Evaluation of Ventilation Controls for Tuberculosis Prevention at a Hospital

Todd Niemeier, MS, CIH

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Contents

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The cover photo is a close-up image of sorbent tubes, which are used by the HHE Program to measure airborne exposures. This photo is an artistic representation that may not be related to this Health Hazard Evaluation.

Highlights of this Evaluation

The Health Hazard Evaluation Program received a request from a hospital in Texas. The employer asked us to evaluate the ventilation controls at the facility because latent tuberculosis infections were identified among the staff.

What We Did

- We evaluated the hospital in September 2010.
- We measured ventilation airflow in some airborne infection isolation rooms, airborne infection isolation anterooms, and standard patient rooms.
- We reviewed ventilation test and balance reports in airborne infection isolation rooms and anterooms.
- We evaluated the use of portable air cleaners in standard patient rooms. This included looking at how the air cleaners work and where they were placed in patient rooms.

What We Found

- All of the airborne infection isolation rooms and anterooms in the hospital are exhausted directly to the outside as recommended.
- All but one of the airborne infection isolation rooms that we measured met Centers for Disease Control and Prevention guidelines to provide at least 6 air changes per hour.
- All but one of the airborne infection isolation rooms we measured met Centers for Disease Control and Prevention guidelines to provide a negative pressure greater than or equal to 0.01 inches of water gauge.

What the Employer Can Do

- Follow Centers for Disease Control and Prevention recommendations for airflow rates in airborne infection isolation rooms and anterooms.
- Maintain a sufficient number of airborne infection isolation rooms to house patients with known or suspected active tuberculosis disease.
- Consider the placement of portable air cleaners with high efficiency particulate air filtration and ultraviolet germicidal irradiation in patient rooms to achieve good air mixing.

We evaluated the ventilation in several airborne infection isolation rooms in a hospital in Texas. Most of the airborne infection isolation rooms met the Centers for Disease Control and Prevention recommendation to provide at least 6 air changes per hour; however, one room was well below the recommended level. The anterooms adjacent to the airborne infection isolation rooms should be rebalanced. Recommendations were made to follow the CDC guidelines for air change rates in airborne infection isolation rooms and anterooms and to maintain a sufficient number of airborne infection isolation rooms for patients with known or suspected active tuberculosis.

What Employees Can Do

- Report suspected problems with the ventilation system in airborne infection isolation rooms or anterooms immediately to supervisors.

Abbreviations

ACH	Air changes per hour
AII	Airborne infection isolation
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
CDC	Centers for Disease Control and Prevention
cfm	Cubic feet per minute
HEPA	High-efficiency particulate air
HHE	Health hazard evaluation
HVAC	Heating, ventilating, and air-conditioning
NIOSH	National Institute for Occupational Safety and Health
TB	Tuberculosis
UVGI	Ultraviolet germicidal irradiation

Introduction

The Health Hazard Evaluation Program received a request from managers of a hospital in April 2010. The request asked us to evaluate the ventilation controls on the 6th floor east medical/surgery unit because 35 employees tested positive for exposure to *Mycobacterium tuberculosis* in early 2010 during the hospital's biannual tuberculin skin test screening. At the time the health hazard evaluation (HHE) request was filed, the source of exposure had not been identified. In March 2010 (prior to the HHE request), the Texas Department of State Health Services and the local county health and human services department requested assistance from the Centers for Disease Control and Prevention (CDC), Division of Tuberculosis Elimination, to work with staff at the local health department to identify the source of the infections. The local county health and human services department staff identified a probable source case for the employee tuberculosis (TB) conversions after the HHE request was made. Specifically, a patient with undiagnosed active TB disease was placed in a non-isolation patient room on the 6th floor east medical/surgery unit for approximately 1 month during late 2009. Although this TB contact investigation had been completed by the time of our evaluation, the hospital requested that the HHE Program continue with its evaluation.

During our September 2010 site visit, we met with hospital management and employee representatives to discuss the HHE request; walked through the facility; observed workplace conditions and work processes and practices; and collected environmental and ventilation measurements. We provided an interim report in December 2011.

