

Targeted Testing of Children for Tuberculosis: Validation of a Risk Assessment Questionnaire

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ABSTRACT. *Objective.* Given the directive of the American Academy of Pediatrics to test children for tuberculosis (TB) only if they are at high risk for the disease, we sought to determine how well a risk assessment questionnaire can predict a positive tuberculin skin test (TST) result among children seen in a medical office setting.

Methods. In a prospective observational study, we identified 31 926 children who received well-child care in 18 pediatric offices of the Kaiser Permanente Northern California Region from August 1996 through November 1998 and who were due to receive a routine TST (Mantoux method) as part of universal screening. Parents were asked to complete a questionnaire about risk factors for TB infection that included demographic information. The TST result at 48 to 72 hours was compared with questionnaire responses to identify responses that were most highly associated with a positive TST result at both the 10-mm and 15-mm cutoffs. A concurrent study was conducted to determine whether parents can recognize induration.

Results. This population was diverse in age (range: 0–18 years), race/ethnicity (white: 37%; Hispanic: 26.4%; Asian: 15.0%; black: 11.8%; other: 8.4%; not stated by parent: 1.6%), and household annual income (range: \$10 524–\$175 282). Overall incidence of positive TST results was 1.0% at the 10-mm cutoff and 0.5% at the 15-mm cutoff. Positive predictive value of selected individual risk factors at the 10-mm cutoff were: child born outside the United States, 10.4%; history of receiving bacille Calmette-Guérin vaccine, 5.5%; and child having lived outside the United States, 5.3%. Using multivariate analysis, we selected a subset of risk factors that were independently and significantly associated with a positive TST result ≥ 10 mm: history of receiving bacille Calmette-Guérin vaccine (odds ratio [OR]: 2.31; 95% confidence interval [CI]: 1.70–3.13); household member with history of positive TST result or TB disease (OR: 1.53; 95% CI: 1.14–2.04); child born outside the United States (OR: 8.63; 95% CI: 6.16–12.09); child having lived outside

the United States (OR: 2.06; 95% CI: 1.49–2.85); and race/ethnicity reported by parent as Asian (OR: 2.28; 95% CI: 1.59–3.27) or Hispanic (OR: 1.57; 95% CI: 1.09–2.26). Several factors were not statistically significant predictors of a positive TST result: age, sex, household annual income, household member infected with human immunodeficiency virus or who had stayed in a homeless shelter, and being an adopted or foster child. Overall sensitivity of the 9 main items on the questionnaire was 80.9%; when a subset of 4 of these questions plus the race/ethnicity questions were used, sensitivity of responses was 83.5%. Parents failed to recognize positive TST results at a rate of 9.9% (for the 10-mm cutoff) and 5.9% (at the 15-mm cutoff).

Conclusion. A 5-question risk assessment questionnaire completed by parents can be used to accurately identify risk factors associated with TB infection in children. In our population, some risk factors suggested by the American Academy of Pediatrics could not be validated. Parents cannot be relied on to read TST results accurately. Screening for TB can be enabled by using a standardized, validated questionnaire to identify children who should be given tuberculin skin testing. *Pediatrics* 2001;107(4). URL: <http://www.pediatrics.org/cgi/content/full/107/4/e54>; ethnic groups, mass screening, physicians' practice patterns, tuberculin test, tuberculosis, children, tuberculin screening, Mantoux test, targeted tuberculin testing.

ABBREVIATIONS. TB, tuberculosis; TST, tuberculin skin test; CDC, Centers for Disease Control and Prevention; AAP, American Academy of Pediatrics; ATS, American Thoracic Society; PPD, purified protein derivative; KPNC, Kaiser Permanente Northern California; HIV, human immunodeficiency virus; PPV, positive predictive value; BCG, bacille Calmette-Guérin; AIDS, acquired immunodeficiency syndrome; OR, odds ratio; CI, confidence interval.

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Testing asymptomatic children for tuberculosis (TB) infection by using the tuberculin skin test (TST) is a familiar task for pediatricians and other primary care physicians. Despite high prevalence in certain high-risk groups, pediatric TB remains a low-prevalence disease in most communities in the United States.¹ Recommendations for how and when to test children were changed and have become more selective by directing that only children at increased risk of TB need such testing.^{2–6} Implementation of these guidelines has been hampered by their complexity and by the traditional resistance of physicians to change.^{7,8} This study assesses the validity of a TB risk assessment questionnaire in pedi-

atric practice and attempts to identify the most predictive set of risk factors.

