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Historical Risks of Tuberculin Skin Test Conversion Among Non-Physician Staff at a Large Urban Hospital

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Background *Nosocomial transmission of Mycobacterium tuberculosis among workers at a 1000-bed inner-city hospital led to an extensive evaluation of this risk among workers with potential exposure to TB patients or laboratory specimens.*
Methods *Retrospective cohort study to determine the incidence and risk of tuberculin skin test (TST) conversions among workers employed 1/1/90 to 9/30/92.*
Results *Personal, community, and occupational risk factors were evaluated in 2,362 workers with potential M. tuberculosis exposure and 886 workers with no known exposure. The 33-month cumulative rate of TST conversion was 5.8% for potentially exposed workers and 2.0% for controls (RR 3.6; 95% CI; 2.2–5.8). Among workers with potential M. tuberculosis exposure, statistically significantly elevated risks were found for nurses, laboratory technicians, pharmacy workers, phlebotomists, housekeepers, clerks, emergency room workers, and emergency responders.*
Conclusions *Workers with patient contact and those employed in certain occupational groups were at increased risk for occupational M. tuberculosis infection.* Am. J. Ind. Med. 42:228–235, 2002. *Published 2002 Wiley-Liss, Inc.*†

KEY WORDS: tuberculosis; hospital workers; occupational exposure; nosocomial transmission; tuberculin skin test

INTRODUCTION

Although the well-documented resurgence of tuberculosis (TB) in the United States in the late 1980s and early 1990s [Barnes and Barrows, 1993; CDC, 1998a, 1999, 2000a] has declined from a peak in 1992 [CDC, 1998a, 1999, 2000a], it has drawn heightened attention to the risks to health care workers caring for patients with infectious *Mycobacterium tuberculosis*. Concern for this hazard is underscored by the emergence of multidrug-resistant (MDR) strains of *M. tuberculosis*, which have been reported in 45 states, since 1993 [CDC, 1999], and have been responsible for at least 12 hospital outbreaks, with five deaths and 18–35% of exposed workers having documented tuberculin skin test (TST) conversions [Menzies et al., 1995]. In 1994, the Centers for Disease Control and Prevention (CDC) recommended that hospitals throughout the country monitor rates of TB infection and disease among their employees and implement control measures to protect those at increased risk [CDC, 1994]. Currently, debate continues over the need for new regulations, originally proposed by the Occupational Safety and Health Administration (OSHA) in 1997 [OSHA, 1997] to protect an estimated 5.3 million workers who work in more than 100,000 hospitals and other settings with an increased risk of *M. tuberculosis* transmission.

While it is now recognized that some groups of hospital workers (i.e., medical students, physicians, nurses) are at

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increased risk for occupationally acquired TB [Sepkowitz, 1994], there have been relatively few published studies that have evaluated the risk among a wide range of occupations [Menzies et al., 1995]. Typically, studies have focused on the risks of *M. tuberculosis* transmission among physicians and nurses during a TB outbreak or in the presence of a particularly infectious patient [Ehrenkranz and Kicklighter, 1972; Catanzaro, 1982; Beck-Sagué et al., 1992; Zaza et al., 1995].

BACKGROUND

The study hospital is a public, university affiliated, 1000-bed inner-city hospital in the southern United States. The hospital employs about 5000 workers in professional, technical, and support positions. Nearly 50,000 patients are admitted and over 850,000 clinic visits are made to the hospital each year. Over the few years prior to and during the study period, the hospital annually cared for 200–260 patients with pulmonary TB, confirmed by laboratory culture of sputum, lavage, or biopsy specimens.

Prior to July 1992, hospital policy required that all employees (except physicians, students, and volunteers) have annual one-step TSTs placed and read by trained employee staff. A nosocomial TB outbreak occurred among nurses and clerks employed on two in-patient medical wards between January and March 1992 [Zaza et al., 1995]. Recognition of this outbreak resulted in the implementation of new TB control measures throughout the hospital, including a change in hospital policy, in July 1992, requiring all employees to have TSTs every 6 months.

