Evaluation of Exposure to Tuberculosis Among Employees at a Medical Center — Arizona

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The employer shall post a copy of this report for a period of 30 calendar days at or near the workplace(s) of affected employees. The employer shall take steps to insure that the posted determinations are not altered, defaced, or covered by other material during such period. [37 FR 23640, November 7, 1972, as amended at 45 FR 2653, January 14, 1980].

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Abbreviations

ACH	Air changes per hour
ACU	Adult care unit
AFB	Acid fast bacilli
AII	Airborne infection isolation
CDC	Centers for Disease Control and Prevention
CFM	Cubic feet per minute
CFR	Code of Federal Regulations
ED	Emergency department
HEPA	High-efficiency particulate air
HHE	Health hazard evaluation
HVAC	Heating, ventilating, and air-conditioning
ICP	Infection control practitioner
ICU	Intensive care unit
NA	Not applicable
NAICS	North American Industry Classification System
NIOSH	National Institute for Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
PAPR	Powered air purifying respirator
PPE	Personal protective equipment
TB	Tuberculosis
TST	Tuberculin skin test

Highlights of the NIOSH Health Hazard Evaluation

The National Institute for Occupational Safety and Health (NIOSH) received a health hazard evaluation request from management representatives at a medical center in Arizona. The request was submitted because of concerns about exposure of employees to *Mycobacterium tuberculosis.*

What NIOSH Did

- We visited the medical center in August 2011.
- We reviewed the policies and practices related to tuberculosis (TB).
- We measured ventilation airflow in airborne infection isolation (AII) rooms and anterooms.
- We interviewed 39 hospital employees. We also reviewed relevant medical records.
- We looked for factors associated with having a new positive tuberculin skin test (TST).
- We observed the respirator fit testing of two employees.

What NIOSH Found

- Eighteen employees had a new positive TST in 2011.
- One employee was diagnosed with active TB in 2011.
- Hospital transmission of TB to employees was likely.
- Seven AII rooms were not functioning properly.
- Working as a certified nursing assistant was associated with having a new positive TST.
- The respiratory protection program and employee training and screening need to be improved.

What Managers Can Do

- Provide annual TB training to all employees. Offer this training during work hours.
- Place signs about AII precautions outside patients' rooms as soon as active TB is suspected.
- Enforce the TB screening of employees.
- Do not use the seven malfunctioning AII rooms until they are repaired.
- Rebalance the heating, ventilating, and air-conditioning systems in AII rooms and adjacent anterooms. Ensure that they have the proper number of air changes per hour and have airflow in the proper direction.
- Improve the procedures for fit testing respirators.

What Employees Can Do

- Get a TST every year if you had a negative TST in the past.
- Get a medical evaluation for TB every year if you had a positive TST in the past.
- Recognize TB symptoms, report these to the nursing supervisor and caring physician, and promptly place patients with these symptoms in AII rooms.
- Close the doors between anterooms and adjacent hallways when housing active TB patients.
- Test the negative pressure of airflow in AII rooms when used for patients in isolation.
- Wear the appropriate respiratory protection when you are in contact with a patient with known or suspected active TB.

Summary

In July 2011, NIOSH received an HHE request from management representatives at a medical center in Arizona. The request concerned the exposure of employees to *Mycobacterium tuberculosis*. The management representatives asked for our assistance in evaluating the infection control and occupational health practices related to TB.

NIOSH investigators examined the recent incidence of active TB and latent TB infection among employees at a medical center. Investigators also assessed the TB-related infection control and occupational health practices. Hospital transmission of TB to employees likely occurred in 2011. The investigation revealed gaps in implementation of administrative, engineering, and PPE controls.

During an on-site evaluation in August 2011, we reviewed the medical center's TB-related occupational health and infection control policies and practices. We also assessed the ventilation in the AII rooms and sputum booth, interviewed 39 employees, reviewed pertinent medical records, and observed the respirator fit testing of two employees. We analyzed the medical center's TB screening data and interview data to identify factors associated with having a new positive TST.

A health hazard from exposure to *Mycobacterium tuberculosis* existed at this medical center. Our investigation revealed 18 (2.3%) employees with a TST conversion in 2011; one of these employees was diagnosed with active TB. Most employees who had TST conversions worked in the hospital during the stay of an active TB patient who was not initially placed in AII. This finding suggests that hospital transmission likely occurred. Certified nursing assistants were significantly more likely to have a TST conversion than other hospital employees. Although the medical center's written tuberculosis control program policy was comprehensive, our investigation revealed gaps in implementation of its administrative, engineering, and PPE controls. We found deficiencies in employee TB-related training and screening. Six AII rooms were under positive pressure, and another AII room had fewer than the recommended 6 ACH during our visit. Additionally, seven anterooms adjacent to AII rooms had fewer than 10 ACH.

We recommended giving TB training to all employees on hire and annually thereafter and considering ways to enforce the requirement for employee TB screening. We recommended that suspect TB patients be promptly placed in an AII room with appropriate signage indicating their status. We also recommended that the seven malfunctioning AII rooms not be used for that purpose. The HVAC systems should be rebalanced to ensure that all AII rooms are under negative pressure relative to adjacent anterooms and/or hallways, and doors between anterooms and adjacent hallways should be closed when active TB patients are housed. Negative pressure of airflow should be tested daily in AII rooms used for patients in isolation. We also recommended improvements in respiratory protection training and in respirator fit-testing procedures.

Keywords: NAICS 622110 (General Medical and Surgical Hospitals), TB, tuberculosis, infectious diseases, infection, hospital, healthcare, ventilation, airborne, American Indian, Native American

Introduction

In July 2011, NIOSH received an HHE request from management representatives at a medical center in Arizona. The request concerned the exposure of employees to *Mycobacterium tuberculosis*. The management representatives asked for our assistance in evaluating the infection control and occupational health practices related to TB.

During an on-site evaluation in August 2011, we observed work processes, work practices, and workplace conditions. We interviewed employees, reviewed employee health and pertinent medical records, and evaluated the ventilation system in selected areas.

Tuberculosis

TB, a disease caused by the bacteria *Mycobacterium 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. The symptoms of active TB disease in any body part include feeling sick or weak, weight loss, fever, and night sweats. The symptoms of TB disease of the lungs also include coughing, chest pain, and coughing up blood.

TB bacteria are released into the air when a person with TB disease of the lungs or throat coughs, sneezes, speaks, or sings. These bacteria can stay in the air for several hours, depending on the environment. Persons who breathe air containing these TB bacteria can become infected.

Persons with latent TB infection have TB bacteria in their bodies, but they are not ill because the bacteria are not active. These persons do not have symptoms of TB disease, and they cannot spread the germs to others. They may develop TB disease in the future but can be treated to prevent this from happening. Persons with TB disease are sick from active TB bacteria when the bacteria are multiplying, which causes destruction of tissue in their body. They usually have symptoms of TB disease and are capable of spreading TB bacteria to others.

Background on the Acute Care Hospital

At the time of our visit, the medical center was a 73-bed healthcare center accredited by the Joint Commission. The medical center had approximately 1,000 employees. The inpatient hospital was built in

1975, and the adjacent outpatient facility was built in 2010. The medical center provided services to people in a 4,400-square-mile area on two American Indian reservations.

