

# Screening for Pediatric Lead Poisoning

## Comparability of Simultaneously Drawn Capillary and Venous Blood Samples

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**Objective.**—To determine the ability of capillary blood lead levels to accurately reflect true blood lead levels in children at risk for lead poisoning.

**Design.**—A correlation study in which lead levels of capillary blood specimens obtained by four different methods were compared with lead levels of simultaneously drawn venous blood specimens.

**Setting.**—A central-city pediatric primary care clinic and door-to-door home visits in one central-city neighborhood.

**Patients.**—Two hundred ninety-five children at high risk for lead poisoning aged 6 months to 6 years.

**Main Outcome Measures.**—Blood lead levels of simultaneously drawn capillary and venous blood specimens.

**Results.**—Lead levels of all four capillary sampling methods were highly correlated (correlation coefficient  $\geq 0.96$ ) with matched venous blood lead levels, with mean capillary-venous differences less than  $0.05 \mu\text{mol/L}$  ( $1 \mu\text{g/dL}$ ).

**Conclusions.**—Capillary sampling is an acceptable alternative to venipuncture for lead-poisoning screening in young children.

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THE CENTERS for Disease Control and Prevention<sup>1</sup> recommended in October 1991 that all children aged 6 months to 6 years be screened for lead poisoning. They also recommended that the erythrocyte protoporphyrin test, which has

been shown to be insensitive at lower levels of exposure, be replaced by the direct measurement of blood lead as the screening test of choice.<sup>2</sup> Since then, progress toward the goal of universal screening has been limited by a number of factors.<sup>3-5</sup> One impediment to implementation has been the difficulty of obtaining venous blood specimens from young children in some clinical settings.<sup>6,7</sup> As an alternative to venous sampling, capillary sampling has been proposed.<sup>1(Appendix 1)</sup>

Of concern is that capillary sampling may not accurately reflect true blood lead levels. Contamination of capillary specimens by lead-soiled fingertips is a well-documented cause of falsely elevated values.<sup>8-10</sup> Falsely lowered values have also been noted.<sup>11</sup> To assess

whether careful attention to protocol and technique may reduce false results to acceptable rates, we correlated blood lead levels obtained by four different capillary sampling methods with simultaneously drawn venous samples.

### Methods

**Study Design.**—Correlate venous and capillary blood samples were obtained from two different populations of children aged 6 months to 6 years following a protocol approved by the human subjects review board of Children's Hospital of Wisconsin. The pilot population consisted of 60 children whose parents consented to dual blood sampling by the Milwaukee Health Department during door-to-door home visits in one economically distressed central-city neighborhood in October 1991. The second population consisted of 235 consecutive children who presented for primary care to the Downtown Health Center, a Milwaukee central-city clinic, and whose parents consented to the dual blood sampling between February 1992 and July 1993. Methods 1, 2 and 3 were alternated by month.

All blood samples obtained from the children at the Downtown Health Center were drawn by a single laboratory technician skilled in pediatric phlebotomy working in a standard satellite laboratory setting within the clinic. All capillary samples obtained during home visits were drawn by a Milwaukee Health Department outreach worker trained in the fingerstick sampling tech-

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nique but without previous laboratory/ phlebotomy experience. The simultaneous venous specimens were obtained by an experienced pediatric phlebotomist who accompanied the outreach worker. Standard supplies were used in all settings and for all four methods. Samples of lots of each product were tested for lead contamination.

Capillary sampling method 1 used wiping the finger to be punctured with an alcohol wipe and allowing it to dry. Method 2 used wiping the finger to be punctured with an alcohol wipe, allowing it to dry, and spraying on silicone coating. Method 3 used washing the child's hands with soap and water, rinsing and drying, and wiping the finger to be punctured with an alcohol wipe. Method 4 (used during home visits) used washing the child's hands with soap and water, rinsing and drying, wiping the finger to be punctured with an alcohol wipe, and rinsing with 1% nitric acid solution. Following fingertip cleaning, 100- to 500- $\mu$ L "micro" specimens of blood were obtained using the standard finger-puncture technique.<sup>11(Appendix 1),12</sup> Then, 2-mL specimens of blood were obtained by venipuncture.

