Identification of Children At Risk for Lead Poisoning: An Evaluation of Routine Pediatric Blood Lead Screening in an HMO-Insured Population

Mary N. Haan, MPH, DrPH*; Marianne Gerson, MD, MPH‡; and B. Anne Zishka, BA, MSW*

ABSTRACT. ***Objectives.*** **To estimate the prevalence of elevated blood lead levels in children receiving well-care checkups; and to evaluate the effectiveness of certain key risk factors in detecting children at higher risk for elevated blood lead levels.**

Design. **Cross-sectional study.**

Setting. **Two facilities of the Kaiser Permanente Medical Care Program (KPMCP) health maintenance organization (HMO), northern California region.**

Patients. **Six hundred thirty-six children, aged 12 to 60 months, who were seen at four KPMCP facilities in two subregions for a well-care checkup from September 1991 through August 1992.**

Interventions. **Blood samples were collected from each child and analyzed for lead content. Participating parents completed a questionnaire that included questions recommended by the Centers for Disease Control and Prevention (CDC) about the child's and the parents' lead exposure via home, workplace, and hobbies.**

Results. **Ninety-six percent of the children had blood lead levels under 10 μg/dL. Blood lead levels declined with increasing age and were higher for black children compared with whites. Age of residential housing, mother's education, and residence in an old house with peeling paint had low sensitivity and positive predictive value for identifying children with blood lead levels over 10 μg/dL.**

Conclusion. **Universal routine screening for elevated blood lead levels in children in an employed, HMO-insured population is not warranted on grounds of prevalence. Responses to CDC questions do not effectively identify high-risk children in this population.** ***Pediatrics* 1996;97:79–83; *child, environmental exposure, lead, lead poisoning, mass screening, socioeconomic factors.***

ABBREVIATIONS. CDC, Centers for Disease Control and Prevention; HMO, health maintenance organization; KPMCP, Kaiser Permanente Medical Care Program; VFN, Vallejo-Fairfield-Napa.

Exposure to high levels of lead has long been recognized as toxic to humans. In the last few years interest in childhood lead poisoning has focused on neurotoxicity of low levels of lead in blood. A number of studies have suggested that low levels of lead exposure may have adverse impacts on cognitive functioning. In children, the lead level that the Centers for Disease Control and Prevention (CDC) considers to be elevated has declined from 60 μg/dL in 1960 to 25 μg/dL in 1985. In October 1991, the CDC issued a new statement that defined childhood lead poisoning by using a tiered approach.

> The goal of all lead poisoning prevention activities should be to reduce children's blood lead levels below 10 μg/dL. . . . Interventions for individual children should begin at blood lead levels of 15 μg/dL (1:1).

In this statement, the CDC called for universal screening of children but advised that such screening need not continue in populations "where large percentages have been screened and found not to have lead poisoning" (1:2).

Most systematic research on childhood lead poisoning has shown that low-income, minority children who live in older housing are at the highest risk of lead poisoning.[2]

The present study was performed to estimate the prevalence of lead exposure and to evaluate the need for routine blood lead screening of children aged 12 to 60 months in a population insured by a health maintenance organization (HMO). It also evaluates the performance of selected CDC questions in identifying lead-exposed children. The Northern California Kaiser Permanente Medical Care Program (KPMCP) is an HMO that covers about 2.5 million people. In 1991, 97.8% (59 541) of its pediatric members aged 12 to 24 months and 50% (63 540) of those aged 25 to 60 months received well-care checkups. In 1991, the Northern California Region KPMCP had 209 897 pediatric members aged 1 to 6 years. According to CDC recommendations, each of these children should be screened at least once at 12 months of age and again at 24 months of age.

The CDC has recommended that physicians ask certain questions that assess exposure indirectly (eg, regarding age of housing or a lead-related parental occupation). We evaluated the performance of selected CDC questions for sensitivity, specificity and predictive value negative in this HMO population.

METHODS

The study included 636 children aged 12 to 60 months who were KPMCP members in 1991 and 1992. They were eligible to participate if they received a well-care checkup during the 2-year study period and if they were within the CDC's recommended age guidelines[4] at the time of their checkup.