According to hospital policy (from at least 1976 through 9/30/92) a positive TST was defined as a reaction at 48–72 hr of at least 10 mm to a Mantoux skin test using five tuberculin units of purified protein derivative (PPD). No negative results were assumed; TST results had to be read and documented by employee health staff in order to be recorded as ''negative.'' However, skin reaction sizes of negative tests (< 10 mm) were not typically recorded on the health records. The employee health staff excluded workers from their annual TST program if they had a documented or clear history of a previously positive TST or diagnosis of TB. No exclusions were made based solely on a history of BCG vaccination.

METHODS

Study Population

We examined the risk of TST conversion for the study period, January 1, 1990, through September 30, 1992, (a period prior to the 1994 CDC guidelines [CDC, 1994]) among hospital workers who had direct contact with patients or with potentially infectious laboratory specimens compared to workers without such contact. This study period was chosen because of the availability of computerized employee payroll records.

Health records of all employees listed in the employee payroll database who had actively worked for at least one quarter during the study period (eligible workers) were reviewed to determine TST results and history of BCG vaccination. Workers (including those who received BCG vaccine) were included in this study if they had at least two TSTs during the study period and tested negative on the first test.

A TST convertor was defined as a person who had a documented positive TST result (any reaction of 10 mm or greater) and a documented previous negative result during the study period. Since conversion could have occurred any time between the positive and prior negative TST, a random date between the negative and positive result dates was assigned using a computerized random-date generator with all dates during the period having an equal probability of selection. Lastly, to address the possibility of our results being influenced by the ''booster'' phenomenon, prior BCG vaccination, or employees' country of birth, we repeated our analyses using only workers with two or more documented negative TSTs prior to conversion.

Eligible workers were grouped into ''patient contact'' and ''no patient contact'' cohorts by evaluation of their geographic location of work and the type of work they performed. Groups selected for each cohort were reviewed with the hospital staff to help insure accuracy of the exposure classifications. The ''patient contact'' cohort consisted of workers with direct patient contact who were employed at stationary work locations anywhere within the hospital (e.g., in-patient ward nurses and clerks, emergency room workers); workers in selected occupations that require direct contact with patients from different areas of the hospital (e.g., respiratory therapists, housekeepers, phlebotomists); and workers who may have contact with potentially infectious patient specimens (e.g., laboratory workers). The ''no patient contact'' cohort consisted of workers employed at stationary work locations or occupations/positions which did not require any direct patient contact (e.g., administrative office workers, medical records clerks, and laundry workers).

Additionally, nurses and clerks (within the ''patient contact'' cohort) employed exclusively on in-patient wards were subdivided into ''high,'' ''medium,'' and ''low'' potential TB exposure groups based on the number of positive pulmonary *M. tuberculosis* cultures submitted from each in-patient ward from 1/89–5/92. Each of the wards comprising the ''high'' (eight adult medical/surgical wards), ''medium'' (nine adult medical/surgical wards), and ''low'' (14 non-medical/surgical wards) TB exposure groups submitted >29, 10–29, and < 10 positive cultures, respectively. The distribution of positive pulmonary *M. tuberculosis* cultures for in-patient wards showed little variation over the time period 1/89–5/92. A random review of areas of hospitalization for 150

patients with positive pulmonary *M. tuberculosis* cultures found that while approximately 25% of the patients changed wards during their hospitalization, none were hospitalized on both medical/surgical wards and non-medical/surgical wards during their stay.

Data Analysis

Employee data extracted from the employee payroll database included worker's name, social security number, date of birth, date of hire, race/ethnicity, gender, home zip code, salary, job titles, and pay station (indicates the specific geographic location of work or department of employment) for each quarter the employee worked at the hospital during the study period. For analysis, age was defined as the worker's age at the midpoint of the study period (May 1, 1991) and salary was defined as the worker's average hourly salary over the study period. For the multivariate analysis, time employed in an occupational classification was calculated as the difference (in days) between date of hire (or, if hired before the beginning of the study, January 1, 1990) and a termination date assigned based on the last quarter for which payroll records were available. For descriptive analysis, duration of employment (in years) was calculated based on date of hire and number of quarters the worker was an active employee at the hospital.

