Transmission of Mycobacterium tuberculosis in schools has been well-documented,1–8 but less information is available concerning transmission of M tuberculosis in buses.5,9–11 In two accounts,5,9 60% and 80% of students exposed to source cases on school buses had positive tuberculin skin tests. The number of students exposed on school buses in these two reports is not large (a total of 86), and the source cases in these instances were very infectious and likely responsible for hundreds of infections in classmates and other students. Public health interventions required to prevent or respond to more usual exposures among large numbers of students have not been outlined in the literature. County, state, and national public health officials embarked on an investigation of five tuberculosis cases among bus drivers and a large number of exposed students to determine the extent of M tuberculosis transmission and the appropriate public health interventions. This report summarizes the findings of an epidemiologic investigation carried out to determine the extent of transmission of M tuberculosis among student contacts of each driver, to identify cases of tuberculosis epidemiologically linked to the bus drivers, and to formulate strategies toward preventing the spread of M tuberculosis in these circumstances.

Between November 1994 and April 1995, five school bus drivers employed by three bus companies based in the state of New York were diagnosed with tuberculosis. Driver 1 was employed by bus company A and transported students in two counties in New York. Drivers 2, 3, and 4 were employed by bus company B and transported students in one of the two counties. Driver 5 was employed by bus company C and transported students in this same county. More than 3000 students in 49 schools of 11 school districts in the two counties involved were exposed to these five bus drivers.

**METHODS**

**Bus Drivers’ Case Histories and Records Review**

Medical records were reviewed for the five bus drivers with tuberculosis. Results of the close contact investigations conducted by the health departments were also reviewed.

**Epidemiologic Investigation**

Tuberculin skin test (TST) screening was offered to all students who rode on a bus with a source case. The respective schools’ bus route rosters were used to identify students who may have been exposed to any one of the five bus drivers. Because some students who were not on a roster may have ridden in a bus driven by one of the five drivers, letters from respective school principals were sent to all parents requesting skin testing of the student if she/he had been exposed to one of the drivers in question. Tuberculin skin tests were administered by the Mantoux method using 5 tuberculin units of purified protein derivative and were read at 48 to 72 hours. Individuals who were known to have prior positive tests were exempted from TST screening, but did undergo an evaluation of symptoms and, if necessary, further clinical and...
radiologic evaluation. Testing of students was conducted at the respective schools by the county health departments between January and June 1995. Students with recent exposure to any of the five drivers and negative TSTs were retested 3 months after the time of last contact. Students with exposure that took place at least 3 months before the screening received only one TST. All exposed students with a TST response of \( \geq 5 \) mm induration received further clinical evaluation including a chest radiograph. Information with respect to birthplace and other demographic characteristics of students were obtained from school records and during skin testing.

Definitions

For greater specificity of epidemiologic analysis, a positive TST result was defined as \( \geq 10 \) mm induration. A student was considered exposed to \( M \) tuberculosis if she/he ever rode in a bus with a driver with tuberculosis from the beginning of the school year to the last day of work by the driver. A secondary case of tuberculosis was defined as an individual with contact to a bus driver with no other exposure to tuberculosis identified, a positive skin test, and signs and symptoms of tuberculosis. Individuals who had an increase in reaction size of \( \geq 10 \) mm and a negative TST administered within the past 2 years were classified as TST converters.\(^{12}\)

Bacteriology and Laboratory Analysis

Sputum specimens were obtained from all cases for acid-fast bacilli (AFB) smears and cultures and, if culture-positive, drug-susceptibility testing. DNA fingerprinting of \( M \) tuberculosis isolates was performed at the New York State Department of Health Laboratory using a DNA probe for insertion sequence IS6110 as described previously.\(^{13}\)

RESULTS

Case Histories and Close Contact Investigations

All bus drivers except driver 4 presented with signs and symptoms of tuberculosis before diagnosis of their condition (Table 1). Sputum specimens were AFB smear-positive for drivers 1, 3, and 5, and negative for drivers 2 and 4. Driver 1 was exposed to a relative with tuberculosis in 1979. Although his TST results from that time are unknown, he did receive isoniazid (INH) prophylaxis for 3 months. Driver 2 was anergic and died shortly after her tuberculosis diagnosis. Drug-susceptibility testing indicated that drivers 3 and 4 were infected with INH-resistant strains. Driver 4 was evaluated for tuberculosis after he was found to have a positive TST during screening of contacts around driver 3. Driver 4 had a documented negative TST in May 1992.

