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Evaluation of Exposure to Tuberculosis Among Employees at a Medical Center

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INTRODUCTION

Tuberculosis (TB), a disease caused by the bacteria *Mycobacterium tuberculosis (M. tuberculosis)*, is spread from person to person through the air. TB usually infects the lungs, but it can also infect other body parts such as the brain, kidneys, or spine. People who are infected by the bacteria but who do not exhibit symptoms have latent TB infection. It is estimated that one-third of the world's population has latent TB infection, and approximately 5%–10% of those infected will develop TB disease within their lifetimes.[(1–5)]

In July 2011, the National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation request from management representatives at a medical center in Arizona concerning exposure of employees to *M. tuberculosis*. They asked for our assistance in evaluating the infection control and occupational health practices related to TB.

At the time of our visit, the medical center included an inpatient hospital with 73 beds and adjacent outpatient facility, and the center had approximately 1000 employees. One nurse, the infection control practitioner, was responsible for all infection control and occupational health activities at the medical center. The medical center's TB policy required annual tuberculin skin testing (TST) of all employees with face-to-face patient contact, which included the majority of employees.

PRIOR GOVERNMENT RESPONSE

In July 2011, the Division of TB Elimination at the Centers for Disease Control and Prevention (CDC) investigated a health care-related TB outbreak at the hospital and identified three related patients with TB disease. Patient 1, the index case and the only sputum acid fast bacilli (AFB) smear-positive or infectious case, was diagnosed in January

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2011. Patient 2, a hospital employee, was diagnosed in May 2011. This employee, a certified nursing assistant in the emergency department (ED), worked there during Patient 1's second admission. Patient 3, Patient 1's spouse, was diagnosed in July 2011. An employee contact investigation revealed 11 TST conversions, suggesting that workplace transmission was responsible for multiple conversions. The investigation found that delays in placing the three patients in respiratory airborne infection isolation (AII) (7 hours to 7 days) contributed to this outbreak. Symptom recognition and consideration of TB as a diagnosis were delayed. Thus, respiratory protection was not used by employees caring for these patients, placing the employees at risk for TB.

To complement the epidemiologic investigation, NIOSH assistance was requested. The purpose of our evaluation was to (1) investigate the incidence of TB disease and latent TB infection among hospital employees in 2011; (2) assess the medical center's TB-related administrative, engineering, and respiratory protection controls; and (3) make recommendations to improve TB-related occupational health and infection control practices.

METHODS

In this column, we describe two components of this evaluation. We (1) held confidential medical interviews with employees and reviewed pertinent medical records, and (2) evaluated the ventilation in the hospital's AII rooms.

Confidential Medical Interviews and Medical Record Review

We selected 41 current and former hospital employees to participate in individual semi-structured confidential interviews. These employees included those with a TST conversion in 2011 and/or those reported to have had exposure to Patient 1 in January 2011. A TST conversion was defined as an employee with a new positive TST who had a previous negative baseline TST. During these interviews, we discussed their knowledge about TB and TB-related medical center procedures, their known exposures to TB, their respiratory protection practices, and other related concerns. We supplemented the information from these interviews with information from employee health and other pertinent medical records.

We described characteristics of the employees who had TST conversions in 2011. We then further analyzed data concerning those employees who were documented as working in three clinical care areas while Patient 1 was not in AII. In these analyses, we compared those employees with a TST conversion in 2011 to those employees who did not have a TST conversion to determine factors associated with conversion. We conducted bivariate analysis with SAS 9.2 (SAS Institute, Cary, N. C.). All statistical tests were 2-tailed, with a P value of less than 0.05 considered statistically significant.

Ventilation Assessment

We walked through the hospital (including the mechanical rooms) and on the roof to observe the ventilation system. We also reviewed ventilation plans with the hospital engineering staff. We measured the pressure difference in the doorways between the AII rooms and adjacent anterooms or adjacent hallways with a TSI DP-Calc micromanometer (TSI, Inc., Shoreview, Minn.) and used smoke tubes to visualize airflow in the doorways.