Population-based demographic data were evaluated by using each employee's most frequent zip code of residence during the study period. Data were extracted from the 1990 US Census of Population and Housing [Census of Population and Housing, 1990] and was included to evaluate socio-demographic factors potentially related to the risk of TST conversion. The incidence rate of TB was determined for employees' zip code of residence by dividing the number of incident TB cases for full years 1990–1992 for each zip code by its 1990 population [CDC, 1990–1992]. Unadjusted rates for each group of interest were calculated by dividing the number of new TST conversions by the number of workers at risk to convert. To assess the risk of TST conversion while controlling for potential confounders, a proportional hazards (P-H) regression model was used [SAS Institute, Inc., 1996]. The assumption of proportionality for this model was tested and met. Risk factors for TST conversion were evaluated in a series of univariate analyses with outbreak wards both included and excluded. Variables considered were exposure group (''patient contact,'' ''no patient contact''), employee age (age at midpoint of study in 10-year intervals), duration of employment (years employed as of last quarter or termination, as quartiles), race (white, non-white), gender, hourly wage (average over study period, as quartiles), and several measures of community TB exposure and socioeconomic status for the employees' zip code of residence, including 3-year TB incidence rate, TST conversion rate among employees residing in a given zip code, average household size, per capita income, unemployment rate, and percentage of incomes below the poverty level. All variables except per capita income, average household size, and unemployment rate were statistically significant at $P < 0.2$ in the univariate analysis.

A stepwise procedure was used to determine which risk factors, found to be statistically significant in the univariate analyses, to include in the final P-H multivariate model until there was no statistically significant change at $P < 0.05$. All adjusted RRs of TST conversion subsequently presented are based on this final P-H model which included variables for exposure group, employee age (RR 1.2; 95% confidence interval [CI] 1.0–1.5), non-white race (RR 1.9; 95% CI 1.2–3.0), 3-year TB incidence rate in employee's zip code of residence (RR 1.0; 95% CI 1.0–1.1), female gender (RR 0.6; 95% CI 0.4–0.8); and duration of employment (RR 0.6; 95% CI 0.5–0.7).

RESULTS

The total number of employees that had adequate health and personnel records and that worked for more than one quarter during the study period was 5,716 (note: housestaff was not included in the hospital TST program during the study period). Of this group, 2,412 (42%) were excluded because they were not eligible to convert their TST during the study; 1,173 were TST positive at entry or upon first testing in the study period, 1,224 had fewer than two TSTs during the study period, and 15 had less than 30 days between their first and last TST. Also, because the focus of this study was on the background rate of conversion throughout the hospital, the 56 workers (47 nurses and 9 clerks) employed on the two in-patient hospital wards involved in a nosocomial TB outbreak during the study period were excluded from all of the following analyses. The following results are thus based on the remaining 3,248 employees, of which 27% (886) were classified as having no known patient contact (''no patient contact'' cohort); and 73% (2,362) were classified as having some contact with patients or patient laboratory specimens (''patient contact'' cohort).

Analysis of the demographic characteristics of the ''no patient contact'' and ''patient contact'' groups revealed relatively small differences in age, hourly wage, and duration of employment (Table I). More notable differences were found for sex and race, with the patient contact group having a larger percentage of female workers and smaller percentage of non-white workers. The racial distribution for the entire study group was 23.5% white, 74% black, and 2.5% other (Asian, American Indian, Latin American, and unspecified). As a group, converters had a lower percentage of females, higher percentage of non-whites, shorter duration of employment, and lower wages than non-converters. The distributions of demographic characteristics of workers who were TST positive upon entry to the study and thus excluded from other analyses are also shown in Table I. This group was older,

TABLE I. Demographic Characteristics by Cohort, Conversion Status, and TST Status Prior to the Study

	n	Age[a] (SD)	Sex (% F)	Race (% non-white)	Years employed[a,b] (SD)	Wage[a,c] $/hr (SD)
Study cohorts						
No patient contact	886	38 (10.6)	64.5	78.6	10.7 (8.2)	11.2 (5.3)
Patient contact	2362	37 (9.7)	80.0	72.7	9.3 (8.0)	12.4 (5.5)
Conversion status						
TST converters	156	37 (9.7)	64.0	84.0	7.6 (7.2)	11.3 (6.0)
Non-converters	3092	37 (10.0)	76.3	73.8	9.8 (8.1)	12.1 (5.4)
TST status at entry						
Study group[d]	3248	37 (10.0)	76.1	74.5	9.7 (8.1)	12.1 (5.5)
TST + at entry[e]	1173	43 (10.5)	75.9	87.9	12.0 (9.7)	12.2 (5.3)