At the time of our visit, one nurse, known as the ICP, was responsible for all infection control and occupational health activities at the medical center. These activities also included employee TST screening and administration of the employee respiratory protection program. The medical center's TB policy required annual TST testing of all employees with face-to-face patient contact.

Investigation by the Centers for Disease Control and Prevention's Division of Tuberculosis Elimination

In July 2011, at the request of the American Indian tribe's Division of Health, CDC's Division of TB Elimination conducted an investigation to describe the epidemiology of TB on the reservation, including the recent occurrence of TB clusters. Part of that investigation focused on a healthcare-related outbreak at the hospital and identified three definite outbreak-related cases of TB. A definite outbreak-related case was defined as culture-confirmed TB with a TB isolate matching the outbreak genotype (PCR 17301) diagnosed since August 1, 2010, in a person who visited, was hospitalized in, or worked in the medical center. Two cases were inpatients during their infectious periods. Patient 1, the only sputum AFB smear-positive case in the outbreak, was diagnosed in January 2011. Patient 2, a hospital employee, was diagnosed in May 2011. This employee was a certified nursing assistant in the ED and was working there during Patient 1's second admission. Patient 3, Patient 1's spouse, was diagnosed in June 2011.

A contact investigation of employees initially focused on employees exposed to Patient 1. However, this was broadened to all employees, including those without direct patient contact. Most employees were screened in a 3-month period starting in April 2011. For CDC's Division of TB Elimination investigation, a TST conversion was defined as an employee with a new positive TST in 2011 who had a previous negative TST after July 12, 2010. This date was chosen to ensure that a TST conversion was appropriately attributed to Patient 1; another active TB patient was hospitalized around that time. Excluded employees included those who were not tested or those who had a prior positive TST, no baseline TST, or a baseline TST before July 12, 2010.

Of 46 employees who reported exposure to Patient 1, 19 (41%) were excluded. Of the remaining 27 employees, 6 (22%) had TST conversions, including Patient 2, the employee with active TB. Of the 1,087 employees who had not reported exposure to Patient 1, 321 (30%) were excluded. Of the remaining 766, 5 (1%) had TST conversions. Employees exposed to Patient 1 were 34 times more likely than employees who were not exposed to Patient 1 to have a TST conversion. This finding suggested that transmission in the workplace was responsible for the employee conversions.

The investigation also found that delays in placing patients in respiratory AII contributed to this outbreak. For the three TB patients, the length of time in the hospital without isolation ranged from 7 hours to 7 days. Although all patients presented with respiratory symptoms, symptom recognition and consideration of TB as a diagnosis were delayed. Thus, respiratory protection was not used, placing employees at risk for TB.

To complement the CDC's Division of TB Elimination investigation, management representatives at the medical center asked NIOSH for assistance regarding the medical center's TB-related infection control and occupational health practices.

The purpose of our evaluation was to (1) investigate the incidence of active TB and latent TB infection among hospital employees from 2009–2011; (2) assess the medical center's TB-related administrative, engineering, and PPE controls; and (3) make recommendations to improve TB-related occupational health and infection control practices.

In response, we (1) reviewed the medical center's TB-related occupational health and infection control policies and practices, (2) evaluated the ventilation in the hospital's AII rooms and sputum booth, (3) held confidential medical interviews with employees and reviewed pertinent medical records, and (4) observed respirator fit testing of two employees.

Review of Tuberculosis-Related Occupational Health and Infection Control Policies and Practices

Prior to the visit, we reviewed the medical center's tuberculosis control program policy, which was last revised on December 18, 2008. We also obtained TB-related training materials for employees and historical employee TST screening records from 2004–2011.

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, Minnesota) and used smoke tubes to visualize airflow in the doorways. We also obtained airflow measurements from supply diffusers and ducted exhausts in all AII patient rooms, bathrooms, and adjacent anterooms to assess the potential for dissemination of airborne *Mycobacterium tuberculosis*. We calculated ACH using the exhaust airflow in these rooms. Airflow measurements were made with a TSI® Accubalance® Plus air capture hood (TSI, Inc., Shoreview, Minnesota). We also reviewed the ventilation controls and service records for the sputum booth in the respiratory therapy department.

Confidential Medical Interviews and Medical Record Review

We selected 42 current and former hospital employees to participate in individual semistructured confidential interviews. These employees were selected because they were reported to have a TST conversion since November 2009 and/or were 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. Of these 42 employees, 22 were reported to have had exposure to Patient 1 in January 2011 but were found to have negative TSTs. The other 20 were reported to have had a TST conversion since November 2009; 11 of these 20 were reported to have had exposure to Patient 1 in January 2011. 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 they had. We supplemented the information gathered 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 those employees who were documented as working in the ACU, ICU, or ED while Patient 1 was not in AII. 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, North Carolina). All statistical tests were 2-tailed, with a *P* value of less than 0.05 considered statistically significant.

Observation of a Respirator Fit-testing Session

We observed a qualitative respirator fit-testing session in which two employees were fit tested at the hospital. We listened to fit-testing instructions given to employees being fit tested and noted specific procedures used for qualitatively fit testing the respirators.

Review of Tuberculosis-Related Occupational Health and Infection Control Policies and Practices

As stated in the medical center's tuberculosis control program policy, the key program personnel are a TB control officer and a TB technician. The TB control officer is responsible for following active TB cases, providing consultation to the medical staff, supervising the chest clinic, keeping current with treatment and other related developments in TB, and providing in-service training and community education as needed. The TB technician is appointed and supervised by the tribe's TB control program and is not a hospital employee. The TB technician provides guidance and assistance to the medical center and is responsible for community contact investigations. The technician also assists with TST testing of hospital employees. The TB technician position had not been continuously filled for close to 2 years. TB technicians from surrounding service units were intermittently staffing this position while continuing to staff their own service unit. At the time of our evaluation, a TB technician and a public health nurse were working together on the TB contact investigations.

The ICP was responsible for all infection control and occupational health activities at the medical center at the time of our visit. These activities also included employee TST screening and administration of the employee respiratory protection program.

Tuberculosis Screening Program

TST testing of all new employees was required on hire, and two-step testing was performed if more than a year had elapsed since the employee's last test. Exceptions included employees with a TST within the past 3 months, a previously positive TST, or an allergy to the test components. Employees with previously positive TSTs or an allergy were required to have a chest x-ray.

Annual TST testing of all employees with face-to-face patient contact was required. Testing was optional for employees without face-to-face patient contact until the spring of 2011, when the outbreak occurred. Test results, including conversion rates, were logged and reviewed by the employee health clinic, TB control program, and the ICP. Employees who converted were evaluated clinically, offered therapy for latent TB infection, and followed by the medical center's chest clinic. Employees with previous positive TST results did not undergo further TST testing, but had an annual symptom evaluation.

