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Descriptive Profile of Tuberculin Skin Testing Programs and Laboratory-Acquired Tuberculosis Infections in Public Health Laboratories

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The increase in numbers of cases of tuberculosis in the United States has placed greater demands on mycobacteriology laboratory workers to produce rapid and accurate results. The greater number of specimens generated by the increased emphasis on detecting the disease has placed these workers at greater risk of laboratory-acquired infection. We surveyed 56 state and territorial public health laboratories to determine the status of existing tuberculin skin testing (TST) programs and to evaluate the frequency of probable laboratory-acquired tuberculosis for each responding mycobacteriology laboratory. Probable laboratory-acquired infections were determined by each laboratory's evaluation of occupational positions, duties, and employee histories and review of medical records. Two-step TST for new employees was routinely practiced in only 33% of responding laboratories, and mycobacteriology laboratorians were found to be most frequently screened when they were compared to employees of other departments. Of 49 (88%) responding laboratories, 13 reported that 21 employees were TST converters from 1990 to 1994. Seven of these 21 employees were documented to have laboratory-acquired infections based on evaluations by their respective laboratories. Based on Centers for Disease Control and Prevention guidelines, converters are categorized on the basis of both a change in the size of the zone of induration and the age of the person being tested. By the definitions in the guidelines, 14 mycobacteriologists were identified as recent converters, 7 of whom were ≥35 years of age and 4 of whom were exposed in the laboratory within a 2-year period. Inadequate isolation procedures, the high volume of specimen handling, and faulty ventilation accounted for these laboratory-associated infections. These results suggest that more frequent periodic evaluations based on documented TST conversions for workers in mycobacterial laboratories should be performed, since this population is at increased risk of becoming infected with *Mycobacterium tuberculosis*. Although general assessments are necessary to accurately and effectively evaluate the risk of tuberculosis transmission, they are especially important for those working in high-risk areas within a public health laboratory.

The resurgence of tuberculosis in the United States, accelerated by the human immunodeficiency virus (HIV) epidemic, an aging population, and increasing immigration, has greatly increased the demand on clinical and public health laboratories to produce rapid and accurate evaluations of specimens suspected to contain *Mycobacterium tuberculosis* (18, 33). In addition, the rapid expansion of tuberculosis surveillance programs in many state and local health departments has contributed to the need for enhanced mycobacteriologic capabilities for mycobacteriology laboratories. Decreasing laboratory resources, rapidly changing laboratory practices and techniques, such as the use of automated culture methods (e.g., the BACTEC TB Diagnostic System; Becton Dickinson, Sparks, Md.) and identification procedures (e.g., PCR), and insufficient attention to safety measures add to the risk that personnel will be infected through occupational exposure.

Few studies have examined the risk of mycobacterial infection among mycobacteriologists in public health laboratories. In a 1986 survey conducted by Vesley and Hartmann, the annual incidence rate of laboratory-acquired infections among full-time employees was estimated to be between 1.4 and 2.7 infections per 1,000 employees (35). However, specific agents responsible for infections were not identified.

In the United Kingdom, updated guidelines on the prevention and control of tuberculosis include laboratory workers handling specimens from infected patients in a definition of staff at risk of acquiring tuberculosis (20). In the United States, however, risks to mycobacteriology laboratory technicians were not specifically addressed in the Centers for Disease Control and Prevention (CDC) *Guidelines for Preventing the Transmission of Mycobacterium tuberculosis in Health-Care Facilities, 1994*] [hereinafter CDC *Guidelines*] when recommendations for periodic tuberculin skin testing (TST) of health care workers were made.

The most important hazard is exposure to laboratory-generated aerosols during processing of sputum and other specimens from tuberculous patients (13, 14, 27). Tubercle bacilli have been reported to survive in heat-fixed smears and to contaminate specimen container surfaces, thus providing potential sources of infection to mycobacteriologists and others (1, 2). In studies conducted in the United Kingdom, laboratory workers found to be at increased risk of infection included microbiology technicians and pathology workers involved in autopsies and the preparation of histopathologic sections (7, 15–17, 29).

In the United States to date, there have been a limited

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number of investigations of laboratory TST programs in state and territorial public health laboratories. To assess state TST programs in relation to their volume of specimen handling and number of probable laboratory-acquired TST conversions, we conducted a survey of state and territorial mycobacteriology laboratories.