Epidemiology

The goal of tuberculin testing is to detect latent TB infection (asymptomatic infection, positive skin test result only) and to begin treatment to prevent progression to TB disease.⁶ In an era of high prevalence of TB disease, implementation of universal screening of children was effective. Overall, US prevalence of TB in children is at an historic low despite an increase during 1988 to 1992.⁹ In the years 1992 to 1997, this increase was followed by both a decrease in total number of cases and an increased proportion of foreign-born TB patients (27%–39%).⁹ Additional detailed data from the Centers for Disease Control and Prevention (CDC) for the years 1985 to 1994 showed that 60% of counties in the United States had no cases of TB disease in children and that only 25 counties (all urban) reported >100 cases during the period.¹

Guidelines

For many communities, universal TB skin testing of children during an era of low TB prevalence has a low yield of positive results and a high rate of false-positive results. One estimate of the rate of TB disease detection by school-based programs is <0.02%.¹⁰ False-positive results (caused primarily by atypical mycobacteria) are thought to outnumber true-positive results by 10:1 in low-prevalence groups.^{2,11} In this context, a recommendation for universal testing has been set aside by the national advisory bodies. In place of universal testing, the guidelines from the American Academy of Pediatrics (AAP) and the CDC call for identification of risk factors for infection and disease and subsequent skin testing only for persons who show risk factors for TB infection.^{3,4,6} In addition, according to AAP, CDC, and the American Thoracic Society (ATS), the only reliable TB test is now tuberculin purified protein derivative (PPD) injected intradermally by the Mantoux method.^{2–6} Three different cutoffs based on these same risk factors were established to define positive versus negative results.^{2,3}

Difficulty in Implementation

Implementation of the new recommendations has been difficult because the decision to do skin testing is based on the patient's medical history, which must be obtained accurately, in detail, and with reasonable ease. The medical history is relied on for correctly identifying individual children as being at high risk or at low risk for TB infection. Full use of the AAP and CDC guidelines should result in no skin testing for children in low-risk groups and frequent skin testing for children who have any risk factors. A risk assessment questionnaire to obtain such a history of risk factors has been proposed.¹² One study used a questionnaire in an urban academic pediatric primary care center but did not identify which risk factors should be included.¹³ In 1998, the State of California implemented a 9-part questionnaire for tuberculin screening among new entrants to child-care centers.¹⁴ Risk assessment questions have been

validated for use in deciding which children should receive a test for blood lead.¹⁵

Another obstacle to full implementation of the AAP guidelines is the need for a return office visit to enable a health professional to measure induration resulting from the Mantoux skin test. The usual practice was for a parent to read the multiple-puncture skin test result and to notify the office of the result by postcard. However, the return rate for these postcards is usually low.¹⁶ Many pediatricians would like to extend home reading of the Mantoux PPD skin test, but this practice is not recommended by any of the national advisory bodies. Some specialized groups (eg, adult health care or safety workers) may read their own skin test results more accurately than other groups might¹⁷; in general, however, experience has shown that patients are not reliable readers of TST reactions.^{18–20}

The primary question examined in this study was whether a risk assessment questionnaire used in an office setting can be a valid predictor of positive TST results in children. The secondary question was whether parents can recognize induration after a TST.

METHODS

Patient Population

The study population was selected from among children and adolescents ≤18 years of age who were members of the Kaiser Permanente Medical Care Program in suburban and urban areas of Northern California (KPNC) and who received a TST during the 28-month study (August 1996 through November 1998). All 34 pediatric offices of KPNC were invited to participate; 18 offices (whose pediatric staffs ranged from 2 to 20 physicians) elected to participate in the study.

Because most of the parents of these pediatric members had insurance obtained through their employers, only a small percentage of children in the study population were receiving public assistance.

The control group consisted of 26 840 children not participating in the study who were randomly selected from computerized KPNC databases and who also received TSTs during the study. We were not able to determine from the electronic data whether each of these children met all eligibility criteria for the survey cohort. The purpose of using the control group was to check for differences in household income, age, sex, and frequency of positive TST results between the surveyed group and the non-surveyed group.