Capillary samples by methods 1, 2, and 3 were obtained at the Downtown Health Center for 99, 98, and 39 children, respectively. Samples by method 4 were obtained for 60 children seen during home visits.

**Laboratory Methods.**—All blood lead measurements were made by the Milwaukee Health Department laboratory (a participant in the Blood Lead Proficiency Testing Program of the Centers for Disease Control and Prevention, Wisconsin State Laboratory of Hygiene, and the US Health Resources and Services Administration) using either flame atomic-absorption spectrophotometry with Delves-cup modification<sup>12</sup> or graphite furnace atomic-absorption spectrophotometry.<sup>13,14</sup>

Table 1.—Descriptive Characteristics

	No. of Patients	Male, %	Black, %	Mean Age, y
Method 1	99	50	87	3.1
Method 2	97	54	85	2.6
Method 3	39	49	82	3.2
Method 4	60	60	100*	3.3

\*Race variable was missing on nine patients.

Table 2.—Venous and Capillary Blood Lead Levels ( $\mu$ mol/L [ $\mu$ g/dL]): Comparison of Paired Samples by Method\*

	Mean Venous Blood Lead Level	Mean Capillary Blood Lead Level	Difference of Means	SD of Differences	Correlation Coefficient	Capillary-Venous Blood Lead Level >0.20 $\mu$ mol/L (> 4 $\mu$ g/dL), %	Capillary-Venous Blood Lead Level $\leq$ -0.20 $\mu$ mol/L ( $\leq$ -4 $\mu$ g/dL), %
Method 1	0.68 (14.2)	0.71 (14.7)	0.02 (0.5)	0.09 (1.9)	0.98	3	0
Method 2†	0.66 (13.8)	0.71 (14.7)	0.04 (0.9)	0.09 (1.9)	0.97	1	0
Method 3	0.69 (14.4)	0.68 (14.2)	-0.01 (-0.2)	0.09 (1.9)	0.96	0	3
Method 4	1.08 (22.5)	1.04 (21.6)	-0.03 (-0.8)	0.13 (2.8)	0.96	2	8

\*Methods 1, 2, and 3 were used with the Downtown Health Clinic. Method 4 was used going door-to-door.

†One extreme outlier was excluded from analysis.

**Statistical Methods.**—The study populations for each method were compared for age, race, and sex. The mean capillary blood lead level, mean venous blood lead level, the difference between the means, the correlation coefficient, and the SD of the differences were calculated for each method. Analysis of the comparability of the capillary samples with their corresponding venous samples was performed using one-way analysis of the variance of the difference between venous and capillary blood lead levels to assess relative differences in the four methods using the MGLH module of Systat (Evanston, Ill). Age, race, and sex of children plus blood lead level itself were also assessed as variables potentially affecting the difference. False-negative rate, false-positive rate, sensitivity, and specificity were calculated for each method, designating 0.97  $\mu$ mol/L or greater ( $\geq$ 20  $\mu$ g/dL) of lead, the level at which the Centers for Disease Control and Prevention recommends medical case management, as positive.

## Results

Demographic characteristics of the study subjects are shown in Table 1. Sex distribution, race distribution, and mean age were similar among all groups and were not statistically related to venous blood lead level or to the difference between venous and capillary blood lead levels. The mean blood lead levels for study subjects (Table 2) were similar for methods 1, 2, and 3 but were significantly higher for study subjects of method 4.

The paired samples of all four methods (excluding an extreme outlier in method 2) had correlation coefficients of 0.96 or greater, with mean capillary-venous differences less than 0.05  $\mu$ mol/L (1  $\mu$ g/dL) (Table 2). Table 2 shows that correlate capillary and venous blood lead levels rarely (in only 4% of cases) varied by more than  $\pm$ 0.20  $\mu$ mol/L ( $\pm$  4  $\mu$ g/dL).

In Table 3, designating 0.97  $\mu$ mol/L or greater ( $\geq$ 20  $\mu$ g/dL) as positive, false-positive rates for methods 1, 2, 3, and 4 were 5% (5/99), 3% (3/97), 0% (0/39), and 3% (2/60), respectively. Corresponding false-negative rates were 1% (1/99), 1% (1/97), 3% (1/39), and 8% (5/60). Sensitivity ranged from 86% (method 4) to

96% (method 2). Specificity ranged from 91% (method 4) to 100% (method 3).