MATERIALS AND METHODS

In October 1995, the Association of State and Territorial Public Health Laboratory Directors (ASTPHLD) mailed questionnaires to 56 public health laboratories representing the 50 states, the District of Columbia, Puerto Rico, the Virgin Islands, Guam, American Samoa, and the Northern Mariana Islands. Information on tuberculosis screening efforts provided for laboratory employees was requested. Specifically, the questionnaires asked for information on the frequency of TST administration, the method used for TST, the interpretation of TST results, and the mechanism used for recording results. The laboratories were asked to identify all laboratory departments in which tuberculin skin tests were administered to employees and whether a two-step TST procedure was used for new employees.

Laboratories were also asked to provide information on the total number of specimens and referred isolates processed for mycobacterial culture, the number of *M. tuberculosis* isolates identified, the number of *M. tuberculosis* isolates tested for drug susceptibility, and the number of *M. tuberculosis* isolates resistant to at least isoniazid (INH) and rifampin for each year from 1990 through 1994.

Interpretation of TST results and follow-up. According to the CDC *Guidelines* (9), interpretations of TST results for health care workers are determined by a change in the size of the zone of induration following the intradermal injection of purified protein derivative-tuberculin, the risk group in which the person is classified, and the age of the person. Persons <35 years of age are classified as recent converters if they experience a ≥10-mm increase in the size of the zone of induration within a 2-year period. Persons ≥35 years of age are classified as recent converters if they experience a ≥15-mm increase in the size of the indurated zone within a 2-year period. Persons positive for HIV or who have risk factors for HIV infection but an unknown HIV status are classified as recent converters if they experience an increase of ≥5 mm in the size of the zone of induration.

For those laboratories reporting TST conversions, specific information gathered included the change in the size of the induration, job category, age, and progression to active tuberculosis of the employee and whether it was considered probable that the conversions resulted from laboratory exposure. Three employee categories were specified: laboratory worker (bench), clerical, and support staff. A laboratory bench worker was defined as any laboratory technologist or technician, student, or laboratory worker who spent 75% or more of their time in direct contact with specimens for mycobacteriology. A clerical worker was defined as any administrative and/or office staff member located within and serving the laboratory area; specific tasks included specimen delivery or transport and administrative details that required entrance to the mycobacteriology area. Support staff was defined as any housekeeping employee with main duties located within the laboratory area. Responsibilities of the support staff also included the disposal and autoclaving of potentially infectious materials.

In our study, active tuberculosis was defined as the following: (i) a smear or culture positive for tubercle bacilli or (ii) a positive reaction to TST, with clinical or radiographic evidence of disease and treatment with two or more antituberculosis medications (10).

Upon completion, the questionnaires were returned to ASTPHLD and the data were coded, entered, and analyzed with Epi Info software (12).

RESULTS

Surveys were completed by microbiology department supervisors, directors, or managers; 47 states and two territories responded to the questionnaire (88% response rate). All of the responding laboratories reported having employee TST programs that used the Mantoux procedure. Two-step TST for new employees was routinely practiced in 15 (32.6%) of the responding laboratories. Only 27 public health laboratories surveyed stated that they had received a copy of the 1994 CDC *Guidelines* (9).

The reported frequency of routine administration of TST to laboratory employees varied, with most facilities testing on an annual basis (Table 1). One laboratory tested all laboratory employees at 3-month intervals. Results were recorded in personnel files, log books, or computer files or with a combination of these record-keeping methods. Readers of TST results were divided into two categories, registered or licensed practicing nurses and others (including physicians, physicians' assistants, and laboratory supervisors). Thirty-six (73.5%) laboratories reported using nurses as readers, while nine (18.4%) laboratories used readers other than nurses.

TABLE 1. Frequencies of administration, methods of documentation, and types of readers of laboratory results from the TST program by the Mantoux method

Variable	No. (%) of responding laboratories
Frequency of routine TST[a]	
Biannual[b]	9 (18.8)
Annual[c]	23 (47.9)
Varies by job category[d]	15 (31.3)
Method of documentation[e]	
Personnel file	16 (34.8)
Log book	8 (17.4)
Computer file	1 (2.2)
Combination of filing systems	21 (45.7)
Readers of laboratory TST results[f]	
Nurses	36 (73.5)
Others[g]	9 (18.4)

[a] Data were not available from one laboratory.
[b] Biannual testing was indicated for all departments.
[c] Annual testing was indicated for all departments.
[d] The testing schedule was dependent on the level of risk defined for a specific department.
[e] Data were not available from three laboratories.
[f] Data were not available from four laboratories.
[g] The "others" category included physicians, physician's assistants, and lab supervisors.

