Prevalence of Lead Poisoning Among Two-Year-Old Children in Vermont

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ABSTRACT. *Objectives.* **The recent redefinition of childhood lead poisoning by the Centers for Disease Control and Prevention means that many more children are considered lead poisoned than previously. The primary purpose of this study was to determine how many 2-year-old children had lead levels of 10 µg/dL or more in a rural state.**

Methods. **Random samples of 334 children drawn from the birth certificate file and 350 children from Vermont Medicaid rosters submitted capillary blood specimens that were confirmed by venous tests if lead levels were 10 µg/dL or more.**

Results. **Participation rates were 63.9% in the birth certificate group and 66.4% in the Medicaid group. In the birth certificate sample, the percentages of children with confirmed lead levels 10 µg/dL or more, 15 µg/dL or more, and 20 µg/dL or more were 9.0 (95% confidence interval [CI], 6.2–12.6), 2.7 (95% CI, 1.2–5.0), and 1.5 (95% CI, 0.5–3.4), respectively. In the Medicaid sample, the corresponding percentages were 14.9 (95% CI, 11.4–19.2), 5.1 (95% CI, 3.1–8.0), and 2.0 (95% CI, 0.8–4.1), respectively. The percentage of children in the state's most urban county with lead levels of 10 µg/dL or more was significantly less than that in the rest of the state in both samples.**

Conclusions. **The prevalence of elevated lead levels in 2-year-old children may be significant in rural states with old housing stock. Medicaid-enrolled children represent a readily identifiable high-risk group.** *Pediatrics* **1995;96:78–81;** ***lead poisoning epidemiology, prevalence, prevention and control, child, preschool.***

ABBREVIATIONS. VDH, Vermont Department of Health; CDC, Centers for Disease Control and Prevention.

In October 1991, the Centers for Disease Control and Prevention (CDC) redefined the blood lead level of concern in children as 10 µg/dL. This change in definition resulted from recent literature suggesting that lead levels as low as 10 to 15 µg/dL were associated with impaired intellectual development in children.[1] A few studies are available to approximate the prevalence of lead levels of 10 µg/dL or more among urban children. Two studies of nonrandom, provider-based samples of high-risk urban children younger than 6 years old in California found prevalences of 7.2% and 8.3%.[2,3] A third study in California took systematic samples of three high-risk urban communities and found prevalences ranging from 14% to 67%.[4] A similar high prevalence of 28% was reported from a Rochester, NY, clinic that served the urban poor.[5]

Studies of children living in suburban areas include one in a Minneapolis health maintenance organization,[6] which found a prevalence of 1.4% of levels of 10 µg/dL or more, and one from the suburbs of Chicago, reporting a prevalence of 2.1%.[7]

The number of children with lead levels of 10 µg/dL or more in rural areas such as Vermont is largely unknown. There is justifiable concern about the problem, however, because Vermont has a high percentage of older housing, which is more likely to contain lead-based paint. Vermont's percentage of housing units built before 1940 (36.5%), for example, is second highest in the nation.[8] The purpose of this study was to determine the prevalence of lead poisoning in children in Vermont so that public health professionals, health care providers, and policy makers could make informed decisions about the intensity and focus of lead screening for children.

METHODS

Study Populations

The Vermont Department of Health (VDH) chose to study 2-year-old children for two reasons. First, the CDC already had recommended universal screening of all children at their 1- and 2-year well child visits. Second, childhood blood lead levels peak at 18 to 24 months of age and were therefore likely to be underestimated if tested at 1 year of age.[9]

The study drew samples from two populations. The first population was children born in Vermont 21 to 24 months before their entry into the study. This sample represented the average experience of children in Vermont. Birth certificates provided identifying information for these children, including their names and addresses.

The second sample was drawn from among 21 to 24 month olds enrolled in the Vermont Medicaid program. Medicaid-eligible children come from low-income families and are therefore at higher risk of lead poisoning according to the Second National Health and Nutrition Examination Survey.[10] The eligibility level for Medicaid in Vermont at the time was 225% of the poverty level. The Vermont Department of Social Welfare provided the parent names, addresses, and phone numbers for the selected Medicaid children.