Results (continued)

From 2004–2006, the TST screening program did not distinguish between employees with and without face-to-face patient contact; screening was required for all employees. Beginning in 2007, the program did make this distinction as described above. Annual compliance percentages for TST screening from 2004–2011 are shown in Figure 1. Of those employees with previously negative TST results, annual compliance percentages for TST screening fluctuated from 56%–94% from 2004–2011. From 2007–2011 when the program distinguished between employees with and without face-to-face patient contact, annual compliance rates for TST screening fluctuated from 71%–94% for employees with face-to-face patient contact and 34%–93% for employees without face-to-face patient contact. The 2011 numbers were as of mid-August 2011.

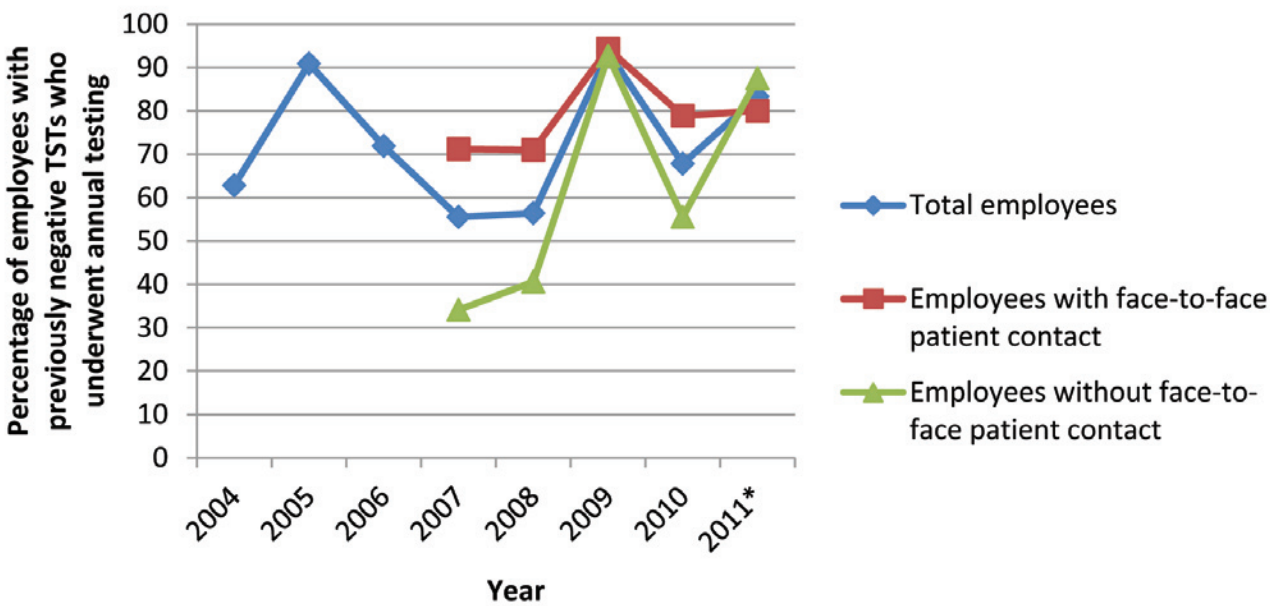

Figure 1. Annual compliance percentages for TST screening among employees with a previously negative TST.
*Note that the percentages for 2011 were as of mid-August 2011.

The annual percentages of employees who had a TST placed but did not return for reading ranged from 0%–16% between 2004 and 2011 (Figure 2). The year 2010 had the highest percentage of employees who did not return for reading at 16%.

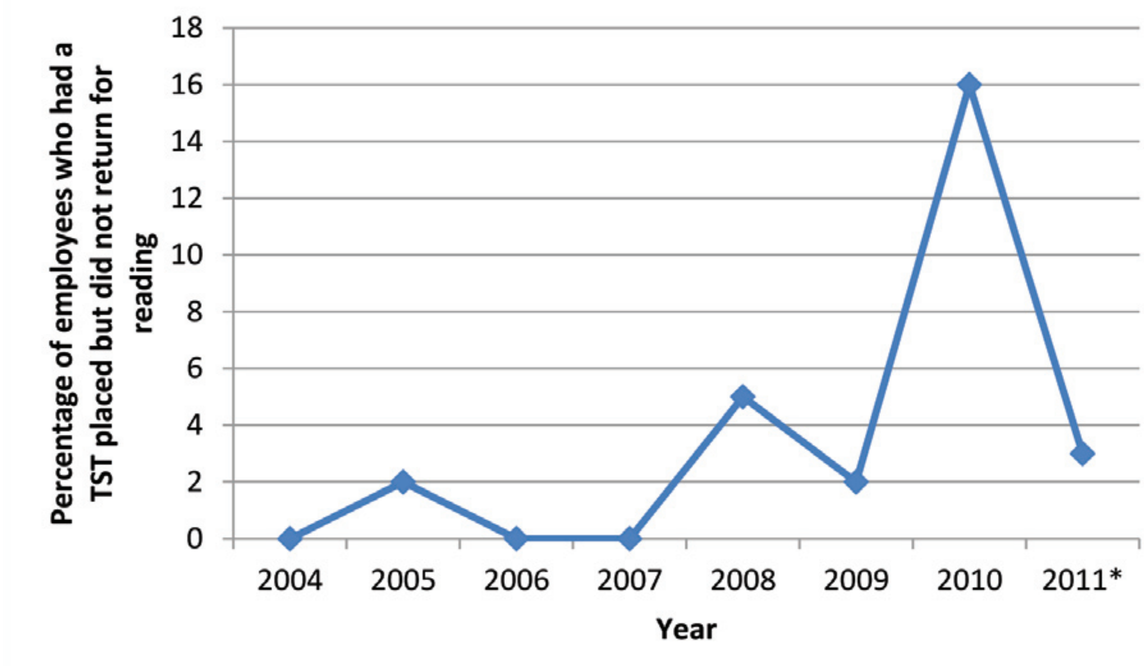

Figure 2. Annual percentages of employees who had a TST placed but did not return for reading.
*Note that the percentages for 2011 were as of mid-August 2011.

Annual percentages of employees tested who had new positive TSTs ranged from 0%–2.3% for all employees from 2004–2011 (Figure 3). From 2007–2011, annual percentages of employees with new positive TSTs ranged from 0.2%–3.6% for employees with face-to-face patient contact and 0%–0.9% for employees without face-to-face patient contact. Again, the 2011 numbers were as of mid-August 2011. The percentage of employees with new positive TSTs was higher for those without face-to-face patient contact than for those with face-to-face patient contact during 2008 (0.8% vs. 0.2%) and 2009 (0.9% vs. 0.4%). The year 2011 saw a significant increase in the percentage of employees with face-to-face patient contact with new positive TSTs though the percentage of employees without face-to-face patient contact remained stable.

