recommendations for management of patients with suspected or confirmed TB disease and the specific recommendations for EDs (see Intensive Care Units [ICUs]). The risk assessment may be used to determine the need for or selection of environmental controls and the frequency of testing HCWs for *M. tuberculosis* infection.

Dialysis Units

Certain patients with TB disease need chronic dialysis for treatment of ESRD (*179–181*). The incidence of TB disease and infection in patients with ESRD might be higher than in the general population (*181–183*) and might be compounded by the overlapping risks for ESRD and TB disease among patients with diabetes mellitus (*39*). In addition, certain dialysis patients or patients who are otherwise immunocompromised (e.g., patients with organ transplants) might be on immunosuppressive medications (*162,183*). Patients with ESRD who need chronic dialysis should have at least one test for *M. tuberculosis* infection to determine the need for treatment of LTBI. Annual re-screening is indicated if ongoing exposure of ESRD patients to *M. tuberculosis* is probable.

Hemodialysis procedures should be performed on hospitalized patients with suspected or confirmed TB disease in an AII room. Dialysis staff should use recommended respiratory protection, at least an N95 disposable respirator. Patients with suspected or confirmed TB disease who need chronic hemodialysis might need referral to a hospital or other setting with the ability to perform dialysis procedures in an AII room until the patient is no longer infectious or another diagnosis is made. Certain antituberculosis medications are prescribed differently for hemodialysis patients (*31*).

Dental-Care Settings

The generation of droplet nuclei containing *M. tuberculosis* as a result of dental procedures has not been demonstrated (*184*). Nonetheless, oral manipulations during dental procedures could stimulate coughing and dispersal of infectious particles. Patients and dental HCWs share the same air space for varying periods, which contributes to the potential for transmission of *M. tuberculosis* in dental settings (*185*). For example, during primarily routine dental procedures in a dental setting, MDR TB might have been transmitted between two dental workers (*186*).

To prevent the transmission of *M. tuberculosis* in dental-care settings, certain recommendations should be followed (*187,188*). Infection-control policies for each dental health-care setting should be developed, based on the community TB risk assessment (Appendix B), and should be reviewed annually, if possible. The policies should include appropriate screening for LTBI and TB disease for dental HCWs, education on the risk for transmission to the dental HCWs, and provisions for detection and management of patients who have suspected or confirmed TB disease.

When taking a patient's initial medical history and at periodic updates, dental HCWs should routinely document whether the patient has symptoms or signs of TB disease. If urgent dental care must be provided for a patient who has suspected or confirmed infectious TB disease, dental care should be provided in a setting that meets the requirements for an AII room (see Environmental Controls). Respiratory protection (at least N95 disposable respirator) should be used while performing procedures on such patients.

In dental health-care settings that routinely provide care to populations at high risk for TB disease, using engineering controls (e.g., portable HEPA units) similar to those used in waiting rooms or clinic areas of health-care settings with a comparable community-risk profile might be beneficial.

During clinical assessment and evaluation, a patient with suspected or confirmed TB disease should be instructed to observe strict respiratory hygiene and cough etiquette procedures (*122*). The patient should also wear a surgical or procedure mask, if possible. Non-urgent dental treatment should be postponed, and these patients should be promptly referred to an appropriate medical setting for evaluation of possible infectiousness. In addition, these patients should be kept in the dental health-care setting no longer than required to arrange a referral.

Nontraditional Facility-Based Settings

Nontraditional facility-based settings include EMS, medical settings in correctional facilities, home-based health-care and outreach settings, long-term–care settings (e.g., hospices and skilled nursing facilities), and homeless shelters. Environmental controls should be implemented based on the types of activities that are performed in the setting.

TB is more common in the homeless population than in the general population (*189–192*). Because persons who visit homeless shelters frequently share exposure and risk characteristics of TB patients who are treated in outpatient clinics, homeless shelters with clinics should observe the same TB infection-control measures as outpatient clinics. ACET has developed recommendations to assist health-care providers, health departments, shelter operators and workers, social service agencies, and homeless persons to prevent and control TB in this population (*189*).

Emergency Medical Services (EMS)

Although the overall risk is low (*193*), documented transmission of *M. tuberculosis* has occurred in EMS occupational settings (*194*), and approaches to reduce this risk have been described (*193,195*). EMS personnel should be included in a comprehensive screening program to test for *M. tuberculosis*

infection and provide baseline screening and follow-up testing as indicated by the risk classification of the setting. Persons with suspected or confirmed infectious TB disease who are transported in an ambulance should wear a surgical or procedure mask, if possible, and drivers, HCWs, and other staff who are transporting the patient might consider wearing an N95 respirator.

The ambulance ventilation system should be operated in the nonrecirculating mode, and the maximum amount of outdoor air should be provided to facilitate dilution. If the vehicle has a rear exhaust fan, use this fan during transport. If the vehicle is equipped with a supplemental recirculating ventilation unit that passes air through HEPA filters before returning it to the vehicle, use this unit to increase the number of ACH (*188*). Air should flow from the cab (front of vehicle), over the patient, and out the rear exhaust fan. If an ambulance is not used, the ventilation system for the vehicle should bring in as much outdoor air as possible, and the system should be set to nonrecirculating. If possible, physically isolate the cab from the rest of the vehicle, and place the patient in the rear seat (*194*).

EMS personnel should be included in the follow-up contact investigations of patients with infectious TB disease. The Ryan White Comprehensive AIDS Resource Emergency Act of 1990 (Public law 101–381) mandates notification of EMS personnel after they have been exposed to a patient with suspected or confirmed infectious TB disease (Title 42 U.S. Code 1994) (http://hab.hrsa.gov/data2/adap/introduction.htm).

Medical Settings in Correctional Facilities

TB is a substantial health concern in correctional facilities; employees and inmates are at high risk (*105,196–205*). TB outbreaks in correctional facilities can lead to transmission in surrounding communities (*201,206,207*). ACET recommends that all correctional facilities have a written TB infection-control plan (*196*), and multiple studies indicate that screening correctional employees and inmates is a vital TB control measure (*204,208,209*).

The higher risk for *M. tuberculosis* transmission in health-care settings in correctional facilities (including jails and prisons) is a result of the disproportionate number of inmates with risk factors for TB infection and TB disease (*203,210*). Compared with the general population, TB prevalence is higher among inmates and is associated with a higher prevalence of HIV infection (*197*), increased illicit substance use, lower socioeconomic status (*201*), and their presence in settings that are at high risk for transmission of *M. tuberculosis*.

A TB infection-control plan should be developed specifically for that setting, even if the institution is part of a multifacility system (*196,211*). Medical settings in correctional facilities should be classified as at least medium risk; therefore, all correctional facility health-care personnel and other staff, including correctional officers should be screened for TB at least annually (*201,203,208*).

Correctional facilities should collaborate with the local or state health department to decide on TB contact investigations and discharge planning (*105,212*) and to provide TB training and education to inmates and employees (*196*). Corrections staff should be educated regarding symptoms and signs of TB disease and encouraged to facilitate prompt evaluation of inmates with suspected infectious TB disease (*206*).

At least one AII room should be available in correctional facilities. Any inmate with suspected or confirmed infectious TB disease should be placed in an AII room immediately or transferred to a setting with an AII room; base the number of additional AII rooms needed on the risk assessment for the setting. Sputum samples should be collected in sputum induction booths or AII rooms, not in inmates' cells. Sputum collection can also be performed safely outside, away from other persons, windows, and ventilation intakes.

Inmates with suspected or confirmed infectious TB disease who must be transported outside an AII room for medically essential procedures should wear a surgical or procedure mask during transport, if possible. If risk assessment indicates the need for respiratory protection, drivers, medical or security staff, and others who are transporting patients with suspected or confirmed infectious TB disease in an enclosed vehicle should consider wearing an N95 disposable respirator.

A respiratory-protection program, including training, education, and fit-testing in the correctional facility's TB infection-control program should be implemented. Correctional facilities should maintain a tracking system for inmate TB screening and treatment and establish a mechanism for sharing this information with state and local health departments and other correctional facilities (*196,201*). Confidentiality of inmates should be ensured during screening for symptoms or signs of TB disease and risk factors.

Home-Based Health-Care and Outreach Settings

Transmission of *M. tuberculosis* has been documented in staff who work in home-based health-care and outreach settings (*213,214*). The setting's infection-control plan should include training that reminds HCWs who provide medical services in the homes of patients or other outreach settings of the importance of early evaluation of symptoms or signs of TB disease for early detection and treatment of TB disease. Training should also include the role of the HCW in educating patients regarding the importance of reporting symptoms or signs of TB disease and the importance of reporting any adverse effects to treatment for LTBI or TB disease.

HCWs who provide medical services in the homes of patients with suspected or confirmed TB disease can help prevent transmission of *M. tuberculosis* by 1) educating patients and other household members regarding the importance of taking medications as prescribed, 2) facilitating medical evaluation of symptoms or signs of TB disease, and 3) administering DOT, including DOT for treatment of LTBI whenever feasible.

HCWs who provide medical services in the homes of patients should not perform cough-inducing or aerosol-generating procedures on patients with suspected or confirmed infectious TB disease, because recommended infection controls probably will not be in place. Sputum collection should be performed outdoors, away from other persons, windows, and ventilation intakes.

HCWs who provide medical services in the homes of patients with suspected or confirmed infectious TB disease should instruct TB patients to observe strict respiratory hygiene and cough etiquette procedures. HCWs who enter homes of persons with suspected or confirmed infectious TB disease or who transport such persons in an enclosed vehicle should consider wearing at least an N95 disposable respirator (see Respiratory Protection).

Long-Term–Care Facilities (LTCFs)

TB poses a health risk to patients, HCWs, visitors, and volunteers in LTCFs (e.g., hospices and skilled nursing facilities) (*215,216*). Transmission of *M. tuberculosis* has occurred in LTCF (*217–220*), and pulmonary TB disease has been documented in HIV-infected patients and other immunocompromised persons residing in hospices (*218,221,222*). New employees and residents to these settings should receive a symptom screen and possibly a test for *M. tuberculosis* infection (see TB Risk Assessment Worksheet).

LTCFs must have adequate administrative and environmental controls, including airborne precautions capabilities and a respiratory-protection program, if they accept patients with suspected or confirmed infectious TB disease. The setting should have 1) a written protocol for the early identification of patients with symptoms or signs of TB disease and 2) procedures for referring these patients to a setting where they can be evaluated and managed. Patients with suspected or confirmed infectious TB disease should not stay in LTCFs unless adequate administrative and environmental controls and a respiratory-protection program are in place. Persons with TB disease who are determined to be noninfectious can remain in the LTCF and do not need to be in an AII room.

Training and Educating HCWs

HCW training and education regarding infection with *M. tuberculosis* and TB disease is an essential part of administrative controls in a TB surveillance or infection-control program. Training physicians and nurse managers is especially essential because of the leadership role they frequently fulfill in infection control. HCW training and education can increase adherence to TB infection-control measures. Training and education should emphasize the increased risks posed by an undiagnosed person with TB disease in a health-care setting and the specific measures to reduce this risk. HCWs receive various types of training; therefore, combining training for TB infection control with other related trainings might be preferable.

Initial TB Training and Education

The setting should document that all HCWs, including physicians, have received initial TB training relevant to their work setting and additional occupation-specific education. The level and detail of baseline training will vary according to the responsibilities of the HCW and the risk classification of the setting.

Educational materials on TB training are available from various sources at no cost in printed copy, on videotape (*223*), on compact discs, and the Internet. The local or state health department should have access to additional materials and resources and might be able to help develop a setting-specific TB education program. Suggested components of a baseline TB training program for HCWs have been described previously. CDC's TB website provides information regarding training and education materials (http://www.cdc.gov/tb). Additional training and education materials are available on CDC's TB Education and Training Resources website (http://www.findtbresources.org) and on other TB-related websites and resources (Appendix E).

Physicians, trainees, students, and other HCWs who work in a health-care setting but do not receive payment from that setting should receive baseline training in TB infection-control policies and practices, the TB screening program, and procedures for reporting an *M. tuberculosis* infection test conversion or diagnosis of TB disease. Initial TB training should be provided before the HCW starts working.

Follow-Up TB Training and Education

All settings should conduct an annual evaluation of the need for follow-up training and education for HCWs based on the number of untrained and new HCWs, changes in the organization and services of the setting, and availability of new TB infection-control information.

If a potential or known exposure to *M. tuberculosis* occurs in the setting, prevention and control measures should include retraining HCWs in the infection-control procedures established to prevent the recurrence of exposure. If a potential or known exposure results in a newly recognized positive TST

or BAMT result, test conversion, or diagnosis of TB disease, education should include information on 1) transmission of *M. tuberculosis*, 2) noninfectiousness of HCWs with LTBI, and 3) potential infectiousness of HCWs with TB disease.

OSHA requires annual respiratory-protection training for HCWs who use respiratory devices (see Respiratory Protection). HCWs in settings with a classification of potential ongoing transmission should receive additional training and education on 1) symptoms and signs of TB disease, 2) *M. tuberculosis* transmission, 3) infection-control policies, 4) importance of TB screening for HCWs, and 5) responsibilities of employers and employees regarding *M. tuberculosis* infection test conversion and diagnosis of TB disease.

TB Infection-Control Surveillance

HCW Screening Programs for TB Support Surveillance and Clinical Care

TB screening programs provide critical information for caring for individual HCWs and information that facilitates detection of *M. tuberculosis* transmission. The screening program consists of four major components: 1) baseline testing for *M. tuberculosis* infection, 2) serial testing for *M. tuberculosis* infection, 3) serial screening for symptoms or signs of TB disease, and 4) TB training and education.

Surveillance data from HCWs can protect both HCWs and patients. Screening can prevent future transmission by identifying lapses in infection control and expediting treatment for persons with LTBI or TB disease. Tests to screen for *M. tuberculosis* infection should be administered, interpreted, and recorded according to procedures in this report (see Supplement, Diagnostic Procedures for LTBI and TB Disease). Protection of privacy and maintenance of confidentiality of HCW test results should be ensured. Methods to screen for infection with *M. tuberculosis* are available (*30,31,39*).

Baseline Testing for *M. tuberculosis* Infection

Baseline testing for *M. tuberculosis* infection is recommended for all newly hired HCWs, regardless of the risk classification of the setting and can be conducted with the TST or BAMT. Baseline testing is also recommended for persons who will receive serial TB screening (e.g., residents or staff of correctional facilities or LTCFs) (*39,224*). Certain settings, with the support of the infection-control committee, might choose not to perform baseline or serial TB screening for HCWs who will never be in contact with or have shared air space with patients who have TB disease (e.g., telephone operators who work in a separate building from patients) or who will never be in contact with clinical specimens that might contain *M. tuberculosis*.

Baseline test results 1) provide a basis for comparison in the event of a potential or known exposure to *M. tuberculosis* and 2) facilitate the detection and treatment of LTBI or TB disease in an HCW before employment begins and reduces the risk to patients and other HCWs. If TST is used for baseline testing, two-step testing is recommended for HCWs whose initial TST results are negative (*39,224*). If the first-step TST result is negative, the second-step TST should be administered 1–3 weeks after the first TST result was read. If either 1) the baseline first-step TST result is positive or 2) the first-step TST result is negative but the second-step TST result is positive, TB disease should be excluded, and if it is excluded, then the HCW should be evaluated for treatment of LTBI. If the first and second-step TST results are both negative, the person is classified as not infected with *M. tuberculosis*.

If the second test result of a two-step TST is not read within 48–72 hours, administer a TST as soon as possible (even if several months have elapsed) and ensure that the result is read within 48–72 hours (*39*). Certain studies indicate that positive TST reactions might still be measurable from 4–7 days after testing (*225,226*). However, if a patient fails to return within 72 hours and has a negative test result, the TST should be repeated (*42*).

A positive result to the second step of a baseline two-step TST is probably caused by boosting as opposed to recent infection with *M. tuberculosis*. These responses might result from remote infections with *M. tuberculosis*, infection with an NTM (also known as MOTT), or previous BCG vaccination. Two-step testing will minimize the possibility that boosting will lead to an unwarranted suspicion of transmission of *M. tuberculosis* with subsequent testing. A second TST is not needed if the HCW has a documented TST result from any time during the previous 12 months (see Baseline Testing for *M. tuberculosis* Infection After TST Within the Previous 12 Months).

A positive TST reaction as a result of BCG wanes after 5 years. Therefore, HCWs with previous BCG vaccination will frequently have a negative TST result (*74,227–232*). Because HCWs with a history of BCG are frequently from high TB-prevalence countries, positive test results for *M. tuberculosis* infection in HCWs with previous BCG vaccination should be interpreted as representing infection with *M. tuberculosis* (*74,227–233*). Although BCG reduces the occurrence of severe forms of TB disease in children and overall might reduce the risk for progression from LTBI to TB disease (*234,235*), BCG is not thought to prevent *M. tuberculosis* infection (*236*). Test results for *M. tuberculosis* infection for HCWs with a history of BCG should be interpreted by using the

same diagnostic cut points used for HCWs without a history of BCG vaccination.