Any child who received the TST as a screening assessment was eligible to participate in the survey portion of the study. Universal screening continued during most of the study and included: 1) 12-month-old infants seen at well-baby visits; 2) day care and kindergarten entrants; and 3) adolescents seen at routine health checks. During the final year of the study, most KPNC medical offices ceased to routinely test 12-month-old infants. Children were excluded from the study if: 1) the skin testing was performed because of illness; 2) corticosteroid agents had recently been used systemically; or 3) measles-containing or varicella vaccine was given within 3 weeks before the study began. We did not test for human immunodeficiency virus (HIV) status, but no children known to be infected with HIV were enrolled. We were unable to verify these criteria for the control children.

Questionnaire

The questionnaire originated with expert opinion highlighting several risk factors.¹² We designed a questionnaire ("Appendix") to summarize the recommendations of the AAP.^{2,3} The questionnaire was translated into both Spanish and Chinese. After a 3-month pilot program of using the questionnaire, the layout and question list were modified. In its final form, the questionnaire included a brief explanation of the study (printed on 1 side of a

page) stapled to the actual questions (printed on 2 sides of a page). One side of the question sheet included spaces for parents' responses; the other side included spaces for the nursing staff's responses. The questionnaire was seen and approved by the steering committee for the study and by the KPNC Institutional Review Board. The institutional review board ruled that because the TST was part of routine medical care, the study as explained in writing met informed consent guidelines. Each of the first 9 categorical risk factors was accompanied by secondary questions for specification. The term "household member" was defined on the questionnaire ("Appendix"). The last 2 questions were demographic: race/ethnicity of the child and highest education level achieved by the parents. The race/ethnicity question was asked with the instruction to "check all that apply" and followed guidelines on use of race and ethnicity in public health.²¹

Study Protocol

At each participating medical office, a physician and nurse served as local study coordinators. As part of the universal skin testing of the groups noted above, the questionnaire was given to the parent by the physician or nurse practitioner who saw the child or the staff member who administered the skin test. Completed questionnaires were collected by the staff and were held until the child's return visit for reading the skin test.

Throughout the study, the skin test antigen used was Tuberculin PPD (Mantoux)—Tubersol (Connaught Laboratories, Swiftwater, PA), mostly from the same lot. Five tuberculin units were injected intradermally. By using a training video obtained from the CDC,²² staff members at each medical office were trained in a standard method for placing and reading the TST.

Appointments for the reading were routinely scheduled for 48 to 72 hours after placement of the skin test. At the return visit, parents were asked by the health care professional (typically, a nurse) to feel the forearm of the child and to answer the question, "Is there a bump there, or not?" No specific coaching was given to parents. On the questionnaire, the nurse reading the TST result recorded dates and times of TST administration and reading, parental interpretation, diameter of induration (mm), licensure of reader, and medical office location. Questionnaires were gathered into batches for semimonthly delivery to the study coordinator's office. After being evaluated for completeness, necessary clarification was obtained from the electronic record of office registrations and from the immunization tracking system. At the conclusion of the study, experienced data entry personnel keyed all questionnaire responses into a corresponding form.

Statistical Analysis

Assuming that the overall KPNC incidence of positive TST results is ~1%, we compared the 2 study methods for predicting skin test positivity in children (ie, by questionnaire and by paren-

tal reading) with results of the reading taken by the nurse. Calculation showed that the sample would need to include 34 000 children to yield 340 positive TST results. Using 95% confidence intervals (CIs) with this sample size would enable us to estimate sensitivity to within 4% for an estimate of 90% and to within 3% for an estimate of 95%.

The study sample was described by age, sex, and self-reported racial/ethnic characteristics. We used home address and federal census tract identification for geocoding and obtained 1990 US Census data on household income for these regions. This method for estimating household income and socioeconomic status was validated previously.²³

Our analysis used the 10-mm cutoff and the 15-mm cutoff to determine rates of positive reactions. The questionnaire was considered positive if it contained a yes response to any question about a risk factor.

Participants and nonparticipants were compared based on age, sex, and household income. In addition, parents who completed the questionnaire but who did not return for TST reading were compared with those who did return for the reading.

Secondarily, we separately calculated the sensitivity, specificity, and positive predictive value (PPV) for the entire questionnaire and for each question at both the 10-mm and 15-mm cutoffs to determine whether some questions are more useful than others or whether some have no value. To identify a subgroup of risk factors useful for independent prediction of TST positivity, we used a logistic regression model with a stepwise procedure (SAS, Cary, NC).