Data Collection and Sample Recruitment

The study was conducted in two areas of the Northern California region from September 1991 through August 1992. The Vallejo-Fairfield-Napa (VFN) area included one medical center and two medical offices, and 25 participating physicians collected

From the *University of California, School of Medicine, Davis; and the ‡Department of Pediatrics, Kaiser Permanente Medical Center, Vallejo, CA.
Received for publication Sep 12, 1994; accepted Feb 6, 1995.
Reprint requests to (M.N.H.) University of California, School of Medicine, Department of Community Health, Davis, CA 95616.
PEDIATRICS (ISSN 0031 4005).

data from randomly selected children chosen from a list of patients with well-care appointments. At the Oakland facility, an interviewer randomly selected children from a list of patients with appointments and tagged their charts. The physicians (n = 22) then attempted to recruit children whose charts were tagged. At the VFN facilities, parents completed the survey form and returned it to the appointment desk. At the Oakland facility, the interviewer administered the survey. All surveys were edited and parents were queried by phone regarding missing data.

Survey Data

The survey contained questions about sociodemographic factors such as ethnicity and education, the child's recent use of health care services, age of housing, recent paint scraping, paint condition, recent remodeling, parental exposure to lead at work, lead-related hobbies, or home activities. Participants indicated whether they lived in housing that was <10 years old (1983 through 1992), 10 to 20 years old (1972 through 1982), or >20 years old (<1972). Respondents reported whether their home's paint was peeling (some or a lot) and whether they had done any remodeling in the past year that involved scraping or sanding paint.

Participants were asked whether anyone in the household was employed in any of a list of occupations that might result in lead exposure.[1] Participants could check more than one option, and these responses were collected for all employed persons living in the house.

The CDC booklet *Preventing Lead Poisoning in Young Children* (1:92) recommends that physicians evaluate children for lead poisoning risk by asking parents five questions:

Does your child—

1. Live in or regularly visit a house with peeling or chipping paint built before 1960? . . .
2. Live in or regularly visit a house built before 1960 with recent, ongoing, or planned renovation or remodeling?
3. Have a brother or sister, housemate, or playmate being followed or treated for lead poisoning (that is, blood lead ≥15 μg/dL)?
4. Live with an adult whose job or hobby involves exposure to lead? . . .
5. Live near an active lead smelter, battery recycling plant, or other industry likely to release lead? (1:92)

Of these, three questions were included in the VFN portion of the study. Questions 1 to 3 were asked at both sites. At the Oakland site, we added the question about hobbies or activities in the home that might incorporate lead (question 4). The fifth CDC question, concerning residence near a lead smelter, was not asked because the investigators thought that it would result in substantial misclassification since most parents would not know whether they lived near such a facility.

Blood Collection and Laboratory Analyses

Two tubes of blood were collected by venipuncture from each participant. At the VFN facilities, blood for lead analyses was collected in a heparinized, lead-free tube. At the Oakland facility, blood for lead analysis was collected in a lead-free, powdered-EDTA-treated tube.

Blood was analyzed for lead, and a routine complete blood count was performed. Blood lead analyses of samples from both sites were performed by using atomic absorption methodology at a single laboratory. Before data collection was begun at each study site, 10 blank tubes were analyzed for lead, and no lead was detected in them. Quality control analyses were performed by testing split blood samples from 19 volunteers. Paired results for 18 of 19 of these split-sample sets were within 2 μg/dL of each other. One set of split-sample results differed by 6 μg/dL (4 μg/dL vs 10 μg/dL).

In summary, the methods used to analyze blood lead levels afforded a precise measure and avoided exogenous lead contamination. All split-sample results were within an acceptable error range.

Statistical Analyses

Univariate and bivariate distributions of blood lead levels for each site were examined overall by age, gender, and ethnicity and for each risk factor separately, by site. Analyses of the CDC question on occupational or hobbies that expose adults in the home to lead were restricted to the Oakland site. Blood lead was not normally distributed (test statistic = 0.84, $P = .0000$). Skewness was 1.97, kurtosis was 6.24, the overall mean was 4.65 compared with a median of 4.0. Medians are reported instead of means and multivariate analyses use the natural log of blood lead as a dependent variable. Multivariate analyses were performed using a linear regression model.