We obtained airflow measurements from supply diffusers and ducted exhausts in all AII patient rooms, bathrooms, and adjacent anterooms to assess potential dissemination of airborne *M. tuberculosis*. We calculated air changes per hour (ACH) based on the exhaust airflow measurements in these rooms. Airflow measurements were made with a TSI Accubalance Plus air capture hood (TSI, Inc., Shoreview, Minn.).

RESULTS

Confidential Medical Interviews and Medical Record Review

Of the 41 employees selected for interviews, 38 employees (93%) participated by phone or in person. These 38 employees included 1) 18 of 19 employees reporting a TST conversion in 2011; and 2) 20 of 22 employees found to be TST negative after reportedly being exposed to Patient 1 in January 2011when that patient was not in AII. Eight (21%) of the 38 interviewed employees reported attending general TB training during their employment at the hospital. Thirty (79%) correctly identified at least two symptoms of TB disease. However, some employees were confused about the difference between latent TB infection and TB disease.

Thirty-six (95%) of the 38 interviewed employees reported access to an N95 respirator or a loose fitting powered-air purifying respirator during their employment at the hospital. Twenty-nine (76%) reported undergoing respirator training, and 25 (66%) reported being fit-tested since starting work at the hospital. Twelve (32%) reported wearing another respirator they had not been fitted for during their employment.

Employees with a Tuberculin Skin Test Conversion in 2011—We reviewed employee health clinic records and other pertinent records for all 19 employees with a TST conversion in 2011. We then analyzed data from 18 of the 19 employees reported to have a TST conversion in 2011. The excluded employee was newly hired and reported a previous negative baseline TST which could not be confirmed. The employee diagnosed with TB disease was included in the 18.

The median age of the 18 employees with documented TST conversion in 2011 was 40 years, with a range of 22–63 years. Fifteen (83%) were female. Races included American Indian (n = 11), white (n = 5), Asian American (n = 1), and “other” (n = 1). Job titles included certified nursing assistant (n = 7), medical support assistant (n = 4), registered nurse (n = 3), physician (n = 3), and other (n = 1). The primary departments where these employees worked included acute care unit (ACU) (n = 9), patient registration (n = 2), ED (n = 2), and intensive care unit (ICU) (n = 1). The other four worked in various locations.

Of the 17 employees with TST conversions in 2011 that were interviewed, 14 (82%) reported having face-to-face contact with a patient known to have TB disease in the prior year. Three (18%) reported having face-to-face contact with someone else known to have TB disease (such as a co-worker). Of the 18 employees with TST conversions in 2011, 10 (56%) were documented in records as having worked in the hospital during Patient 1’s stay when that patient was not in AII.

Of the 18 employees with TST conversions in 2011, 4 (22%) had an underlying medical condition that put them at greater risk of progression to TB disease such as diabetes mellitus or an immuno-compromising condition. Of the 17 employees diagnosed with latent TB infection and who had undergone a medical evaluation, all were offered treatment with isoniazid. Thirteen (81%) started treatment with isoniazid; 2 (15%) of the 13 had prematurely discontinued treatment by the time of the interviews.

Employee with Health-Care Associated Tuberculosis Disease—The employee with TB disease was working as a certified nursing assistant in the hospital's ED and began having symptoms of cough and shortness of breath beginning March 2011. The employee was diagnosed with pulmonary TB disease in May 2011 after multiple ED presentations. This employee had no pertinent medical history that increased the employee's risk of TB disease. The employee then started a standard four-drug TB regimen and was receiving directly observed therapy at the time of our visit. Though the employee initially reported no known history of working with patients with TB disease, a review of the ED shift records found that the employee was working during a January 2011 ED shift when Patient 1 was evaluated without being placed in AII.

Characteristics Associated with Tuberculin Skin Test Conversion—We further analyzed data for those employees who were documented as working in three clinical care areas while Patient 1 was not in AII. In these analyses, we compared characteristics of eight non-physician employees with a TST conversion in 2011 and 17 non-physician employees without a TST conversion. We excluded physicians from the analysis because we were not able to obtain staffing records for all physicians working in January 2011.