Tuberculosis

Tuberculosis, 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. 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 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 destroys tissue in their body. They usually have symptoms of TB disease and are capable of spreading TB bacteria to others.

Hospital Background

The hospital was an eight-story structure built in 1983, with an expansion built in 1995. It was a 683,000 square foot building with 441 beds and 1,200 employees. The hospital was maintained by seven full-time engineers. Each of the eight floors had two designated airborne infection isolation (AII) rooms. When an AII room was not available for a person with suspected or confirmed TB or other airborne infectious disease, the person was placed into a room with a portable air cleaner that was fitted with a high efficiency particulate air (HEPA) filter and ultraviolet germicidal irradiation (UVGI).

The hospital was close to the United States-Mexico border. The county's reported TB incidence rate for 2008 was 12.8 per 100,000 population, compared to the national rate of 4.2 per 100,000 population. The hospital's TB policy required TB screening for healthcare workers with direct patient care responsibilities every 6 months by tuberculin skin test or, for those with previous positive tuberculin skin test results, by symptom screening.

Assessment

Two HHE Program industrial hygienists visited the hospital on September 13–14, 2010. During the visit we held an opening meeting with management and employee representatives and walked through the hospital, mechanical rooms, and roof top to observe the ventilation system. We reviewed ventilation plans with the hospital engineering staff and AII room test and balance reports. We obtained airflow measurements at supply diffusers and ducted return vents in multiple AII rooms and adjacent anterooms throughout the hospital (rooms 209, 239, 240, 622, 722, and 759) to assess the potential for dissemination of *M. tuberculosis*. We also obtained airflow measurements in two standard (non-isolation) patient rooms (rooms 602 and 611). These two rooms were chosen because the index TB patient had been housed in these rooms, and hospital managers requested airflow measurements in these areas to better understand the potential for *M. tuberculosis* transmission. We measured airflow in cubic feet per minute (cfm) with a TSI® Alnor® EBT™ Balometer® and calculated the number of air changes per hour (ACH) on the basis of the exhaust airflow for these areas. We measured the pressure difference at the doorway between the AII rooms and adjacent anterooms, between the anterooms and adjacent hallways, and between standard patient rooms and adjacent hallways using a TSI® DP-Calc™ micromanometer. We also used ventilation smoke tubes to visualize airflow at the doorways for the areas listed above. Finally, we evaluated the use of portable air cleaners with HEPA filters and UVGI that were placed in standard patient rooms to house patients with potential airborne infections when AII rooms were not available. This included visually inspecting the units to see how they operated and understand where they were placed in patient rooms.

Results and Discussion

Airborne Infection Isolation Rooms

All of the AII rooms and anterooms in the hospital were exhausted directly to the outside as recommended. Most of the patient rooms had one supply diffuser and one ducted exhaust. Bathrooms attached to the patient rooms had an additional ducted exhaust. Anterooms also had one supply diffuser and one ducted exhaust. The hospital health and safety director reported that for the isolation room on the 6th floor east unit, supply and exhaust air were irradiated in the duct using UVGI for supplemental air cleaning. We did not evaluate this UVGI system. The other isolation rooms in the hospital did not have in-duct UVGI systems. The heating, ventilation, and air-conditioning (HVAC) systems serving the isolation rooms were constant air volume systems, meaning that the airflow rate in these areas remained steady throughout the day but the temperature of the air varied depending on the thermostat set points. The hospital health and safety director reported that the isolation room supply ducts delivered approximately 8%–10% outdoor air to these areas.

The airflow measurements for AII rooms are presented in Table 1. The airflow values are presented as an average of three measurements. When the hospital was constructed in 1983, the AII rooms were designed to provide at least 6 ACH. AII rooms 239, 240, 722, and 759 had greater than 6 ACH on the basis of our exhaust airflow measurements. However, AII room 209 had 3.3 ACH and 622 had 5.8 ACH. ACH calculations did not include exhaust measurements from adjacent patient room bathrooms. CDC recommends that AII rooms in hospitals constructed or renovated prior to 2001 have at least 6 ACH. Whenever feasible, the airflow should be increased to 12 ACH [CDC 2005].