Sensitivity, Specificity and Predictive Value. We examined the sensitivity, specificity, and positive and negative predictive values of four of the CDC questions. We also calculated the sensitivity, specificity, and predictive values of the mother's education to contrast these estimates with those of another identified risk factor for elevated blood lead.

RESULTS

Sample Characteristics

Vallejo-Fairfield-Napa (VFN). We surveyed 305 children in VFN from August 20, 1991 through January 6, 1992, which resulted in an overall participation rate of 75.7% of the 403 children invited to participate. The participation rates did not vary by age or gender. Participation rates by ethnicity were: other/mixed, 100% (19), Hispanics, 85.4% (41), blacks, 81.3% (65), whites 74.7% (139), and Asians 66% (41).

Oakland. We surveyed 331 children at Oakland from April 1992 through July 1992, which resulted in an overall participation rate of 59.1%. Participation varied by age: for children age 12 to 23 months, the rate was 57.3% (138); for those aged 24 to 35 months, 48.8% (41); 36 to 47 months, 47.6% (30); and 48 to 60 months, 70.9% (122). Participation varied by ethnic group: the participation rate was highest among Hispanics (66.3%) (57); that of whites was 51.6% (81); blacks, 62.6% (132); Asians, 63.1% (53); and other/mixed, 53.3% (8).

Sociodemographics

Compared with VFN, Oakland respondents were significantly more likely to be black, and had a significantly higher proportion of mothers with at least some college education (Table 1). The percentage with at least one employed household member was about the same at both sites (95.1% at VFN and 96.4% at Oakland). Ninety-five percent of respondents in both sites reported Kaiser as their regular source of health care.

Blood Lead Level Results

In both study sites, the blood lead levels ranged from less than detectable (under 2 μg/dL) through 19 μg/dL (Table 2). The median blood lead level was 4 μg/dL in VFN and Oakland overall.

Age. Median blood lead levels did not vary much by age. In VFN, the median blood lead level (μg/dL) was 4.0 μg/dL for ages 12 to 23 months, 24 to 35 months, and 36 to 47 months; for 48 to 60 months it was 3.0 μg/dL. In Oakland, the median blood lead level was 5.0 μg/dL for ages 12 to 23 months and 24 to 35 months; it was 4.0 μg/dL for ages 36 to 47 months and 48 to 60 months.

Ethnicity. Fig 1 shows the percentage distribution of blood lead levels for whites, blacks, and Hispanics by study site. The medians for whites, blacks,

TABLE 1. Sociodemographic Characteristics of Kaiser Permanente Medical Care Program Pediatric Sample by Study Site and Overall

Category	Percentage in Category		Total (n)	*P* Value*
	VFN	Oakland		
Race				
White	45.6	24.5	220	<0.0001
Black	21.2	39.9	197	<0.0001
Hispanic	13.5	17.2	98	0.24
Asian	13.4	16.0	94	0.42
Other/mixed	6.3	2.4	27	0.025
Mother's education:				
<High school graduate	4.6	5.7	33	0.66
High school graduate	26.2	14.8	129	0.001
Some college+	68.8	79.5	473	0.003
Don't know or missing	0.4	0	1	NA
Father's education:				
<High school graduate	5.9	9.1	48	0.17
High school graduate	26.9	17.8	141	0.008
Some college+	64.9	71.9	436	0.07
Don't know or missing	2.3	1.2	11	NA

Abbreviations: VFN, Vallejo-Fairfield-Napa facilities; NA, number too small to compute.
* *P* value comparing VFN to Oakland.

TABLE 2. Distribution of Blood Lead Levels for Study Sample

Lead level (μg/dL)	VFN n (%)	Oakland n (%)
Not detectable	3 (1.0)	6 (2.0)
2–4	187 (61.2)	175 (53.0)
5–9	106 (34.8)	134 (40.0)
10–14	6 (2.0)	14 (4.0)
15–19	3 (1.0)	2 (1.0)

Abbreviation: VFN, Vallejo-Fairfield-Napa facilities.