[a]Means for age, years employed, and hourly wage are presented.
[b]Years of employment at end of study or date of termination.
[c]Average wage during study period.
[d]Eligible workers for the study who were TST negative upon entry into the study group.
[e]Workers that were TST positive upon entry to the study and were thus excluded from the study group.

had a higher percentage of non-whites, and was employed longer compared to the study group.

The crude 33-month TST conversion rates by demographic characteristics are shown in Table II. Statistically significant increased rates of TST conversion were associated with male gender and non-white race ($P < 0.05$). Also, statistically significant trends of increasing TST conversion were associated with decreasing hourly wage and duration of employment ($P < 0.05$). No statistically significant association of TST conversion was observed for age.

Table III shows that the 33-month cumulative rate of TST conversion was 5.8% (138/2,362) in the ''patient contact'' group, compared to 2.0% (18/886) in the ''no patient contact'' group. The unadjusted relative risk (not shown in Table III) was 2.9 (95% CI 1.8–4.7); after adjustment the risk was 3.6 (95% CI 2.2–5.8).

While most workers (85%) stayed in the same job over the study period, there was some movement between jobs, which varied among occupational groups. The following analyses were limited to only those workers who always stayed within the same occupational category throughout the entire study period.

The TST conversion rate for all nurses with patient contact was 5.5% (RR 6.5; 95% CI 3.2–13.1). Among in-patient ward nurses, a statistically significant trend (chi-square for linear trend, $P < 0.01$) was observed with TST conversion rate and the number of positive TB cultures from the in-patient wards on which the nurses worked. Conversions occurred in 12.5, 9, and 1.8% of the nurses in the ''high,'' ''medium,'' and ''low'' TB exposure groups, respectively. The relative risks were statistically significantly elevated for nurses in the ''high'' (RR 12.6) and ''medium'' (RR 6.0) exposure groups, but not the low (RR 2.9) exposure group.

The TST conversion rate for all clerks with patient contact was 6.1% (RR 4.3; 95% CI 1.6–11.9). Among in-patient ward clerks, those who worked on wards in the ''high''- and ''medium''-exposure groups had similar rates of conversion, 13.6% (RR 7.9) and 12.5% (RR 12.2), respectively, and the relative risks were statistically significantly

TABLE II. Rate of Conversion by Demographic Characteristics

Demographic characteristic	Converters/n	Rate (%)
Gender[a]		
Female	100/2460	4.1
Male	56/788	7.1
Race[a]		
White	25/835	3.0
Non-white	131/2413	5.4
Age (years)		
16–25	23/377	6.1
26–35	51/1120	4.6
36–45	48/1116	4.3
46–55	28/467	6.0
Over 55	6/167	3.6
Hourly wage[b,c] ($)		
2.50–7.75	61/706	8.6
7.76–10.50	31/891	3.5
10.51–14.50	29/778	3.7
Over 14.50	35/870	4.0
Years employed[c,d]		
Less than 2.5	33/601	5.5
2.5–5.5	57/820	7.0
5.6–13.7	33/905	3.6
Over 13.7	33/922	3.6

[a]*t*-test statistically significant at $P < 0.05$.
[b]Average wage during 33-month study period.
[c]Chi-square for trend statistically significant at $P < 0.05$.
[d]Years of employment at end of study or date of termination.