Age, race, number of years worked at the hospital, and having an underlying high-risk medical condition were not significantly associated with TST conversion. However, working as a certified nursing assistant was significantly associated with having a TST conversion compared to all other job titles (75% vs. 18%, $P = 0.01$). No other risk factors for TST conversion were identified.

Ventilation Assessment

At the time of our visit, the hospital maintained 18 AII rooms, including multiple rooms in the ACU and pediatric unit and one room each in the ICU and ED. The AII rooms often were also used as standard patient rooms. All AII rooms in the ACU had dedicated anterooms, which served as the only path in and out of the AII rooms. In the pediatric unit, one anteroom served a set of two AII rooms. These rooms also had additional doors directly between the AII rooms and adjacent hallways allowing for bypass of the anteroom. When these rooms were used for AII, staff reportedly only entered and exited the AII room via the anteroom doorway. The AII room in the ICU had both an anteroom and a doorway between the AII room and adjacent ICU suite. The ED AII room did not have an anteroom.

Constant air volume heating, ventilation, and air conditioning (HVAC) systems served the isolation rooms and were installed approximately 12 years prior to our evaluation. The AII rooms had single pass ventilation; all air was directly exhausted via ducts to the outside on the roof of the hospital. These rooftop exhausts were located more than 25 feet away from any outdoor air intakes and were appropriately labeled as coming from an AII. The hospital engineering staff reported that the HVAC supply ducts delivered 10%–100% of outdoor air throughout the hospital, depending on the outdoor temperature.

Electronic door pressure monitors with low pressure alarms monitored the pressure between AII rooms and adjacent hallways. All AII rooms were fitted with an electronic door pressure monitor except for the ED AII room. These room pressure monitors allowed staff to change damper settings on ducted air returns, which could change the rooms between negative pressure and positive pressure. In some AII rooms, we had to change the settings from positive pressure to negative pressure before making airflow measurements. Additional settings allowed users to reverse the current damper setting on the ducted exhausts. This control setting was independent of the positive and negative pressure settings, allowing users to reverse the damper setting in the ducted exhausts from open to closed or vice versa. When tested, some of the electronic door pressure monitors did not alarm when the AII rooms were not under appropriate negative pressure. Hospital engineering staff reported that these electronic pressure monitors had not been calibrated since they were installed approximately 12 years prior to our evaluation.

When the electronic sensors were placed in the negative pressure mode, six AII rooms in the ACU and pediatric unit were under positive or neutral pressure relative to the anterooms and/or hallways as determined using smoke tubes. All of the other AII rooms in the ACU, pediatric unit, and the AII room in the ED were under negative pressure relative to adjacent areas. The AII room in the ICU was under slight positive pressure relative to the adjacent anteroom when the exhaust fan in the anteroom was turned on. When this exhaust fan was turned off, the room was under negative pressure relative to both the adjacent anteroom and main ICU area. In AII rooms that were under negative pressure relative to adjacent anterooms and hallways, pressure measurements ranged from −0.0040 to −0.0265 inches of water gauge. The CDC recommends that AII rooms should be under negative pressure relative to adjacent areas, and should be maintained at a negative pressure greater than 0.01 inches of water gauge. [(6)]

All but one of the AII rooms under negative pressure relative to adjacent anterooms or hallways had more than the CDC-recommended 6 ACH based on the amount of air exhausted from the patient room. [(6)]Airflow measurements were made in the 13 anterooms that served the AII rooms. The calculated ACH, on the basis of exhaust airflow in these anterooms, ranged from 0–34 ACH. Seven of the 13 anterooms provided fewer than the CDC-recommended 10 ACH for newly constructed or renovated facilities. [(6)] When AII rooms were occupied by patients with airborne infectious diseases, hospital staff kept the door between the AII rooms and anterooms closed. However, it was noted that the hospital staff usually did not close the door between the anterooms and hallways because it was reportedly difficult to observe patients in the AII rooms.