Table 2 indicates the public health laboratory departments in which employee skin tests were administered. Ninety-two percent of the laboratories surveyed reported administration of tuberculin skin tests to employees working in the mycobacteriology department, and 33 (68.8%) reported administration of tuberculin skin tests to all microbiology personnel. Personnel in other departments were not tested in many of the public health laboratories. Departments reporting infrequent TST of personnel (<15%) included hematology, pathology, cytology, virology, medium preparation and sterilization, and phlebot-

TABLE 2. Laboratory departments in which TST is conducted

Laboratory or department[a]	No. (%) of responding laboratories
Mycobacteriology	44 (91.7)
Microbiology	33 (68.8)
Parasitology	27 (56.3)
Mycology	27 (56.3)
Serology	20 (41.7)
Chemistry	16 (33.3)
Immunology	15 (31.3)
Specimen receiving	12 (25.0)
Office or support staff	11 (22.9)
Hematology	7 (14.6)
Pathology	3 (6.3)
Cytology	2 (4.2)
Virology	2 (4.2)
Other[b]	15 (31.3)

[a] Laboratories were allowed to indicate more than one department.
[b] Other categories included environmental testing, epidemiology, sterilization, and medium preparation.

omy. It is important to note that not all state public health laboratories have all these departments.

State health laboratories provided information about TST conversions in their mycobacteriology laboratory from 1 January 1990 to 31 December 1994 as indicated by a change in the size of the induration since the last TST. Among the 49 laboratories that responded to the questionnaire, 13 (26.5%) (12 state laboratories and 1 territorial laboratory) reported TST conversions among their mycobacteriology laboratory personnel. From these 13 laboratories, a total of 21 employees were positive for TST conversion. Follow-up calls were made to the 13 laboratories to determine if converters were evaluated for suspected laboratory-acquired exposures. Seven of the 21 infections were determined to be laboratory acquired based on each laboratory's evaluation of an employee's occupational position, duties, and history and on a review of medical records. In six of the 21 cases, the source of infection could not be determined. One case was attributed to an accidental needle-stick injury. None of the TST converters identified developed active tuberculosis. Six of the seven were mycobacteriology laboratory bench workers, and one was an equipment technician. The average age of all 21 TST converters was 40 years (range, 25 to 59). The average age of those with confirmed laboratory-acquired infections was 38 years (range, 25 to 56).

Of the seven converters identified as having acquired their infections in the laboratory, four were infected while performing tasks associated with isolation procedures. These tasks included inoculum preparation, medium inoculation, and equipment maintenance. Other factors identified as contributing to acquiring laboratory-associated infection included handling a high volume of specimens and working with inadequate ventilation. In one laboratory, it was determined that two mycobacteriologists were infected with *M. tuberculosis* because of a faulty exhaust system that compromised the negative pressure required to prevent the spread of contaminated air to uncontaminated areas. Another mycobacteriologist became infected while performing the PCR procedure, although the specific task associated with the procedure was not defined.

To assess recent conversions according to CDC standards, we further examined the 21 infected employees. Of the 21 employees identified as converters by their respective laboratory's criteria, 14 met the CDC criteria for being recent TST converters. Seven (50%) TST converters were ≥35 years of age, and it was considered probable that three cases of infection resulted from laboratory exposure. One of the workers <35 years old was identified as having been exposed in the laboratory.

The numbers of specimens and referred isolates processed for mycobacterial culture, strain identification, and drug susceptibility are shown in Table 3; 25 (52%) mycobacteriology laboratories processed 5,000 or fewer specimens per year, and 23 (48%) laboratories processed more than 5,000 specimens per year. Thirty-three (69%) laboratories identified >100 isolates per year as *M. tuberculosis*, 34 (72%) laboratories performed drug susceptibility testing on >50 isolates of *M. tuberculosis* per year, and only nine (20%) laboratories identified >10 isolates as being resistant to at least INH and rifampin (Table 3).