BAMT does not require two-step testing and is more specific than skin testing. BAMT that uses *M. tuberculosis*-specific antigens (e.g., QFT-G) are not expected to result in false-positive results in persons vaccinated with BCG. Baseline test results should be documented, preferably within 10 days of HCWs starting employment.

Baseline Testing for *M. tuberculosis* Infection After TST Within the Previous 12 Months

A second TST is not needed if the HCW has a documented TST result from any time during the previous 12 months. If a newly employed HCW has had a documented negative TST result within the previous 12 months, a single TST can be administered in the new setting (Box 1). This additional TST represents the second stage of two-step testing. The second test decreases the possibility that boosting on later testing will lead to incorrect suspicion of transmission of *M. tuberculosis* in the setting.

A recent TST (performed in ≤12 months) is not a contraindication to a subsequent TST unless the test was associated with severe ulceration or anaphylactic shock, which are substantially rare adverse events (*30,237–239*). Multiple TSTs are safe and do not increase the risk for a false-positive result or a TST conversion in persons without infection with mycobacteria (*39*).

Baseline Documentation of a History of TB Disease, a Previously Positive Test Result for *M. tuberculosis* Infection, or Completion of Treatment for LTBI or TB Disease

Additional tests for *M. tuberculosis* infection do not need to be performed for HCWs with a documented history of TB disease, documented previously positive test result for *M. tuberculosis* infection, or documented completion of treatment for LTBI or TB disease. Documentation of a previously positive test result for *M. tuberculosis* infection can be substituted for a baseline test result if the documentation includes a recorded TST result in millimeters (or BAMT result), including the concentration of cytokine measured (e.g., IFN-γ). All other HCWs should undergo baseline testing for *M. tuberculosis* infection to ensure that the test result on record in the setting has been performed and measured using the recommended diagnostic the recommended procedures (see Supplement, Diagnostic Procedures for LTBI and TB Disease).

A recent TST (performed in ≤12 months) is not a contraindication to the administration of an additional test unless the TST was associated with severe ulceration or anaphylactic

BOX 1. Indications for two-step tuberculin skin tests (TSTs)

Situation	Recommended testing
No previous TST result	Two-step baseline TSTs
Previous negative TST result (documented or not) >12 months before new employment	Two-step baseline TSTs
Previous documented negative TST result ≤12 months before new employment	Single TST needed for baseline testing; this test will be the second-step
≥2 previous documented negative TSTs but most recent TST >12 months before new employment	Single TST; two-step testing is not necessary (result would have already boosted)
Previous documented positive TST result	No TST
Previous undocumented positive TST result*	Two-step baseline TST(s)
Previous BCG† vaccination	Two-step baseline TST(s)
Programs that use serial BAMT,§ including QFT¶ (or the previous version QFT)	See Supplement, Use of QFT-G** for Diagnosing *M. tuberculosis* Infections in Health-Care Workers (HCWs)

* For newly hired health-care workers and other persons who will be tested on a routine basis (e.g., residents or staff of correctional or long-term–care facilities), a previous TST is not a contraindication to a subsequent TST, unless the test was associated with severe ulceration or anaphylactic shock, which are substantially rare adverse events. If the previous positive TST result is not documented, administer two-step TSTs or offer BAMT. **SOURCES:** Aventis Pasteur. Tuberculin purified protein derivative (Mantoux) Tubersol® diagnostic antigen. Toronto, Ontario, Canada: Aventis Pasteur; 2001. Parkdale Pharmaceuticals. APLISOL (Tuberculin purified protein derivative, diluted [stabilized solution]). Diagnostic antigen for intradermal injection only. Rochester, MI: Parkdale Pharmaceuticals; 2002. Froeschle JE, Ruben FL, Bloh AM. Immediate hypersensitivity reactions after use of tuberculin skin testing. Clin Infect Dis 2002;34:E12–3.

† Bacille Calmette-Guérin.

§ Blood assay for *Mycobacterium tuberculosis*.

¶ QuantiFERON®-TB test.

** QuantiFERON®-TB Gold test.

shock, which are substantially rare adverse events (*30,237,238*). However, the recent test might complicate interpretation of subsequent test results because of the possibility of boosting.

Serial Follow-Up of TB Screening and Testing for *M. tuberculosis* Infection

The need for serial follow-up screening for groups of HCWs with negative test results for *M. tuberculosis* infection is an institutional decision that is based on the setting's risk classification. This decision and changes over time based on updated risk assessments should be official and documented. If a serial follow-up screening program is required, the risk assessment for the setting (Appendix B) will determine which HCWs should be included in the program and the frequency of screening. Two-step TST testing should not be performed for follow-up testing.

If possible, stagger follow-up screening (rather than testing all HCWs at the same time each year) so that all HCWs who work in the same area or profession are not tested in the same month. Staggered screening of HCWs (e.g., on the anniversary of their employment or on their birthdays) increases opportunities for early recognition of infection-control problems that can lead to conversions in test results for *M. tuberculosis* infection. Processing aggregate analysis of TB screening data on a periodic regular basis is important for detecting problems.

HCWs with a Newly Recognized Positive Test Result for *M. tuberculosis* Infection or Symptoms or Signs of TB Disease

Clinical Evaluation

Any HCW with a newly recognized positive test result for *M. tuberculosis* infection, test conversion, or symptoms or signs of TB disease should be promptly evaluated. The evaluation should be arranged with employee health, the local or state health department, or a personal physician. Any physicians who evaluate HCWs with suspected TB disease should be familiar with current diagnostic and therapeutic guidelines for LTBI and TB disease (*31,39*).

The definitions for positive test results for *M. tuberculosis* infection and test conversion in HCWs are included in this report (see Supplement, Diagnostic Procedures for LTBI and TB Disease). Symptoms of disease in the lung, pleura, or airways, and the larynx include coughing for ≥3 weeks, loss of appetite, unexplained weight loss, night sweats, bloody sputum or hemoptysis, hoarseness, fever, fatigue, or chest pain. The evaluation should include a clinical examination and symptom screen (a procedure used during a clinical evaluation in which patients are asked if they have experienced any symptoms or signs of TB disease), chest radiograph, and collection of sputum specimens.

If TB disease is diagnosed, begin antituberculosis treatment immediately, according to published guidelines (*31*). The diagnosing clinician (who might not be a physician with the institution's infection-control program) should notify the local or state health department in accordance with disease reporting laws, which generally specify a 24-hour time limit.

If TB disease is excluded, offer the HCW treatment for LTBI in accordance with published guidelines (see Supplements, Diagnostic Procedures for LTBI and TB Disease; and Treatment Procedures for LTBI and TB Disease [*39,240*]). If the HCW has already completed treatment for LTBI and is part of a TB screening program, instead of participating in serial skin testing, the HCW should be monitored for symptoms of TB disease and should receive any available training, which should include information on the symptoms of TB disease and instructing the HCW to report any such symptoms immediately to occupational health. In addition, annual symptom screens should be performed, which can be administered as part of other HCW screening and education efforts. Treatment for LTBI should be offered to HCWs who are eligible (*39*).

HCWs with a previously negative test result who have an increase of ≥10 mm induration when examined on follow-up testing probably have acquired *M. tuberculosis* infection and should be evaluated for TB disease. When disease is excluded, HCWs should be treated for LTBI unless medically contraindicated (*39,240*).

Chest Radiography

HCWs with a baseline positive or newly positive TST or BAMT result should receive one chest radiograph to exclude a diagnosis of TB disease (or an interpretable copy within a reasonable time frame, such as 6 months). After this baseline chest radiograph is performed and the result is documented, repeat radiographs are not needed unless symptoms or signs of TB disease develop or a clinician recommends a repeat chest radiograph (*39,116*). Instead of participating in serial testing for *M. tuberculosis* infection, HCWs with a positive test result for *M. tuberculosis* infection should receive a symptom screen. The frequency of this symptom screen should be determined by the risk classification for the setting.

Serial follow-up chest radiographs are not recommended for HCWs with documentation of a previously positive test result for *M. tuberculosis* infection, treatment for LTBI or TB disease, or for asymptomatic HCWs with negative test results for *M. tuberculosis* infection. HCWs who have a previously positive test result for *M. tuberculosis* infection and who change jobs should carry documentation of a baseline chest radiograph

result (and the positive test result for *M. tuberculosis* infection) to their new employers.

Workplace Restrictions

HCWs with a baseline positive or newly positive test result for *M. tuberculosis* infection should receive one chest radiograph result to exclude TB disease (or an interpretable copy within a reasonable time frame, such as 6 months).

HCWs with confirmed infectious pulmonary, laryngeal, endobroncheal, or tracheal TB disease, or a draining TB skin lesion pose a risk to patients, HCWs, and others. Such HCWs should be excluded from the workplace and should be allowed to return to work when the following criteria have been met: 1) three consecutive sputum samples (*109–112*) collected in 8–24-hour intervals that are negative, with at least one sample from an early morning specimen (because respiratory secretions pool overnight); 2) the person has responded to antituberculosis treatment that will probably be effective (can be based on susceptibility results); and 3) the person is determined to be noninfectious by a physician knowledgeable and experienced in managing TB disease (see Supplements, Estimating the Infectiousness of a TB Patient; Diagnostic Procedures for LTBI and TB Disease; and Treatment Procedures for LTBI and TB Disease).

HCWs with extrapulmonary TB disease usually do not need to be excluded from the workplace as long as no involvement of the respiratory track has occurred. They can be confirmed as noninfectious and can continue to work if documented evidence is available that indicates that concurrent pulmonary TB disease has been excluded.

HCWs receiving treatment for LTBI can return to work immediately. HCWs with LTBI who cannot take or do not accept or complete a full course of treatment for LTBI should not be excluded from the workplace. They should be counseled regarding the risk for developing TB disease and instructed to report any TB symptoms immediately to the occupational health unit.

HCWs who have a documented positive TST or BAMT result and who leave employment should be counseled again, if possible, regarding the risk for developing TB disease and instructed to seek prompt evaluation with the local health department or their primary care physician if symptoms of TB disease develop. Consider mailing letters to former HCWs who have LTBI. This information should be recorded in the HCWs' employee health record when they leave employment.

Asymptomatic HCWs with a baseline positive or newly positive TST or BAMT result do not need to be excluded from the workplace. Treatment for LTBI should be considered in accordance with CDC guidelines (*39*).

Identification of Source Cases and Recording of Drug-Susceptibility Patterns

If an HCW experiences a conversion in a test result for *M. tuberculosis* infection, evaluate the HCW for a history of suspected or known exposure to *M. tuberculosis* to determine the potential source. When the source case is identified, also identify the drug susceptibility pattern of the *M. tuberculosis* isolate from the source. The drug-susceptibility pattern should be recorded in the HCW's medical or employee health record to guide the treatment of LTBI or TB disease, if indicated.

HCWs with Medical Conditions Associated with Increased Risk for Progression to TB Disease

In settings in which HCWs are severely immunocompromised, additional precautions must be taken. HIV infection is the highest risk factor for progression from LTBI to TB disease (*22,39,42,49*). Other immunocompromising conditions, including diabetes mellitus, certain cancers, and certain drug treatments, also increase the risk for rapid progression from LTBI to TB disease. TB disease can also adversely affect the clinical course of HIV infection and acquired immunodeficiency syndrome (AIDS) and can complicate HIV treatment (*31,39,53*).

Serial TB screening beyond that indicated by the risk classification for the setting is not indicated for persons with the majority of medical conditions that suppress the immune system or otherwise increase the risk for infection with *M. tuberculosis* progressing to TB disease (*58*). However, consideration should be given to repeating the TST for HIV-infected persons whose initial TST result was negative and whose immune function has improved in response to highly active antiretroviral therapy (HAART) (i.e., those whose CD4-T lymphocyte count has increased to >200 cells/mL).

All HCWs should, however, be encouraged during their initial TB training to determine if they have such a medical condition and should be aware that receiving medical treatment can improve cell-mediated immunity. HCWs should be informed concerning the availability of counseling, testing, and referral for HIV (*50,51*). In addition, HCWs should know whether they are immunocompromised, and they should be aware of the risks from exposure to *M. tuberculosis* (*1*). In certain cases, reassignment to areas in which exposure is minimized or nonexistent might be medically advisable or desirable.

Immunocompromised HCWs should have the option of an assignment in an area or activity where the risk for exposure to *M. tuberculosis* is low. This choice is a personal decision for the immunocompromised HCW (*241*) (http://www.eeoc.gov/laws/ada.html). Health-care settings should provide education and follow infection-control recommendations (*70*).

Information provided by HCWs regarding their immune status and request for voluntary work assignments should be treated confidentially, according to written procedures on the confidential handling of such information. All HCWs should be made aware of these procedures at the time of employment and during initial TB training and education.

Problem Evaluation

Contact investigations might be initiated in response to 1) conversions in test results in HCWs for *M. tuberculosis* infection, 2) diagnosis of TB disease in an HCW, 3) suspected person-to-person transmission of *M. tuberculosis*, 4) lapses in TB infection-control practices that expose HCWs and patients to *M. tuberculosis*, or 5) possible TB outbreaks identified using automated laboratory systems (*242*). In these situations, the objectives of a contact investigation might be to 1) determine the likelihood that transmission of *M. tuberculosis* has occurred; 2) determine the extent of *M. tuberculosis* transmission; 3) identify persons who were exposed, and, if possible, the sources of potential transmission; 4) identify factors that could have contributed to transmission, including failure of environmental infection-control measures, failure to follow infection-control procedures, or inadequacy of current measures or procedures; 5) implement recommended interventions; 6) evaluate the effectiveness of the interventions; and 7) ensure that exposure to *M. tuberculosis* has been terminated and that the conditions leading to exposure have been eliminated.

Earlier recognition of a setting in which *M. tuberculosis* transmission has occurred could be facilitated through innovative approaches to TB contact investigations (e.g., network analysis and genetic typing of isolates). Network analysis makes use of information (e.g., shared locations within a setting that might not be collected in traditional TB contact investigations) (*45*). This type of information might be useful during contact investigations involving hospitals or correctional settings to identify any shared wards, hospital rooms, or cells. Genotyping of isolates is universally available in the United States and is a useful adjunct in the investigation of *M. tuberculosis* transmission (*44,89,243,244*). Because the situations prompting an investigation are likely to vary, investigations should be tailored to the individual circumstances. Recommendations provide general guidance for conducting contact investigations (*34,115*).

General Recommendations for Investigating Conversions in Test Results for *M. tuberculosis* Infection in HCWs

A test conversion might need to be reported to the health department, depending on state and local regulations. Problem evaluation during contact investigations should be accomplished through cooperation between infection-control personnel, occupational health, and the local or state TB-control program. If a test conversion in an HCW is detected as a result of serial screening and the source is not apparent, conduct a source case investigation to determine the probable source and the likelihood that transmission occurred in the health-care setting (*115*).

Lapses in TB infection control that might have contributed to the transmission of *M. tuberculosis* should be corrected. Test conversions and TB disease among HCWs should be recorded and reported, according to OSHA requirements (http://www.osha.gov/recordkeeping). Consult *Recording and Reporting Occupational Injuries and Illness* (OSHA standard 29 Code of Federal Regulations [CFR], 1904) to determine recording and reporting requirements (*245*).

Investigating Conversions in Test Results for *M. tuberculosis* Infection in HCWs: Probable Source Outside the Health-Care Setting

If a test conversion in an HCW is detected and exposure outside the health-care setting has been documented by the corresponding local or state health department, terminate the investigation within the health-care setting.

Investigating Conversions in Test Results for *M. tuberculosis* Infection in HCWs: Known Source in the Health-Care Setting

An investigation of a test conversion should be performed in collaboration with the local or state health department. If a conversion in an HCW is detected and the HCW's history does not document exposure outside the health-care setting but does identify a probable source in the setting, the following steps should be taken: 1) identify and evaluate close contacts of the suspected source case, including other patients and visitors; 2) determine possible reasons for the exposure; 3) implement interventions to correct the lapse(s) in infection control; and 4) immediately screen HCWs and patients if they were close contacts to the source case. For exposed HCWs and patients in a setting that has chosen to screen for infection with *M. tuberculosis* by using the TST, the following steps should be taken:

- administer a symptom screen;
- administer a TST to those who had previously negative TST results; baseline two-step TST should not be performed in contact investigations;
- repeat the TST and symptom screen 8–10 weeks after the end of exposure, if the initial TST result is negative (*33*);

- administer a symptom screen, if the baseline TST result is positive;
- promptly evaluate (including a chest radiograph) the exposed person for TB disease, if the symptom screen or the initial or 8–10-week follow-up TST result is positive; and
- conduct additional medical and diagnostic evaluation (which includes a judgment about the extent of exposure) for LTBI, if TB disease is excluded.