The desired sample size for each group was 370 based on an estimated prevalence of 10% to 14% and a desired precision of 3%. The samples were drawn at random from the birth certificates and Medicaid databases by computer.

The first phase of the study was conducted in three areas of the state from November 16, 1992, through January 30, 1993, and tested 65 children from the birth certificate sample and 67 from the Medicaid sample. Children from the remainder of the state were tested in the second phase from May 1 through September 30, 1993.

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Recruitment

There are 12 local public health offices in Vermont, all under the direction of the VDH. Public health nurses from these offices contacted the families of children selected for the study by telephone or mail. In some cases they made home visits. Individuals were not considered nonparticipants until after at least five contact attempts on five different days had been made.

Participation in the study was voluntary. Children who had moved from the state were considered ineligible for the study and were dropped from the sample.

Data Collection

Families that agreed to participate signed the consent form and then completed a questionnaire that asked the first four standard lead-screening questions suggested in the CDC's October 1991 report.[1] The fifth question, on lead-using industries, was omitted, because there are few point sources of lead pollution in Vermont. They were also asked if their children had had blood lead tests since 18 months of age. Any blood lead results since 18 months of age were used in this survey in place of the test at 2 years of age. The public health nurse contacted the ordering physician to obtain the exact values, the names of the laboratories, and the dates of any such tests reported by the parents.

Specimen Collection and Analysis

After informed consent was obtained, capillary blood specimens were collected by public health nurses at the local offices of the VDH. Nurses used the sampling protocol included in the October 1991 CDC publication with minimal modification. Lead-free sample collection kits were provided by the VDH laboratory, and blood samples went to the VDH laboratory for analysis.

Follow-Up of Elevated Lead Levels

Children with capillary sample results of 10 μg/dL or more required a venous blood test for confirmation. The public health nurse contacted the family to arrange the venipuncture. The blood was drawn at the patient's local hospital laboratory using lead-free materials supplied by the VDH laboratory. The venous specimens were then sent to the VDH laboratory for analysis. The results of all blood lead tests were sent to identified providers.

Data Analysis

Participation rates for each sample were calculated as the number of individuals with acceptable blood lead test results divided by the number of individuals selected to participate in the study and not known to have moved out of state. An acceptable blood lead test result was a capillary sample result less than 10 μg/dL or a venous sample result at any level from a sample drawn by the public health nurse or a local physician. Nonparticipants fell into the following categories: (1) residents of the state refusing to participate, (2) residents that could not be contacted, and (3) residents failing to return for confirmatory testing when indicated.

Statistical testing of continuous variables was done using analysis of variance. Testing of differences in categorical variables was done using χ^2 and Fisher's exact tests, as appropriate. StatXact software was used to generate exact confidence limits around proportions.[11]

Laboratory Analysis

Blood lead analyses were performed at the VDH laboratory using Zeeman-corrected graphite furnace atomic absorption spectrophotometry. The VDH laboratory participates in both CDC and College of American Pathologists proficiency programs and is certified by the Health Care Financing Administration under the 1988 Clinical Laboratory Improvement Act. All blood samples were analyzed in duplicate and reported as valid tests only when they met stringent quality assurance standards.

RESULTS

Participation Rates

Attempts were made to contact a total of 977 children for the study, 58 of whom were determined to have moved out of state and were ineligible for the study. Of the 919 remaining children, 392 were from the birth certificate file; 396 were from the Medicaid roster; and 131 were in both. The 131 children were part of both study populations, making the effective sample sizes 523 and 527 in the birth certificate and Medicaid groups, respectively.

Using an acceptable blood lead test result as a definition of participation, participation rates were 63.9% (334 of 523) in the birth certificate group and 66.4% (350 of 527) in the Medicaid group. Participation rates were higher in both samples outside of Vermont's most populous county, Chittenden, reaching 67.8% in the birth certificate sample and 72.5% in the Medicaid sample.

Of the 189 nonparticipants in the birth certificate sample, 50.8% could not be contacted; 40.2% were contacted and refused any test; and 9.0% refused a venous sample after an elevated capillary result. The percentages were very similar in the Medicaid sample. The mean age of participants in both samples was 23.6 months.