RESULTS

Patient Population

A total of 33 553 questionnaires were completed by parents of eligible children who received TSTs during the study. Enrollment was somewhat seasonal and peaked in the summer months of 1997; this observation was consistent with school enrollment requirements. Mean enrollment by site was 1580 (range: 83–5664; median: 1115). We were able to geocode 27 189 of these 33 553 participants.

We were able to geocode 21 816 of the 26 840 children in the control cohort. The survey and control cohorts had similar gender distribution and geocoded annual family income (Table 1). The control group was significantly younger ($P < .001$).

Among the 3 groups of survey responders—those who returned for a reading at the appropriate time

TABLE 1. Demographic Characteristics of Children in Study and Control Groups

	Study Group	Control Group	P Value
Number (%) of children			.35
Male	16 869 (50.3)	13 391 (49.9)	
Female	16 684 (49.7)	13 449 (50.1)	
Number (%) of children aged			<.001
0–4 y	18 345 (54.7)	20 525 (76.5)	
5–9 y	7345 (21.9)	3374 (12.6)	
10–14 y	5718 (17.0)	1868 (7.0)	
15–18 y	2145 (6.4)	1073 (4.0)	
Number (%) of children by race/ethnicity			
White	11 801 (37.0)	NA	
Hispanic	8419 (26.4)		
Asian	4791 (15.0)		
Black	3782 (11.8)		
Middle Eastern	305 (1.0)		
Native American	293 (0.9)		
Other	2029 (6.5)		
Not stated	506 (1.6)		
Household annual income			.32
Mean	\$59 004	\$58 828	
Standard deviation	\$19 949	\$19 083	

NA indicates not applicable.

(2–3 days), those who returned at other times, and those who never returned for a reading—no difference was seen in the following variables: sex of child, whether child had received bacille Calmette-Guérin (BCG) vaccine, whether household member had history of TB, whether child was foreign-born, whether household member had HIV/acquired immunodeficiency syndrome (AIDS), whether household member had worked or lived in jail/prison, and whether the child was a foster or adopted child. The groups differed in parents' educational level (adherent mothers were more likely to have completed college or graduate school), household member lived outside the United States (children who never returned for TST reading were less likely to have a household member who lived outside the United States), household member lived in a homeless shelter (more likely among those who never returned for TST reading), race/ethnicity (those who did not return for TST reading were more likely to be black and less likely to be Hispanic or Asian), income (adherent patients earned approximately \$3000 more per year), and age (children who did not return for TST reading were ~6 months older than children who did return for TST reading).

Among the survey cohort, 27 204 participants had a valid TST result, defined as a result read at 2 to 3 days and for which the exact induration size was recorded. Of the 6349 participants who did not have a valid TST result reported on the questionnaire, 4722 had valid results recorded in the electronic immunization tracking system. In the control group, 14 786 children had valid TST results.

TST Results

For 21 214 patients, TST results were reported in the questionnaires as well as recorded in the computer databases of KPNC. Mean difference in induration size was 0.014 mm (standard deviation \pm 2.49 mm), a difference that is not significantly different from zero ($P = .42$). Given this high level of agreement between the 2 available sources of information, data from the electronic record were used in place of any TST result missing from the questionnaire. Remaining analyses of the survey cohort used the sample of 31 926 patients who had valid readings recorded in either source. Unless otherwise noted, all results reported here pertain to this group of patients.

In the survey cohort, the overall prevalence of TST positivity was 1.0% ($n = 325$) at the 10-mm cutoff and was 0.5% ($n = 160$) at the 15-mm cutoff. Positivity varied between medical centers and ranged from 0% to 2.1% at the 10-mm cutoff and from 0% to 1.62% at the 15-mm cutoff. Rate of positivity in the control group was 1.3% ($n = 193$) for the 10-mm cutoff and 0.6% ($n = 95$) for the 15-mm cutoff. Positivity rates of the survey and control cohorts differed significantly for the 10-mm cutoff ($P = .004$) and for the 15-mm cutoff ($P = .05$).

Analysis of Risk Factors

Because sensitivity, specificity, and PPV of risk factors did not appreciably differ for the 10-mm and

15-mm cutoffs, only the 10-mm cutoff data are presented (Table 2).