TABLE III. Risk of Conversion by Cohort and Those Occupational Groups With "Patient Contact"*

Occupations/work Areas	n	% Conversion	RR[a]	95% CI
Cohorts				
No patient contact	886	2.0	Reference group	—
Patient contact	2362	5.8	3.6	2.2–5.8
Nurses				
All nurses	525	5.5	6.5	3.2–13.1
Nurses high wards[b]	96	12.5	12.6	5.4–29.6
Nurses medium wards[c]	100	9.0	6.0	2.5–14.6
Nurses low wards[d]	273	1.8	2.9	0.9–10.0
Clerks				
All clerks with contact	114	6.1	4.3	1.6–11.9
Clerks high wards[b]	22	13.6	7.9	1.6–38.8
Clerks medium wards[c]	16	12.5	12.2	2.5–59.8
Clerks low wards[d]	50	2.0	1.9	0.2–15.1
Other occupations				
Lab workers	106	6.6	5.8	2.2–15.1
Pharmacy	48	10.4	5.2	1.9–14.5
Phlebotomists	29	6.9	5.2	1.1–25.1
Emergency services	146	6.9	4.6	2.0–10.9
Housekeepers	103	12.6	4.4	1.9–10.0
Neonatal/pediatrics	42	2.4	3.1	0.4–25.9
Food service workers	49	6.1	2.9	0.8–10.2
Emergency responders	145	6.9	2.8	1.1–6.7
Obstetrics/gynecology	101	2.0	2.8	0.6–14.1
Outpatient clinics staff	85	2.4	2.5	0.5–12.1
Social services	131	3.8	2.2	0.8–6.0
Surgery/anesthesia	121	2.5	2.0	0.6–7.1
Orderly/patient escorts	34	8.8	1.5	0.4–5.5
Radiology	37	2.7	1.4	0.2–10.7
Respiratory therapists	62	3.2	1.1	0.1–8.2
Dietician/nutrition	20	none	—	—

*Analysis included only workers always employed in the same cohorts and occupational groups during the 33-month study period.
[a]All relative risks (RR) were adjusted for age, race, gender, duration of employment, and TB incidence rate in the employees' zip code of residence.
[b]"High wards" consisted of eight in-patient wards each of which had over 30 positive pulmonary TB cultures from 1/89–5/92.
[c]"Medium wards" consisted of nine in-patient wards each of which had 10–30 positive pulmonary TB cultures from 1/89–5/92.
[d]"Low wards" consisted of 14 wards each of which had less than 10 positive pulmonary TB cultures from 1/89–5/92.

elevated. Only 2% of clerks in the ''low''-exposure group converted; the increased relative risk (1.9) was not statistically significant.

Evaluation of sixteen other occupations and work areas revealed statistically significantly elevated relative risks for lab workers (5.8), pharmacy workers (5.2), phlebotomists (5.2), housekeepers (4.4), emergency room workers (4.6), and emergency responders, such as emergency medical technicians and paramedics (2.8). For some of these occupations, we were able to compare the rate of TST conversions among workers with ''patient contact'' to those in the same occupation with ''no patient contact''. The rate of TST conversions among clerks with ''patient contact'' was 6.1% (7/114), over three-times higher than among clerks with ''no patient contact,'' 1.8% (6/329). Food service workers with ''patient contact'' had a 6.9% (3/49) rate of TST conversion compared to a rate of 1.5% (1/69) for food service workers with ''no patient contact.'' Also, pharmacy workers with ''patient contact'' had a TST conversion rate of 10.4% (5/48), which was notably higher than pharmacy workers with ''no patient contact'' (none of 15). Among lab workers who may routinely handle specimens containing *M. tuberculosis* (i.e., pathology, cytology, bacteriology, urinalysis, autopsy) the TST conversion rate was 14.3% (3/21), about twofold higher

than lab workers who are not known to routinely handle specimens containing *M. tuberculosis* (i.e., hematology, blood bank, chemistry, serology) 7.5% (3/40).

To address the possibility that workers had a false negative TST prior to ''conversion,'' and that the apparent conversion represented a ''booster'' phenomenon [Thompson et al., 1979] rather than a true conversion, we repeated our analyses using only workers with two or more documented negative TSTs prior to conversion. This approach had variable effects on our point estimates of the risk of conversion for several of the exposure groups, but did not affect the overall findings. Except for phlebotomists, the elevated risks identified in the previous analyses remained elevated (Table IV).