If no additional conversions in the test results for *M. tuberculosis* infection are detected in the follow-up testing, terminate the investigation. If additional conversions in the tests for *M. tuberculosis* infection are detected in the follow-up testing, transmission might still be occurring, and additional actions are needed: 1) implement a classification of potential ongoing transmission for the specific setting or group of HCWs; 2) the initial cluster of test conversions should be reported promptly to the local or state health department; 3) possible reasons for exposure and transmission should be reassessed and 4) the degree of adherence to the interventions implemented should be evaluated.

Testing for *M. tuberculosis* infection should be repeated 8–10 weeks after the end of exposure for HCW contacts who previously had negative test results, and the circle of contacts should be expanded to include other persons who might have been exposed. If no additional TST conversions are detected on the second round of follow-up testing, terminate the investigation. If additional TST conversions are detected on the second round of follow-up testing, maintain a classification of potential ongoing transmission and consult the local or state health department or other persons with expertise in TB infection control for assistance.

The classification of potential ongoing transmission should be used as a temporary classification only. This classification warrants immediate investigation and corrective steps. After determination has been made that ongoing transmission has ceased, the setting should be reclassified as medium risk. Maintaining the classification of medium risk for at least 1 year is recommended.

Investigating a Conversion of a Test Result for *M. tuberculosis* Infection in an HCW with an Unknown Exposure

If a test conversion in an HCW is detected and the HCW's history does not document exposure outside the health-care setting and does not identify a probable source of exposure in the setting, additional investigation to identify a probable source in the health-care setting is warranted.

If no source case is identified, estimate the interval during which the HCW might have been infected. The interval is usually 8–10 weeks before the most recent negative test result through 2 weeks before the first positive test result. Laboratory and infection-control records should be reviewed to identify all patients (and any HCWs) who have had suspected or confirmed infectious TB disease and who might have transmitted *M. tuberculosis* to the HCW. If the investigation identifies a probable source, identify and evaluate contacts of the suspected source. Close contacts should be the highest priority for screening.

The following steps should be taken in a setting that uses TST or BAMT to screen for *M. tuberculosis*: 1) administer a symptom screen and the test routinely used in the setting (i.e., TST or BAMT) to persons who previously had negative results; 2) if the initial result is negative, the test and symptom screen should be repeated 8–10 weeks after the end of exposure; 3) if the symptom screen, the first test result, or the 8–10-week follow-up test result is positive, the presumed exposed person should be promptly evaluated for TB disease, including the use of a chest radiograph; and 4) if TB disease is excluded, additional medical and diagnostic evaluation for LTBI is needed, which includes a judgment regarding the extent of exposure (see Investigating Conversions in Test Results for *M. tuberculosis* Infection in HCWs: Known Source in the Health-Care Setting).

Investigations That Do Not Identify a Probable Source

If serial TB screening is performed in the setting, review the results of screening of other HCWs in the same area of the health-care setting or same occupational group. If serial TB screening is not performed in the setting or if insufficient numbers of recent results are available, conduct additional TB screening of other HCWs in the same area or occupational group. If the review and screening yield no additional test conversions, and no evidence to indicate health-care–associated transmission exists, then the investigation should be terminated.

Whether HCW test conversions resulted from exposure in the setting or elsewhere or whether true infection with *M. tuberculosis* has even occurred is uncertain. However, the absence of other data implicating health-care–associated transmission suggests that the conversion could have resulted from 1) unrecognized exposure to *M. tuberculosis* outside the health-care setting; 2) cross reactivity with another antigen (e.g., BCG or nontuberculous mycobacteria); or 3) errors in applying, reading, or interpreting the test result for *M. tuberculosis* infection. If the review and screening identify additional test conversions, health-care–associated transmission is more probable.

Evaluation of the patient identification process, TB infection-control policies and practices, and environmental controls to identify lapses that could have led to exposure and

transmission should be conducted. If no problems are identified, a classification of potential ongoing transmission should be applied, and the local or state health department or other persons with expertise in TB infection control should be consulted for assistance. If problems are identified, implement recommended interventions and repeat testing for *M. tuberculosis* infection 8–10 weeks after the end of exposure for HCWs with negative test results. If no additional test conversions are detected in the follow-up testing, terminate the investigation.

Conversions in Test Results for *M. tuberculosis* Infection Detected in Follow-Up Testing

In follow-up testing, a classification of potential ongoing transmission should be maintained. Possible reasons for exposure and transmission should be reassessed, and the appropriateness of and degree of adherence to the interventions implemented should be evaluated. For HCWs with negative test results, repeat testing for *M. tuberculosis* infection 8–10 weeks after the end of exposure. The local or state health department or other persons with expertise in TB infection control should be consulted.

If no additional conversions are detected during the second round of follow-up testing, terminate the investigation. If additional conversions are detected, continue a classification of potential ongoing transmission and consult the local or state health department or other persons with expertise in TB infection control.

The classification of potential ongoing transmission should be used as a temporary classification only. This classification warrants immediate investigation and corrective steps. After a determination that ongoing transmission has ceased, the setting should be reclassified as medium risk. Maintaining the classification of medium risk for at least 1 year is recommended.

Investigating a Case of TB Disease in an HCW

Occupational health services and other physicians in the setting should have procedures for immediately notifying the local administrators or infection-control personnel if an HCW is diagnosed with TB disease so that a problem evaluation can be initiated. If an HCW is diagnosed with TB disease and does not have a previously documented positive test result for *M. tuberculosis* infection, conduct an investigation to identify the probable sources and circumstances for transmission (see General Recommendations for Investigating Conversions in Test Results for *M. tuberculosis* Infection in HCWs). If an HCW is diagnosed with TB disease, regardless of previous test result status, an additional investigation must be conducted to ascertain whether the disease was transmitted from this HCW to others, including other HCWs, patients, and visitors.

The potential infectiousness of the HCW, if potentially infectious, and the probable period of infectiousness (see Contact Investigations) should be determined. For HCWs with suspected or confirmed infectious TB disease, conduct an investigation that includes 1) identification of contacts (e.g., other HCWs, patients, and visitors), 2) evaluation of contacts for LTBI and TB disease, and 3) notification of the local or state health department for consultation and investigation of community contacts who were exposed outside the health-care setting.

M. tuberculosis genotyping should be performed so that the results are promptly available. Genotyping results are useful adjuncts to epidemiologically based public health investigations of contacts and possible source cases (especially in determining the role of laboratory contamination) (*89,166,243,246–261*). When confidentiality laws prevent the local or state health department from communicating information regarding a patient's identity, health department staff should work with hospital staff and legal counsel, and the HCW to determine how the hospital can be notified without breaching confidentiality.

Investigating Possible Patient-to-Patient Transmission of *M. tuberculosis*

Information concerning TB cases among patients in the setting should be routinely recorded for risk classification and risk assessment purposes. Documented information by location and date should include results of sputum smear and culture, chest radiograph, drug-susceptibility testing, and adequacy of infection-control measures.

Each time a patient with suspected or confirmed TB disease is encountered in a health-care setting, an assessment of the situation should be made and the focus should be on 1) a determination of infectiousness of the patient, 2) confirmation of compliance with local public health reporting requirements (including the prompt reporting of a person with suspected TB disease as required), and 3) assessment of the adequacy of infection control.

A contact investigation should be initiated in situations where infection control is inadequate and the patient is infectious. Patients with positive AFB sputum smear results are more infectious than patients with negative AFB sputum smear results, but the possibility exists that patients with negative sputum smear results might be infectious (*262*). Patients with negative AFB sputum smear results but who undergo aerosol-generating or aerosol-producing procedures (including bronchoscopy) without adequate infection-control measures create

a potential for exposure. All investigations should be conducted in consultation with the local public health department.

If serial surveillance of these cases reveals one of the following conditions, patient-to-patient transmission might have occurred, and a contact investigation should be initiated:

- A high proportion of patients with TB disease were admitted to or examined in the setting during the year preceding onset of their TB disease, especially when TB disease is identified in patients who were otherwise unlikely to be exposed to *M. tuberculosis*.
- An increase occurred in the number of TB patients diagnosed with drug-resistant TB, compared with the previous year.
- Isolates from multiple patients had identical and characteristic drug susceptibility or DNA fingerprint patterns.

Surveillance of TB Cases in Patients Indicates Possible Patient-to-Patient Transmission of *M. tuberculosis*

Health-care settings should collaborate with the local or state health department to conduct an investigation. For settings in which HCWs are serially tested for *M. tuberculosis* infection, review HCW records to determine whether an increase in the number of conversions in test results for *M. tuberculosis* infection has occurred. Patient surveillance data and medical records should be reviewed for additional cases of TB disease. Settings should look for possible exposures from previous or current admissions that might have exposed patients with newly diagnosed TB disease to other patients with TB disease, determining if the patients were admitted to the same room or area, or if they received the same procedure or went to the same treatment area on the same day.

If the investigation suggests that transmission has occurred, possible causes of transmission of *M. tuberculosis* (e.g., delayed diagnosis of TB disease, institutional barriers to implementing timely and correct airborne precautions, and inadequate environmental controls) should be evaluated. Possible exposure to other patients or HCWs should be determined, and if exposure has occurred, these persons should be evaluated for LTBI and TB disease (i.e., test for *M. tuberculosis* infection and administer a symptom screen).

If the local or state health department was not previously contacted, settings should notify the health department so that a community contact investigation can be initiated, if necessary. The possibility of laboratory errors in diagnosis or the contamination of bronchoscopes (*82,169*) or other equipment should be considered (*136*).

Contact Investigations

The primary goal of contact investigations is to identify secondary cases of TB disease and LTBI among contacts so that therapy can be initiated as needed (*263–265*). Contact investigations should be collaboratively conducted by both infection-control personnel and local TB-control program personnel.

Initiating a Contact Investigation

A contact investigation should be initiated when 1) a person with TB disease has been examined at a health-care setting, and TB disease was not diagnosed and reported quickly, resulting in failure to apply recommended TB infection controls; 2) environmental controls or other infection-control measures have malfunctioned while a person with TB disease was in the setting; or 3) an HCW develops TB disease and exposes other persons in the setting.

As soon as TB disease is diagnosed or a problem is recognized, standard public health practice should be implemented to prioritize the identification of other patients, HCWs, and visitors who might have been exposed to the index case before TB infection-control measures were correctly applied (*52*). Visitors of these patients might also be contacts or the source case.

The following activities should be implemented in collaboration with or by the local or state health department (*34,266*): 1) interview the index case and all persons who might have been exposed; 2) review the medical records of the index case; 3) determine the exposure sites (i.e., where the index case lived, worked, visited, or was hospitalized before being placed under airborne precautions); and 4) determine the infectious period of the index case, which is the period during which a person with TB disease is considered contagious and most capable of transmitting *M. tuberculosis* to others.

For programmatic purposes, for patients with positive AFB sputum smear results, the infectious period can be considered to begin 3 months before the collection date of the first positive AFB sputum smear result or the symptom onset date (whichever is earlier). The end of the infectious period is the date the patient is placed under airborne precautions or the date of collection of the first of consistently negative AFB sputum smear results (whichever is earlier). For patients with negative AFB sputum smear results, the infectious period can begin 1 month before the symptom onset date and end when the patient is placed under airborne precautions.

The exposure period, the time during which a person shared the same air space with a person with TB disease for each contact, should be determined as well as whether transmission occurred from the index patient to persons with whom the index patient had intense contact. In addition, the following should be determined: 1) intensity of the exposure based

on proximity, 2) overlap with the infectious period of the index case, 3) duration of exposure, 4) presence or absence of infection-control measures, 5) infectiousness of the index case, 6) performance of procedures that could increase the risk for transmission during contact (e.g., sputum induction, bronchoscopy, and airway suction), and 7) the exposed cohort of contacts for TB screening.

The most intensely exposed HCWs and patients should be screened as soon as possible after exposure to *M. tuberculosis* has occurred and 8–10 weeks after the end of exposure if the initial TST result is negative. Close contacts should be the highest priority for screening.

For HCWs and patients who are presumed to have been exposed in a setting that screens for infection with *M. tuberculosis* using the TST, the following activities should be implemented:

- performing a symptom screen;
- administering a TST to those who previously had negative TST results;
- repeating the TST and symptom screen 8–10 weeks after the end of exposure, if the initial TST result is negative;
- promptly evaluating the HCW for TB disease, including performing a chest radiograph, if the symptom screen or the initial or 8–10-week follow-up TST result is positive; and
- providing additional medical and diagnostic evaluation for LTBI, including determining the extent of exposure, if TB disease is excluded.

For HCWs and patients who are presumed to have been exposed in a setting that screens for infection with *M. tuberculosis* using the BAMT, the following activities should be implemented (see Supplement, Surveillance and Detection of *M. tuberculosis* Infections in Health-Care Settings). If the most intensely exposed persons have test conversions or positive test results for *M. tuberculosis* infection in the absence of a previous history of a positive test result or TB disease, expand the investigation to evaluate persons with whom the index patient had less contact. If the evaluation of the most intensely exposed contacts yields no evidence of transmission, expanding testing to others is not necessary.

Exposed persons with documented previously positive test results for *M. tuberculosis* infection do not require either repeat testing for *M. tuberculosis* infection or a chest radiograph (unless they are immunocompromised or otherwise at high risk for TB disease), but they should receive a symptom screen. If the person has symptoms of TB disease, 1) record the symptoms in the HCW's medical chart or employee health record, 2) perform a chest radiograph, 3) perform a full medical evaluation, and 4) obtain sputum samples for smear and culture, if indicated.

The setting should determine the reason(s) that a TB diagnosis or initiation of airborne precautions was delayed or procedures failed, which led to transmission of *M. tuberculosis* in the setting. Reasons and corrective actions taken should be recorded, including changes in policies, procedures, and TB training and education practices.

Collaboration with the Local or State Health Department

For assistance with the planning and implementation of TB-control activities in the health-care setting and for names of experts to help with policies, procedures, and program evaluation, settings should coordinate with the local or state TB-control program . By law, the local or state health department must be notified when TB disease is suspected or confirmed in a patient or HCW so that follow up can be arranged and a community contact investigation can be conducted. The local or state health department should be notified as early as possible before the patient is discharged to facilitate followup and continuation of therapy by DOT (*31*). For inpatient settings, coordinate a discharge plan with the patient (including a patient who is an HCW with TB disease) and the TB-control program of the local or state health department.

Environmental Controls

Environmental controls are the second line of defense in the TB infection-control program, after administrative controls. Environmental controls include technologies for the removal or inactivation of airborne *M. tuberculosis*. These technologies include local exhaust ventilation, general ventilation, HEPA filtration, and UVGI. These controls help to prevent the spread and reduce the concentration of infectious droplet nuclei in the air. A summary of environmental controls and their use in prevention of transmission of *M. tuberculosis* is provided in this report (see Supplement, Environmental Controls), including detailed information concerning the application of environmental controls.

Local Exhaust Ventilation

Local exhaust ventilation is a source-control technique used for capturing airborne contaminants (e.g., infectious droplet nuclei or other infectious particles) before they are dispersed into the general environment. In local exhaust ventilation methods, external hoods, enclosing booths, and tents are used. Local exhaust ventilation (e.g., enclosed, ventilated booth) should be used for cough-inducing and aerosol-generating procedures. When local exhaust is not feasible, perform cough-inducing and aerosol-generating procedures in a room that meets the requirements for an AII room.

General Ventilation

General ventilation systems dilute and remove contaminated air and control airflow patterns in a room or setting. An engineer or other professional with expertise in ventilation should be included as part of the staff of the health-care setting or hire a consultant with expertise in ventilation engineering specific to health-care settings. Ventilation systems should be designed to meet all applicable federal, state, and local requirements.

A single-pass ventilation system is the preferred choice in areas in which infectious airborne droplet nuclei might be present (e.g., AII rooms). Use HEPA filtration if recirculation of air is necessary.

AII rooms in health-care settings pre-existing 1994 guidelines should have an airflow of ≥6 ACH. When feasible, the airflow should be increased to ≥12 ACH by 1) adjusting or modifying the ventilation system or 2) using air-cleaning methods (e.g., room-air recirculation units containing HEPA filters or UVGI systems that increase the equivalent ACH). New construction or renovation of health-care settings should be designed so that AII rooms achieve an airflow of ≥12 ACH. Ventilation rates for other areas in health-care settings should meet certain specifications (see Risk Classification Examples). If a variable air volume (VAV) ventilation system is used in an AII room, design the system to maintain the room under negative pressure at all times. The VAV system minimum set point must be adequate to maintain the recommended mechanical and outdoor ACH and a negative pressure ≥0.01 inch of water gauge compared with adjacent areas.

