [95% CI 41.1–44.2]; $P = .003$). Although initial BLLs for children with SCD and children without SCD were not significantly different (11.30 mcg/dL [95% CI 5.5–17.1] vs 11.79 mcg/dL [95% CI 11.3–12.3]; $P = .86$), children with SCD had significantly higher peak BLLs (42.59 mcg/dL [95% CI 28.6–56.6] vs 23.06 mcg/dL [95% CI 22.5–23.6]; $P = .008$). Additionally, a significantly higher percentage of children with BLLs ≥45 mcg/dL, the level at which hospitalization and chelation is typically recommended, was found among those with SCD (27% [95% CI 13.8%–44.1%] vs 4.7% [95% CI 3.7%–5.8%]; $P < .001$). Among risk factors for lead exposure, significant differences were found when comparing Black children with and without SCD for the proportion of children reported in the parental questionnaire to be chewing nonfood items (41.4% [95% CI 23.5%–61.1%] vs 10.3% [95% CI 8.5%–12.5%]; $P < .001$); children reported in the parental questionnaire to be eating soil, paint, or clay (44.8% [95% CI 26.5%–64.3%] vs 15.4% [95% CI 13.1%–17.8%]; $P < .001$); and children with nursing notes documenting pica in their discussions with parents or providers (60% [95% CI 40.6%–77.3%] vs 18.6% [95% CI 16.3%–21.2%]; $P < .001$).

When comparing the observed prevalence of SCD in Black children with BLLs ≥15 mcg/dL (2.14%) with the estimated prevalence of SCD among Black children in NYC overall (0.43%),[15] the difference was statistically significant ($P < .001$; 95% CI 1.5%–2.9%). This difference was more pronounced when limiting the analysis to Black children with BLLs ≥15 mcg/dL born to foreign-born mothers. In this subsample, 19 of 520 children (3.65%) had SCD, whereas estimated prevalence of SCD among children born to foreign-born Black mothers in NYC is 0.63%[13]; this difference was statistically significant ($P < .001$; 95% CI 2.2%–5.7%).

TABLE 1 Demographic Characteristics of Non-Hispanic Black Children With Blood Lead Levels (BLLs) ≥15 mcg/dL in New York City (NYC) Lead Registry, 2005–2019 ($N = 1728$)

Characteristic	Number (%)
Gender	
Male	972 (56.3)
Female	756 (43.8)
Medicaid enrollment	
Yes	1311 (75.9)
No	417 (24.1)
Country of birth of mother	
United States	445 (25.8)
Outside of United States	520 (30.1)
Unknown	763 (44.2)
Country of birth of child	
United States	852 (49.3)
Outside the United States	122 (7.1)
Unknown	754 (43.6)
SCD status	
SCD	37 (2.1)
No SCD	1691 (97.9)

DISCUSSION

Our analyses with ∼15 years of NYC lead registry data found a potential association between SCD and lead poisoning in children. Among Black children with BLLs ≥15 mcg/dL, children with SCD had significantly higher peak BLLs, as well as a higher percentage of severe lead poisoning (BLL ≥45 mcg/dL), compared with those without SCD. Furthermore, SCD was significantly more prevalent among Black children with BLLs ≥15 mcg/dL compared with the SCD prevalence estimate in Black children in NYC overall.

Children with SCD were significantly more likely to engage in both pica behavior and chewing nonfood items, compared with those without SCD. This highlights a potentially modifiable risk factor for lead poisoning in children with SCD, because pica can be treated with nutritional and behavioral interventions. Pica refers to the ingestion of nonfood items, which is similar to but distinguishable from chewing and mouthing nonfood items; all 3 behaviors are considered risk factors for lead exposure. Although no studies have assessed the prevalence of chewing or mouthing nonfood items in children with SCD, previous literature has documented a high prevalence of pica behavior in children with SCD; however, the cause remains unclear.[16]

The reason for the potential association between SCD and lead poisoning among Black children in NYC is unknown. One possible explanation could be a nutritional

TABLE 2 Comparing Demographic Characteristics, Blood Lead Levels (BLLs), and Risk Factors for Lead Exposure in Children With Sickle Cell Disease (SCD) Versus Children Without SCD Among Non-Hispanic Black Children With BLLs ≥15 mcg/dL in New York City (NYC) Lead Registry, 2005–2019