Sensitivity was highest for household member foreign-born (61.1%), followed by child foreign-born (53.0%) and child lived outside United States (48.0%). The PPV for individual risk factors ranged from 0.5% to 10.4%. Highest PPVs at the 10-mm cutoff were seen for child foreign-born (10.4%), child lived outside United States (5.3%), and child received BCG vaccine (5.5%). Little difference was seen for these variables at the 15-mm cutoff (data not shown).

TST positivity was statistically significantly related to each of the following: whether child received BCG vaccine, whether a household member had history of TB, whether child was foreign-born or had lived outside the United States, whether a household member was foreign-born, parents' education level, and race/ethnicity. TST positivity was not significantly related to whether a household member had HIV/AIDS, whether a household member had worked or lived in jail/prison, whether a household member had lived in a homeless shelter, whether the child was a foster or adopted child, age of child, and sex of child.

Overall, 14 633 questionnaires (46%) had ≥ 1 risk factor positive at the 10-mm cutoff (sensitivity: 80.9%; specificity: 54.4%; PPV: 1.8%; Table 3). When total number of affirmative responses to questions about risk factors was calculated for each subject at the 10-mm cutoff, PPV for having ≥ 4 risk factors was 14.4%; for having ≥ 5 risk factors, 10.7%; and for having ≥ 6 risk factors, 22.2%.

Geocoding of census tracts showed mean household income to be \$59 004 (standard deviation: \$19 949; range: \$10 524–\$175 282). Household income was not associated with TST result ($P = .48$ for the 10-mm cutoff and $P = .93$ for the 15-mm cutoff).

In the multivariate analysis, possible predictors included each of the 9 questions on the questionnaire and race/ethnicity. Parental education was not included because of its high rate of missing data. Positivity of 5 statistically significant variables was established at the 10-mm cutoff: history of BCG vaccination, household member with history of TB, child foreign-born or having lived outside the United States, and Asian or Hispanic race/ethnicity (Table 4). The 15-mm cutoff for TST positivity was associated with the same statistically significant predictors (data not shown).

If a shortened survey had only these 5 questions, a positive response to any one of these questions would be associated with a sensitivity of 83.5%, specificity of 47.5%, and PPV of 1.6% for the 10-mm cutoff (Table 5). When these questions were taken cumulatively, 67 parents answered yes to them all. The specificity rises to as high as 99.8% with a concomitant increase of PPV to 19.4%; sensitivity drops to 4.1% (Table 5). At the 15-mm cutoff, a single affirmative response to these questions was associated with a sensitivity of 88.0%, specificity of 47.3%, and PPV of 0.8% (data not shown).

TABLE 2. Sensitivity, Specificity, and PPV of 31 926 Questionnaires for Predicting TST Positivity (≥ 10 mm)

Question	Number of Questionnaires With Any Response	Number of Affirmative Responses	Sensitivity of Affirmative Responses (%)	Specificity of Affirmative Responses (%)	PPV (%)	P Value*
Child received BCG vaccine	30 601	2216	41.0	93.1	5.5	<.001
Household member with history of TB	31 284	4286	25.4	86.4	1.8	<.001
Child born outside United States	31 803	1618	53.0	95.4	10.4	<.001
Child lived outside United States	31 725	2865	48.0	91.4	5.3	<.001
Household member born outside United States	31 433	9217	61.1	71.0	2.0	<.001
Household member HIV-positive or has AIDS	31 765	131	0.3	99.6	0.8	<.99
Household member worked or lived in jail/prison	31 740	1954	4.1	93.8	0.7	.12
Household member lived in homeless shelter	31 748	253	0.6	99.2	0.8	<.99
Foster or adopted child	31 673	570	2.2	98.2	1.2	.55
Father's level of education	21 055					<.001
≤ 8 th grade	698		13.9	96.8	4.0	
9th–11th grade	1076		19.8	91.7	2.3	
High school graduate	4606		31.7	69.7	1.0	
Some college or technical school	7896		54.0	32.1	0.8	
College degree	4149		77.2	12.4	0.8	
Graduate school	2630		100	0	1.0	
Mother's level of education	21 320					<.001
≤ 8 th grade	526		4.7	97.6	1.7	
9th–11th grade	934		12.5	93.2	1.6	
High school graduate	4209		22.9	74.2	0.8	
Some college or technical school	9083		54.7	31.5	0.7	
College degree	4292		80.7	11.5	0.8	
Graduate school	2456		100	0	0.9	
Race/ethnicity	31 420					<.001
White	11 801		17.3	62.2	0.5	
Black	3782		7.2	87.9	0.6	
Hispanic	8419		28.9	73.2	1.1	
Asian	4719		39.6	85.0	2.6	
Middle Eastern	305		1.6	99.0	1.6	
Native American	293		1.3	99.1	1.3	
Other	2029		4.1	93.5	0.6	
Not stated	319					

* P value for test of association between question response and PPV outcome using χ^2 test or Fisher's exact test.