ACH measurements for anterooms that were adjacent to AII rooms are also presented in Table 1. All of the anterooms supplied more air than exhausted and provided less than 2 ACH, on the basis of return airflow. CDC recommends that for anterooms to function properly, more air should be exhausted from the room than supplied to it to remove potential infectious aerosols that can enter from the AII room. CDC also recommends that anterooms in newly constructed or renovated facilities provide at least 10 ACH [CDC 2005].

Table 1. Airflow measurements and air change rates in airborne infection isolation rooms and anterooms on September 13–14, 2010

Room	Measured supply airflow (cfm)	Measured exhaust airflow (cfm)	Calculated ACH*
AIIs			
Room 209	82	78	3.3
Room 239	164	395	14.3
Room 240	341	394	14.3
Room 622	87	118	5.8
Room 722	184	265	11.3
Room 759	122	291	12.3
Anterooms			
Room 209	126	21	1.9
Room 239/240	329	0	N/A
Room 622	66	0	N/A
Room 722	103	7	0.5
Room 759	69	22	1.7

N/A = not applicable

*Based on exhaust airflow measurements

We compared some of the AII room air change rates that we calculated to those found in the hospital's most recent test and balance report from 2009. We noted a large discrepancy between our calculations and those provided in the test and balance report. Upon further review, we determined that the room size measurements used for the 2009 report were incorrect, which affected the subsequent ACH calculations.

The results of the ventilation pressure measurements for AII rooms and anterooms are presented in Table 2. We used smoke to visualize airflow and found that all of the AII rooms were under negative pressure relative to adjacent anterooms. Additionally, all of the AII rooms except room 209 had a negative pressure differential greater than or equal to 0.01 inches of water gauge. CDC recommends keeping AII rooms under negative pressure relative to adjacent areas, and maintaining them at a negative pressure greater than 0.01 inches of water gauge [CDC 2005]. In patient room 209, a television located directly below the exhaust air return hindered exhaust airflow. We informed hospital engineering managers immediately, and they addressed the problem during our site visit and we measured the exhaust airflow in this room. The hospital reported that they conduct a daily visual smoke or tissue test when housing patients with airborne infectious disease in AII rooms.

Table 2. Air pressure measurements obtained in airborne infection isolation rooms and anterooms on September 13–14, 2010

Room	Air pressure relationship to adjacent area	Pressure differential relative to adjacent area (inches of water gauge)
AIIs		
Room 209	Negative to anteroom	−0.005
Room 239	Negative to anteroom	−0.019
Room 240	Negative to anteroom	−0.013
Room 622	Negative to anteroom	−0.013
Room 722	Negative to anteroom	−0.18
Room 759	Negative to anteroom	−0.015
Anterooms		
Room 209	Positive to hallway	+0.007
Room 239/240	Positive to hallway	+0.017
Room 622	Neutral to hallway	+0.001
Room 722	Neutral to hallway	+0.001
Room 759	Negative to hallway	−0.014

The pressure relationship between anterooms and AII rooms and hallways is also presented in Table 2. Anterooms 239/240 and 209 were under positive pressure relative to adjacent hallways, while anterooms 622, 722, and 759 were either under neutral or negative pressure relative to adjacent hallways. CDC and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) indicate that in anterooms, air movement relative to the hallway can be either positive or negative [CDC 2005; ASHRAE 2011]. The Frances J. Curry National Tuberculosis Center [2007] has recommended that AII anterooms be maintained at either neutral or negative pressure with respect to the adjacent hallway and maintained at positive pressure with respect to the AII room.

Standard Patient Rooms

Each standard patient room had a fan coil unit that recirculated and conditioned the air within the room. Additionally, each room had an outdoor air supply on an exterior wall that provided conditioned outdoor air to the room by a fan coil unit. Exhaust air from the patient bathrooms was ducted directly outdoors. No additional return or exhaust ventilation was provided.

Room 602 provided approximately 2 ACH of outdoor air. Room 611 provided less than 0.5 ACH of outdoor air. ASHRAE recommends that patient rooms provide a minimum of 2 ACH of outdoor air and 6 ACH of total air [ASHRAE 2011].