From 1990 to 1994 in laboratories across the United States, yearly increases in the number of specimens processed were statistically significant ($P < 0.05$) (Fig. 1). During these 5 years, state public health laboratories experienced approximately a 16% increase in the mean number of isolates submitted for mycobacterial culture and an 18% increase in the mean number of isolates identified as *M. tuberculosis*. The number of isolates identified as *M. tuberculosis* submitted for drug susceptibility testing has also increased by an estimated 21% since 1990 (Fig. 2). These numbers are consistent with recent published reports (5, 34).

TABLE 3. Specimens and referred isolates processed yearly for mycobacterial culture, strain identification, and drug susceptibility between 1990 and 1994 in state and territorial public health laboratories

Yearly volume[a]	No. (%)[b] of responding laboratories
No. of specimens and referred specimens processed for mycobacterial culture[c]	
≤1,000	4 (8)
1,001–5,000	21 (44)
5,001–10,000	10 (21)
>10,000	13 (27)
No. of specimens positive for *M. tuberculosis*[c]	
≤100	15 (31)
101–500	16 (33)
501–1,000	12 (25)
>1,000	5 (10)
No. of *M. tuberculosis* isolates tested for drug susceptibility[d]	
≤10	4 (9)
11–50	9 (19)
51–100	7 (15)
>100	27 (57)
No. of *M. tuberculosis* isolates resistant to at least INH and rifampin[e]	
≤1	16 (35)
2–5	17 (37)
6–10	4 (9)
>10	9 (20)

[a] Yearly volume indicates the mean volume of specimens received between the years 1990 and 1994.
[b] Percentages may not total 100 because of rounding.
[c] One survey was excluded because specimens were sent to another laboratory for referral and isolation.
[d] Data were not available from two laboratories.
[e] Data were not available from three laboratories.

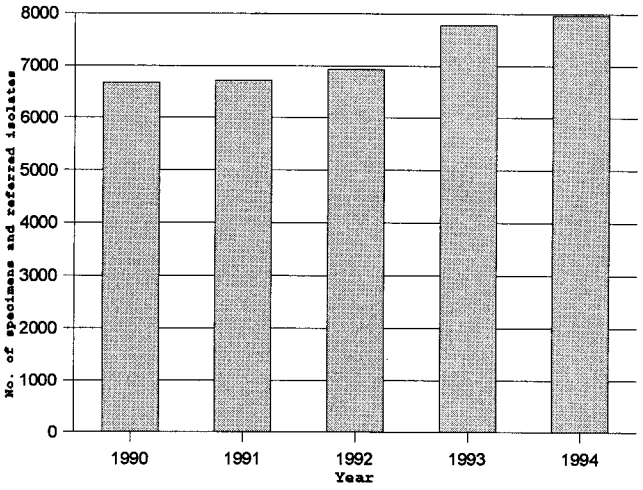

FIG. 1. Mean numbers of specimens and referred isolates submitted for mycobacterial culture.

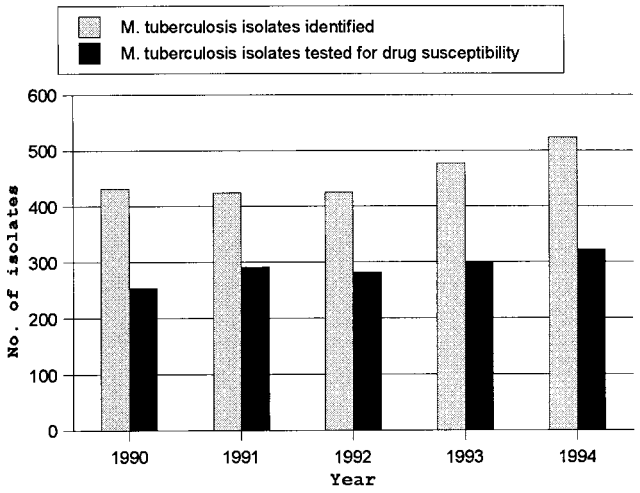

FIG. 2. Mean numbers of isolates identified as *M. tuberculosis* and mean numbers of *M. tuberculosis* isolates tested for drug susceptibility.