Based on the risk assessment for the setting, the required number of AII rooms, other negative-pressure rooms, and local exhaust devices should be determined. The location of these rooms and devices will depend partially on where recommended ventilation conditions can be achieved. Grouping AII rooms in one area might facilitate the care of patients with TB disease and the installation and maintenance of optimal environmental controls.

AII rooms should be checked for negative pressure by using smoke tubes or other visual checks before occupancy, and these rooms should be checked daily when occupied by a patient with suspected or confirmed TB disease. Design, construct, and maintain general ventilation systems so that air flows from clean to less clean (more contaminated) areas. In addition, design general ventilation systems to provide optimal airflow patterns within rooms and to prevent air stagnation or short-circuiting of air from the supply area to the exhaust area.

Health-care settings serving populations with a high prevalence of TB disease might need to improve the existing general ventilation system or use air-cleaning technologies in general-use areas (e.g., waiting rooms, EMS areas, and radiology suites). Applicable approaches include 1) single-pass, nonrecirculating systems that exhaust air to the outside, 2) recirculation systems that pass air through HEPA filters before recirculating it to the general ventilation system, and 3) room-air recirculation units with HEPA filters and/or UVGI systems.

Air-Cleaning Methods

High-Efficiency Particulate Air (HEPA) Filters

HEPA filters can be used to filter infectious droplet nuclei from the air and must be used 1) when discharging air from local exhaust ventilation booths or enclosures directly into the surrounding room or area and 2) when discharging air from an AII room (or other negative-pressure room) into the general ventilation system (e.g., in settings in which the ventilation system or building configuration makes venting the exhaust to the outside impossible).

HEPA filters can be used to remove infectious droplet nuclei from air that is recirculated in a setting or exhausted directly to the outside. HEPA filters can also be used as a safety measure in exhaust ducts to remove droplet nuclei from air being discharged to the outside. Air can be recirculated through HEPA filters in areas in which 1) no general ventilation system is present, 2) an existing system is incapable of providing sufficient ACH, or 3) air-cleaning (particulate removal) without affecting the fresh-air supply or negative-pressure system is desired. Such uses can increase the number of equivalent ACH in the room or area.

Recirculation of HEPA filtered air can be achieved by exhausting air from the room into a duct, passing it through a HEPA filter installed in the duct, and returning it to the room or the general ventilation system. In addition, recirculation can be achieved by filtering air through HEPA recirculation systems installed on the wall or ceiling of the room or filtering air through portable room-air recirculation units.

To ensure adequate functioning, install HEPA filters carefully and maintain the filters according to the instructions of the manufacturer. Maintain written records of all prefilter and HEPA maintenance and monitoring (*114*). Manufacturers of room-air recirculation units should provide installation instructions and documentation of the filtration efficiency and of the overall efficiency of the unit (clean air delivery rate) in removing airborne particles from a space of a given size.

UVGI

UVGI is an air-cleaning technology that can be used in a room or corridor to irradiate the air in the upper portion of the room (upper-air irradiation) and is installed in a duct to irradiate air passing through the duct (duct irradiation) or incorporated into room air-recirculation units. UVGI can be used in ducts

that recirculate air back into the same room or in ducts that exhaust air directly to the outside. However, UVGI should not be used in place of HEPA filters when discharging air from isolation booths or enclosures directly into the surrounding room or area or when discharging air from an AII room into the general ventilation system. Effective use of UVGI ensures that *M. tuberculosis,* as contained in an infectious droplet nucleus is exposed to a sufficient dose of ultraviolet-C (UV-C) radiation at 253.7 nanometers (nm) to result in inactivation. Because dose is a function of irradiance and time, the effectiveness of any application is determined by its ability to deliver sufficient irradiance for enough time to result in inactivation of the organism within the infectious droplet. Achieving a sufficient dose can be difficult for airborne inactivation because the exposure time can be substantially limited; therefore, attaining sufficient irradiance is essential.

For each system, follow design guidelines to maximize UVGI effectiveness in equivalent ACH. Because air velocity, air mixing, relative humidity, UVGI intensity, and lamp position all affect the efficacy of UVGI systems, consult a UVGI system designer before purchasing and installing a UVGI system. Experts who might be consulted include industrial hygienists, engineers, and health physicists.

To function properly and minimize potential hazards to HCWs and other room occupants, upper-air UVGI systems should be properly installed, maintained, and labeled. A person knowledgeable in the use of ultraviolet (UV) radiometers or actinometers should monitor UV irradiance levels to ensure that exposures in the work area are within safe exposure levels. UV irradiance levels in the upper-air, where the air disinfection is occurring, should also be monitored to determine that irradiance levels are within the desired effectiveness range.

UVGI tubes should be changed and cleaned according to the instructions of the manufacturer or when irradiance measurements indicate that output is reduced below effective levels. In settings that use UVGI systems, education of HCWs should include 1) basic principles of UVGI systems (mechanism and limitations), 2) potential hazardous effects of UVGI if overexposure occurs, 3) potential for photosensitivity associated with certain medical conditions or use of certain medications, and 4) the importance of maintenance procedures and record-keeping. In settings that use UVGI systems, patients and visitors should be informed of the purpose of UVGI systems and be warned about the potential hazards and safety precautions.

Program Issues

Personnel from engineering, maintenance, safety and infection control, and environmental health should collaborate to ensure the optimal selection, installation, operation, and maintenance of environmental controls. A written maintenance plan should be developed that outlines the responsibility and authority for maintenance of the environmental controls and addresses HCW training needs. Standard operating procedures should include the notification of infection-control personnel before performing maintenance on ventilation systems servicing TB patient-care areas.

Personnel should schedule routine preventive maintenance for all components of the ventilation systems (e.g., fans, filters, ducts, supply diffusers, and exhaust grills) and air-cleaning devices. Quality control (QC) checks should be conducted to verify that environmental controls are operating as designed and that records are current. Provisions for emergency electrical power should be made so that the performance of essential environmental controls is not interrupted during a power failure.

Respiratory Protection

The first two levels of the infection-control hierarchy, administrative and environmental controls, minimize the number of areas in which exposure to *M. tuberculosis* might occur. In addition, these administrative and environmental controls also reduce, but do not eliminate, the risk in the few areas in which exposures can still occur (e.g., AII rooms and rooms where cough-inducing or aerosol-generating procedures are performed). Because persons entering these areas might be exposed to airborne *M. tuberculosis*, the third level of the hierarchy is the use of respiratory protective equipment in situations that pose a high risk for exposure (see Supplement, Respiratory Protection).

On October 17, 1997, OSHA published a proposed standard for occupational exposure to *M. tuberculosis* (*267*). On December 31, 2003, OSHA announced the termination of rulemaking for a TB standard (*268*). Previous OSHA policy permitted the use of any Part 84 particulate filter respirator for protection against TB disease (*269*). Respirator use for TB had been regulated by OSHA under CFR Title 29, Part 1910.139 (29CFR1910.139) (*270*) and compliance policy directive (CPL) 2.106 (Enforcement Procedures and Scheduling for Occupational Exposure to Tuberculosis). Respirator use for TB is regulated under the general industry standard for respiratory protection (29 CFR 1910.134, http://www.osha.gov/SLTC/respiratoryprotection/index.html) (*271*). General information concerning respiratory protection for aerosols, including *M. tuberculosis*, has been published (*272–274*).

Indications for Use

Respiratory protection should be used by the following persons:

- all persons, including HCWs and visitors, entering rooms in which patients with suspected or confirmed infectious TB disease are being isolated;

- persons present during cough-inducing or aerosol-generating procedures performed on patients with suspected or confirmed infectious TB disease; and
- persons in other settings in which administrative and environmental controls probably will not protect them from inhaling infectious airborne droplet nuclei. These persons might also include persons who transport patients with suspected or confirmed infectious TB disease in vehicles (e.g., EMS vehicles or, ideally, ambulances) and persons who provide urgent surgical or dental care to patients with suspected or confirmed infectious TB disease (see Supplement, Estimating the Infectiousness of a TB Patient).

Laboratorians conducting aerosol-producing procedures might require respiratory protection. A decision concerning use of respiratory protection in laboratories should be made on an individual basis, depending on the type of ventilation in use for the laboratory procedure and the likelihood of aerosolization of viable mycobacteria that might result from the laboratory procedure.

Respiratory-Protection Program

OSHA requires health-care settings in which HCWs use respiratory protection to develop, implement, and maintain a respiratory-protection program. All HCWs who use respiratory protection should be included in the program (see Supplement, Respiratory Protection).

Training HCWs

Annual training regarding multiple topics should be conducted for HCWs, including the nature, extent, and hazards of TB disease in the health-care setting. The training can be conducted in conjunction with other related training regarding infectious disease associated with airborne transmission. In addition, training topics should include the 1) risk assessment process and its relation to the respirator program, including signs and symbols used to indicate that respirators are required in certain areas and the reasons for using respirators; 2) environmental controls used to prevent the spread and reduce the concentration of infectious droplet nuclei; 3) selection of a particular respirator for a given hazard (see Selection of Respirators); 4) operation, capabilities, and limitations of respirators; 5) cautions regarding facial hair and respirator use (*275,276*); and 6) OSHA regulations regarding respirators, including assessment of employees' knowledge.

Trainees should be provided opportunities to handle and wear a respirator until they become proficient (see Fit Testing). Trainees should also be provided with 1) copies or summaries of lecture materials for use as references and 2) instructions to refer all respirator problems immediately to the respiratory program administrator.

Selection of Respirators

Respiratory protective devices used in health-care settings for protection against *M. tuberculosis* should meet the following criteria (*277,278*):

- certified by CDC/National Institute for Occupational Safety and Health (NIOSH) as a nonpowered particulate filter respirator (N-, R-, and P-series 95%, 99%, and 100% filtration efficiency), including disposable respirators, or PAPRs with high efficiency filters (*279*);
- ability to adequately fit respirator wearers (e.g., a fit factor of ≥100 for disposable and half facepiece respirators) who are included in a respiratory-protection program; and
- ability to fit the different facial sizes and characteristics of HCWs. (This criterion can usually be met by making respirators available in different sizes and models.)

The fit of filtering facepiece respirators varies because of different facial types and respirator characteristics (*10,280–289*). Assistance with selection of respirators should be obtained through consultation with respirator fit-testing experts, CDC, occupational health and infection-control professional organizations, peer-reviewed research, respirator manufacturers, and advanced respirator training courses.

Fit Testing

A fit test is used to determine which respirator fits the user adequately and to ensure that the user knows when the respirator fits properly. After a risk assessment is conducted to validate the need for respiratory protection, perform fit testing during the initial respiratory-protection program training and periodically thereafter in accordance with federal, state, and local regulations.

Fit testing provides a means to determine which respirator model and size fits the wearer best and to confirm that the wearer can don the respirator properly to achieve a good fit. Periodic fit testing of respirators on HCWs can serve as an effective training tool in conjunction with the content included in employee training and retraining. The frequency of periodic fit testing should be determined by the occurrence of 1) risk for transmission of *M. tuberculosis*, 2) a change in facial features of the wearer, 3) medical condition that would affect respiratory function, 4) physical characteristics of respirator (despite the same model number), or 5) a change in the model or size of the assigned respirator (*281*).

Respirator Options: General Recommendations

In situations that require respiratory protection, the minimum respiratory protection device is a filtering facepiece

(nonpowered, air-purifying, half-facepiece) respirator (e.g., an N95 disposable respirator). This CDC/NIOSH-certified respirator meets the minimum filtration performance for respiratory protection in areas in which patients with suspected or confirmed TB disease might be encountered. For situations in which the risk for exposure to *M. tuberculosis* is especially high because of cough-inducing and aerosol-generating procedures, more protective respirators might be needed (see Respirator Options: Special Circumstances).

Respirator Options: Special Circumstances

Visitors to AII rooms and other areas with patients who have suspected or confirmed infectious TB disease may be offered respirators and should be instructed by an HCW on the use of the respirator before entering an AII room (Supplement, Frequently Asked Questions [FAQs] User-Seal Check in Respiratory Protection section). Particulate respirators vary substantially by model, and fit testing is usually not easily available to visitors.

The risk assessment for the setting might identify a limited number of circumstances (e.g., bronchoscopy or autopsy on persons with suspected or confirmed TB disease and selected laboratory procedures) for which a level of respiratory protection that exceeds the minimum level provided by an N95 disposable respirator should be considered. In such circumstances, consider providing HCWs with a level of respiratory protection that both exceeds the minimum criteria and is compatible with patient care delivery. Such protection might include more protective respirators (e.g., full-facepiece respirators or PAPRs) (see Supplement, Respiratory Protection). Detailed information regarding these and other respirators has been published (*272,273,278,290*).

In certain settings, HCWs might be at risk for both inhalation exposure to *M. tuberculosis* and mucous membrane exposure to bloodborne pathogens. In these situations, the HCW might wear a nonfluid-resistant respirator with a full-face shield or the combination product surgical mask/N95 disposable respirator to achieve both respiratory protection and fluid protection.

When surgical procedures (or other procedures requiring a sterile field) are performed on persons with suspected or confirmed infectious TB disease, respiratory protection worn by HCWs must also protect the surgical field. The patient should be protected from the HCW's respiratory secretions and the HCW from infectious droplet nuclei that might be expelled by the patient or generated by the procedure. Respirators with exhalation valves and PAPRs do not protect the sterile field.

Settings in which patients with suspected or confirmed infectious TB disease will not be encountered do not need a respiratory-protection program for exposure to *M. tuberculosis*. However, these settings should have written protocols for the early identification of persons with symptoms or signs of TB disease and procedures for referring these patients to a setting where they can be evaluated and managed. Filtering facepiece respirators should also be available for emergency use by HCWs who might be exposed to persons with suspected or confirmed TB disease before transfer. In addition, respirators and the associated respiratory-protection program might be needed to protect HCWs from other infectious diseases or exposures to harmful vapors and gases. Their availability or projected need for other exposures should be considered in the selection of respirators for protection against TB to minimize replication of effort.

Surgical or procedure masks are designed to prevent respiratory secretions of the wearer from entering the air. To reduce the expulsion of droplet nuclei into the air, persons with suspected or confirmed TB disease should be instructed to observe respiratory hygiene and cough etiquette procedures (*122*) and should wear a surgical or procedure mask, if possible, when they are not in AII rooms. These patients do not need to wear particulate respirators.

Patients with suspected or confirmed TB disease should never wear any kind of respiratory protection that has an exhalation valve. This type of respirator does not prevent droplet nuclei from being expelled into the air.

Cough-Inducing and Aerosol-Generating Procedures

General Recommendations

Procedures that involve instrumentation of the lower respiratory tract or induction of sputum can increase the likelihood that droplet nuclei will be expelled into the air. These cough-inducing procedures include endotracheal intubation, suctioning, diagnostic sputum induction, aerosol treatments (e.g., pentamidine therapy and nebulized treatments), bronchoscopy, and laryngoscopy. Gastric aspiration and nasogastric tube placement can also induce cough in certain patients. Other procedures that can generate aerosols include irrigating TB abscesses, homogenizing or lyophilizing tissue, performing autopsies on cadavers with untreated TB disease, and other processing of tissue that might contain tubercle bacilli and TB laboratory procedures.

If possible, postpone cough-inducing or aerosol-generating procedures on patients with suspected or confirmed infectious TB disease unless the procedure can be performed with recommended precautions. When a cough-inducing or aerosol-generating procedure must be performed on a patient

with suspected or confirmed infectious TB disease, use a local exhaust ventilation device (e.g., booth or special enclosure). If using this device is not feasible, perform the procedure in a room that meets the ventilation requirements for an AII room.

After completion of cough-inducing procedures, keep patients in the AII room or enclosure until coughing subsides. Patients should be given tissues and instructed to cover the mouth and nose with tissues when coughing. Tissues should be disposed of in accordance with the infection-control plan.

Before the booth, enclosure, or room is used for another patient, allow enough time for the removal of ≥99% of airborne contaminants. This interval will vary based on the efficiency of the ventilation or filtration system (Table 1).

For postoperative recovery, do not place the patient in a recovery room with other patients; place the patient in a room that meets the ventilation requirements for an AII room. If the room does not meet the ventilation requirements for an AII room, air-cleaning technologies (e.g., HEPA filtration and UVGI) can be used to increase the number of equivalent ACH (see Supplement, Environmental Controls).

Perform all manipulations of suspected or confirmed *M. tuberculosis* specimens that might generate aerosols in a BSC. When in rooms or enclosures in which cough-inducing or aerosol-generating procedures are being performed, respiratory protection should be worn.

Special Considerations for Bronchoscopy

Bronchoscopy can result in the transmission of *M. tuberculosis* either through the airborne route (*63,81,86,162*) or a contaminated bronchoscope (*80,82,163–169*). Whenever feasible, perform bronchoscopy in a room that meets the ventilation requirements for an AII room (see Supplement, Environmental Controls). Air-cleaning technologies can be used to increase equivalent ACH. If a bronchoscopy must be performed in a positive-pressure room (e.g., OR), exclude TB disease before performing the procedure. Examine three spontaneous or induced sputum specimens for AFB (if possible) to exclude a diagnosis of TB disease before bronchoscopy is considered as a diagnostic procedure (*110,291*).