One-way analysis of variance of differences of paired samples showed a significant ( $P<.005$ ), albeit small, amount of variation accounted for by method. Capillary specimens obtained by methods 3 and 4, which included hand washing, measured, on average, slightly lower than the blood lead levels of corresponding venous specimens. Capillary specimens for methods 1 and 2, which did not include hand washing, measured slightly higher than corresponding venous specimens. A limited number of pair-wise comparisons using  $t$  tests showed that methods 3 and 4 were statistically different from methods 1 and 2 ( $P<.05$ ). Method 3 did not differ significantly from method 4, and method 1 did not differ significantly from method 2. Because method 4 specimens were obtained in the field rather than in the clinic and the blood lead levels obtained were higher than those of the other methods, it seemed prudent to analyze separately methods 1, 2, and 3, which were performed under uniform conditions and had no significant study population differences. Overall, one-way analysis of variance still showed significant differences ( $P<.02$ ) associated with sampling method. Method 3 was significantly different from the other two methods in pair-wise comparisons (same  $t$  tests as just described).

Regression analysis, using a model that included sampling method and venous blood lead level, revealed that the difference between capillary and venous blood lead levels was negatively correlated with measured venous blood lead level ( $\beta = -.053$ ;  $P<.001$ ). Thus, the predicted capillary-venous difference for a venous blood lead level of 1.45  $\mu$ mol/L (30  $\mu$ g/dL) was 0.05  $\mu$ mol/L (1.06  $\mu$ g/dL) less than that predicted for a venous blood lead level of 0.48  $\mu$ mol/L (10  $\mu$ g/dL).

## Comment

Each of the four capillary sampling methods tested showed excellent correlation with corresponding venous blood lead measurements. Variation between capillary and venous samples averaged less than 0.05  $\mu$ mol/L (1  $\mu$ g/dL). Only 13 (4%) of 295 matched pairs var-

Table 3—Sensitivity and Specificity by Method Designating  $\geq 0.95 \mu\text{mol/L}$  ( $\geq 20 \mu\text{g/dL}$ ) as Positive\*

	False Negatives, %	False Positives, %	Sensitivity, %	Specificity, %
Method 1	1	5	95	94
Method 2†	1	3	96	96
Method 3	3	0	88	100
Method 4	8	3	86	91

\*Methods 1, 2, and 3 were used with the Downtown Health Clinic. Method 4 was used going door-to-door.  
†One extreme outlier was excluded from analysis.

ied by more than  $0.20 \mu\text{mol/L}$  ( $4 \mu\text{g/dL}$ ). Only one capillary sample appeared to have been grossly contaminated (venous,  $0.20 \mu\text{mol/L}$  [ $4 \mu\text{g/dL}$ ] vs capillary,  $2.40 \mu\text{mol/L}$  [ $50 \mu\text{g/dL}$ ]). Sensitivity and specificity for each method were adequate for screening tests<sup>15</sup> and far superior to the previously used erythrocyte protoporphyrin test.<sup>2,16,17</sup>

Among the different capillary sam-

pling methods, the two that required hand washing with soap and water were marginally better at eliminating skin contamination. Nevertheless, where hand washing with soap and water was too cumbersome, methods using only alcohol wiping performed well. The use of silicone-spray skin coating or a dilute nitric acid wash following alcohol wiping appeared to confer no additional ben-

efit. The higher false-negative rate of method 4 (8%) may have been due to hemodilution from excessive fingertip squeezing caused by technician inexperience, as has been reported elsewhere.<sup>18</sup>

Our data suggest that appropriately performed capillary sampling is an acceptable alternative to venipuncture for lead-poisoning screening in young children. However, prior to chelation or other significant intervention, a confirmatory venous blood lead level is necessary. Based on its ease of performance, capillary sampling may be preferred for mass screening strategies both to determine prevalence of lead poisoning within communities and for case finding in known high-prevalence areas.

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