To examine the annual variation of TST conversions and the potential effect of the nosocomial TB outbreak on other hospital workers, the rates and risks of TST conversion by year were evaluated. While the conversion rates varied from year to year for both exposure groups, the annual rate of conversions for the ''patient contact'' group remained approximately two to threefold higher than for the ''no patient contact'' group for each of the study years. The respective annual conversion rates among the ''patient contact'' group for 1990,1991, and January 1–September 30, 1992 were 1.1, 2.3, and 1.9%, as compared to 0.6, 0.9, and 0.6% for the ''no patient contact'' group. Aside from nurses in the ''medium'' exposure group (highest in 1990) and emergency responders (highest in 1992), the annual rates for all other occupations with significantly elevated risks of TST conversion were highest during 1991, the year prior to the nosocomial TB outbreak.

DISCUSSION

This study provides an extensive evaluation of the risk of *M. tuberculosis* infection among a large group of workers employed in a variety of occupations and hospital areas, many of which have not been previously examined. Additionally, the study design incorporated an internal, non-exposed comparison group, accounted for lack of information concerning workers' country of origin and BCG vaccination status, addressed the potential for a ''booster'' phenomenon, and controlled for non-occupational and socioeconomic risk factors. This hospital differs from many of the health facilities previously evaluated by other investigators with regard to the large number of patients with laboratory-confirmed TB and the nearly complete compliance of full-time salaried workers (other than housestaff) with its TST screening program [Blumberg et al., 1995]. While these data represent one large urban hospital, we have no reason to believe that this hospital is substantially different than other large city hospitals that see a large number of patients with TB.

Although there is considerable evidence that workers who provide direct patient care are at greater risk for TB infection than workers who did not provide direct patient care [Mikol et al., 1952; Beck-Sagué et al., 1992; Dooley et al., 1992; Pearson et al., 1992; Zaza et al., 1995; Rullan et al., 1996; Boudreau et al., 1997; Behrman and Shofer, 1998], the results among studies are inconsistent. One explanation for the differences may be variation in the admission rates of TB patients [Bailey et al., 1995; Christie et al., 1998]. In institutions with fewer than 10 admissions for TB annually, the annual worker risk of infection was less than 0.2%, as

TABLE IV. Risk of TST Conversion Accounting for Potential "Booster" Phenomenon for "Patient Contact" Groups With Elevated Risks*

Occupations	Data not accounting for potential "booster" phenomenon[a]		Data accounting for potential "booster" phenomenon[b]	
	Converters	RR (95% CI)[c]	Converters	RR (95% CI)[c]
All Nurses	52	6.5 (3.2–13.1)	38	6.0 (2.8–13.0)
Lab workers	7	5.8 (2.2–15.1)	6	6.1 (2.1–17.3)
Pharmacy	5	5.2 (1.9–14.5)	5	6.4 (2.2–18.1)
Phlebotomists	2	5.2 (1.1–25.1)	0	Not available[d]
Emergency services	10	4.6 (2.0–10.9)	7	4.0 (1.5–10.9)
Housekeepers	13	4.4 (1.9–10.0)	10	4.6 (1.8–11.6)
All clerks	17	4.3 (1.6–11.9)	16	4.3 (1.4–13.0)
Emergency responders	10	2.8 (1.1–6.7)	8	2.6 (1.0–6.9)

*Analysis included only workers always employed in the same occupations during the 33-month study period.
[a]Analyses including workers with one or more documented negative TSTs prior to conversion.
[b]Analyses including only workers with two or more documented negative TSTs prior to conversion.
[c]All relative risks (RR) were calculated using the "no patient contact" group as a reference group and were adjusted for age, race, gender, duration of employment, and TB incidence rate in the employees' zip code of residence.
[d]There were no convertors who met the analysis criteria for this group.

compared to institutions such as the hospital we studied, with more than 200 admissions for TB annually and an annual worker infection rate between 1 and 10% [Menzies et al., 1995]. Additionally, several studies have used prevalence, instead of incidence, rates to identify occupational groups at risk [Dooley et al., 1992; Bailey et al., 1995], which may be more reflective of prior occupational and non-occupational infection.