In a patient who is intubated and mechanically ventilated, minimize the opening of circuitry. For HCWs present during bronchoscopic procedures on patients with suspected or confirmed TB disease, a respirator with a level of protection of at least an N95 disposable respirator should be worn. Protection greater than an N95 disposable respirator (e.g., a full-facepiece elastomeric respirator or PAPR) should be considered.

TABLE 2. Ventilation recommendations for selected areas in new or renovated health-care settings

Health-care setting	Minimum mechanical ACH*	Minimum outdoor ACH*	Air movement relative to adjacent areas	Air exhausted directly outdoors†
Microbiology laboratory	6	§	In	Yes
Anteroom to AII¶ room	10	§	In/Out	Yes
AII room**††	12	2	In	Yes
Autopsy suite	12	§	In	Yes
Bronchoscopy room	12	2	In	Yes
Emergency department and radiology waiting rooms	12–15§§	2	In	Yes
Operating room or surgical room	15¶¶	3§§	Out	§
	25***	15¶¶		
		5***		

SOURCES: CDC. Guidelines for preventing the transmission of *Mycobacterium tuberculosis* in health-care facilities, 1994. MMWR 1994;43(No. RR-13). American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. Health care facilities [Chapter 7]. 2003 ASHRAE handbook: HVAC applications. Atlanta, GA: American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc.; 2003:7.1–7.14.

* Air changes per hour.

† If it is not possible to exhaust all the air to the outdoors in existing or renovated facilities, the air can be recirculated after passing through high efficiency particulate air (HEPA) filtration.

§ American National Standards Institute (ANSI)/American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE). Standard 62.1-2004, Ventilation for Acceptable Indoor Air Quality, should be consulted for outside air recommendations in areas that are not specified. **SOURCE:** ANSI/ASHRAE. Standard 62.1-2004—ventilation for acceptable indoor air quality. Atlanta, GA: ASHRAE; 2004.

¶ Airborne infection isolation.

** Settings with existing AII rooms should have an airflow of ≥6 mechanical ACH; air-cleaning devices can be used to increase the equivalent ACH.

†† Patients requiring a protective environment room (e.g., severely immunocompromised patients) who also have TB disease require protection from common airborne infectious microorganisms.

§§ Recommendation of the American Institute of Architects (AIA) (air is recirculated through HEPA filters). **SOURCE:** AIA. Guidelines for design and construction of hospital and health care facilities. Washington, DC: AIA; 2001.

¶¶ Recommendation of ASHRAE (100% exhaust). **SOURCE:** ANSI/ASHRAE. Standard 62.1-2004—ventilation for acceptable indoor air quality. Atlanta, GA: ASHRAE; 2004.

*** Recommendation of ASHRAE (air is recirculated through HEPA filters). **SOURCE:** ANSI/ASHRAE. Standard 62.1-2004—ventilation for acceptable indoor air quality. Atlanta, GA: ASHRAE; 2004.

Special Considerations for Administration of Aerosolized Pentamidine and Other Medications

Patients receiving aerosolized pentamidine (or other aerosolized medications) who are immunocompromised and have a confirmed or suspected pulmonary infection (i.e., pneumocystis pneumonia [PCP] or pneumonia caused by *P. jaroveci,* formerly *P. carinii*) are also at risk for TB disease. Patients receiving other aerosolized medications might have an immunocompromising condition that puts them at greater risk for TB disease. Patients should be screened for TB disease before initiating prophylaxis with aerosolized pentamidine; a medical history, test for infection with *M. tuberculosis*, and a chest radiograph should be performed.

Before each subsequent treatment with aerosolized pentamidine, screen patients for symptoms or signs of TB disease. If symptoms or signs are present, evaluate the patient for TB disease. Patients with suspected or confirmed TB disease should be administered oral prophylaxis for *P. jaroveci* instead of aerosolized pentamidine if clinically practical. Patients receiving other aerosolized medication might have immunocompromising conditions; therefore, if warranted, they should be similarly screened and evaluated, and treatment with oral medications should be considered.

Supplements

Estimating the Infectiousness of a TB Patient

General Principles

Transmission of *M. tuberculosis* is most likely to result from exposure to persons who have 1) unsuspected pulmonary TB disease and are not receiving antituberculosis treatment, 2) diagnosed TB disease and are receiving inadequate therapy, or 3) diagnosed TB disease and are early in the course of effective therapy. Administration of effective antituberculosis treatment has been associated with decreased infectiousness among persons who have TB disease (*292*). Effective treatment reduces coughing, the amount of sputum produced, the number of organisms in the sputum, and the viability of the organisms in the sputum. However, the duration of therapy required to decrease or eliminate infectiousness varies (*293*). Certain TB patients are never infectious, whereas those with unrecognized or inadequately treated drug-resistant TB disease might remain infectious for weeks or months (*2,3,87,94,162,294–297*). In one study, 17% of transmission occurred from persons with negative AFB smear results (*262*). Rapid laboratory methods, including PCR-based techniques, can decrease diagnostic delay and reduce the duration of infectiousness (*298*).

The infectiousness of patients with TB correlates with the number of organisms they expel into the air (*299*). The number of organisms expelled are related to the following factors: 1) presence of cough lasting ≥3 weeks; 2) cavitation on chest radiograph; 3) positive AFB sputum smear result; 4) respiratory tract disease with involvement of the lung or airways, including larynx; 5) failure to cover the mouth and nose when coughing; 6) lack of, incorrect, or short duration of antituberculosis treatment (*300*); or 7) undergoing cough-inducing or aerosol-generating procedures (e.g., sputum induction, bronchoscopy, and airway suction). Closed and effectively filtered ventilatory circuitry and minimized opening of such circuitry in intubated and mechanically ventilated patients might minimize exposure (see Intensive Care Units [ICUs]).

Persons with extrapulmonary TB disease usually are not infectious unless they have concomitant pulmonary disease, nonpulmonary disease located in the oral cavity or the larynx, or extrapulmonary disease that includes an open abscess or lesion in which the concentration of organisms is high, especially if drainage from the abscess or lesion is extensive, or if aerosolization of drainage fluid is performed (*69,72,77,83,301*). Persons with TB pleural effusions might also have concurrent unsuspected pulmonary or laryngeal TB disease. These patients should be considered infectious until pulmonary TB disease is excluded. Patients with suspected TB pleural effusions or extrapulmonary TB disease should be considered pulmonary TB suspects until concomitant pulmonary disease is excluded (*302*).

Although children with TB disease usually are less likely than adults to be infectious, transmission from young children can occur (*135,137*). Therefore, children and adolescents with TB disease should be evaluated for infectiousness by using the majority of the same criteria as for adults. These criteria include presence of cough lasting ≥3 weeks; cavitation on chest radiograph; or respiratory tract disease with involvement of lungs, airways, or larynx. Infectiousness would be increased if the patient were on nonstandard or short duration of antituberculosis treatment (*300*) or undergoing cough-inducing or aerosol-generating procedures (e.g., sputum induction, bronchoscopy, and airway suction). Although gastric lavage is useful in the diagnosis of pediatric TB disease, the grade of the positive AFB smear result does not correlate with infectiousness. Pediatric patients who might be infectious include those who are not on antituberculosis treatment, who have just been started on treatment or are on inadequate treatment, and who have extensive pulmonary or laryngeal involvement (i.e., coughing ≥3 weeks, cavitary TB disease, positive AFB sputum smear results, or undergoing cough-inducing or aerosol-generating

procedures). Children who have typical primary TB lesions on chest radiograph and do not have any of these indicators of infectiousness might not need to be placed in an AII room.

No data exist on the transmission of *M. tuberculosis* and its association with the collection of gastric aspirate specimens. Children who do not have predictors for infectiousness do not need to have gastric aspirates obtained in an AII room or other special enclosure; however, the procedure should not be performed in an area in which persons infected with HIV might be exposed. Because the source case for pediatric TB patients might be a member of the infected child's family, parents and other visitors of all hospitalized pediatric TB patients should be screened for TB disease as soon as possible to ensure that they do not become sources of health-care–associated transmission of *M. tuberculosis* (*303–306*).

Patients who have suspected or confirmed TB disease and who are not on antituberculosis treatment usually should be considered infectious if characteristics include

- presence of cough;
- cavitation on chest radiograph;
- positive AFB sputum smear result;
- respiratory tract disease with involvement of the lung or airways, including larynx;
- failure to cover the mouth and nose when coughing; and
- undergoing cough-inducing or aerosol-generating procedures (e.g., sputum induction, bronchoscopy, and airway suction).

If a patient with one or more of these characteristics is on standard multidrug therapy with documented clinical improvement usually in connection with smear conversion over multiple weeks, the risk for infectiousness is reduced.

Suspected TB Disease

For patients placed under airborne precautions because of suspected infectious TB disease of the lungs, airway, or larynx, airborne precautions can be discontinued when infectious TB disease is considered unlikely and either 1) another diagnosis is made that explains the clinical syndrome or 2) the patient has three negative AFB sputum smear results (*109–112*). Each of the three consecutive sputum specimens should be collected in 8–24-hour intervals (*124*), and at least one specimen should be an early morning specimen because respiratory secretions pool overnight. Generally, this method will allow patients with negative sputum smear results to be released from airborne precautions in 2 days.

Hospitalized patients for whom the suspicion of TB disease remains after the collection of three negative AFB sputum smear results should not be released from airborne precautions until they are on standard multidrug antituberculosis treatment and are clinically improving. If the patient is believed to not have TB disease because of an alternate diagnosis or because clinical information is not consistent with TB disease, airborne precautions may be discontinued. Therefore, a patient suspected of having TB disease of the lung, airway, or larynx who is symptomatic with cough and not responding clinically to antituberculosis treatment should not be released from an AII room into a non-AII room, and additional sputum specimens should be collected for AFB examination until three negative AFB sputum smear results are obtained (*30,31*). Additional diagnostic approaches might need to be considered (e.g., sputum induction) and, after sufficient time on treatment, bronchoscopy.

Confirmed TB Disease

A patient who has drug-susceptible TB of the lung, airway, or larynx, who is on standard multidrug antituberculosis treatment, and who has had a substantial clinical and bacteriologic response to therapy (i.e., reduction in cough, resolution of fever, and progressively decreasing quantity of AFB on smear result) is probably no longer infectious. However, because culture and drug-susceptibility results are not usually known when the decision to discontinue airborne precautions is made, all patients with suspected TB disease should remain under airborne precautions while they are hospitalized until they have had three consecutive negative AFB sputum smear results, each collected in 8–24-hour intervals, with at least one being an early morning specimen; have received standard multidrug antituberculosis treatment (minimum of 2 weeks); and have demonstrated clinical improvement.

Discharge to Home of Patients with Suspected or Confirmed TB Disease

If a hospitalized patient who has suspected or confirmed TB disease is deemed medically stable (including patients with positive AFB sputum smear results indicating pulmonary TB disease), the patient can be discharged from the hospital before converting the positive AFB sputum smear results to negative AFB sputum smear results, if the following parameters have been met:

- a specific plan exists for follow-up care with the local TB-control program;
- the patient has been started on a standard multidrug antituberculosis treatment regimen, and DOT has been arranged;
- no infants and children aged <4 years or persons with immunocompromising conditions are present in the household;
- all immunocompetent household members have been previously exposed to the patient; and

- the patient is willing to not travel outside of the home except for health-care–associated visits until the patient has negative sputum smear results.

Patients with suspected or confirmed infectious TB disease should not be released to health-care settings or homes in which the patient can expose others who are at high risk for progressing to TB disease if infected (e.g., persons infected with HIV or infants and children aged <4 years). Coordination with the local health department TB program is indicated in such circumstances.

Drug-Resistant TB Disease

Because the consequences of transmission of MDR TB are severe, certain infection-control practitioners might choose to keep persons with suspected or confirmed MDR TB disease under airborne precautions during the entire hospitalization or until culture conversion is documented, regardless of sputum smear results. The role of drug resistance in transmission is complex. Transmission of drug-resistant organisms to persons with and without HIV infection has been documented (*54,307–309*). In certain cases, transmission from patients with TB disease caused by drug-resistant organisms might be extensive because of prolonged infectiousness as a result of delays in diagnosis and delays in initiation of effective therapy (*53,94,98,101,255,310,311*).

HIV-Associated TB Disease

Although multiple TB outbreaks among HIV-infected persons have been reported (*51,52,99*), the risk for transmission does not appear to be increased from patients with TB disease and HIV infection, compared with TB patients without HIV infection (*54,312–315*). Whether persons infected with HIV are more likely to be infected with *M. tuberculosis* if exposed is unclear; however, after infected with *M. tuberculosis*, the risk for progression to TB disease in persons infected with HIV is high (*316*). Progression to TB disease can be rapid, as soon as 1 month after exposure (*51,53,54,101*).

Diagnostic Procedures for LTBI and TB Disease

LTBI is a condition that develops after exposure to a person with infectious TB disease, and subsequent infection with *M. tuberculosis* occurs where the bacilli are alive but inactive in the body. Persons who have LTBI but who do not have TB disease are asymptomatic (i.e., have no symptoms), do not feel sick, and cannot spread TB to other persons.

Use of QFT-G for Diagnosing *M. tuberculosis* Infections in Health-Care Workers (HCWs)

In the United States, LTBI has been traditionally diagnosed based on a positive TST result after TB disease has been excluded. In vitro cytokine-based immunoassays for the detection of *M. tuberculosis* infection have been the focus of intense research and development. This document uses the term "BAMT" to refer to blood assay for *M. tuberculosis* infection currently available in the United States.

One such BAMT is QFT (which is PPD-based) and the subsequently developed version, QFT-G. QFT-G measures cell-mediated immune responses to peptides representative of two *M. tuberculosis* proteins that are not present in any BCG vaccine strain and are absent from the majority of nontuberculosis mycobacteria. This assay was approved by FDA in 2005 and is an available option for detecting *M. tuberculosis* infection. CDC recommendations for the United States on QFT and QFT-G have been published (*35*).

QFT-G is an in vitro test based on measuring interferon-gamma (IFN-γ) released in heparinized whole blood when incubated overnight with mitogen (serving as a positive control), Nil (i.e., all reagents except antigens, which sets a baseline), and peptide simulating ESAT-6 (6-kDa early secretory antigenic target) and CFP-10 (10-kDa culture filtrate protein) (measured independently), two different proteins with similar amino acid sequences specific for *M. tuberculosis* (Box 2). The sequences of ESAT-6 and CFP-10 are not related to each other. The genes encoding these two proteins are usually found next to each other in an operon (i.e., are coexpressed and translated from an mRNA product containing both genes). Although mycobacterial genomes contain multiple copies of each family, QFT-G and Elispot detect immunoreactivity associated only with the ESAT-6 protein and CFP-10 protein encoded by the genes in the region of deletion (RD1). In addition, virulence attributes are associated with the RD1 genes only and not the other homologues.

Specific antigens of these two proteins are found in *M. tuberculosis*–complex organisms (i.e., *M. tuberculosis, M. bovis, M. africanum, M. microti, M. canetti, M. caprae,* and *M. pinnipedii*), but not in the majority of other mycobacteria or in vaccine-variant *M. bovis*, BCG. Lymphocytes from the majority of persons who have been infected by *M. tuberculosis* complex indicate their sensitivity to ESAT-6 or CFP-10 by releasing IFN-γ, whereas infection by the majority of other mycobacteria, including BCG, does not appear to cause this sensitivity.

The blood tests using IFN-γ methods require one less patient visit, assess responsiveness to *M. tuberculosis* antigens, and do not boost anamnestic immune responses. Interpretation

BOX 2. Interpretation of QuantiFERON®-TB Gold test (QFT-G) results

QFT-G result	Interpretation
Positive	
ESAT-6 or CFP-10* responsiveness detected	*Mycobacterium tuberculosis* infection probable
Negative	
No ESAT-6 and CFP-10 responsiveness detected	*M. tuberculosis* infection unlikely, but cannot be excluded, especially when 1. any illness is consistent with TB disease, and 2. the likelihood of progression to TB disease is increased (e.g., because of immunosuppression)
Indeterminate	Test not interpretable

* ESAT-6 is a 6-kDa early secretory antigenic target, and CFP-10 is 10-kDa culture filtrate protein.

of the BAMT result is less subjective than interpretation of a skin test result, and the BAMT result might be affected less by previous BCG vaccination and sensitization to environmental mycobacteria (e.g., *M. avium* complex) than the PPD-based TST. BAMT might be more efficient and cost effective than TST (*35*). Screening programs that use BAMT might eliminate the need for two-step testing because this test does not boost sensitization.