Participants and nonparticipants in the birth certificate sample were compared with respect to selected maternal characteristics recorded on their birth certificates. The mothers of participants had a mean of 13.3 years of education; 25.3% were college graduates; 22.9% smoked during pregnancy. Mothers of nonparticipants had a mean of 12.9 years of education; 18.8% were college graduates; 25.5% smoked during pregnancy. The only difference between the two groups that reached statistical significance was mean years of maternal education.

Blood Lead Test Results

Overall, 9.0% (95% confidence interval, 6.2–12.6) of the birth certificate sample and 14.9% (95% confidence interval, 11.4–19.2) of the Medicaid sample had confirmed lead levels of concern, that is, 10 μg/dL or more (Table 1). Roughly 1.5% of the birth certificate sample and 2.0% of the Medicaid sample had lead levels of 20 μg/dL or more, levels that triggered investigation of their living environments. Children in the birth certificate sample who were not enrolled in Medicaid had a prevalence of 6.3% with levels of 10 μg/dL or more and 0.8% with levels of 15 μg/dL or more. The highest confirmed test result was 33 μg/dL, in a child who had not been tested previously.

The prevalence of lead levels of 10 μg/dL or more was lower in the state's least rural county, Chittenden, than in the remainder of the state. In the birth certificate sample, the prevalence was 1.3% in Chittenden County and 11.2% in the rest of the state ($P = .008$). In the Medicaid sample, the prevalence

TABLE 1. Confirmed Blood Lead Level by Type of Sample, Vermont, 1993

Blood Lead Level, μg/dL	Birth Certificate (n = 334) No. (%, 95% CI)	Medicaid (n = 350) No. (%, 95% CI)
10+	30 (9.0, 6.2–12.6)	52 (14.9, 11.4–19.2)
15+	9 (2.7, 1.2–5.0)	18 (5.1, 3.1–8.0)
20+	5 (1.5, 0.5–3.4)	7 (2.0, 0.8–4.1)

was 7.1% in Chittenden County and 16.8% in the rest of the state ($P = .04$).

Sensitivity and Specificity of Screening Questions

Some 34.0% of the birth certificate sample and 42.9% of the Medicaid sample lived in housing built before 1960 which had peeling or chipping paint. Roughly one third of parents in both samples reported that they lived in housing of that age that had been renovated in the last 2 years. These two screening questions had the highest sensitivity for blood lead levels of 10 μg/dL or more (Table 2).

Fewer than 3% of children in either sample had siblings or playmates being followed for lead poisoning. Eight percent of both samples lived with adults whose jobs or hobbies involved exposure to lead. These two screening questions had the lowest sensitivity. An affirmative answer to one or more of the four screening questions was a more sensitive screen than any question alone, but it was also less specific.

One or more risk factors, the definition of high risk, was reported by 45.2% of parents in the birth certificate sample and 52.4% of parents in the Medicaid sample. In the birth certificate sample, fewer children (7.0%) at high risk had been tested since 18 months of age by their private physicians than children at low risk (13.1%). The same was true in the Medicaid sample: 10.0% vs 16.3%.

Concordance of Capillary and Venous Blood Lead Measures

Just less than half (42.4%) of the elevated capillary samples (≥10 μg/dL) subject to confirmation were confirmed as elevated by the venous samples in the birth certificate group. The corresponding figure in the Medicaid group was 53.6%. Predictive values generally increased at higher capillary blood lead levels (Table 3). Although some capillary sample results were followed by higher venous sample results, none of the capillary results in the 10- to 14-μg/dL range were followed by venous sample results of more than 19 μg/dL in either group.

DISCUSSION

This study is the first population-based survey of lead levels in children in a rural state since the CDC's 1991 change in the definition of lead levels of concern. It found prevalences intermediate between those found in urban and suburban areas elsewhere.