Among the 18 occupational groups evaluated in our study, increased risks have been previously reported, and appear to be indicative of workplace practices and exposures, among nurses [Mikol et al., 1952; Dooley et al., 1992; Boudreau et al., 1997], clerks [Boudreau et al., 1997], ward-based dietary staff [Mikol et al., 1952], laboratory workers (i.e., microbiology technicians, histologists, and pathologists) [Mikol et al., 1952; Reid, 1957; Harrington and Shannon, 1976; Sugita et al., 1990; Grist and Emslie, 1991], emergency department staff [Behrman and Shofer, 1998], and housekeepers [Berman et al., 1981; Louther et al., 1997]. While increased risks among these occupations have been previously reported, the risks for most groups are not well characterized, due in part to the lack of studies and the limitations of the study designs. In our study, ward nurses were found to have significantly increased risks of TST conversion related to the number of positive TB cultures from the in-patient wards on which they worked. To our knowledge, this type of relationship has not been previously reported among nurses or other occupational groups.

In addition to those occupations that previously were identified as having an increased risk, our study found significantly elevated risks for TST conversion among pharmacy workers, phlebotomists, and emergency responders. Workers employed in these occupations may not have been previously identified, possibly due to small group sizes and perhaps a lower index of suspicion. For emergency responders and phlebotomists, the increased risks are more readily apparent in terms of frequent and close patient contact. The increased risks found among pharmacy workers, if indeed occupationally related, are more difficult to explain and potentially more disturbing as these workers are not typically involved in direct patient care. Unfortunately, the specific activities and exposures that contribute to workers' increased risk cannot be identified by studies such as ours. For a few occupations, some explanations were offered by hospital employees. For instance, the increased risk observed among ward clerks may be related to exposure occurring when patients congregate in the ward clerk's area to use the telephones. The increased risk observed among pharmacy workers may be a consequence of exposure to persons with active TB who were waiting for medications in the outpatient pharmacy area.

Our study has several limitations. Only limited information was available concerning workers' BCG vaccination status and no information was available concerning employees' country of birth, which is a recognized risk factor for TB, most likely resulting from reactivation of remotely acquired infection [CDC, 1998b]. Also, the lack of two-step testing creates difficulty in definitively evaluating the impact of the ''booster'' phenomenon. We sought to address these limitations by an analysis restricted to workers with two or more documented negative TSTs prior to conversion. The results of this analysis did not affect our overall findings.

We used the hospital's definition of a TST conversion, which differs from the current CDC guidelines which recommend that only specific increases in induration (the magnitude of which depends on a variety of risk factors) be considered evidence of a true TST conversion. [CDC, 1994, 2000b]. Although this may have produced a systematic error in estimating rates, it is unlikely to introduce differential misclassification by exposure group. Additionally, an analysis (data not shown) to determine the risk of having a positive TST with a change in induration of at least 10 mm (i.e., those workers with a positive TST 20 mm or larger) revealed that the risk was still significantly greater in workers with ''patient contact'' as compared to those with ''no patient contact'' (OR 3.5; 95% CI 1.6–7.9).

This study only addresses TST conversion rates for exposure groups as defined by occupation or work area, potentially leading to misclassification of the actual exposure. However, it is unlikely that any such misclassification bias would be large enough to change the overall pattern of risks observed for certain occupational groups. Also, workers with uncertain exposures were more likely to be designated as ''exposed'' resulting in more conservative point estimates of risk.

While findings from this study present an historical picture of nosocomial TB transmission among various groups of workers in this hospital, these data are useful to similar types of institutions trying to understand their own risks, and are essential to the development of appropriate worker protection guidelines. Additionally, these data provide an invaluable baseline for comparison to more current rates to help determine the efficacy of TB control measures. The results of more recent evaluations of TST conversions at this hospital provide evidence that implementation of a comprehensive TB control program, including administrative controls, engineering controls, and worker personal respiratory protection can reduce the risk of *M. tuberculosis* transmission among health care workers [Blumberg et al., 1995]. Further, in our study, demonstration of increased risk for *M. tuberculosis* infection among various occupational classifications with and without close patient contact underscores the importance of: (1) following the CDC recommendations [CDC, 1994] of including all health-care facility personnel in TST programs, not just those providing patient care, and (2) implementing effective TB transmission controls in all areas where employees may be exposed to infectious individuals, not just patient care areas. Hopefully, as these

recommendations are adopted, additional data concerning the risks of nosocomial *M. tuberculosis* transmission among various occupational groups employed within health-care-facilities and the efficacy of specific TB control measures will become available.

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