Other cytokine-based immunoassays are under development and might be useful in the diagnosis of *M. tuberculosis* infection. Future FDA-approved products, in combination with CDC-issued recommendations, might provide additional diagnostic alternatives. For guidance on the use of these and related technologies, CDC plans to periodically publish recommendations on the diagnosis of *M. tuberculosis* infection. BAMT can be used in both testing and infection-control surveillance programs for HCWs.

Use of Tuberculin Skin Test (TST) for Diagnosing *M. tuberculosis* Infections in HCWs

The TST is frequently the first step of a TB diagnostic evaluation that might lead to diagnosing LTBI. Although currently available preparations of PPD used in TST are <100% sensitive and specific for the detection of LTBI, the TST is currently the most widely used diagnostic test for *M. tuberculosis* infection in the United States. The TST is less sensitive in patients who have TB disease.

The TST, like all medical tests, is subject to variability (*74,228,317*), but many of the inherent variations in administering and reading TST results can be avoided by training and attention to detail (*318*). Details of TST administration and TST result reading procedures are suggested in this report to improve the technical aspects of TST placement and reading, thus reducing observer variations and improving test reliability (Appendix F). These checklists were developed for the National Health and Nutrition Examination Survey (NHANES) to standardize TST placement and reading for research purposes. The suggested TST training recommendations are not mandatory.

Adherence to TST

Operational policies, procedures, and practices at healthcare settings can enhance HCW adherence to serial TST. In 2002, one focus group study identified potential barriers and facilitators to adherence with routine TST (*319*). HCWs identified structural factors (e.g., inconvenient TST screening schedules and locations and long waiting times) that negatively affected adherence. Facilitators to help HCWs adhere to routine TST included active follow-up by supervisors and occupational health staff and work-site visits for TST screening. Misinformation and stigma concerning TB also emerged in the discussions, indicating the need for additional training and education for HCWs.

Administering the TST

For each patient, a risk assessment should be conducted that takes into consideration recent exposure to *M. tuberculosis*, clinical conditions that increase risk for TB disease if infected, and the program's capacity to deliver treatment for LTBI to determine if the TST should be administered.

The recommended method for TST is the Mantoux method (Appendix F) (*223,318,320–322*). Mantoux TST training materials supporting the guidance in this report are available at http://www.cdc.gov/tb (*223,318,320–325*). Multipuncture tests (e.g., Tine® tests) are not as reliable as the Mantoux method of skin testing and should not be used as a diagnostic test in the United States (*30*). Contact the state and local health department for TST resources.

Reading the TST Result

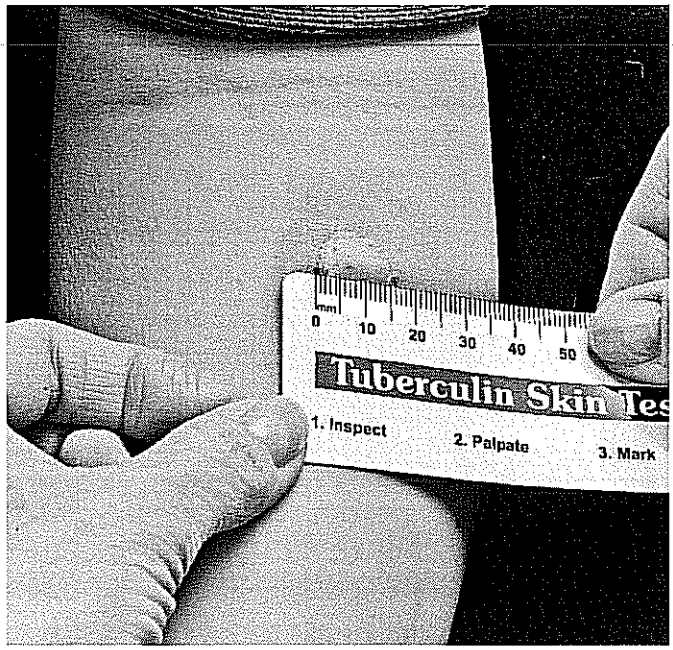
The TST result should be read by a designated, trained HCW 48–72 hours after the TST is placed (*39,326,327*). If the TST was not read between 48–72 hours, ideally, another TST should be placed as soon as possible and read within 48–72 hours (*39*). Certain studies indicate that positive TST reactions might still be measurable from 4–7 days after testing (*225,226,328*). However, if a patient fails to return within 72 hours and has a negative test result, the TST should be repeated (*42*). Patients and HCWs should not be allowed to read their own TST results. HCWs do not typically measure their own TST results reliably (*48*).

Reading the TST result consists of first determining the presence or absence of induration (hard, dense, and raised formation) and, if induration is present, measuring the diameter of induration transverse (perpendicular) to the long axis of the forearm (Figure 1) (*39,318*). Erythema or redness of the skin should not be considered when reading a TST result (Appendix F).

Interpreting TST Results

The positive-predictive value of a TST is the probability that a person with a positive TST result is actually infected with *M. tuberculosis*. The positive predictive value is dependent on the prevalence of infection with *M. tuberculosis* in the population being tested and the sensitivity and specificity of the test (*228,329,330*).

FIGURE 1. The tuberculin skin test result in this picture should be recorded as 16 mm. The "0" mm ruler line is inside the edge of the left dot.



In populations with a low prevalence of *M. tuberculosis* infection, the probability that a positive TST result represents true infection with *M. tuberculosis* can be substantially low, especially if the cut point is set too low (i.e., the test is not adequately specific and a low prevalence exists in the population). In populations with a high prevalence of infection with *M. tuberculosis* and inadequate test specificity, the probability that a positive TST result using the same cut point represents true infection with *M. tuberculosis* is much higher.

Interpreting TST Results in HCWs

TST result interpretation depends on two factors: 1) measured TST induration in millimeters and 2) the person's risk for being infected with *M. tuberculosis* and risk for progression to TB disease if infected.

Intepretations of TST and QFT results vary according to the purpose of testing (Box 3). A TST result with no induration (0 mm) or a measured induration below the defined cut point for each category is considered to signify absence of infection with *M. tuberculosis*.

In the context of TST screening as part of a TB infection-control program, the interpretation of TST results occurs in two distinct parts. The first is the interpretation by standard criteria, without regard to personal risk factors or setting-specific factors of the TST results for infection control, surveillance, and referral purposes. The second is the interpretation by individualized criteria to determine the need for treatment of LTBI.

Determining the need for treatment of LTBI is a subsequent and separate task. For infection-control and surveillance purposes, TST results should be interpreted and recorded under strict criteria, without considering setting-based or personal risk factors (see Supplement, Diagnostic Procedures for LTBI and TB Disease). Any HCW with a positive TST result from serial TB screening should be referred to a medical provider for an evaluation and to determine the need for treatment of LTBI based on individual risk (Box 3).

Interpreting the TST Result for Infection Control and Surveillance

On baseline TST testing, a TST result of ≥10 mm is considered positive for the majority of HCWs, and a TST result of ≥5 mm is considered positive for HCWs who are infected with HIV or who have other immunocompromising conditions (Box 3). All HCWs with positive baseline TST results should be referred for medical and diagnostic evaluation; additional skin testing does not need to be performed.

On serial screening for the purposes of infection-control surveillance, TST results indicating an increase of ≥10 mm within 2 years should be interpreted and recorded as a TST

BOX 3. Interpretations of tuberculin skin test (TST) and QuantiFERON®-TB test (QFT) results according to the purpose of testing for *Mycobacterium tuberculosis* infection in a health-care setting

Purpose of testing	TST	QFT
1. Baseline	1. ≥10 mm is considered a positive result (either first- or second-step): 0–9 mm is considered a negative result	1. Positive (only one-step)
2. Serial testing without known exposure	2. Increase of ≥10 mm is considered a positive result (TST conversion)	2. Change from negative to positive (QFT conversion)
3. Known exposure (close contact)	3. ≥5 mm is considered a positive result in persons who have a baseline TST result of 0 mm; an increase of ≥10 mm is considered a positive result in persons with a negative baseline TST result or previous follow-up screening TST result of >0 mm	3. Change to positive

conversion. For the purposes of assessing and monitoring infection control, TST conversion rates should be regularly determined. Health-care settings with a substantial number of HCWs to be tested might have systems in place that can accurately determine the TST conversion rate every month (e.g., from among a group of HCWs tested annually), whereas smaller settings might have imprecise estimates of their TST conversion rate even with annual assessments.

The precision of the setting's TST conversion rate and any analysis assessing change from baseline TST results will depend on the number and frequency of HCWs tested. These factors should be considered when establishing a regular interval for TB screening for HCWs.

After a known exposure in a health-care setting, close HCW contacts who have TST results of ≥5 mm should be considered to have positive TST results, which should be interpreted as new infections only in HCWs whose previous TST result is 0 mm. However, HCWs 1) with a baseline or follow-up TST result of >0 mm but <10 mm with a health-care–associated exposure to *M. tuberculosis* and 2) who then have an increase of ≥10 mm should be considered to have a TST conversion because of a new infection (Box 3).

In a contact investigation, a follow-up TST should be administered 8–10 weeks after the end of exposure (rather than 1–3 weeks later, as in two-step testing). In this instance, a change from a negative TST result to a positive TST result should not be interpreted as a boosted reaction. The change in the TST result indicates a TST conversion, recent exposure, transmission, and infection.

All HCWs who are immunocompromised should be referred for a medical and diagnostic evaluation for any TST result of ≥5 mm on baseline or follow-up screening. Because infection-control staff will usually not know the immune status of the HCWs being tested, HCWs who have TST results of 5–9 mm should be advised that such results can be an indication for referral for medical evaluation for HCWs who have HIV infection or other causes of severe immunosuppression.

After an HCW has met criteria for a positive TST result, including HCWs who will not receive treatment for LTBI, repeat TSTs are not necessary because the results would not provide any additional information (*30*). This approach applies to HCWs who have positive TST results but who will not receive treatment for LTBI after medical evaluation. For future TB screening in settings that are medium risk, instead of participating in serial skin testing, the HCW should receive a medical evaluation and a symptom screen annually.

Interpreting the TST Result for Medical and Diagnostic Referral and Evaluation

HCWs who have positive TST results and who meet the criteria for referral should have a medical and diagnostic evaluation. For HCWs who are at low risk (e.g., those from low-incidence settings), a baseline result of ≥15 mm of induration (instead of ≥10 mm) might possibly be the cut point. The criteria used to determine the need for treatment of LTBI has been presented.

When making decisions for the diagnosis and treatment of LTBI, setting-based risk factors (e.g., the prevalence of TB disease and personal risk factors such as having an immunocompromising condition or known contact with a TB case) should be assessed when choosing the cut point for a positive TST result. The medical evaluation can occur in different settings, including an occupational health clinic, local or state health department, or private medical clinic.

When 15 mm is used as the cut point, TST results of 10–14 mm can be considered clinically negative (*331*). These HCWs should not have repeat TST, and the referring physician might

not recommend treatment for LTBI. This issue of false-positive TST results might be especially true in areas of the country where the prevalence of infection with NTM is high.

HCWs who have TST results of 5–9 mm on baseline two-step testing should be advised that such results might be an indication for treatment of LTBI if the HCW is a contact of a person with infectious TB disease, has HIV infection, or has other causes of severe immunosuppression (e.g., organ transplant and receipt of the equivalent of ≥15 mg/day of prednisone for ≥1 month). The risk for TB disease in persons treated with corticosteroids increases with higher dose and longer duration of corticosteroid use. TNF-α antagonists also substantially increase the risk for progression to TB disease in persons with LTBI (*332*).

HCWs with negative baseline two-step TST results who are referred for medical evaluation for an increase of ≥10 mm induration on follow-up TST screening, including those who are otherwise at low risk for TB disease, probably acquired *M. tuberculosis* infection since receiving the previous TST and should be evaluated for TB disease. If disease is excluded, the HCW should be offered treatment for LTBI if they have no contraindication to treatment.

QC Program for Techniques for TST Administration and Reading TST Results

Random variation (i.e., differences in procedural techniques) in TST administration and reading TST results can cause false-positive or false-negative TST results. Many of the variations in administering and reading TST results can be avoided by conducting training and maintaining attention to details. HCWs who are responsible for TST procedures should be trained to reduce variation by following standardized operational procedures and should be observed by an expert TST trainer. All TST procedures (i.e., administering, reading, and recording the results) should be supervised and controlled to detect and correct variation. Corrective actions might include coaching and demonstration by the TST trainer. Annual re-training is recommended for HCWs responsible for administering and reading TST results.

One strategy to identify TST procedure variation is to use a QC tool (Appendix F). The expert TST trainer should observe the procedures and indicate procedural variation on the observation checklists. An expert trainer includes persons who have documented training experience.

QC for Administering TST by the Mantoux Method

Ideally, the TST trainer should participate in QC TST administrations with other TST trainers to maintain TST trainer certification. State regulations specify who is qualified to administer the test by injection. The TST trainer should first ensure antigen stability by maintaining the manufacturer's recommended cold chain (i.e., controlling antigen exposure to heat and light from the time it is out of refrigeration until the time it is placed back into refrigeration or until the vial is empty or expired). The TST trainer should prevent infection during an injection by preparing the skin and preventing contamination of solution, needle, and syringe.

The TST trainer should prevent antigen administration errors by controlling the five rights of administration: 1) right antigen; 2) right dose; 3) right patient; 4) right route; and 5) right time for TST administration, reading, and clinical evaluation (*333*). Finally, the TST trainer should observe and coach the HCW trainee in administering multiple intradermal injections by the Mantoux method. The TST trainer should record procedural variation on the observation checklist (Appendix F). TST training and coaching should continue until more than 10 correct skin test placements (i.e., ≥6 mm wheal) are achieved.

For training purposes, normal saline for injection can be used instead of PPD for intradermal injections. Volunteers are usually other HCWs who agree to be tested. Attempt to recruit volunteers who have known positive TST results so the trainees can practice reading positive TST results. A previous TST is not a contraindication to a subsequent TST unless the test was associated with severe ulceration or anaphylactic shock, which are substantially rare adverse events (*30,237,238*).

Model TST Training Program

A model TST training program for placing TST and reading TST results has been produced by NHANES (*326*). The number of hours, sessions, and blinded independent duplicate reading (BIDR) readings should be determined by the setting's TB risk assessment. The following information can be useful for a model TST training program. The suggested TST training recommendations are not mandatory.

Initial training for a TST placer ideally consists of three components.

- Introductory lecture and demonstration by an expert TST placer or trainer. An expert TST trainer is a qualified HCW who has received training on administering multiple TST and reading multiple TST results (consider 3 hours of lecture).
- Supervised practical work using procedural checklists observed and coached by the expert TST trainer (Appendix F) (consider 9 hours of practical work).
- Administration of more than 10 total skin tests on volunteers by using injectable saline and producing more than 10 wheals that measure 6–10 mm.

TST training should include supervised TST administration, which is a procedure in which an expert TST trainer supervises a TST trainee during all steps on the procedural observation

checklist for TST administration (Appendix F). Wheal size should be checked for all supervised TST administrations, and skin tests should be repeated if wheal size is inadequate (i.e., <6 mm). TST training and coaching should continue until more than10 correct skin test placements (i.e., ≥6 mm wheal) are achieved.

QC for Reading TST Results by the Palpation Method

The TST trainer should participate in QC readings with other TST trainers to maintain TST trainer certification. When training HCWs to read TST results, providing measurable TST responses is helpful (i.e., attempt to recruit volunteers who have known positive TST results so that the trainees can practice reading positive TST results).

TST readers should correctly read both measurable (>0 mm) and nonmeasurable responses (0 mm) (e.g., consider reading more than 20 TST results [at least 10 measurable and at least 10 nonmeasurable], if possible). The TST trainer should observe and coach the HCW in reading multiple TST results by the Palpation method and should record procedure variation on the observation checklist (Appendix F).

The TST trainer should conduct BIDRs for comparison with the HCW's reading. BIDRs are performed when two or more consecutive TST readers immediately measure the same TST result by standard procedures, without consulting or observing one another's readings, and record results independently (may use recommended procedural observation checklist; Appendix F). BIDRs help ensure that TST readers continue to read TST results correctly.

Initial training for a TST reader ideally should consist of multiple components.

- Receiving an introductory lecture and demonstration by an expert TST reader. Training materials are available from CDC (*223,318*) and CDC-sponsored Regional Model and Training Centers and should also be available at the local or state health department (consider 6 hours for lecture and demonstration).
- Receiving four sessions of supervised practical work using procedural checklists (observed and coached by an expert TST reader) (consider 16 hours of practical work).
- Performing BIDR readings (consider more than 80, if possible). TST trainers should attempt to organize the sessions so that at least 50% of the TST results read have a result of >0 mm according to the expert TST reader.
- Performing BIDR readings on the last day of TST training (consider more than 30 BIDR readings out of the total 80 readings, if possible). TST trainers should attempt to ensure that at least 25% of persons tested have a TST result of >0 mm, according to the expert TST reader.
- Missing no more than two items on the procedural observation checklist (Appendix F) for three random observations by an expert TST reader.
- Performing all procedures on the checklist correctly during the final observation.