Hispanics, Asians, and others, respectively, were 4.0 (whites), 4.0 (blacks), 4.0 (Hispanics), 4.0 (Asians), and 3.0 (other/mixed). In a multivariate linear regression model, mean blood lead in black children was 25% higher than in non-Hispanic white children after adjustment for age, gender, study site, housing age and mother's education (*P* = .0001). No other ethnic comparisons were statistically significant.

Exposures to Lead

Age of Housing. The proportion of children living in housing more than 20 years old in VFN was much smaller (32.5%) than the proportion in Oakland (65%). More people in Oakland (64.4%) reported that their houses had peeling paint either inside or outside than in VFN (42.6%). Other housing conditions also tended to be worse in Oakland. More houses both were older than 20 years and had peeling paint in Oakland (47.7%) than in VFN (19.0%). A number of parents—6.9% in Oakland and 5.2% in VFN—reported that they did not know the age of their residence. Fig 2 shows the percent distribution of blood lead by age of housing. A multivariate linear regression model included housing age as indicator variables (ref = <10 years old, 10<20 years old, more than 20 years old), age, and gender. In this model, mean blood lead levels were 19% higher for children living in housing aged 10<20 years old (*P* = .008) and 29% higher for children living in housing aged more than 20 years old (*P* = .0002) compared with children living in housing <10 years old.

Exposures to Lead From Occupations or Hobbies. In VFN, 33.1% of respondents and in Oakland, 25.7% of respondents reported that at least one person in the household held a job that often results in lead exposure. The most common potentially lead-related occupations were: construction (33.3%), steel welding/cutting (9.9%), police work (11.9%), plumbing (12.0%), painting and paint manufacture (11.7%), and auto repair (10.5%).

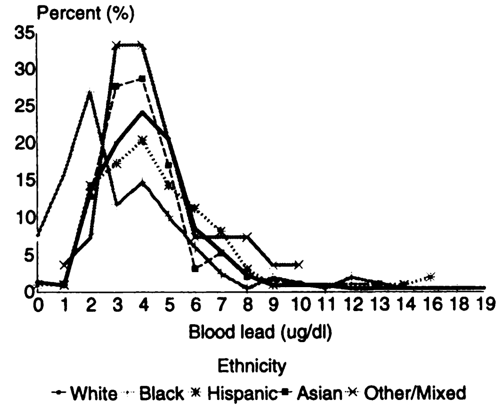

Fig 1. Blood lead distribution by ethnicity.

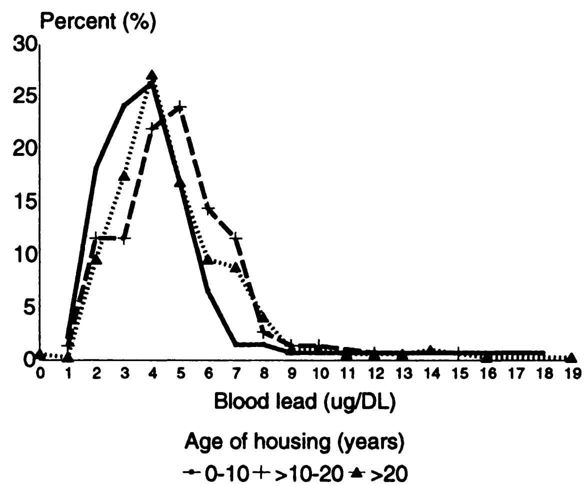

Fig 2. Blood lead distribution by age of housing.

Two hundred sixty-seven (87.5%) reported that someone in the home had at least one lead-related hobby or activity. Lead-using activities included: making stained/leaded glass (.66%), making fishing sinkers or bullets (2.9%), working with cars, car parts, or car batteries (28.5%), soldering (7.9%), shooting guns at a range (4.3%), painting pictures (3.3%), painting a house or furniture (34.1%), working with model cars or boats (4.9%), and making pottery (4.3%).

CDC Criteria and Blood Lead Levels

We found that 34.6% of the children met none of the CDC risk criteria, 35.1% met only one and 30.3% met two or more. In a multivariate linear regression model, adjusting for age, gender, ethnicity, and mother's education, we found no association between number of CDC lead screening criteria present and blood lead levels.