	Children With SCD ($N = 37$)		Children Without SCD ($N = 1691$)		
	Mean/Percentage	95% CI	Mean/Percentage	95% CI	*P*
Age, mo					
Age at first BLL test	22.9	18.0–27.8	27.9	26.3–29.4	.06
Age at first BLL ≥15 mcg/dL	52.0	40.4–63.7	41.0	39.5–42.6	.07
Age at peak BLL	62.8	50.3–75.3	42.7	41.1–44.2	.003
BLL (mcg/dL)					
First BLL	11.3	5.5–17.1	11.8	11.3–12.3	.86
First BLL ≥15 mcg/dL	27.3	22.1–32.5	21.5	21.1–22.0	.03
Peak BLL	42.6	28.6–56.6	23.1	22.5–23.6	.008
Percentage with BLL ≥45 mcg/dL[a]	27.0	13.8–44.1	4.7	3.7–5.8	<.001
Risk factors, %					
Medicaid enrollment	73.0	55.9–86.2	75.9	73.8–78.0	.68
Pre-1960 housing	97.1	85.1–99.9	88.8	87.2–90.3	.17
Lead-based paint hazards	78.1	60.0–90.7	79.2	77.0–81.2	.89
Recent household repairs or renovations	13.8	3.9–31.7	26.1	23.4–29.0	.13
Recent water-damaged paint in home	20.7	8.0–39.7	25.1	22.4–28.0	.59
Household members in high-risk occupations	17.2	5.9–35.8	10.8	8.9–12.9	.24
Foreign-born child	10.3	2.2–27.4	12.4	10.4–14.7	1.00
Foreign-born mother	65.5	45.7–82.1	52.4	49.1–55.6	.16
Travel outside United States	13.8	3.9–31.7	21.7	19.2–24.5	.31
Use of imported consumer products	6.9	0.9–22.8	7.8	6.2–9.7	1.00
Pervasive developmental delay in children age >3 y	0	0–40.1	3.4	1.7–6.0	1.00
Mouthing nonfood items	65.5	45.7–82.1	58.1	54.9–61.3	.42
Chewing nonfood items	41.4	23.5–61.1	10.3	8.5–12.5	<.001
Eats soil, paint, or clay	44.8	26.5–64.3	15.3	13.1–17.8	<.001
Plays outside where there is bare soil	10.3	2.2–27.4	3.24	2.2–4.6	.07
Pica reported in interview with nurse	60.0	40.6–77.3	18.6	16.3–21.2	<.001

[a] Unit expressed as percentage (%).

deficiency contributing to the higher prevalence of pica, and in turn risk for lead exposure, because children with SCD are at risk for micronutrient deficiencies[17]; for instance, US children with SCD have been found to have lower mean zinc levels, although not generally in the zinc deficiency range, when compared with children without SCD,[15] and zinc deficiency has been linked to pica.[18]

Regardless of cause, our finding has significant public health and health policy implications. If a higher risk for lead poisoning in children with SCD is present, as our data suggest, then it would be important to consider raising awareness among both health care providers and caregivers of children with SCD about the potential need for more frequent BLL testing and about addressing behaviors that increase risk for lead exposure. Additionally, we found that the mean age at peak BLL in Black children with SCD was 5 years; this raises the question of whether children with SCD might need to be tested for lead poisoning at older ages than current guidelines recommend (ages 1 and 2 years).

Our investigation has several limitations. First, our data set is limited to children with BLLs ≥15 mcg/dL because this is the level at which DOHMH conducted its investigations in 2005. It is possible that the potential association between SCD and lead poisoning only exists at these BLLs. Next, SCD information in the lead registry relies on reports from health care providers, rather than documentation of laboratory results, so some children with SCD may have been missed. Additionally, the small number of children with SCD restricted our ability to assess the relative contribution of different risk factors in a multivariable model, which might have provided insights into how various factors influence the relationship between SCD and lead poisoning. Furthermore, our analysis was limited to non-Hispanic Black children because of the demographic composition of the children with SCD in our data set; thus, we were unable explore the impact of lead exposure risk factors across diverse racial and ethnic groups. Finally, the cross-sectional nature of this study prevents us from establishing a causal association.

CONCLUSIONS

We found a potential association between SCD and childhood lead poisoning, given both the significantly higher peak BLLs in children with SCD and the increased prevalence of SCD among children with lead poisoning compared with the general population, with pica behaviors emerging as a potentially important risk factor. This investigation could have public health implications for childhood BLL testing and lead poisoning prevention guidelines. However, further research is needed to understand this potential association more fully. In NYC, we plan to conduct a future study that links BLL data with SCD results from the New York State Newborn Screening Program; this will allow for more accurate SCD classifications, a larger cohort of children with SCD, inclusion of all racial and ethnic groups in the analyses, and multivariable analyses.

ABBREVIATIONS

BLL: blood lead level
CI: confidence interval
DOHMH: NYC Department of Health and Mental Hygiene
NYC: New York City
SCD: sickle cell disease
Sect.: Section
U.S.C.: US Code

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