A high proportion of family members and friends of drivers 1, 3, and 5 were TST-positive (25% to 100%) (Table 1). Very few close contacts were identified for drivers 2 and 4. Although drivers 2, 3, and 4 worked for the same bus company, driver 2 did not come in contact with drivers 3 or 4. However, driver 4 was a friend of driver 3, the likely source of his infection. Drivers 3 and 4 often sat together in the closed bus of driver 3 while waiting for students to be dismissed from school and enter their buses. \( M \) tuberculosis isolates of drivers 3 and 4 were identical by DNA fingerprinting.

Secondary Cases Among Students Exposed to the Bus Drivers

One 14-year-old student was diagnosed with tuberculosis. This student had a positive TST (18 mm) in March 1995, during screening of students exposed to driver 3. A few weeks before testing, the patient had upper respiratory symptoms and was started on clarithromycin but showed no clinical improvement. A chest radiograph revealed infiltrates in the left upper and right lower lobes and enlarged left hilar lymph nodes. Sputum specimens were AFB smear- and culture-negative. The patient had clinical and radiographic improvement with antituberculosis therapy. Other than contact with driver 3, the patient had no identified risk factor for tuberculosis. None of the chest radiographs for other students were abnormal and no other secondary cases of active tuberculosis disease were identified with respect to drivers 1, 2, 4, or 5.

TST Screening of Students

Although more than 3300 students were exposed to the five bus drivers, no student was potentially exposed to more than one driver. Drivers 1 and 5 were substitute drivers and operated different bus routes each day. Therefore, students were potentially

<table>
<thead>
<tr>
<th>Driver</th>
<th>Age, Sex, Place of Birth</th>
<th>Date of Diagnosis</th>
<th>Signs and Symptoms</th>
<th>Sputum AFB Smear (Burden)</th>
<th>Sputum Culture</th>
<th>Chest Radiograph</th>
<th>Close Contacts: No. TST-positive/No. Tested*</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>51 y; male, US</td>
<td>Nov. 1994</td>
<td>&gt;6 weeks’ cough,</td>
<td>Positive (many)</td>
<td>Positive</td>
<td>Infiltrates, cavity</td>
<td>5/5</td>
</tr>
<tr>
<td>2</td>
<td>46 y; female, US</td>
<td>Jan. 1995</td>
<td>3 weeks’ cough,</td>
<td>Negative</td>
<td>Positive</td>
<td>Infiltrates</td>
<td>0/2</td>
</tr>
<tr>
<td>3</td>
<td>44 y; male, Haiti</td>
<td>Feb. 1995</td>
<td>5 days’ cough,</td>
<td>Positive (no</td>
<td>Positive</td>
<td>Infiltrates, consolidation</td>
<td>11/17</td>
</tr>
<tr>
<td>4</td>
<td>30 y; male, Trinidad</td>
<td>Mar. 1995</td>
<td>pleuritic chest</td>
<td>qualitative result)</td>
<td>Positive (INH resistant)</td>
<td>Infiltrates</td>
<td>1/1</td>
</tr>
<tr>
<td>5</td>
<td>31 y; male, Haiti</td>
<td>Mar. 1995</td>
<td>1 week fever,</td>
<td>Positive (no</td>
<td>Positive</td>
<td>Infiltrates, cavity</td>
<td>4/12</td>
</tr>
</tbody>
</table>

* Number of close contacts TST-positive/number close contacts tested.
exposed to these two drivers only infrequently (once or twice). Drivers 2, 3, and 4 operated regular bus routes.

A total 3278 students were screened. Five hundred ninety-one students (18.0%) exposed to drivers 1, 3, or 4 were skin tested twice because the initial test was performed before the elapse of 3 months from the time of last contact with the respective driver. Of the total, 91 (2.8%) students were born outside of the United States (US) and birthplace was unknown for 714 (21.8%) students. Among foreign-born students and students whose birthplace was unknown, the proportion who were TST-positive were 8.8% and 1.7%, respectively.