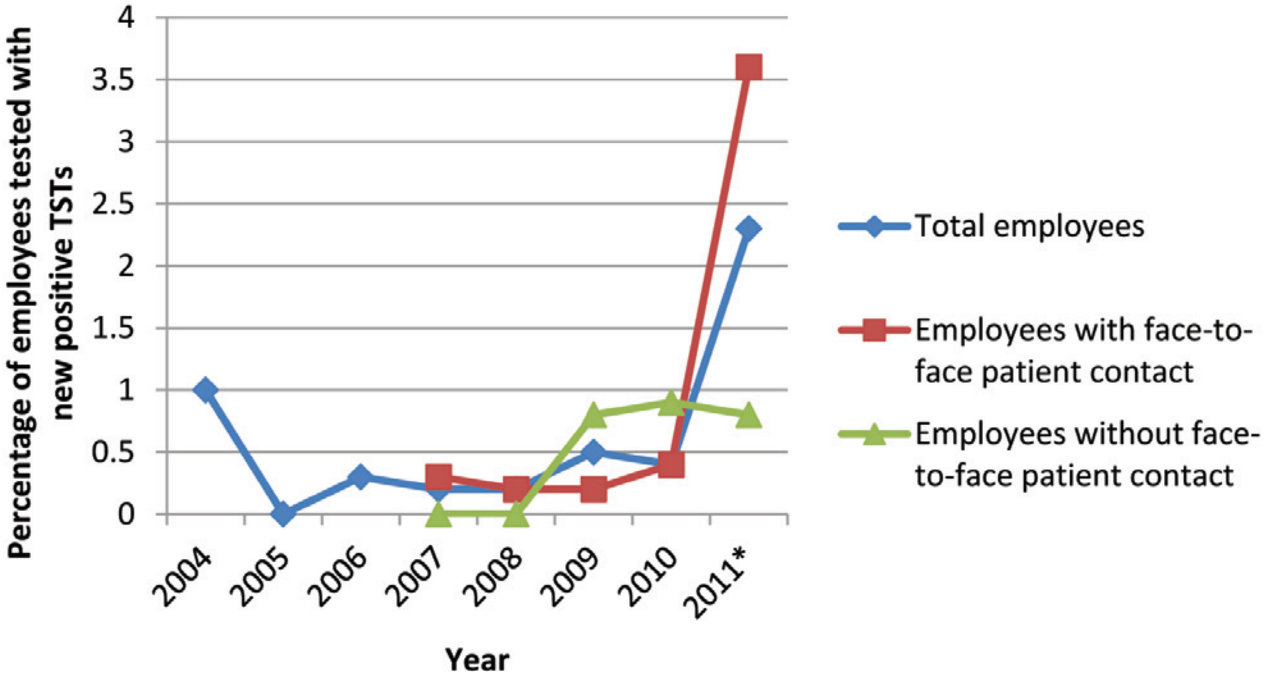

Figure 3. Annual percentages of employees tested with new positive TSTs.
*Note that the percentages for 2011 were as of mid-August 2011.

Respiratory Protection Program

At the time of our HHE, the employee respiratory protection program was administered by the ICP. This program was a component of the medical center's tuberculosis control program policy. The program contained all of the basic elements required by the OSHA respiratory protection standard, including respirator selection, medical evaluation, respirator training, fit testing, respirator use, and handling of disposable respirators [29 CFR 1910.134].

The medical center's written fit-testing procedures included all the elements required by the OSHA respiratory protection standard [29 CFR 1910.134]. The program required medical clearance prior to fit testing. Employees were required to complete a medical questionnaire, which contained all of the questions in the OSHA Respirator Medical Evaluation Questionnaire, Appendix C, to the OSHA respiratory protection standard [29 CFR 1910.134].

Figure 4. The 3M 1860 N95 respirator in the regular size stocked by the hospital. Photo © 2011 3M Company. All rights reserved.

Figure 5. The 3M 1870 respirator stocked by the hospital. Photo © 2011 3M Company. All rights reserved.

Figure 6. The Kimberly-Clark PFR95 respirator stocked by the hospital. Photo © 2006 Kimberly-Clark Worldwide, Inc. All rights reserved.

The hospital stocked four N95 filtering facepiece respirators. These included the 3M™1860 (small and regular sizes), 3M™ 1870 regular size, and Kimberly Clark PFR95 models, all of which were NIOSH-approved (Figures 4–6).

Additionally, the hospital stocked loose-fitting PAPRs (MAXAIR® cuff system by Bio-Medical Devices Intl.) (Figure 7). Units were pre-assembled in Sterile Processing and were available in the ACU, ICU, walk-in clinic, radiology, ED, sterile processing, and the infection control/employee health office. Employees were trained annually on use and care of the PAPRs. After each training session, they took a quiz, which was filed in their employee health record.

Ventilation Assessment

At the time of our visit, the hospital maintained 18 AII rooms, including eight rooms each in the ACU (Q8, Q9, Q10, Q11, Q12, Q17, Q18, Q19) and pediatric unit (R9, R11, R12, R14, R21, R23, R24, R26), and one room each in the ICU and ED. The AII rooms were often used as standard patient rooms as well. 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. The AII rooms in the pediatric unit also had additional doors directly between the AII rooms and adjacent hallways allowing healthcare personnel to bypass the anteroom to enter the patient room. We were told that when patients with airborne infectious diseases were placed in these AII rooms, the doorway between the hallway and AII room was kept shut, and hospital staff entered and exited the AII room via the anteroom doorway. The ICU AII room had an anteroom and a doorway between the AII room and adjacent ICU suite (similar to the pediatric AII room design). The ED AII room opened directly to the ED (i.e., it had no anteroom).

The HVAC systems serving the isolation rooms were installed approximately 12 years ago. They were constant air volume systems, meaning that the airflow rate in these areas remained steady throughout the day, but the air temperature varied depending on the thermostat set points. The AII rooms in the hospital had single pass ventilation; all air was directly exhausted to the outside on the roof of the hospital via ducts. These rooftop exhausts were located more than 25 feet away from any outdoor air intakes and were appropriately labeled. The hospital engineering staff reported that the HVAC supply ducts delivered approximately 10% of outdoor air in the summer and up to 100% outdoor air in the winter, depending on the outdoor temperature.

Figure 7. The MAXAIR® cuff system, a PAPR system, stocked by the hospital. Photo © 2004–2010 Bio-Medical Devices International. All rights reserved.

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 AII room in the ED. These room pressure monitors allowed staff to change damper settings on ducted air returns in the AII rooms, which changed 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 is 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. 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 ago. Many of the relative pressure readings on the electronic door monitors were much different than the readings we observed with our calibrated micromanometer (Table A1).

The results of pressure measurements for AII rooms are presented in the Appendix. When the electronic sensors were placed in the negative pressure mode, six AII rooms were under positive or neutral pressure relative to the anterooms and/or hallways. These included rooms Q8, Q11, Q12, Q17, R11, and R21. All of the other AII rooms in the ACU (R9, R12, R14, R23, R24, R26), pediatric unit (Q9, Q10, Q18, Q19), and the AII room in the ED (ED6) were under negative pressure relative to adjacent areas. The ICU AII room 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 ICU AII 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 airflow measurements and calculated ACH rates for AIIs and anterooms are also found in the Appendix. The airflow values are presented as an average of three measurements. All but one of the AII rooms under negative pressure relative to adjacent anterooms or hallways had more than 6 ACH based on the amount of air exhausted from the patient room (note: ACH calculations did not include exhaust measurements from adjacent patient room bathrooms). Rooms with more than 6 ACH included R12, R14, R23, R24, R26, Q9, Q10, Q18, Q19, ER6, and the ICU AII rooms. AII room R9 was calculated to have 5.7 ACH. Airflow measurements were collected in the 13 anterooms that served the AII rooms. The calculated ACH, on the basis of exhaust airflow in these anterooms, ranged from 0–33.6 ACH. Seven of the thirteen anterooms (R9/R11, R21/R23, R24/R26, Q8, Q9, Q12, and Q19) provided fewer than 10 ACH. When AII rooms were occupied by patients with potentially 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. Hospital managers indicated that closing this door made it difficult to observe patients in AII rooms.