TABLE 3. Number of Risk Factors Identified by Affirmative Responses to First Nine Items of Questionnaire Among 31 842 Children* (TST Positivity ≥ 10 mm)

Number of Risk Factors	Number (%) of Questionnaires	Sensitivity of Affirmative Responses (%)	Specificity of Affirmative Responses (%)	PPV (%)
≥ 1	14 633 (46.0)	80.9	54.4	1.8
≥ 2	5810 (18.2)	64.9	82.2	3.6
≥ 3	1876 (5.9)	46.1	94.5	7.5
≥ 4	617 (1.9)	27.9	98.3	14.4
≥ 5	131 (0.4)	5.3	99.6	10.7
≥ 6	9 (0.03)	0.6	99.98	22.2
≥ 7	4 (0.01)	0	99.99	0

* Excludes returned questionnaires in which respondents answered <5 questions.

Parental Reading of TST Results

In 24 902 patients, TST readings by both the parents and the health professional were available. Using the health professional's reading as the true reading, sensitivity was 90.1% at the 10-mm cutoff and 94.1% at the 15-mm cutoff; and specificity was 98.7% at the 10-mm cutoff and 98.2% at the 15-mm cutoff. Parents, thus, failed to detect positive TST results in 9.9% of cases at the 10-mm cutoff and in 5.9% of cases at the 15-mm cutoff.

DISCUSSION

To the extent that our study population reflects the general population demographics of California, the findings in this study support the risk assessment approach to tuberculin testing. This approach has been advocated by the AAP, CDC, and ATS.^{2–6} An office-based questionnaire was found practical and workable and validated several of the previously identified risk factors for TB infection. Risk factors were found to predict TST

TABLE 4. ORs and 95% CIs for Logistic Model Predictors of Positive TST Result (≥ 10 mm) in 29 699 Children

Predictor	OR	95% CI
Child received BCG vaccine	2.31	(1.70,3.13)
Child born outside United States	8.63	(6.16,12.09)
Household member with history of TB	1.53	(1.14,2.04)
Child lived outside United States	2.06	(1.49,2.85)
Race/ethnicity		
White	1	
Black	1.42	(0.86,2.36)
Asian	2.28	(1.59,3.27)
Hispanic	1.57	(1.09,2.26)
Middle Eastern	1.97	(0.75,5.18)
Native American	1.10	(0.26,4.76)
Other	0.99	(0.51,1.92)

TABLE 5. Number of Risk Factors Identified by Affirmative Responses to Logistic Model Predictors of Positive TST Result (≥ 10 mm) Among 31 836 Participants Whose Tests Were Read Between Two and Three Days and Who Responded to at Least Three of the Five Identified Questions

Number of Factors Affirmed	<i>n</i>	Sensitivity (%)	Specificity (%)	PPV (%)
1	16 823	83.5	47.5	1.59
2	5297	66.7	83.9	4.04
3	1514	48.9	95.7	10.4
4	471	25.9	98.8	17.6
5	67	4.1	99.8	19.4

positivity independently at different levels of sensitivity and specificity.

Study Sample

Our study drew from a large base of patients in a mixed urban-suburban area of Northern California. Past studies have shown that the >2.5 million members of KPNC (including ~800 000 children) are representative of the surrounding region's population except for population groups at the extremes of socioeconomic status.²³ Our study cohort was diverse in age, income, and racial/ethnic identity. The study group had similar income and gender as the group of all children receiving TSTs.