To avoid confounding of the epidemiologic analysis by infections acquired outside of the US, Bacille bâlié de Calmette-Guérin vaccination, and boosting, we analyzed TST results for US-born students separately. The median age of US-born students varied by driver, ranging from 5.3 years for those exposed to driver 2 to 15.6 years for those exposed to driver 5 (Table 2). The proportion of US-born students who were TST-positive was relatively low for drivers 1, 2, 4, and 5 (range, 0.3% to 1.1%), but was significantly higher (9.9%) for driver 3. Driver 3 transported students from four different schools, and for one school, 8 (44%) of 18 US-born students exposed to this driver were TST-positive. Compared with students with the lowest TST positivity rate, ie, those exposed to driver 2, only students who were exposed to driver 3 were significantly more likely to be TST-positive (relative risk = 39.3; 95% confidence interval, 8.8, 174.8) (Table 3).

Two US-born students, 1 exposed to driver 3 and 1 to driver 4, had TST conversions (Table 2). The student exposed to driver 3 was a 6-year-old child who had a negative TST (0 mm) in March 1995 and a positive one (10 mm) in May 1995. A 13-year-old student who was exposed to driver 4 had a negative TST (0 mm) in April 1995, followed by a positive one (11 mm) in June 1995. Neither of these students had signs and symptoms of active tuberculosis disease.

DISCUSSION

Previous studies that have investigated exposure to a source case with tuberculosis on a bus document that substantial transmission of M tuberculosis can result from exposure in such a closed setting. In these reports, students exposed on a bus to a tuberculosis case were 2 to 20 times more likely to have a positive TST compared with students who were not exposed to M tuberculosis on a bus.

In the current investigation, there is no definite evidence of transmission of M tuberculosis to students from drivers 1, 2, or 5. Among US-born students potentially exposed to these three drivers, the prevalence of positive TST reactions was low. There were no secondary cases of tuberculosis or TST conversions associated with any of these three drivers. The sputum of Driver 2 was AFB smear-negative and therefore unlikely to transmit M tuberculosis. Although the sputum of drivers 1 and 5 was AFB smear-positive and a substantial proportion of their family members and close contacts were TST-positive (100% and 25%, respectively), indicating that both drivers were infectious, the transmission of M tuberculosis to students probably did not occur because both were substitute drivers and the frequency of their contacts with any 1 student was low.

It is possible that 1 of the 2 students who had a TST conversion may have been infected by driver 4. However, this result is discrepant with the findings that none of the other 87 students exposed to this driver were TST-positive and because sputum specimens from driver 4 were AFB-negative. Other possible explanations for this student’s TST conversion include an unidentified exposure to another patient with tuberculosis, a misreading of the TST, or a false-positive TST reaction. Such false-positive reactions have been described when the TST is used in low disease prevalence populations.

The highest risk for M tuberculosis infection was found for students exposed to driver 3. This driver had AFB smear-positive sputum and 65% of his close contacts were TST-positive. Compared with US-born students with the lowest TST positivity rate (those potentially exposed to driver 2), US-born students exposed to this driver were significantly more likely to be TST-positive, with 1 student having a documented conversion and another having active tuberculosis disease. A greater percentage of students exposed to driver 3 were TST-positive compared with students exposed to the other drivers. With respect to the school where 44% of students exposed to driver 3 were TST-positive, it was learned that in this particular case he would arrive at the school with the children 15 to 20 minutes early. School policy did not allow the children to disembark before the scheduled

<table>
<thead>
<tr>
<th>Source</th>
<th>Relative Risk (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver 2</td>
<td>1.0 (reference)</td>
</tr>
<tr>
<td>Driver 1</td>
<td>2.8 (0.6, 12.6)</td>
</tr>
<tr>
<td>Driver 3</td>
<td>39.3 (8.8, 174.8)</td>
</tr>
<tr>
<td>Driver 4</td>
<td>4.1 (0.4, 44.8)</td>
</tr>
<tr>
<td>Driver 5</td>
<td>2.6 (0.2, 28.2)</td>
</tr>
</tbody>
</table>

TABLE 2. Results of Tuberculin Skin Test (TST) Screening of US-Born Students, by Bus Driver