An Emerson 7-AT sputum induction chamber sputum booth in the respiratory therapy department was used to collect sputum samples from suspected TB patients approximately three to four times per year. According to the manufacturer, the chamber supplied a variable airflow rate from 150 to 270 CFM, which is equivalent to a rate of 250 to 460 ACH. Air was drawn into the booth via an inlet with a pre-filter on the top of the booth. Air was passed through a large filter on the back of the booth and exhausted back into the room. Internal alarms indicated when the blower malfunctioned, when leaks in the chamber occurred, or when filters needed changing. We were unable to access the exhaust air filter to determine the type of filter present. Using smoke, we determined that air was flowing in the correct direction (i.e., exhausted through a large filter on the back of the unit). The unit was serviced twice per year by a contractor according to manufacturer specifications and documented in service records. The unit was last serviced in February 2011; it was scheduled for service again in August 2011.

Confidential Medical Interviews and Medical Record Review

Of the 42 employees selected for interviews, 39 employees (93%) participated by phone or in person; we were unable to reach three employees. These 39 employees included 19 (95%) of 20 employees reported to have had a TST conversion since November 2009 and 20 (91%) of 22 employees who were reported to have had exposure to Patient 1 when that patient was not in AII in January 2011 but were found to have a negative TST. We reviewed employee health clinic records and other pertinent medical records for all 20 employees reported to have had a TST conversion since November 2009.

For the 40 employees who completed interviews and/or who had medical records reviewed, the median age was 37 years, with a range of 22 to 63 years. Thirty-three (82%) were female; 18 (45%) were American Indian, 17 (42%) were white, 2 (5%) were Asian American, and 2 (5%) considered themselves an "other" race.

Thirty-nine (98%) of the 40 employees had face-to-face contact with patients during their work. The median amount of time the 39 interviewed employees reported working at the hospital was 2 years, with a range of 9 months to 32 years. Other work characteristics are shown in Table 1.

Table 1. Work characteristics of employees who completed interviews and/or who had medical records reviewed

Work Characteristic	No. (%) Employees n = 40
Job title	
Registered nurse	17 (42)
Certified nursing assistant	10 (25)
Physician	4 (10)
Medical support assistant	6 (15)
Other	3 (8)
Primary department	
Adult care unit	24 (60)
Emergency department	7 (18)
Patient registration	2 (5)
Intensive care unit	2 (5)
Other	5 (12)

Eight (21%) of the 39 interviewed employees reported having attended general TB training during their employment at the hospital. Thirty-one (79%) correctly identified at least two symptoms of active TB, but some employees did not know the difference between latent and active TB. We also heard various answers on procedures for a patient suspected of having active TB and for an employee exposed to a patient with active TB. Thirty-seven (95%) of the 39 interviewed employees reported having annual TSTs prior to our visit.

Regarding respiratory protection, 37 (95%) of the 39 interviewed employees reported having access to an N95 respirator or PAPR during their employment at the hospital though some reported that N95 respirators were difficult to find. Thirty (77%) reported having undergone respirator training since they started work at the hospital, with most reporting that they had undergone training on use of the PAPRs and not the N95 respirators. Twenty-five (64%) reported that they had respirator fit testing since starting work at the hospital, and 23 reported being successfully fitted. Although some employees reported fit testing within the past year, others had not been fit tested in 10 years. Nineteen reported knowing what respirator they were fitted for either by model or by description. Twelve (31%) reported ever wearing another respirator they had not been fitted for during their employment.

Of the 31 employees reporting contact with any patient suspected or known to have active TB disease, 27 (87%) reported always wearing a fit-tested N95 respirator or PAPR, 3 (10%) reported sometimes wearing either, and 1 (3%) reported never wearing either.

Employee with Healthcare Associated Active Tuberculosis

When diagnosed on May 11, 2011, the employee with active TB was working as a certified nursing assistant in the hospital's ED. The employee had no pertinent medical history that increased the risk of the employee for active TB and was diagnosed after multiple ED presentations for cough and shortness of breath beginning March 8, 2011. The employee was treated with antibiotics and steroids for presumptive pneumonia. The employee again sought medical care and was hospitalized on April 20, 2011. The employee's sputum AFB smear was negative on April 20, 2011, and the culture became positive for *Mycobacterium tuberculosis* on May 11, 2011, after the hospital discharge. The employee was readmitted to an AII room in the hospital, started on a standard 4-drug TB regimen, discharged, 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 active TB disease, a review of the ED shift records found that the employee was working during a January 24, 2011, ED shift when Patient 1 was evaluated without being placed in AII.

Employees with a Tuberculin Skin Test Conversion in 2011

We excluded one of the 19 employees reported to have a TST conversion in 2011 from subsequent analysis. This employee, who was a new hire within the last year, reported a previous negative baseline TST, but this negative result was not documented.

The median age of the 18 employees with documented TST conversion in 2011 was 40 years, with a range of 22 to 63 years. Fifteen (83%) were female. Eleven (61%) were American Indian, five (28%) were white, 1 (6%) was Asian American, and one (6%) was an "other" race.

Their job titles included certified nursing assistant (n = 7), medical support assistant (n = 4), registered nurse (n = 3), physician (n = 3), and other (n = 1). Primary departments worked included ACU (n = 9), patient registration (n = 2), ED (n = 2), and ICU (n = 1). The other four worked in various locations. Seventeen (94%) of the 18 employees reported having face-to-face contact with patients during their job.

Fourteen (82%) of the 17 interviewed employees with TST conversions reported having face-to-face contact with a patient known to have active TB in the prior past year. None of the 17 interviewed employees reported having face-to-face contact with anyone in their household or community known to have active TB, and three reported having face-to-face contact with someone else known to have active TB (such as a coworker). Ten (56%) of the 18 employees with TST conversions were documented in hospital records as having worked in the hospital during Patient 1's stay when that patient was not in AII. Two (11%) of the 18 employees with TST conversions had no known face-to-face contact with anyone known to have active TB.

Four (22%) of the 18 employees with TST conversions had an underlying medical condition that put them at greater risk of progression to active TB. Seventeen (94%) employees with TST conversions had undergone medical evaluation for their TST conversion at the time of the interviews. The other one was waiting to be seen. Twelve of these 17 employees were seen in the medical center's chest clinic. Of the 16 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, and 2 (15%) of 13 had prematurely discontinued treatment by the time of the interviews.