The age difference between study and control groups most likely reflects selection of symptomatic children (ie, younger children, who have more respiratory illnesses) and the California-mandated use of the Mantoux test for new entrants to child care centers during the study. Comparison of children who did and who did not return for skin test readings showed better adherence by some groups, that is, better adherence was seen among children who were of Hispanic or Asian race/ethnicity or whose household had higher income and/or education. Adherence in nonstudy settings can most likely be increased by requiring that children be screened for TB risk factors before entering school or child care centers.²⁴

TST Results

Excellent correlation was seen between the handwritten TST results reported on the questionnaire and those entered in the computer database that tracked all

immunizations and skin tests. We believe that 1 factor benefiting this study was the initial video training demonstrating a standard approach to TST administration and reading.²² Annual recertification in this training can easily be made part of any medical office's quality improvement efforts. Physicians should be included in this training because their participation could prevent the poor performance reported by Kendig et al²⁵ for 1 group of pediatricians: only 7% correctly identified a 15-mm induration.

Because a positive TST result is not a reportable condition, little is known about the prevalence of this positivity throughout the United States. The prevalence seen in our study (1.0% at the 10-mm cutoff) is lower than that reported for the public school system in Santa Clara County, California (1.9% of kindergarten children and 8.3% of high school students).²⁶ Two of our sites were in that county. In New York City, 2.1% of new school entrants had positive TST results; among the subgroup of these children for whom birthplace was known, TST positivity rate was 0.5% for US-born children and 9.2% for foreign-born children.²⁷ In a national sample of low-income adolescents and young adults, overall positivity rate was 4.2%; the rate was 2.4% in US-born youth and was 32.7% in foreign-born youth.²⁸ In these 2 studies,^{27,28} independent risk factors for positive TST result included race/ethnicity and foreign birthplace.

Use of Questionnaires to Determine TB Risk

This questionnaire was used without undue burden on office staff or parents. The future use of such a questionnaire is twofold: to limit the number of unnecessary TB skin tests and to identify as accurately as possible those children with a positive result; however, existence of 2 cutoffs for determining a positive result makes application of the questionnaire somewhat complicated. The 47.5% specificity of our modified 5-question survey at the 10-mm cutoff indicated that for 14 960 of 31 525 children with negative TST results, surveys showed no TB risk factors and, thus, no need for testing. However, the 88% sensitivity of the questions at the 15-mm cutoff indicated that our questions failed to identify 19 (12%) of the 159 true-positive TST results. Is this level of sensitivity high enough? The answer is a policy decision best left to experts.

Validating Prediction of Risk Factors for Positive TST Result

Medical practice is at its best when it is evidence-based. The recommendations of the AAP, CDC, and ATS for choosing some risk factors and not others represent expert opinion and are based on the well-documented higher incidence of disease in populations identified by the chosen risk factors.^{9,29} This study validates 8 risk factors: child received BCG vaccine, household member who had history of TB, child was born outside the United States, child had lived outside the United States, household member who was born outside the United States, parental education level, and Hispanic or Asian race/ethnicity. The present study did not validate several risk factors: household member who had HIV/AIDS,

household member who had worked or lived in a jail/prison in the past 5 years, household member who had lived in a homeless shelter, household income, age of child, gender of child, and whether the child had been adopted or a foster child.

Five risk factors remain significant independent predictors in the multivariate model: BCG vaccination status, foreign-born children, child had lived outside United States, household member with history of TB, and either Asian or Hispanic race/ethnicity. These findings are consistent with the population-specific TB rates in children.^{1,9} It may seem counterintuitive that the 2 variables—having received the BCG vaccine and having been born in a foreign country—would each still contribute independent information to the model after adjusting for the other. In our sample, only 43% of the children born outside the United States had received the BCG vaccine, so these 2 variables are not perfectly correlated. In California, 93% of pediatric TB cases are seen among minority children, and 42% of pediatric TB cases are seen in children who are foreign-born.²⁹ In addition, we believe that BCG vaccination history is a marker for high rates of TB in a given country of origin; for example, as has been known for some time (and recently demonstrated in Botswana), TB exposure (and not BCG vaccination) causes positive TST results. In that population with a high rate of BCG vaccination (>90%), 79% of children younger than 5 years of age showed no induration after receiving TST.³⁰ BCG vaccination status should be considered in determining risk for TB exposure but should not affect the Mantoux skin test reading.^{2,11}

Using these risk factors in a nonstigmatizing way may be difficult, but we believe it imperative that we recognize who is most at risk and that we target this population for testing. Strategies for early prevention (ie, in young children) are beneficial.