Sensitivity and Specificity of CDC Questions. The sensitivity and specificity of four of the CDC questions are relatively low with the exception of the question about having a potentially lead-using job or a lead-using hobby (Table 3). These results suggest that asking about occupational or leisure time use of lead may result in 72% of children being correctly identified as being at-risk for a blood lead level ≥10 μg/dL. The specificity is somewhat lower, so that approximately 46% of children would be incorrectly identified as being at-risk for such a blood lead level. The positive predictive values (the proportion of children with a positive test who have a blood lead level ≥10 μg/dL) of all four questions are quite low. For example, only 6.02% of children whose parents reported a lead-using job or hobby actually had a blood lead level ≥10 μg/dL. An analysis of the impact of the mother's education on blood lead level is provided for contrast purposes. The sensitivity of mother's education was quite low, while the specificity was quite high. However, the positive predictive value of mother's education was substantially higher than that of the other factors. Not surprisingly, the negative predictive values are quite high for all factors.

COMMENT

The study reported here was conducted with healthy children from employed, insured families. Children were only included in the study if they had come to a facility for a routine well-care visit; our sample is a relatively middle-class, employed, and multicultural population with consistent access to medical care.

TABLE 3. Sensitivity and Specificity of Four CDC Questions for Detecting Blood Lead Levels ≥10 μg/dL

	Sensitivity	Specificity	Predictive Value	
			+	−
Living in old home	56%	50.9%	4.6%	96.6%
Lives in/visits old peeling building	48%	62.4%	4.9%	96.7%
Recent remodeling	28%	80.9%	5.6%	96.5%
Lead-related job/hobby	72%	54%	6.02%	97.9%
Mother's education	24%	95.6%	18.2%	96.8%

Abbreviation: CDC, Centers for Disease Control and Prevention.

Questions may be raised about the representativeness of this sample for all KPMCP pediatric members. Data from 1990 and 1991 for the KPMCP Northern California Region show that about 90% of children aged 12 to 36 months and 50% of those aged 36 to 60 months are seen annually for routine checkups. These percentages were similar for Oakland and VFN. Utilization of preventive pediatric health checkups is clearly routine throughout most of the KPMCP membership. Our sample was representative of the KPMCP pediatric population.

The results that we have presented here are, of course, subject to certain limitations. First, our questions about older housing do not precisely match the CDC questions in that we used a more recent age cut-off of before 1970, while CDC questions refer to 1960 and earlier. Environmental Protection Agency standards affecting lead paint in houses were instituted in 1978, meaning that housing in our study that was <10 years old would cover the years 1982 through 1992. Housing in this age group would presumably have little or no lead. That age of housing questions are related to blood lead level within the restricted range that we found argues for the validity of these measures.

Similarly, misclassification regarding occupational or leisure time lead exposure is likely to be high. Parents may not know if they are being exposed to lead. Those who are aware of lead exposure may not admit it out of fear of criticism, and this tendency may be particularly true for home uses. If parents are unaware of lead exposure, the proportion of cases of elevated blood lead levels in their children associated with parental occupational or leisure time lead use would be underestimated. If parents are misreporting exposure, the reverse would be true.

Most research on this topic has repeatedly shown that low-income, urban children are at higher risk of lead poisoning. Sixty-five percent of the Oakland children and 32.5% of the VFN children lived in older housing, long considered a major source of childhood lead exposure, so lead exposure in our sample was possible. Although living in old housing did predict higher blood lead levels within the limited ranges we found, it did not result in substantial numbers of blood lead levels within the CDC range of concern.