Characteristics Associated with Tuberculin Skin Test Conversion

We compared characteristics of 8 non-physician employees with a TST conversion in 2011 and 17 non-physician employees without a TST conversion, all of whom were documented to have worked in the ACU, the ICU, or the ED while Patient 1 was not in AII. We excluded physicians from the analysis because we were not able to obtain staffing records for all physicians working while Patient 1 was not in AII.

Age and the number of years worked at the hospital were not significantly associated with TST conversion. However, working as a certified nursing assistant was significantly associated with having a TST conversion (75% vs. 18%, *P* = 0.01). Additional results of this analysis are shown in Table 2. No other risk factors for TST conversion were identified.

Table 2. Characteristics associated with having a tuberculin skin test conversion

Variable	No. (%) employees with TST conversion n = 7 or 8*	No. (%) employees without TST conversion n = 17	*P* value
American Indian race	6 (75)	5 (29)	0.08
Certified nursing assistant	5 (75)	3 (18)	0.01
Work primarily in ACU	6 (75)	13 (76)	1
Have underlying high-risk condition	1 (12)	0 (0)	0.3
Knew at least two active TB symptoms	5 (71)	14 (82)	0.6
Reported access to respiratory protection	7 (100)	17 (100)	1
Underwent respirator training	5 (71)	15 (88)	0.6
Underwent respirator fit testing	4 (57)	11 (61)	0.7
Ever wore a non-fit tested respirator	4 (57)	5 (31)	0.4

*Sample size varied because one employee was not interviewed but information was gathered from hospital records.

Observation of a Respirator Fit-testing Session

At the time of our visit, the medical center's fit-testing session included N95 respirator training with no stand-alone training session for these types of respirators. During the two fit tests, we observed deficiencies in the respirator training components as required by the OSHA respiratory protection standard [29 CFR 1910.134]. For example, the training we observed did not include information on the limitations and capabilities of the respirator or procedures for maintenance and storage of the respirator.

The medical center employed qualitative fit testing, consisting of a sensitivity test and a fit test using saccharin. Both employees whose fit tests we observed passed their tests. Although the medical center's written fit-testing procedures included all the elements required by the OSHA respiratory protection standard [29 CFR 1910.134], we noted the following deviations from these procedures.

- During the first fit test, the employee had the top strap of the Kimberly Clark PFR95 respirator placed correctly over the ear and high at the top back of his head, but the bottom strap was incorrectly placed above his ears rather than below the ears. During the second fit test, the employee had the upper strap of the 3M 1860 respirator crossed over the lower strap, and both were positioned low on her head. Neither of these inappropriate placements was corrected by the fit tester. Typically, for N95 respirators, when head straps are placed properly, the lower strap should be worn around the neck, below the ears. The top strap should sit above the ears and around the crown of the head, securing the filtering facepiece respirator to the user's face [NIOSH 2011]. Failure to wear a respirator as designed compromises the fit and leads to insufficient protection.
- Only one of the two employees was given a mirror to assist with positioning the respirator on the face. Part 1, Section A.1 of Appendix A of the OSHA respiratory protection standard, states that "A mirror shall be available to assist the subject in evaluating the fit and positioning of the respirator" [29 CFR 1910.134].

Results (continued)

- Neither employee wore their respirator for the recommended 5 minutes to test for comfort [29 CFR 1910.134].
- The medical center's tuberculosis control program policy states that each exercise shall be performed for 1 minute, and the aerosol concentration should be replenished using half of the original number of squeezes every 30 seconds. This protocol was not followed. The test exercises were not timed, many lasted less than 1 minute, and the aerosol concentration was not replenished every 30 seconds.

Discussion

Healthcare personnel in the United States have been shown to be at higher risk of acquiring TB than the general population [Menzies et al. 2007]. In the United States, multiple healthcare-associated TB outbreaks have been reported with both patient-to-patient and patient-to-healthcare personnel transmission occurring [Cookson and Jarvis 1997]. Consistently, the most important factor favoring nosocomial transmission has been close contact with patients with unrecognized active TB disease [Craven et al. 1975; Catanzaro 1982; Kantor et al. 1988; Pearson et al. 1992; Griffith et al. 1995].

In our evaluation, a noticeable increase in the number of employees with a TST conversion occurred in 2011. Of the 18 conversions, 10 occurred in employees documented in hospital records as having worked in the hospital during a single active 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 active TB as a diagnosis, and subsequent AII and respiratory protection usage 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, and respiratory therapists are at high risk [Catanzaro 1982; Dooley et al. 1992; Zaza et al. 1995; Boudreau et al. 1997]. Most studies have grouped nursing assistants, also known as nursing technicians or nurse aides, together with registered nurses. One study, separating nursing assistants from registered nurses, showed that nursing assistants had higher rates of TST conversion [Ball 1997]. Nursing assistants, medical support assistants, and clerks are among the first healthcare personnel to encounter a patient in the

Discussion (continued)

ED or on admission to an inpatient unit before a determination of isolation precautions has been made. 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 immediately 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; this task requires 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, which may have facilitated TB transmission.

Although the medical center's tuberculosis control program policy is comprehensive, our investigation revealed gaps in the implementation of the administrative, engineering, and PPE controls. It is likely that some of these deficiencies contributed to the outbreak at the hospital.

First, the TB technician position was not continuously filled for close to 2 years before our investigation. During this time, the ICP was responsible for all infection control and occupational health activities at the medical center. These activities include employee TST screening and administration of the employee respiratory protection program. Having a permanent TB technician, an ICP, and an employee health nurse will facilitate managing the medical center's TB control program and aid in addressing some of the deficiencies we noted.

Second, only 21% of the 39 interviewed employees reported ever having attended any TB training or educational sessions during their employment at the hospital. Our interviews revealed gaps in their knowledge about the symptoms of active TB, the difference between latent and active TB, as well as the procedures for a patient suspected of having active TB and an employee exposed to a patient with active TB. General TB training of all hospital employees is necessary upon hire and annually [CDC 2005].

Third, on the basis of less than full compliance with the TST screening program, efforts to improve and enforce screening should be strengthened. These efforts should include having all eligible employees participate in the testing and return for reading.

Fourth, 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 *Mycobacterium tuberculosis* transmission from patients with active TB disease housed in AII rooms to hospital staff and other patients. The electronic pressure monitors were last calibrated 12 years ago on installation. The relative pressure difference reading on these units were often very different than the readings taken with our calibrated micromanometer. In some cases the electronic pressure monitors indicated that AII rooms were under negative pressure, but our measurements (including visual smoke testing and micromanometer readings) indicated that AII rooms 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 [Pavelchak et al. 2000]. For this reason, CDC recommends daily monitoring of rooms with pressure sensors with smoke tubes or other visual methods when the rooms are used by patients with known or suspected TB.

The electronic door monitors allowed staff to easily switch AII rooms from positive to negative pressure. Though all of the AII rooms were supposed to be in negative pressure mode, we found that the controls for some rooms were in the positive pressure mode and had to be switched to the negative pressure mode before we made our measurements. Additionally, the electronic door monitors allowed users to reverse the dampers in the exhaust ductwork, which added additional confusion to the function of the ventilation system in the AII rooms.