Parental Readings of TST Results

Despite anecdotal experience, widespread published evidence has shown the unreliability of TST readings performed by patients or their parents.^{18–20,24} We have shown a nearly 10% false-negative rate for readings performed by parents who looked for induration at the 10-mm cutoff. Moreover, populations with the highest risk for TB are least likely to be able to read it themselves.²⁰ TST readings, therefore, should not be performed by parents.

Study Limitations

A limitation of this study is that our study population is not representative of the socioeconomic extremes in California; in particular, our study population clearly underrepresents inner-city children,²³ a substantial percentage of whom can be assumed to have low household income. Having low household income (ie, being eligible for Medicaid as insurance) was not shown to be an independent predictor of TST positivity in either Rochester (NY)¹³ or Baltimore (MD).³¹ However, we did not study ethnic differences between the low-income populations of California, Rochester, and Baltimore. If these low-income populations are not ethnically comparable,

then the findings from Rochester¹³ and Baltimore³¹ may not provide a fair basis of comparison for low-income Californians. As another limitation, our sample is not comparable with the US population in racial/ethnic diversity. Instead, our sample reflects the racial/ethnic mix in California and had a much higher percentage of Hispanic and Asian children.

In addition, we tested children who came to the office for well-child care; this type of care is not a general requirement among the US population. Offering the questionnaire may have introduced a selection bias away from risk groups, given that our control population had a higher rate of TST positivity (1.3%) than in the study population (1.0%). However, the control group did not exclude symptomatic children receiving diagnostic TSTs.

Despite use of a training program in our study, another potential problematic area is variable skill of health care professionals in reading TST results. We did not attempt to measure variation between readers. In addition, knowing the results of the questionnaire may have introduced observer bias among the nurses who read the TST results. Among parents who completed the questionnaire, some may have made errors in reading the somewhat complex questionnaire; for example, some US-born children may have had BCG vaccination status misreported as a result of parents not correctly understanding this term. In addition, the sensitive nature of several of the questions (eg, time spent in a jail) may have led some respondents to misrepresent the truth. The low prevalence of some risk factors in our study population (eg, HIV-positive household member, time spent in a jail/prison, time spent in a homeless shelter) may have prevented validation of these risk factors.

Recommendations

We support the call for a model of targeted tuberculin testing that attempts to prevent TB disease in children by focusing first on improved contact investigations led by the public health department of active TB cases in adults.^{6,32}

We also recommend that the AAP and CDC make more specific recommendations about implementing risk factor assessment. This measure could be preceded by additional study in other settings, but it may be difficult to reproduce the numbers required for statistical significance. Our plan is to use our 5 validated questions as a screening tool in well-child care.

We believe that in each community, public health personnel, pediatricians, family practitioners, and school officials should agree on local solutions that address local problems. A community model using a risk assessment questionnaire would precisely describe the demographics of the local population and identify populations (eg, immigrants, refugees, new entrants to child care, and new entrants to school) for screening by the questionnaire. Tuberculin skin testing would be required only for children whose screening questionnaire results indicate risk. All TSTs should be read by a specifically trained health professional.

CONCLUSION

Our results show that a large number of risk factors can be assessed by condensing them into a questionnaire format and that this questionnaire can be successfully implemented in a variety of medical office settings for use before tuberculin skin testing. The risk factors identified in the AAP guidelines (and, thus, originating as expert opinion) have various levels of validity as used in a risk assessment tool in our population. We have also shown that a questionnaire containing a limited number of questions (ie, 5 questions) can be a valid risk assessment tool. It is now time to adapt such a questionnaire for use in other populations and to educate physicians in how to implement it.

APPENDIX

Questionnaire on Risk Factors for Positive TST Result in Children

1. Has your child ever received BCG (a TB vaccine sometimes given in foreign countries)?
2. Has there ever been TB or a positive skin test for TB in any household member? This includes your child, extended family, overnight guests, frequent visitors, babysitters, and day-care providers.
3. Was your child born outside the United States?
4. Has your child lived outside the United States for more than a month?
5. Was any household member (like the list of people in question 2) born outside the United States?
6. Does any household member have HIV or AIDS?
7. Has any household member worked in or been put in jail or prison in the last 5 years?
8. Has any household member ever lived in a homeless shelter?
9. Is your child a foster child or adopted child?
10. How would you describe your child's race or ethnicity? (Multiple-choice list appears on original questionnaire.)
11. Finally, for both mother and father, what is the highest level of school completed? (List appears on original questionnaire.)

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