TST training and coaching should continue until the HCW is able to perform all procedures correctly and until a satisfactory measurement is achieved (i.e., the trainer and the trainee read the TST results within 2 mm of each other). For example, if the trainer reads the TST result as 11 mm (this might be considered the gold standard reading), the trainee's reading should be between 9–13 mm to be considered correct. Only a single measurement in millimeters should be recorded (not 11 mm x 11 mm or 11 mm x 15 mm). QC Procedural Observation Checklists (Appendix F) are recommended by CDC as a tool for use during TST training.

Special Considerations in TST

Anergy. The absence of a reaction to a TST does not exclude a diagnosis of TB disease or infection with *M. tuberculosis*. In immunocompromised persons, delayed-type hypersensitivity (DTH) responses (e.g., tuberculin reactions) can decrease or disappear more rapidly, and a limited number of otherwise healthy persons apparently are incapable of reacting to tuberculin even after diagnosed infection with *M. tuberculosis*. This condition, called anergy, can be caused by multiple factors (e.g., advanced HIV infection, measles infection, sarcoidosis, poor nutrition, certain medications, vaccinations, TB disease itself, and other factors) (*307,334–338*). However, anergy testing in conjunction with TB skin testing is no longer recommended routinely for screening for *M. tuberculosis* infection (*336*).

Reconstitution of DTH in HIV-infected persons taking antiretroviral therapy (ART). In one prospective study (*340*), TB patients who initially had negative TST results had positive TST results after initiation of HAART. HCWs must be aware of the potential public health and clinical implications of restored TST reactivity among persons who have not been diagnosed with TB disease but who might have LTBI. After the initiation of HAART repeat testing for infection with *M. tuberculosis* is recommended for HIV-infected persons previously known to have negative TST results (*58*). Recommendations on the prevention and treatment of TB in HIV-infected persons have been published (*39,53,240*).

Pregnancy. Tens of thousands of pregnant women have received TST since the test was developed, and no documented episodes of TST-related fetal harm have been reported (*341*). No evidence exists that the TST has adverse effects on the pregnant mother or fetus (*39*). Pregnant HCWs should be included in serial skin testing as part of an infection-control program or a contact investigation because no contraindication for skin

testing exists (*342*). Guidelines issued by the American College of Obstetricians and Gynecologists (ACOG) emphasize that postponement of the diagnosis of infection with *M. tuberculosis* during pregnancy is unacceptable (*343*).

Booster phenomenon and two-step testing. In certain persons with LTBI, the DTH responsible for TST reactions wanes over time. Repeated TST can elicit a reaction called boosting in which an initial TST result is negative, but a subsequent TST result is positive. For example, a TST administered years after infection with *M. tuberculosis* can produce a false-negative result. This TST might stimulate (or boost) the person's ability to react to tuberculin, resulting in a positive result to a subsequent test (including the second step of a two-step procedure) (*36,74,316,342,343*). With serial testing, a boosted reaction on a subsequent TST might be misinterpreted as a newly acquired infection, compared with the false-negative result from the initial TST. Misinterpretation of a boosted reaction as a new infection with *M. tuberculosis* or TST conversion might prompt unnecessary investigations to find the source case, unnecessary treatment for the person tested, and unnecessary testing of other HCWs. The booster phenomenon can occur in anyone, but it is more likely to occur in older persons, persons with remote infection with *M. tuberculosis* (i.e., infected years ago), persons infected with NTM, and persons with previous BCG vaccination (*39,229,234,344,345*).

All newly employed HCWs who will be screened with TST should receive baseline two-step TST upon hire, unless they have documentation of either a positive TST result or treatment for LTBI or TB disease (*39,224*). Any setting might have HCWs at risk for boosting, and a rate of boosting even as low as 1% can result in unnecessary investigation of transmission. Therefore, two-step TSTs are needed to establish a baseline for persons who will receive serial TST (e.g., residents or staff of correctional facilities or LTCFs). This procedure is especially important for settings that are classified as low risk where testing is indicated only upon exposure. A reliable baseline test result is necessary to detect health-care–associated transmission of *M. tuberculosis*. Guidance for baseline TST for HCWs is included in this report (Box 3). To estimate the frequency of boosting in a particular setting, a four-appointment schedule of TST administration and reading (i.e., appointments for TST administration and reading both TST results) is necessary, rather than the three-appointment schedule (i.e., appointments for the administration of both tests, with reading of the second-step TST result only) (*196*).

Two-step testing should be used only for baseline screening, not in contact investigations. In a contact investigation, for persons with a negative TST, a follow-up test should be administered 8–10 weeks after the end of exposure (rather than 1–3 weeks later, as in a two-step TST). In this instance, a change from a negative to a positive TST result suggests that recent exposure, transmission, and infection occurred and should not be interpreted as a boosted response.

After a known exposure in a health-care setting (close contact to a patient or HCW with infectious TB disease), TST results of ≥5 mm should be considered positive and interpreted as a new infection in HCWs whose previous TST result is 0 mm. If an HCW has a baseline or follow-up TST result of >0 mm but ≤10 mm, a health-care–associated exposure to *M. tuberculosis*, and an increase in the TST size of ≥10 mm, the result should be interpreted as the HCW having a TST conversion because of new infection.

BCG vaccination. In the United States, vaccination with BCG is not recommended routinely for anyone, including HCWs or children (*227*). Previous BCG vaccination is not a contraindication to having a TST or two-step skin testing administered. HCWs with previous BCG vaccination should receive baseline and serial skin testing in the same manner as those without BCG vaccination (*233*) (Box 1).

Previous BCG vaccination can lead to boosting in baseline two-step testing in certain persons (*74,231,344–346*). Distinguishing a boosted TST reaction resulting from BCG vaccination (a false-positive TST result) and a TST result because of previous infection with *M. tuberculosis* (true positive TST result) is not possible (*39*). Infection-control programs should refer HCWs with positive TST results for medical evaluation as soon as possible (Box 3).

Previous BCG vaccination increases the probability of a boosted reaction that will probably be uncovered on initial two-step skin testing. For an HCW with a negative baseline two-step TST result who is a known contact of a patient who has suspected or confirmed infectious TB disease, treatment for LTBI should be considered if the follow-up TST result is ≥5 mm, regardless of BCG vaccination status.

PPD preparations for diagnosing infection with *M. tuberculosis*. Two PPD preparations are available in the United States: Tubersol® (Aventis Pasteur, Swiftwater, Pennsylvania) (*237*) and APLISOL® (Parkdale Pharmaceuticals, Rochester, Michigan) (*238*). Compared with the U.S. reference PPD, no difference exists in TST interpretation between the two preparations (*347*). However, when Tubersol and Aplisol were compared with each other, a slight difference in reactivity was observed. Aplisol produced slightly larger reactions than Tubersol, but this difference was not statistically significant (*347*). The difference in specificity, 98% versus 99%, is limited. However, when applied in large institutional settings that test thousands of workers annually who are at low risk for infection with *M. tuberculosis*, this difference in specificity might affect the rate of positive TST results observed.

TB screening programs should use one antigen consistently and should realize that changes in products might make serial changes in TST results difficult to interpret. In one report, systematic changes in product use resulted in a cluster of pseudoconversions that were believed to have erroneously indicated a health-care–associated outbreak (*348*). Persons responsible for making decisions about the choice of pharmacy products should seek advice from the local or state health department's TB infection-control program before switching PPD preparations and should inform program staff of any changes.

Chest Radiography

Chest radiographic abnormalities can suggest pulmonary TB disease. Radiographic abnormalities that are consistent with pulmonary TB disease include upper-lobe infiltration, cavitation, and effusion. Infiltrates can be patchy or nodular and observed in the apical (in the top part of the lungs) or subapical posterior upper lobes or superior segment of the lower lobes in the lungs. HCWs who have positive test results for *M. tuberculosis* infection or symptoms or signs of TB disease, regardless of test results for *M. tuberculosis* infection, should have a chest radiograph performed to exclude a diagnosis of TB disease. However, a chest radiograph is not a substitute for tests for *M. tuberculosis* infection in a serial TB screening program for HCWs.

Persons who have LTBI or cured TB disease should not have repeat chest radiographs performed routinely (*116*). Repeat radiographs are not needed unless symptoms or signs of TB disease develop or a clinician recommends a repeat chest radiograph (*39,116*).

A chest radiograph to exclude pulmonary TB disease is indicated for all persons being considered for treatment of LTBI. If chest radiographs do not indicate pulmonary TB and if no symptoms or signs of TB disease are present, persons with a positive test result for infection with *M. tuberculosis* might be candidates for treatment of LTBI. In persons with LTBI, the chest radiograph is usually normal, although it might demonstrate abnormalities consistent with previous healed TB disease or other pulmonary conditions. In patients with symptoms or signs of TB disease, pulmonary infiltrates might only be apparent on a computed tomography (CT) scan. Previous, healed TB disease can produce radiographic findings that might differ from those associated with current TB disease, although a substantial overlap might exist. These findings include nodules, fibrotic scars, calcified granulomas, or basal pleural thickening. Nodules and fibrotic scars might contain slowly multiplying tubercle bacilli and pose a high risk for progression to TB disease. Calcified nodular lesions (calcified granulomas) and apical pleural thickening pose a lower risk for progression to TB disease (*31*).

Chest Radiography and Pregnancy

Because TB disease is dangerous to both mother and fetus, pregnant women who have a positive TST result or who are suspected of having TB disease, as indicated by symptoms or other concerns, should receive chest radiographs (with shielding consistent with safety guidelines) as soon as feasible, even during the first trimester of pregnancy (*31,39,341*).

Chest Radiography and HIV-Infected Persons

The radiographic presentation of pulmonary TB in persons infected with HIV might be apical; however, apical cavitary disease is less common among such patients. More common chest radiograph findings for HIV-infected persons are infiltrates in any lung zone, mediastinal or hilar adenopathy, or, occasionally, a normal chest radiograph. Typical and cavitary lesions are usually observed in patients with higher CD4 counts, and more atypical patterns are observed in patients with lower CD4 counts (*31,49,94,142,349–354*). In patients with symptoms and signs of TB, a negative chest radiograph result does not exclude TB. Such patients might be candidates for airborne precautions during medical evaluation.

Evaluation of Sputum Samples

Sputum examination is a critical diagnostic procedure for pulmonary TB disease (*30*) and is indicated for the following persons:

- anyone suspected of having pulmonary or laryngeal TB disease;
- persons with chest radiograph findings consistent with TB disease (current, previous, or healed TB);
- persons with symptoms of infection in the lung, pleura, or airways, including larynx;
- HIV-infected persons with any respiratory symptoms or signs, regardless of chest radiograph findings; and
- persons suspected of having pulmonary TB disease for whom bronchoscopy is planned.

Sputum Specimen Collection

Persons requiring sputum collection for smear and culture should have at least three consecutive sputum specimens obtained, each collected in 8–24-hours intervals (*124*), with at least one being an early morning specimen (*355*). Specimens should be collected in a sputum induction booth or in an AII room. In resource-limited settings without environmental containment or when an AII room is not available, sputum collection can be performed safely outside of a building, away from other persons, windows, and ventilation intakes. Patients should be instructed on how to produce an adequate sputum specimen (containing little saliva) and should be supervised and observed by an HCW during the collection of sputum, if possible (*30*). If the patient's specimen is determined to be

inadequate, it should still be sent for bacteriologic testing, although the inadequate nature of the specimen should be recorded. The HCW should wear an N95 disposable respirator during sputum collection.

Sputum Induction

For patients who are unable to produce an adequate sputum specimen, expectoration can be induced by inhalation of an aerosol of warm, hypertonic saline. Because sputum induction is a cough-inducing procedure, pre-treatment with a bronchodilator should be considered in patients with a history of asthma or other chronic obstructive airway diseases. Medical assistance and bronchodilator medication should be available during any sputum induction in the event of induced bronchospasm (*109,356,357*).

The patient should be seated in a small, well-ventilated sputum induction booth or in an AII room (see Environmental Controls; and Supplement, Environmental Controls). For best results, an ultrasonic nebulizer that generates an aerosol of approximately 5 mL/minute should be used. A 3% hypertonic saline is commercially available, and its safety has been demonstrated. At least 30 mL of 3% saline should be administered; administration of smaller volumes will have a lower yield. Higher concentrations can be used with an adjustment in the dose and closer monitoring for adverse effects.

Patients should be instructed to breathe deeply and cough intermittently. Sputum induction should be continued for up to 15 minutes or until an adequate specimen (containing little saliva) is produced. Induced sputum will often be clear and watery. Any expectorated material produced should be labeled as expectorated sputum and sent to the laboratory.

Laboratory Examination

Detection of AFB in stained smears by microscopy can provide the first bacteriologic indication of TB disease. Laboratories should report any positive smear results within 24 hours of receipt of the specimen (*30*). A positive result for AFB in a sputum smear is predictive of increased infectiousness. Smears allow presumptive detection of mycobacteria, but definitive identification, strain typing, and drug-susceptibility testing of *M. tuberculosis* require that a culture be performed (*30*). Negative AFB sputum smear results do not exclude a diagnosis of TB disease, especially if clinical suspicion of disease is high. In the United States, approximately 63% of patients with reported positive sputum culture results have positive AFB sputum smear results (*26*).

A culture of sputum or other clinical specimen that contains *M. tuberculosis* provides a definitive diagnosis of TB disease. In the majority of cases, identification of *M. tuberculosis* and drug-susceptibility results are available within 28 days (or 4–6 weeks) when recommended rapid methods such as liquid culture and DNA probes are used. Negative culture results are obtained in approximately 14% of patients with confirmed pulmonary TB disease (*4,5*). Testing sputum with rapid techniques (e.g., NAA) facilitates the rapid detection and identification of *M. tuberculosis* but should not replace culture and drug-susceptibility testing in patients with suspected TB disease (*30,125,358*). Mixed mycobacterial infection can obscure the identification of *M. tuberculosis* during the laboratory evaluation (e.g., because of cross-contamination or dual infections) and can be distinguished by the use of mycobacterial species-specific DNA probes (*359*). Examination of colony morphology on solid culture media can also be useful.

Drug-susceptibility tests should be performed on initial isolates from all patients to assist in identifying an effective antituberculosis treatment regimen. Drug-susceptibility tests should be repeated if sputum specimens continue to be culture-positive after 3 months of antituberculosis treatment or if culture results become positive for *M. tuberculosis* after a period of negative culture results (*30,31*).

Bronchoscopy

If possible, bronchoscopy should be avoided in patients with a clinical syndrome consistent with pulmonary or laryngeal TB disease because bronchoscopy substantially increases the risk for transmission either through an airborne route (*63,80,81,162,360*) or a contaminated bronchoscope (*80,82,163–169*), including in persons with negative AFB sputum smear results. Microscopic examination of three consecutive sputum specimens obtained in 8–24-hour intervals, with at least one obtained in the early morning, is recommended instead of bronchoscopy, if possible. In a patient who is intubated and mechanically ventilated, closed circuitry can reduce the risk for exposure.

If the suspicion for pulmonary TB disease is high or if the patient is seriously ill with a disorder, either pulmonary or extrapulmonary, that is believed to be TB disease, multidrug antituberculosis treatment using one of the recommended regimens should be initiated promptly, frequently before AFB smear results are known (*31*). Obtaining three sputum samples is safer than performing bronchoscopy. For AFB smear and culture results, three sputum samples have an increased yield compared with a single specimen (*110,357*), and induced specimens have better yield than specimens obtained without induction. Sputum induction is well-tolerated (*90,109,132,133,357,361,362*), even in children (*134,356*), and sputum specimens (either spontaneous or induced) should be obtained in all cases before a bronchoscopy (*109,356,363,364*).

In circumstances where a person who is suspected of having TB disease is not on a standard antituberculosis treatment regimen and the sputum smear results (possibly including induced specimens) are negative and a reasonably high suspicion for TB disease remains, additional consideration to initiate treatment for TB disease should be given. If the underlying cause of a radiographic abnormality remains unknown, additional evaluation with bronchoscopy might be indicated; however, in cases where TB disease remains a diagnostic possibility, initiation of a standard antituberculosis treatment regimen for a period before bronchoscopy might reduce the risk for transmission. Bronchoscopy might be valuable in establishing the diagnosis; in addition, a positive culture result can be both of clinical and public health importance to obtain drug-susceptibility results. Bronchoscopy in patients with suspected or confirmed TB disease should not be undertaken until after consideration of the risks for transmission of *M. tuberculosis* (*30,63,81,162,360*). If bronchoscopy is performed, because it is a cough-inducing procedure, additional sputum samples for AFB smear and culture should be collected after the procedure to increase the diagnostic yield.