In several AII rooms, airflow parameters including direction of airflow, relative pressure difference between AII rooms and adjacent areas, and calculated ACH did not meet CDC recommendations [CDC 2005]. Smoke that visualized airflow showed that some of the AII rooms were under positive or neutral pressure relative to adjacent anterooms and/or hallways. Additionally, some of the AII rooms had a pressure differential of less than 0.01 inches of water gauge. CDC recommends that AII rooms be under negative pressure relative to adjacent areas and be maintained at a negative pressure greater than 0.01 inches of water gauge [CDC 2005]. CDC also recommends that AII rooms in hospitals constructed or renovated before 2001 have at least 6 ACH. Whenever feasible, the airflow should be increased to 12 ACH [CDC 2005].

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 [CDC 2005]. 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 collect measurements of 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 (ten of thirteen) exhausted more air from these areas than supplied. CDC recommends that for anterooms to function properly, more air should be exhausted from the room than is supplied to it to remove potentially infectious aerosols that can enter from the AII room [CDC 2005]. We also noted that many of the anterooms provided fewer than 10 ACH, based on exhaust airflow. CDC recommends that anterooms provide at least 10 ACH [CDC 2005].

Finally, the hospital uses PAPRs and N95 respirators for protection against TB. While employees were trained to use PAPRs, they were not trained to use N95 respirators separate from the fit-testing session. This training did not include all of the required elements of the OSHA respiratory protection standard [29 CFR 1910.134]. Comprehensive training will help ensure the proper use of respirators by employees, and has been shown to improve the rates of adequate fit by fit testing [Winter et al. 2010]. Also of concern were the reports by almost one third of interviewed employees that they had worn another respirator for which they had not been fitted during their employment. We also observed deficiencies in the fit-testing procedures, particularly concerning placement of the respirators and adherence to the test exercise protocols including the replenishment of aerosol concentration, all of which can invalidate the test.

Our evaluation was subject to limitations. First, our assessment of the ventilation system occurred in August 2011, several months after the three active TB patients were hospitalized. Thus, we were unable to make any conclusions on the adequacy of engineering

Discussion (continued)

controls during that time. Second, we interviewed only a small subset of the more than 1,000 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. Though we interviewed all employees reported to have a TST conversion since November 2009, our comparative sample of employees without a TST conversion was limited to those working in the ED and ACU when Patient 1 was not in AII. Because of the small size of this population, we were unable to control for multiple factors simultaneously. Third, we observed only one fit tester over two fit-testing sessions, so our observations were not likely to be representative of all fit-testing sessions and all fit testers at the medical center.

Conclusions

A health hazard from exposure to *Mycobacterium tuberculosis* existed at this medical center. Our investigation revealed 18 (2.3%) employees with a TST conversion in 2011, and this included one employee diagnosed with active TB. 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. Although the medical center's written tuberculosis control program policy was comprehensive, our investigation revealed gaps in the implementation of administrative, engineering, and PPE controls.

Recommendations

On the basis of our findings, we recommend the actions listed below to create a more healthful workplace. These recommendations include preliminary recommendations given at the closing conference of our site visit as well as additional recommendations based on further analysis of our findings. We encourage the medical center to use a labor-management health and safety committee or working group to discuss the recommendations in this report and develop an action plan. Those involved in the work can best set priorities and assess the feasibility of our recommendations for the specific situation at the medical center. Our recommendations are based on the hierarchy of controls approach according to CDC guidelines [CDC 2005]. This approach groups actions by their likely effectiveness in reducing or removing hazards.

More comprehensive recommendations can be found in CDC's "Guidelines for Preventing the Transmission of *Mycobacterium tuberculosis* in Health-Care Settings, 2005" at http://www.cdc.gov/mmwr/preview/mmwrhtml/rr5417a1.htm?s_cid=rr5417a1_e [CDC 2005].

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 [CDC 2005]. Administrative controls are management-dictated work practices and policies to reduce or prevent exposures to workplace hazards. The effectiveness of administrative changes in work practices for controlling workplace hazards is dependent on management commitment and employee acceptance. Regular monitoring and reinforcement are necessary to ensure that control policies and procedures are not circumvented in the name of convenience.

1. Continue to conduct an annual TB risk assessment using the TB risk assessment worksheet found in CDC's "Guidelines for Preventing the Transmission of *Mycobacterium tuberculosis* in Health-Care Settings, 2005" [CDC 2005]. This assessment serves as an ongoing 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 for employees with direct patient contact should include the procedures for patients known or suspected of having active TB and for reporting healthcare personnel exposure to a patient with active TB. Training should be tailored to education level and clinical role. General training and education materials can be found on CDC's TB website at http://www.cdc.gov/tb/.

3. Hire a permanent TB technician, and consider separating out the duties of the ICP and the employee health nurse.

4. Encourage all triage nurses to offer face masks to any patient who is actively coughing or complains of coughing.

Promptly place any patients with 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.

5. Continue annual TST placement and symptom screening of all employees with face-to-face patient contact during work hours. Define more clearly which employees are considered to have direct patient contact and are required to have annual TST screening. Medical support assistants in patient areas should be considered to have direct patient contact. Enforce the requirement for employee TB screening. Enforcement methods could include disabling privileges to electronic health records or disabling access to patient care areas.

6. Ensure that employees found to have new TST conversions have access to a prompt medical evaluation. Try to accommodate the schedules of employees who work at night.

7. Close the door between the anteroom and adjacent hallway when housing patients with active TB (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 [CDC 2005]. Engineering controls prevent the spread and reduce the concentration of airborne *Mycobacterium tuberculosis* in ambient air. These technologies include local exhaust, ventilation, general ventilation, HEPA filtration, and ultraviolet germicidal irradiation. Engineering controls are very effective in protecting employees without placing primary responsibility of implementation on the employee.

1. Do not use rooms Q8, Q11, Q12, Q17, R11, or R21 as AII rooms because they are under positive pressure. Also, do not use room R9 as an AII room because it is exhausting fewer than 6 ACH. Ensure that hospital staff understand that these rooms should not be used to house patients with known or suspected airborne infectious diseases until changes are made to the rooms to meet AII requirements.

Recommendations (continued)

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 and at least 10 ACH in anterooms, on the basis of exhaust airflow per CDC guidelines [CDC 2005].

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. Until this can be done, do not turn on the exhaust fan in the ICU AII anteroom when housing patients with airborne infectious diseases if employees are using the anteroom as an area to don respirators before entering the AII room.

4. 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.

5. Follow the CDC-recommended schedule for maintaining proper negative pressure in AII rooms [CDC 2005]:
   - 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.
   - If pressure-sensing devices are used in AII rooms occupied by patients with suspected or confirmed TB disease, use smoke tubes or other visual means to check negative pressure daily.
   - If the AII rooms are not being used for patients who have suspected or confirmed TB disease but potentially could be used for such patients, check negative pressure monthly.

6. Instruct staff not to rely on electronic door pressure monitors to determine if rooms are under negative pressure. These monitors were not calibrated regularly and were inaccurate. If the use of the electronic door pressure monitors continues, ensure that they are calibrated periodically according to manufacturer guidelines.