With the exception of the questions about having a lead-related job or hobby, none of the CDC questions was sensitive or specific, and all had low positive predictive value. By contrast, mother's education had low sensitivity but very high specificity and a relatively high positive predictive value. Negative predictive values were quite high, reflecting the low prevalence of elevated blood lead levels. If a child does not live in an old home, the probability that he or she will have an elevated blood lead level is low, as reflected by the negative predictive value for that question. These results suggest that asking parents about their occupational exposure to and leisure time use of lead may be a useful and potentially productive screening tool. The higher specificity and positive predictive value of the mother's education reveal the importance of targeting low-income children for screening. These results also suggest that using the CDC questions to identify children who are at-risk for a blood lead level ≥10 μg/dL may result in substantial expenditure of funds and provider and patient time in following up unaffected children for a rather small yield (generally >6%) of real cases. Conversely, targeting mothers with low education would result in a lower number of children being incorrectly classified as negative and would yield the highest proportion of real cases of an elevated blood lead level of the five factors examined. However, using this type of targeted screening would be accompanied by lower sensitivity.

If CDC recommendations for universal screening were implemented in the KPMCP pediatric population and if each child were screened at 1 year of age and at 2 years of age, the total cost for blood lead analysis (currently $13.50 per test for anodic stripping voltammetry, a less precise test than others available) would exceed $4 million in a 5-year period. This estimate does not include the cost of retesting, staff time spent in follow-up, or member time spent attending appointments. Less tangible costs, such as the emotional and financial impact of a diagnosis of elevated blood lead values on the child and family, must also be considered.

Our results suggest that universal routine screening for elevated blood lead levels in children in an employed, HMO-insured population is probably not warranted on grounds of prevalence. The recently published NHANES III data demonstrated a 76% decline in the geometric mean BLL, from 15 μg/dL in the NHANES II data (1976 through 1980) to 3.6 μg/dL in the NHANES III data (1988 to 1991).[3] We report an overall mean of 4.65 μg/dL in our population. Nor do CDC questions effectively identify children in this population who may be at high-risk of lead poisoning. CDC recommendations that all children in an area be screened until such screening shows that the area does not hold a high-risk of lead poisoning are not likely to be effective in such circumstances.

Universal screening is very costly at present, especially because a less expensive test, the free erythrocyte protoporphyrin test, is unable to detect the newly recommended lower blood lead levels. According to the CDC recommendations, all children with blood lead levels of 10 to 19 μg/dL should be retested, and those whose blood lead levels are 15 to 19 μg/dL should receive nutritional and environmental counseling.

Except for retesting and counseling, CDC guidelines do not indicate any appropriate medical intervention for children with blood lead levels of 10 to 19 μg/dL. Educating providers about important sources of lead exposure could also be as effective as screening in reducing blood lead. Such education would also be less costly than screening and could therefore be more widely applied. Educational intervention would also avoid any negative consequences of screening.

Our data agree with other research, including NHANES III, which supports the idea that minority children and children of low socioeconomic status are at higher risk for an elevated blood lead level. Our data did not support the findings of some recent studies that reported the CDC questionnaire was a useful screening tool for identifying cases of children with lead poisoning.[4,5] We do not find support for use of CDC screening questions as a means to identify cases of disease. However, based on the negative predictive value, children who are not exposed to these factors are much less likely to have an elevated blood lead level.

ACKNOWLEDGMENTS

Funding was provided by the Sidney R. Garfield Memorial Fund, the Permanente Medical Group, Inc, and the Kaiser Foundation Health Plan, Inc.

We thank pediatricians from the Kaiser Permanente Medical Centers in Vallejo, Fairfield, Napa, and Oakland for recruiting patients for the study.

The Medical Editing Department, Kaiser Foundation Research Institute, provided editorial assistance.

REFERENCES

1. US Department of Health and Human Services. Centers for Disease Control. Preventing lead poisoning in young children: a statement by the Centers for Disease Control. October 1991. Atlanta, GA: USDHHS, 1991
2. US Department of Health and Human Services. Agency for Toxic Substances and Disease Registry. Case studies in environmental medicine: lead toxicity by SE Royce and HL Needleman. Atlanta, GA: USDHHS, ATSDR, 1990
3. Pirkle JL, et al. The decline in blood lead levels in the United States. *JAMA*. 1994;272:284–291
4. Binns HJ, et al. Is there lead in the suburbs? Risk assessment in Chicago suburban pediatric practices. *Pediatrics*. 1994;93:164–171
5. Nordin JD, et al. Prevalence of excess lead absorption and associated risk factors in children enrolled in a midwestern health maintenance organization. *Pediatrics*. 1994;93:172–177