TABLE 2. Sensitivity and Specificity of Screening Questions by Type of Sample Using Confirmed Lead Levels of Greater Than 10 μg/dL as the Definition of Disease, Vermont, 1993

Screening Question	Birth Certificate		Medicaid	
	Sensitivity (%)	Specificity (%)	Sensitivity (%)	Specificity (%)
House built before 1960	48.1	67.4	60.0	60.0
House renovation	57.1	69.9	44.4	67.3
Contact with lead-poisoned child	3.6	97.4	6.5	98.1
Take-home exposure	10.7	91.9	8.9	92.1
One or more of above	63.3	56.6	67.3	50.2

TABLE 3. Positive Predictive Value of Various Capillary Sample Results for Two Different Venous Lead Levels, Vermont, 1993

Capillary Blood Lead Level, μg/dL	Birth Certificate		Medicaid	
	Venous Level 10+ (%)	Venous Level 15+ (%)	Venous Level 10+ (%)	Venous Level 15+ (%)
10–14	33.6	2.7	38.5	10.2
15–19	55.0	15.0	60.9	13.0
20+	55.6	44.4	75.0	50.0

The study's primary weakness is the relatively low participation rate in both samples. In the birth certificate sample, this was in part because address information came from birth certificates and was 2 years out of date. A similar percentage could not be contacted in the Medicaid sample, however, despite their addresses being kept relatively current. This suggests that a large share of those nonparticipants who could not be contacted probably represent refusals rather than changes of address.

One advantage of using the birth certificate file to identify a sample, however, was the comparison of participants and nonparticipants that this made possible. The comparison indicates that participants were of higher socioeconomic status than nonparticipants, suggesting that the prevalence estimates are underestimates.

Self-selection bias is unlikely to account for the entire difference between the observed prevalences and the Agency for Toxic Substances and Disease Registries' estimate that 17% of American preschool children had blood lead levels of more than 15 μg/dL in 1984.[12] Some of the difference is attributable to declining lead levels in the United States;[13] some may derive from the rural nature of Vermont, because lead levels in children tend to be higher in urban areas.[12]

The lower prevalence of lead levels of 10 μg/dL or more in Chittenden County is inconsistent with the tendency for lead levels to be higher in more urban areas nationally. Chittenden is Vermont's most urban county, with a population of 133 000. In combination with Grand Isle County, it qualifies as a standard metropolitan statistical area. It is, however, still largely rural; its largest city, Burlington, had a 1991 estimated population of 39 000. Furthermore, higher average income levels in Chittenden County may more than compensate for its semiurban nature.[14] Therefore, it may not be safe to assume that the most urban-like areas of a rural state will have the highest prevalences of lead poisoning.

Large percentages of both samples reported risk factors related to the condition or renovation of pre-1960 housing. These two questions performed little better than chance, however, in identifying children with elevated lead levels. The numbers were too small for the questions on lead-poisoned playmates and take-home exposure to determine whether they added much to the discriminating power of the two questions on housing. Overall, if this study had screened only high-risk children in the birth certifi-

cate sample, only 63.3% of children with blood lead levels of 10 μg/dL or more would have been tested.

There was no indication that being at high risk according to these screening questions was associated with a greater likelihood of having been screened by providers before this study, at least since 18 months of age. CDC recommendations call for high-risk children to be screened at well child visits, including those at 18 months of age. This suggests either that high-risk children are less likely to see providers for preventive care than low-risk children or that the pattern of screening of children by providers in Vermont to date has been shaped by factors other than the child's risk level as determined by the CDC risk questionnaire.

The capillary screening test had a predictive value of roughly 42% in this population using the CDC's technique. The higher predictive values in the Medicaid population are expected given the greater prevalence of elevated lead levels in that group.

Conclusions

Lead poisoning at levels thought to be harmful but too low to cause overt symptoms exists in a significant number of 2-year-olds in Vermont, especially among those enrolled in Medicaid. Pediatricians who practice in other rural states with old housing stock should take note of study findings. The study also should have implications for public health workers and policy makers involved in housing policy or otherwise concerned about the primary prevention of lead poisoning.

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ON LEARNING A NEW LANGUAGE

There is abundant evidence that the best time to learn new languages is relatively early in life. Individuals who are exposed to a foreign language after they are 8 or 10 years old will eventually learn the foreign language, but they may never acquire the facility with this language that occurs naturally in young children. In fact, the very brain structures that are used to learn a second language are different from those involved in learning a mother tongue. An intriguing recent case report showed that a bilingual patient who suffered a specific stroke-like lesion developed severe impairments in mother tongue production, with substantially better performance in her rarely-spoken second language. This is consistent with the notion that learning languages is still possible in older individuals, but that the neural mechanisms and even the brain structures that are involved are quite different.

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