7. Confirm that the exhaust filter in the sputum booth is a HEPA filter.

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 such as AII rooms. PPE is the least effective means for controlling employee exposures. Proper use of PPE requires a comprehensive program, and calls for a high level of employee involvement and commitment to be effective. The use of PPE requires the choice of the appropriate equipment to reduce the hazard and the development of supporting programs such as training, change-out schedules, and medical assessment. PPE should not be relied upon as the sole method for limiting employee exposures.

1. Develop, implement, and maintain a written respiratory protection program for employees to protect against TB and other airborne infectious diseases. All employees who may need to wear respirators should receive training, receive medical clearance, and undergo fit testing annually as defined in the OSHA respiratory protection standard [29 CFR 1910.134].

2. Improve training to include specific indications for respirator use and how to put on, wear, and remove respiratory protection. Consider offering a training session separate from the fit-testing procedures. Having a separate training session that multiple employees can attend may also be time-saving to fit testers. This training should include all required elements defined in the OSHA respiratory protection standard [29 CFR 1910.134].

3. Follow the OSHA respiratory protection standard [29 CFR 1910.134] to ensure that employees use only PAPRs or N95 respirators for which they have been fit tested.

4. Ensure that those conducting fit testing follow the procedures defined in Appendix A of the OSHA respiratory protection standard [29 CFR 1910.134] to ensure the validity of the test. Important components of fit-testing procedures include:

   - Showing the test subject how to put on a respirator, how it should be positioned on the face, and how to determine an acceptable fit. Straps should not be crossed, and a mirror should be available to assist this process.
   - Having the test subject perform a seal check.
   - Describing the fit test, the exercises, and the test subject's responsibilities during the test procedures. The respirator to be tested should be worn for at least 5 minutes before the start of the fit test.
   - Having the test subject perform a taste threshold screening without wearing a respirator to determine whether the individual being tested can detect the taste of saccharin.
   - Performing each test exercise listed in the medical center's tuberculosis control program policy for 1 minute. Every 30 seconds, the aerosol concentration should be replenished using half of the original number of squeezes during the screening test.

5. Repeat fit tests for those employees whose previous fit tests did not include all of the required components of fit testing as defined in Appendix A of the OSHA respiratory protection standard [29 CFR 1910.134].

6. Offer additional training to fit testers to strengthen their knowledge about respirators and their use and to improve the validity of fit-testing procedures.

7. Conduct annual evaluations of the workplace to ensure that the written respiratory protection program is properly implemented, and observe employees to ensure that they are using the respirators properly [29 CFR 1910.134].

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Appendix: Ventilation Measurements

Table A1. Ventilation airflow and pressure measurements and calculated ACH in AII rooms and adjacent anterooms on August 9–11, 2011

Room	Measured supply airflow (CFM)	Measured exhaust airflow (CFM)	Calculated ACH*	Observed air pressure relationship to adjacent area	Pressure differential relative to adjacent area (inches of water gauge)	Observed electronic door pressure monitor reading (inches of water gauge)
ED and ICU						
ED6	161	310	15.6	Negative to ED	−0.0105	No monitor
ICU (anteroom fan on)	284	487	21.4	Negative to ICU suite; slightly positive to anteroom	−0.0140 (ICU suite) +0.0005 (anteroom)	−0.0085
ICU (anteroom fan off)	284	487	21.4	Negative to ICU suite and anteroom	−0.0250 (ICU suite) −0.0250 (anteroom)	+0.115
Anteroom ICU	45	203	33.6	Negative to ICU suite	Not measured	NA
ACU						
Patient room R9	154	94	5.7	Negative to anteroom and hallway	−0.0075 (anteroom) −0.0080 (hallway)	−0.00093
Patient room R11	145	36	2.2	Positive to anteroom and hallway	+0.0060 (anteroom) +0.0060 (hallway)	−0.00160
Anteroom R9/ R11	0	51	7.2	Not measured	Not measured	NA
Patient room R12	207	242	14.5	Negative to anteroom and hallway	−0.0125 (anteroom) −0.0105 (hallway)	Not operable
Patient room R14	185	223	13.4	Negative to anteroom and hallway	−0.0150 (anteroom) Not measured relative to hallway	−0.00635
Anteroom R12/ R14	0	139	17.7	Not measured	Not measured	NA
Patient room R21	193	56	3.4	Positive to anteroom and hallway	+0.0085 (anteroom) +0.0075 (hallway)	−0.0050
Patient room R23	177	197	12.0	Negative to anteroom and hallway	−0.0040 (anteroom) −0.0040 (hallway)	−0.0020

Table A1. Ventilation airflow and pressure measurements and calculated ACH in AII rooms and adjacent anterooms on August 9–11, 2011 (continued)

Room	Measured supply airflow (CFM)	Measured exhaust airflow (CFM)	Calculated ACH*	Observed air pressure relationship to adjacent area	Pressure differential relative to adjacent area (inches of water gauge)	Observed electronic door pressure monitor reading (inches of water gauge)
Anteroom R21/ R23	48	54	6.9	Not measured	Not measured	NA
Patient room R24	187	153	9.3	Negative to anteroom and hallway	−0.0140 (anteroom) −0.0070 (hallway)	Not collected
Patient room R26	219	384	22.9	Negative to anteroom and hallway	−0.0265 (anteroom) −0.0225 (hallway)	−0.0215
Anteroom R24/ R26	0	46	6.0	Not measured	Not measured	NA
Pediatric Unit						
Patient room Q8	264	223	11.2	Neutral to anteroom	−0.0020	−0.00049
Anteroom Q8	37	37	6.7	Not measured	Not measured	NA
Patient room Q9	178	185	10.0	Negative to anteroom	−0.0060	−0.0066
Anteroom Q9	0	0	0	Not measured	Not measured	NA
Patient room Q10	164	224	12.1	Negative to anteroom	−0.01450	−0.0145
Anteroom Q10	0	72	13.2	Not measured	Not measured	NA
Patient room Q11	148	164	9.9	Positive to anteroom	+0.0070	−0.00013
Anteroom Q11	No supply vent	68	11.1	Not measured	Not measured	NA
Patient room Q12	297	86	5.2	Positive to anteroom	+0.012	Not operable
Anteroom Q12	No supply vent	50	8.2	Not measured	Not measured	NA
Patient room Q17	333	251	13.7	Positive to anteroom	+0.0060	−0.00020
Anteroom Q17	51	69	12.6	Not measured	Not measured	NA
Patient room Q18	195	280	15.1	Negative to anteroom	−0.0050	−0.00350
Anteroom Q18	62	88	16.2	Not measured	Not measured	NA
Patient room Q19	172	133	7.2	Negative to anteroom	−0.0060	−0.0097
Anteroom Q19	48	0	0	Not measured	Not measured	NA

* Based on exhaust airflow measurements in patient room

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Acknowledgments and Availability of Report

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found. HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease.

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Copies of this report have been sent to employee and management representatives at the medical center, the state health department, the tribal health department, and the Occupational Safety and Health Administration Regional Office. The report may be viewed and printed at http://www.cdc.gov/niosh/hhe/. Copies may be purchased from the National Technical Information Service at 5825 Port Royal Road, Springfield, Virginia 22161.

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