<table>
<thead>
<tr>
<th>No. of students screened</th>
<th>Driver 1</th>
<th>Driver 2</th>
<th>Driver 3</th>
<th>Driver 4</th>
<th>Driver 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median age (range)</td>
<td>11.2 yrs (3.8–18.4)</td>
<td>5.3 yrs (2.1–17.9)</td>
<td>12.7 yrs (5.5–15.4)</td>
<td>9.1 yrs (5.2–15.2)</td>
<td>2.6 (2.1–18.7)</td>
</tr>
<tr>
<td>No. TST-positive (%)</td>
<td>11 (0.8)</td>
<td>2 (0.3)</td>
<td>10 (9.9)</td>
<td>1 (1.1)</td>
<td>1 (0.7)</td>
</tr>
<tr>
<td>No. TST converter</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>
time. Therefore, the children waited on the bus with the driver and, because it was winter, the windows were closed. This may have contributed to prolonged exposure of the students to infectious airborne droplet nuclei in a poorly ventilated environment.

The findings of this investigation provide no convincing evidence of transmission of *M tuberculosis* to students exposed to four of the five bus drivers with active tuberculosis. However, there is strong evidence that driver 3 transmitted *M tuberculosis* to student contacts in his bus route and to driver 4.

Several factors that may have influenced transmission on the buses could not be analyzed in this investigation. Most importantly, the extent of ventilation on all buses is not known. All of these drivers were diagnosed with tuberculosis in the winter months and it is likely that windows on the buses were closed. The duration of routes within these school districts were roughly equivalent, ranging from 25 to 35 minutes, and we had no information concerning the seating of children on the buses. Therefore, any difference among students exposed to different drivers according to these factors could not be ascertained.

An issue brought forth as a result of this investigation is whether or not the health of school children can be better protected by requiring annual TST screening of all school bus drivers. There were strong community and media requests that public health officials require such testing. Our findings suggest that transmission of *M tuberculosis* to students would not have been prevented by annual TST screening. Driver 1 was previously exposed to a family member with tuberculosis and had been prescribed INH prophylaxis. Driver 2 would have tested negative as she was anergic. Driver 3 had immigrated from a country with a high incidence of tuberculosis and was likely previously infected, because he had disease consistent with tuberculosis reactivation (i.e., right upper lobe consolidation). Even if he had been found to be TST-positive via annual screening, he would not have been a candidate for INH prophylaxis because he was older than 35. Driver 4 seems to have been recently infected (after the beginning of the school year) by driver 3. Therefore, screening at the beginning of the school year would not have been effective in preventing development of tuberculosis disease in this patient. Bus company C, the employer of driver 5, required TST screening of its drivers once every 2 years. Although driver 5 was a new employee, he was not screened by the company before his diagnosis because he had a negative TST in December 1993. Whether driver 5 would have had been found to be TST-positive if screened at the beginning of the 1994 to 1995 school year is unknown.

Currently, the only occupational groups identified as being at high-risk for *M tuberculosis* infection are health care workers, migrant workers, and employees of high-risk congregate settings such as correctional facilities, mental institutions, and shelters for the homeless. A recent study investigating the association between occupation and tuberculosis found the rates of *M tuberculosis* infection among unemployed individuals, certain categories of health care workers, and those with jobs with extensive animal contact to be higher than expected when age, sex, race, and country of birth were accounted for. The rate among bus drivers was not higher than expected. However, the Centers for Disease Control and Prevention recommends that local health departments identify groups at high-risk for *M tuberculosis* transmission and infection using surveillance data from their populations. A substantial proportion of employees of the three bus companies involved in this investigation were foreign-born (between 16% and 30% among those for whom the place of birth was known; data not shown). Immigrants from countries where tuberculosis is common are at a higher risk of having tuberculosis infection. These findings support the development of prevention strategies, such as TST screening of certain occupational groups, based on the epidemiologic factors within the respective community.

Effective prevention strategies must also ensure adequate and prompt access to health care for persons at risk for tuberculosis so that tuberculosis disease can be quickly diagnosed and treated before there is exposure of large numbers of other individuals. Four of the five drivers involved in this investigation continued to work for several days or weeks after becoming symptomatic. Communities and employers need to be informed of the need for proper medical attention for individuals with the signs and symptoms of tuberculosis, and of the need to implement measures for reducing the risk of transmission of tuberculosis. Employers also should implement mechanisms that encourage sick employees to promptly seek health care and evaluation for tuberculosis without fearing loss of salary.

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**REFERENCES**

10. The Lodi Tuberculosis Working Group. A school- and community-


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