DISCUSSION

Accounts of tuberculosis acquired in laboratories were scant prior to the review by Sulkin and Pike in 1951 (32). Subsequently, surveys of laboratory-acquired tuberculosis infections within the United States and in other countries have been conducted to document the incidence and possible sources of the infection (27). Several relevant studies report laboratory-acquired tuberculosis infections among laboratory personnel (7, 15, 17, 19, 23–25, 29–31, 35). TST conversion rates among hospital employees have been reported to be as high as 1.7 to 2% per year (8, 28). In a review of annual health care worker screenings, TST conversion rates were found to be from <1 to 5% in the years from 1960 to 1990 (6). Although these surveys provide some indication of the nature of laboratory-acquired tuberculosis exposure, to date few have quantified the national incidence of these infections (14).

We have presented an assessment of laboratory workers who were at increased risk for occupational exposure to *M. tuberculosis*. The discovery of TST conversions in the mycobacteriology departments of public health laboratories emphasizes the risk of working directly with mycobacterial specimens. The results from 49 public health laboratories provide a preliminary estimate of the occurrence of TST conversions among this group. Analysis of 21 employee conversions indicated that many laboratories were not familiar with the CDC criteria for classification of recent TST conversions. Because of the limited sample size, we could not define the level of risk associated with specific jobs, job tasks, duration of exposure, or interactions among these factors. Also, since our survey was limited to state and territorial public health laboratories, it is difficult to relate these findings to circumstances in hospital or private laboratories. Nevertheless, our survey provides a baseline estimate of the incidence of TST conversion and of laboratory-acquired infections in U.S. public health laboratories.

The CDC have recommended the use of periodic (3, 6, or 12 months) tuberculin screening to define levels of risk for health care workers and institutions (9). All public health laboratories responding to our survey had established TST programs that used the Mantoux procedure, but less than 35% reported using the recommended two-step TST for new employees. This practice would be helpful in establishing a more accurate baseline rate of prevalence of existing infection so that a subsequent test giving a positive response would indicate a true conversion (22).

Calculations of the rate of mycobacteriology laboratory-associated infections based on the 13 laboratories reporting positive conversions were attempted. The total number of mycobacterial laboratory personnel was obtained for each year and personnel rotation schedules were taken into account. Estimated rates of conversion ranged from 6.7 to 50%, and mycobacteriology laboratories with higher rates of laboratory-associated infections also had lower numbers of workers. This calculation overestimates rates of conversion, since we were unable to obtain the numbers of mycobacteriologists employed in those laboratories with no documented TST conversions.

According to the CDC *Guidelines* (9), laboratory workers are to be considered at high risk for tuberculosis, but criteria for determining probable laboratory-acquired infections are not specifically addressed. The Occupational Safety and Health Administration's national enforcement guidelines on tuberculosis require employees that have or develop a positive purified protein derivative skin test to complete an Occupational Safety and Health Administration report form for occupational injuries and illness (26). Currently, there is no national occupational surveillance system for tracking laboratorians who become infected with *M. tuberculosis* on the job. Moreover, inclusion criteria for technicians remain vague because no clear definitions exist regarding department, tasks, or type of institution for a consistent application of the occupational designation (11, 21).

In this survey, infections due to occupational accidents, needle injuries, improper laboratory techniques, or equipment failures were reported to have occurred, but no standardized algorithm was used to determine the incidence of laboratory-acquired infections among all public health laboratories. Although the CDC *Guidelines* (9) provide recommendations applicable to workers in health care settings, 40% of state public health laboratories responded that they had not received a copy. Respondents included top and middle managers and one nurse from these laboratories. This finding suggests that the information relevant to preventing the transmission of *M. tuberculosis* has not always been adequately disseminated.

Recognition is key for the control of laboratory-acquired tuberculosis infections, and priority should be given to assessing each laboratory's level of risk on a yearly basis so that a tuberculosis infection control plan can be developed and evaluated regularly. Classification of risk for a specific occupation in which persons work with and are exposed to clinical specimens containing viable *M. tuberculosis* organisms should be based on the prevalence of tuberculosis in the community and the particular characteristics of the laboratory environment (4, 9). In our investigation, protocols were not always in place for identifying and managing workers who may have laboratory-acquired infections. Assessments of occupational tuberculosis transmission should be based on epidemiologic evaluations, and results should be documented on standardized forms or in employee records so that further study or appropriate follow-up of employee conditions may be performed. TST and risk assessments are recommended at 3-, 6-, or 12-month intervals to evaluate appropriate interventions.

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