DISCUSSION

Health care personnel in the United States have been shown to be at higher risk of acquiring TB than the general population. [(7)] In the United States, multiple health care-associated TB outbreaks have been reported with both patient-to-patient and patient-to-health care personnel transmission occurring. [8] Consistently, the most important factor favoring nosocomial transmission has been close contact with patients with unrecognized TB disease, as was found in this hospital. [9–13]

Ten TST conversions in 2011 occurred in employees documented in hospital records as having worked in the hospital during a single pulmonary TB patient's stay when that patient was not in AII. This finding suggests that hospital transmission occurred in these cases. Prompt symptom recognition, consideration of TB disease as a diagnosis, and subsequent AII and respiratory protection use were all delayed and contributed to this outbreak.

Our analysis revealed that certified nursing assistants were significantly more likely to have a TST conversion than other hospital employees. Multiple studies have shown that physicians, nurses, respiratory therapists, and nursing assistants are at high risk. [9,14–17] Nursing assistants and clerks are among the first health care personnel to encounter a patient in the ED or on admission to an inpatient unit. Nursing assistants often evaluate a patient's vital signs before a comprehensive medical assessment has been conducted. It is important to convey a patient's need for isolation precautions immediately after the assessment has been made and upon admission to an inpatient unit. In addition to their daily responsibilities, the nursing assistants at this hospital also served as interpreters for some of the patients, requiring close face-to-face contact with patients. Some nursing assistants recalled interpreting for the reportedly hard-of-hearing Patient 1 when she was not in AII. This interaction may have facilitated TB transmission.

Although the medical center's TB control program policy was comprehensive, our investigation revealed gaps in the implementation of the administrative, engineering, and respiratory protection controls. It is likely that some of these deficiencies contributed to the outbreak at the hospital. First, we found gaps in attending TB training and gaps in knowledge about the symptoms of TB disease.

Second, although the hospital's HVAC system in the AII rooms was a constant air volume system that exhausted air directly outside of the building without recirculation, we observed ventilation deficiencies. These deficiencies could increase the potential for *M. tuberculosis* transmission from patients with TB disease housed in AII rooms to hospital staff and other patients. In several AII rooms, the direction of airflow, relative pressure difference between AII rooms and adjacent areas, and calculated ACH did not meet CDC recommendations. [6] Smoke that visualized airflow and relative pressure measurements showed that some of the AII rooms were under positive or neutral pressure relative to adjacent anterooms and/or hallways. The relative pressure readings of the electronic pressure monitors, which had not been recently calibrated, were much different than those taken with our calibrated micromanometer.

In some cases, the electronic pressure monitors indicated that AII rooms were under negative pressure, but our measurements and smoke tube airflow tests indicated that they were under positive pressure. This problem has been reported commonly in the scientific literature. In one study of 38 hospital AII rooms with electrical or mechanical devices to continuously monitor air pressurization, half had actual airflow at the door in the direction opposite that indicated by the continuous monitors. [18] The additional functions of these electronic door monitors allowing users to both switch AII rooms between positive and negative pressure and reverse the dampers in the exhaust ductwork, added additional confusion to the function of the ventilation system in the AII rooms.

Use of the anterooms was suboptimal because the doorways between the anterooms and hallways always remained open. When used properly, an anteroom can reduce the escape of potentially infectious aerosols during the opening and closing of the door to an AII room and can buffer an AII room from pressure fluctuations in the corridor. [6] However, as configured, they functioned as less contaminated vestibules between the AII rooms and the hallways; this setup might not prevent the escape of potentially infectious aerosols into the hallways. We did not measure the direction of airflow between the anterooms and hallways because it was hospital practice to keep the doorway between these areas open. However, most anterooms (10 of 13) exhausted more air from these areas than was supplied. CDC recommends that for anterooms to function properly, more air should be exhausted from the room than is supplied to it. [6]

Our evaluation was subject to limitations. First, our assessment of the ventilation system occurred in August 2011, several months after the three TB disease patients were hospitalized. Thus, we were unable to come to any conclusions on the adequacy of engineering controls during the time that the three patients with TB disease were hospitalized. Second, we interviewed only a small subset of the more than 1000 employees at the medical center. Thus, the self-reported TB-related practices of employees in other locations of the medical center, particularly the outpatient center, were not known.