Smoke tubes showed that both patient rooms were under slight positive pressure relative to adjacent hallways. The pressure differential in Room 602 was measured at +0.003 inches of water gauge relative to the adjacent hallway. In Room 611, the pressure differential was measured at +0.001 inches of water gauge relative to the adjacent hallway. ASHRAE does not have a recommendation for the pressure relationship between standard patient rooms and adjacent areas [ASHRAE 2011] because these rooms should not be used for patients with known or suspected airborne infectious diseases.

Portable Air Cleaners

When AII rooms were at full capacity, non-isolation patient rooms equipped with portable air cleaners with HEPA filtration and UVGI were used to house potentially infectious patients. Our review of the manufacturer's performance specifications of these filtration units indicate that they reportedly provided 650 cfm on the high speed fan setting and 450 cfm on the low speed fan setting. The hospital used these units to recirculate air within the room. Thus this unit did not alter the room's pressure relationship to adjacent hallways. The standard patient rooms were not under negative pressure relative to the adjacent hallways when the portable air cleaners were in use. This could allow *M. tuberculosis* aerosols, if present, to pose an infection risk to other hospital staff.

The portable air cleaners were capable of being modified to exhaust air directly outside, and could be used to place the room under negative pressure relative to the adjacent hallway. CDC discusses the use of portable air cleaners to augment the general ventilation system and recommends that they provide greater than 12 equivalent ACH [CDC 2005]. These types of units have been demonstrated to be effective in removing bioaerosols and aerosolized particles from room air [CDC 2005]. However, the effectiveness can vary depending on the room's configuration, the furniture and persons in the room, the placement of the HEPA filtration unit compared with the supply diffusers and exhaust grilles, and the degree of mixing of air within the room [CDC 2005].

Conclusions

The hospital had an adequate ventilation system for most of the AII rooms to help reduce the risk of exposures to *M. tuberculosis.* However, one AII room was slightly below the CDC recommendation of 6 ACH for existing facilities (5.8 ACH), while another AII room only had 3.3 ACH. We noted a discrepancy between our calculated air change rates and the contractor's rates which we believe resulted from an error in their room size measurements. The hospital used portable air cleaners with HEPA filtration and UVGI in standard patient rooms when AII rooms were unavailable to house patients with airborne infectious disease. Though these recirculating units have been demonstrated to be effective in removing bioaersols from room air, their effectiveness can vary, and they are considered supplemental ventilation units. They should not be relied on in place of maintaining a sufficient number of AII rooms that meet the CDC guidelines.

Recommendations

On the basis of our findings, we recommend the actions listed below to create a more healthful workplace. We encourage the hospital 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. Our recommendations are based on the hierarchy of controls approach which groups actions by their likely effectiveness in reducing or removing hazards. In most cases, the preferred approach is to eliminate hazardous materials or processes and install engineering controls to reduce exposure or shield employees. Until such controls are in place, or if they are not effective or feasible, administrative measures and/or personal protective equipment may be needed.

Engineering Controls

Engineering controls reduce exposures to employees by removing the hazard from the process or placing a barrier between the hazard and the employee. Engineering controls are very effective at protecting employees without placing primary responsibility of implementation on the employee.

1. Ensure that room volume is correctly measured when calculating air change rates for AII rooms.
2. Provide at least 6 ACH in all AII rooms. Twelve air changes per hour are recommended for new or renovated healthcare settings and whenever feasible, including the use of supplemental ventilation to increase the number of equivalent air changes per hour [CDC 2005].
3. Modify the outdoor air supply vent located in room 611 to provide at least 2 ACH, as recommended by ASHRAE [2011].
4. Maintain enough AII rooms to provide airborne precautions for all patients who have suspected or confirmed TB disease on the basis of a risk assessment for the hospital [CDC 2005]. When using portable air cleaners to augment the general ventilation carefully consider the placement of these units so that maximum air mixing is achieved. These units should provide greater than 12 equivalent ACH and should be placed away from obstacles, such as furniture, medical equipment, and walls. If these units are used as a temporary measure in non-isolation rooms, they should be exhausted directly outside, the rooms should be maintained under negative pressure, and there should be no recirculation of room air to other parts of the facility.

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