CONCLUSION

A health hazard from exposure to *M. tuberculosis* existed at this medical center. Our investigation revealed 18 (2.3%) employees with a TST conversion in 2011; this included one employee diagnosed with TB disease. Most of these employees worked in the hospital during the time when Patient 1 was not in AII, suggesting that hospital transmission occurred in these cases. Working as a certified nursing assistant was significantly associated with having a TST conversion. Our investigation revealed gaps in the implementation of administrative, engineering, and respiratory protection controls.

RECOMMENDATIONS

On the basis of our findings, we recommended to the medical center the actions listed below to protect employees from TB transmission. More comprehensive recommendations for other medical centers can be found in CDC's "Guidelines for Preventing the Transmission of *Mycobacterium tuberculosis* in Health-Care Settings, 2005." [6]

Administrative Controls

The most important level of TB controls is the use of administrative measures to reduce the risk for exposure to persons who might have TB disease. [6]

1. Continue to conduct an annual TB risk assessment using the TB risk assessment worksheet found in the CDC guidelines. [6] This assessment serves as a tool for evaluating the quality of TB infection control and identifying needed improvements in infection control measures.
2. Provide general TB training during working hours to all employees on hire and annually thereafter to ensure a thorough understanding of the disease, its transmission, and ways to prevent it. Training should be tailored to education level and clinical role.
3. Encourage all triage nurses to offer face masks to any patient who complains of coughing. Promptly place any patients reporting TB symptoms in a properly functioning AII room until the patients have had three negative smears for AFB in their sputa. Place signs indicating AII as soon as the determination is made and immediately upon admission to an inpatient unit.
4. Continue annual TST placement and symptom screening of all employees with face-to-face patient contact during work hours. Enforce the requirement for employee TB screening.
5. Close the door between the anteroom and adjacent hallway when housing patients with TB disease (or other airborne infectious diseases) to reduce the escape of potentially infectious aerosols when the door to an AII room is opened or closed.

Engineering Controls

Engineering controls are the second line of defense in the TB infection control program and can prevent the spread and reduce the concentration of airborne *M. tuberculosis* in ambient air.[6]

1. Do not use rooms found to be under positive pressure or found to have fewer than 6 ACH as AII rooms until changes are made to the rooms to meet AII requirements.
2. Rebalance the HVAC system to ensure that all AII rooms are under negative pressure relative to adjacent anterooms and/or hallways. Additionally, provide at least 6 ACH in all AII rooms in hospitals constructed or renovated prior to 2001. Whenever feasible, the airflow should be increased to 12 ACH. In newly constructed or renovated facilities, anterooms should have at least 10 ACH. [6]
3. Reduce the amount of airflow exhausted from the ICU anteroom to ensure that this room is maintained under positive pressure relative to the adjacent AII room and is at neutral or negative pressure relative to the adjacent ICU suite. Disable the mechanically controlled dampers in the ducted returns in rooms designated as AII rooms so that these rooms cannot be switched into “positive pressure” mode. Also, ensure dampers in the exhaust ductwork are positioned to maximize exhaust airflow in AII rooms.
4. Follow the CDC-recommended schedule for maintaining proper negative pressure in AII rooms:[6]

- Check AII rooms for negative pressure before occupancy.

- If an AII room is occupied by a patient, use smoke tubes or other visual means to check daily for negative pressure, even if it has a pressure-sensing device.
- Check negative pressure monthly in any AII rooms that could be used for patients with suspected or confirmed TB disease.

Personal Protective Equipment

The third level of the hierarchy of controls is the use of respiratory protection in situations that pose a high risk for exposure. PPE is the least effective means for controlling exposures.

1. Develop, implement, and maintain a written respiratory protection program for employees for all respiratory hazards (including TB). This includes following all requirements described in the Occupational Safety and Health Administration (OSHA) respiratory protection standard.[(19)]
2. Follow the OSHA respiratory protection standard to ensure that employees use only respirators for which they have been fit-tested.[(19)]

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References

1. Styblo K. Recent advances in epidemiological research in tuberculosis. Adv Tuberc Res. 1980; 20:1–63. [PubMed: 7395639]
2. Dye C, Scheele S, Dolin P, Pathania V, Raviglione MC. Consensus statement. Global burden of tuberculosis: Estimated incidence, prevalence, and mortality by country. WHO global surveillance and monitoring project. JAMA. 1999; 282(7):677–686. [PubMed: 10517722]
3. Jasmer RM, Nahid P, Hopwell PCL. Clinical practice. Latent tuberculosis infection. N Engl J Med. 2002; 347(23):1860–1866. [PubMed: 12466511]
4. Stewart GR, Robertson BD, Young DB. Tuberculosis: A problem with persistence. Nat Rev Microbiol. 2003; 1:97–105. [PubMed: 15035039]
5. Vynnycky E, Fine PE. Lifetime risks, incubation period, and serial interval of tuberculosis. Am J Epidemiol. 2000; 152:247–263. [PubMed: 10933272]
6. Centers for Disease Control and Prevention (CDC). Guidelines for preventing transmission of *Mycobacterium tuberculosis* in health-care settings. MMWR. 2005; 54(RR-17):1–141.
7. Menzies D, Joshi R, Pai M. Risk of tuberculosis infection and disease associated with work in health care settings. Int J Tuberc Lung Dis. 2007; 11(6):593–605. [PubMed: 17519089]
8. Cookson ST, Jarvis WR. Prevention of nosocomial transmission of *Mycobacterium tuberculosis*. Infect Dis Clin North Am. 1997; 11(2):385–409. [PubMed: 9187953]
9. Catanzaro A. Nosocomial tuberculosis. Am Rev Respir Dis. 1982; 125(5):559–562. [PubMed: 7081816]
10. Craven RB, Wenzel RL, Atuk NO. Minimizing tuberculosis risk to hospital personnel and students exposed to unsuspected disease. Ann Intern Med. 1975; 82(5):628–632. [PubMed: 1137257]
11. Kantor HS, Poblete R, Pusateri SL. Nosocomial transmission of tuberculosis from unsuspected disease. Am J Med. 1988; 84(5):833–838. [PubMed: 3364442]
12. Pearson ML, Jereb JA, Frieden TR, et al. Nosocomial transmission of multidrug-resistant *Mycobacterium tuberculosis*. Ann Intern Med. 1992; 117(3):191–196. [PubMed: 1352093]

13. Griffith DE, Hardeman JL, Zhang Y, Wallace RJ, Mazurek GH. Tuberculosis outbreak among health care workers in a community hospital. Am J Respir Crit Care Med. 1995; 152(2):808–811. [PubMed: 7633747]

14. Dooley SW, Villarino ME, Lawrence M, et al. Nosocomial transmission of tuberculosis in a hospital unit for HIV-infected patients. JAMA. 1992; 267(19):2632–2634. [PubMed: 1573751]

15. Boudreau AY, Baron SL, Steenland NK, et al. Occupational risk of Mycobacterium tuberculosis infection in hospital workers. Am J Ind Med. 1997; 32(5):528–534. [PubMed: 9327078]

16. Zaza S, Blumberg HM, Beck-Sauge C, et al. Nosocomial transmission of *Mycobacterium tuberculosis*: Role of health care workers in outbreak propagation. J Infect Dis. 1995; 172(6): 1542–1549. [PubMed: 7594714]

17. Ball R. Tuberculosis skin test conversion among health care workers at a military medical center. Military Med. 1997; 162(5):338–343.

18. Pavelchak N, DePersis RP, London M, et al. Identification of factors that disrupt negative air pressurization of respiratory isolation rooms. Infect Control Hosp Epidemiol. 2000; 21(3):191–195. [PubMed: 10738988]

19. Federal Register. 29 CFR 1910. 134.