Treatment Procedures for LTBI and TB Disease

Treatment for LTBI

Treatment for LTBI is essential to control and eliminate TB disease in the United States because it substantially reduces the risk that infection with *M. tuberculosis* will progress to TB disease (*10,28*). Certain groups of persons are at substantially high risk for developing TB disease after being infected, and every effort should be made to begin treatment for LTBI and to ensure that those persons complete the entire course of treatment (Table 3).

Before beginning treatment of LTBI, a diagnosis of TB disease should be excluded by history, medical examination, chest radiography, and, when indicated, bacteriologic studies. In addition, before offering treatment of LTBI, ensure that the patient has not experienced adverse reactions with previous isoniazid (INH) treatment (*215*).

Candidates for Treatment of LTBI

Persons in the following groups at high risk should be administered treatment for LTBI if their TST result is ≥5 mm or if their BAMT result is positive, regardless of age (*31,39*):

- persons infected with HIV,
- recent contacts with a person with TB disease,
- persons with fibrotic changes on chest radiograph consistent with previous TB disease,
- organ transplant recipients, and
- other immunosuppressed persons (e.g., persons receiving ≥15 mg/day of prednisone for ≥1 month).

Persons in the following groups at high risk should be considered for treatment of LTBI if their TST result is ≥10 mm, or if the BAMT result is positive:

- persons with TST or BAMT conversions;
- persons born or who have lived in developing countries or countries with a high-incidence of TB disease;
- persons who inject illicit drugs;
- residents and employees in congregate settings that are at high risk (i.e., correctional facilities and LTCFs [e.g., hospices and skilled nursing facilities]), hospitals and other health-care facilities, residential settings for persons with HIV/AIDS or other immunocompromising conditions, and homeless shelters;
- personnel from mycobacteriology laboratories;
- persons with any of the following clinical conditions or other immunocompromising conditions that place them at high risk for TB disease:
  - — silicosis,
  - — diabetes mellitus,
  - — chronic renal failure,
  - — certain hematologic disorders (e.g., leukemias and lymphomas),
  - — other specific malignancies (e.g., carcinoma of the head, neck, or lung),
  - — unexplained weight loss of ≥10% of ideal body weight,
  - — gastrectomy, or
  - — jejunoileal bypass;
- persons living in areas with high incidence of TB disease; and
- children aged <4 years; and

TABLE 3. Standard drug regimens for treatment of latent TB infection (LTBI)*

Drugs	Months of duration	Interval	Minimum no. of standard doses*
Isoniazid (INH)	9†	Daily	270
		Twice weekly	76
INH	6	Daily	180
		Twice weekly	52
Rifampin (RIF)	4	Daily	120
Rifampin/Pyrazinamide (RIF/PZA or RZ)	§	§	§

* **SOURCE:** American Thoracic Society, CDC. Targeted tuberculin testing and treatment of latent tuberculosis infection. MMWR 2000;49(No. RR-6).

† Nine months of INH is preferred, but 6 months of INH or 4 months of rifampin are acceptable alternatives.

§ Generally should not be offered for treatment of LTBI. **SOURCE:** CDC. Update: adverse event data and revised American Thoracic Society/CDC recommendations against the use of rifampin and pyrazinamide for treatment of latent tuberculosis infection—United States, 2003. MMWR 2003;52:735–9.

- infants, children, and adolescents exposed to adults at high risk for developing TB disease.

Persons who use tobacco or alcohol (*40,41*), illegal drugs, including injection drugs and crack cocaine (*43–48*), might also be at increased risk for infection and disease, but because of the multiple other potential risk factors that commonly occur among such persons, use of these substances has been difficult to identify as separate risk factors.

Persons with no known risk factors for TB disease can be considered for treatment of LTBI if their TST result is ≥15 mm. However, programs to screen HCWs for infection with *M. tuberculosis* should only be conducted among groups at high risk. All testing activities should be accompanied by a plan for follow-up care for persons with LTBI or, if it is found, TB disease. A decision to test for infection with *M. tuberculosis* should be based on a commitment to treat LTBI after a medical examination (*39*).

Persons who might not be good candidates for treatment of LTBI include those with a previous history of liver injury or a history of excessive alcohol consumption. Active hepatitis and end-stage liver disease (ESLD) are relative contraindications to the use of INH for treatment of LTBI (*39,240*). If the decision is made to treat such patients, baseline and follow-up monitoring of serum aminotransaminases should be considered.

For persons who have previous positive TST or BAMT results and who completed treatment for LTBI previously, treating them again is not necessary. Documentation of completed therapy for LTBI is critical. Instead of participating in serial skin testing, the HCW should receive a medical evaluation and a symptom screen annually. A symptom screen is a procedure used during a clinical evaluation in which patients are asked if they have experienced any departure from normal in function, appearance, or sensation related to TB disease (e.g., cough).

Screening HCWs for infection with *M. tuberculosis* is an essential administrative measure for the control of transmission of *M. tuberculosis* in health-care settings. By conducting TB screening, ongoing transmission of *M. tuberculosis* can be detected, and future transmission can be prevented by identifying lapses in infection control and identifying persons infected with *M. tuberculosis* and TB disease. The majority of individual HCWs, however, do not have the risk factors for progression to disease that serve as the basis for the current recommendations for targeted testing and treatment of LTBI. The majority of HCWs in the United States do not provide care in areas in which the prevalence of TB is high. Therefore, HCWs should be tested, as determined by risk classification for the health-care setting, and can be categorized as having a positive test result or conversion for *M. tuberculosis* infection. HCWS can be categorized as part of the TB infection-control program for the purpose of surveillance and referral, but they might not necessarily be candidates for treatment of LTBI.

HCWs should receive serial screening for infection with *M. tuberculosis* (either TST or BAMT), as determined by the health-care setting's risk classification (Appendix B). For infection-control purposes, the results of the testing should be recorded and interpreted as part of the TB infection-control program as either a 1) negative TST result, 2) previously documented positive TST or BAMT result, or 3) TST or BAMT conversion. All recordings of TST results should also document the size of the induration in millimeters, not simply as negative or positive. BAMT results should be recorded in detail. The details should include date of blood draw, result in specific units, and the laboratory interpretation (positive, negative, or indeterminate) and the concentration of cytokine measured (e.g., IFN-γ).

To determine whether treatment for LTBI should be indicated, HCWs should be referred for medical and diagnostic evaluation according to the TST result criteria (Box 5). In conjunction with a medical and diagnostic evaluation, HCWs with positive test results for *M. tuberculosis* should be considered for treatment of LTBI (Box 5) after TB disease has been excluded by further medical evaluation. HCWs cannot be compelled to take treatment for LTBI, but they should be encouraged to do so if they are eligible for treatment.

HCWs' TST or BAMT results might be considered positive as part of the TB infection-control program for the purposes of surveillance and referral (i.e., meet the criterion for a conversion), and this occurrence is important to note. However, not all of these HCWs may be considered candidates for treatment of LTBI, according to the individual medical and diagnostic evaluation. After an HCW has been classified as having a positive result or conversion for *M. tuberculosis* infection, additional testing for *M. tuberculosis* infection is not necessary.

Treatment Regimens for LTBI

For persons suspected of having LTBI, treatment of LTBI should not begin until TB disease has been excluded. Persons highly suspected of having TB disease should receive the standard multidrug antituberculosis treatment regimen for TB disease until the diagnosis is excluded. Standard drug regimens for the treatment of LTBI have been presented (Table 3); however, modifications to those regimens should be considered under certain circumstances, including HIV infection, suspected drug resistance, and pregnancy (*47,365*).

Reports of severe liver injury and death associated with the combination of rifampin and pyrazinamide (RZ) for treatment of LTBI (*366–368*) prompted the American Thoracic Society and CDC to revise previous recommendations (*39,53*) to indicate that RZ generally should not be offered for the

treatment of LTBI (*240*). If the potential benefits substantially outweigh the demonstrated risk for severe liver injury and death associated with this regimen and the patient has no contraindications, a physician with experience treating LTBI and TB disease should be consulted before using this regimen (*246*). Clinicians should continue the appropriate use of rifampin and pyrazinamide in standard multidrug antituberculosis treatment regimens for the treatment of TB disease (*31*). Collaborate with the local or state health department on decisions regarding DOT arrangements.

For all regimens for treatment of LTBI, nonadherence to intermittent dosing (i.e., once or twice weekly) results in a larger proportion of total doses missed than daily dosing. DOT should be used for all doses during the course of treatment of LTBI whenever feasible (*31*). Collaborate with the local or state health department on decisions regarding DOT arrangements.

Contacts of patients with drug-susceptible TB disease. Persons with a previously negative TST or BAMT result who are contacts of patients with drug-susceptible TB disease and who subsequently have a positive TST result (≥5 mm) or positive BAMT result should be evaluated for treatment of LTBI, regardless of age. The majority of persons who are infected with *M. tuberculosis* will have a positive TST result within 6 weeks of exposure (*74,228,369–371*). Therefore, contacts of patients with drug-susceptible TB disease with negative TST (or BAMT) results should be retested 8–10 weeks after the end of exposure to a patient with suspected or confirmed TB disease. Persons infected with *M. tuberculosis* should be advised that they possibly can be reinfected with *M. tuberculosis* if re-exposed (*246,372–375*). Persons infected with HIV, persons receiving immunosuppressive therapy, regardless of TST result, and persons with a previous positive TST or BAMT result who are close contacts of a person with suspected or confirmed TB disease should be considered for treatment of LTBI.

The interpretation of TST results is more complicated in a contact investigation among HCWs who have negative baseline TST results from two-step testing but where the induration was >0 mm on the baseline TST or subsequent serial testing. Differences in the TST results between the contact investigation and previous baseline and serial TST could be a result of 1) inter-test variability in reaction size; 2) intervening exposure to NTM, BCG, or *M. tuberculosis*; and 3) reversion. In practice, for TST, only inter-test variability and exposure to or infection with NTM or *M. tuberculosis* are likely.

Treatment of LTBI should not be started until a diagnosis of TB disease has been excluded. If uncertainty exists concerning the presence of TB disease because of an ambiguous chest radiograph, a standard multidrug antituberculosis treatment regimen can be started and adjusted as necessary based on the results of sputum cultures and the patient's clinical response (*31*). If cultures are obtained without initiating therapy, treatment for LTBI should not be initiated until all culture results are reported as negative.

Contacts of patients with drug-resistant TB disease. Treatment for LTBI caused by drug-resistant or MDR TB disease is complex and should be conducted in consultation with the local or state health department's infection-control program and experts in the medical management of drug-resistant TB. In certain instances, medical decision making for the person with LTBI will benefit from the results of drug susceptibility testing of the isolate of the index TB case. Treatment should be guided by susceptibility test results from the isolate to which the patient was exposed and presumed to be infected (*31,376,377*).

Pretreatment Evaluation and Monitoring of Treatment

The pretreatment evaluation of persons who are targeted for treatment of LTBI provides an opportunity for health-care providers to 1) establish rapport with patients; 2) discuss details of the patient's risk for progression from LTBI to TB disease; 3) explain the benefits of treatment and the importance of adhering to the drug regimen; 4) review possible adverse effects of the regimen, including interactions with other medications; and 5) establish an optimal follow-up plan.

Monitoring for adverse effects of antituberculosis medications must be individualized. Persons receiving treatment for LTBI should be specifically instructed to look for symptoms associated with the most common reactions to the medications they are taking (*39*). Laboratory testing should be performed to evaluate possible adverse effects (*31,39*). Routine laboratory monitoring during treatment of LTBI is indicated for patients with abnormal baseline test results and for persons with a risk for hepatic disease. Baseline laboratory testing is indicated for persons infected with HIV, pregnant women, women in the immediate postpartum period (usually within 3 months of delivery), persons with a history of liver disease, persons who use alcohol regularly, and those who have or are at risk for chronic liver disease.

All patients being treated for LTBI should be clinically monitored at least monthly, including a brief clinical assessment conducted in the person's primary language for signs of hepatitis (e.g., nausea, vomiting, abdominal pain, jaundice, and yellow or brown urine). Patients receiving treatment for LTBI should be advised about the adverse effects of the drugs and the need for prompt cessation of treatment and clinical evaluation if adverse effects occur.

Because of the risk for serious hepatic toxicity and death, the use of the combination of RZ for the treatment of LTBI generally should not be offered. If RZ is used, a physician with experience treating LTBI and TB disease should be consulted

before the use of this regimen. In addition, more extensive biochemical and clinical monitoring is recommended (*240*).

Treatment for TB Disease

Suspected or confirmed TB cases must be reported to the local or state health department in accordance with laws and regulations. Case management for TB disease should be coordinated with officials of the local or state health department. Regimens for treatment of TB disease must contain multiple drugs to which the organisms are susceptible. For persons with TB disease, treatment with a single drug can lead to the development of mycobacterial resistance to that drug. Similarly, adding a single drug to a failing antituberculosis treatment regimen can lead to resistance to the added drug (*31*).

For the majority of patients, the preferred regimen for treating TB disease consists of an initiation 2-month phase of four drugs (INH, rifampin, pyrazinamide, and ethambutol) and at least a 4-month continuation phase of INH and rifampin (for a minimum total treatment of 6 months). Ethambutol may be discontinued if supporting drug susceptibility results are available. Completion of therapy is based on the number of doses taken within a maximal period and not simply 6 months (*31*). Persons with cavitary pulmonary TB disease and positive culture results of sputum specimens at the completion of 2 months of therapy should receive a longer (7-month continuation) phase because of the significantly higher rate of relapse (*31*).

TB treatment regimens might need to be altered for persons infected with HIV who are on ART (*49*). Whenever feasible, the care of persons with both TB disease and HIV infection should be provided by or in consultation with experts in the management of both TB and HIV-related disease (*31*). To prevent the emergence of rifampin-resistant organisms, persons with TB disease, HIV infection, and CD4 cell counts of <100 cells/mm^3 should not be treated with highly intermittent (i.e., once or twice weekly) regimens. These patients should receive daily treatment during the intensive phase by DOT (if feasible) and daily or three times weekly by DOT during the continuation phase (*378*). Detailed information on TB treatment for persons infected with HIV has been published and is available (http://www.dhfs.state.wi.us/AIDS-HIV/Resources/Overviews/AIDS_HIV.htm, http://www.hiv-druginteractions.org, and http://www.cdc.gov/nchstp/tb/TB_HIV_Drugs/TOC.htm) and published (*31,53*).

Drug-susceptibility testing should be performed on all initial isolates from patients with TB disease. When results from drug-susceptibility tests become available, the antituberculosis treatment regimen should be reassessed, and the drugs used in combination should be adjusted accordingly (*376,377,379–381*). If drug resistance is present, clinicians who are not experts in the management of patients with drug-resistant TB disease should seek expert consultation (*31*) and collaborate with the local or state health department for treatment decisions.

The major determinant of the outcome of treatment is adherence to the drug regimen. Therefore, careful attention should be paid to measures designed to enable and foster adherence (*31,319,382*). DOT is an adherence-enhancing strategy in which a trained HCW or other specially trained person watches a patient swallow each dose of medication and records the dates that the DOT was observed. DOT is the standard of care for all patients with TB disease and should be used for all doses during the course of therapy for TB disease and for LTBI, whenever feasible. Plans for DOT should be coordinated with the local or state health department (*31*).

Reporting Serious Adverse Events

HCWs should report serious adverse events associated with the administration of tuberculin antigen or treatment of LTBI or TB disease to the FDA MedWatch, Adverse Event Reporting System (AERS), telephone: 800-FDA-1088, fax: 800-FDA-0178, http://www.fda.gov/medwatch. Report Form 3500, Physicians' Desk Reference. Specific instructions for the types of adverse events that should be reported are included in MedWatch report forms.

Surveillance and Detection of *M. tuberculosis* Infections in Health-Care Settings

TB disease should be considered for any patient who has symptoms or signs of disease, including coughing for ≥3 weeks, loss of appetite, unexplained weight loss, night sweats, bloody sputum or hemoptysis, hoarseness, fever, fatigue, or chest pain. The index of suspicion for TB disease will vary by individual risk factors, geographic area, and prevalence of TB disease in the population served by the health-care setting. Persons exposed to patients with infectious TB disease might acquire LTBI, depending on host immunity and the degree and duration of exposure. Diagnostic tests for TB disease include chest radiography and laboratory tests of sputum (examination for AFB and culture). The treatment of persons with TB disease involves vital aspects of TB control by stopping transmission of *M. tuberculosis* and preventing persons with LTBI from developing infectious TB disease (*36*).

In the majority of the U.S. population, targeted testing for LTBI and TB disease is performed to identify persons with LTBI and TB disease who would benefit from treatment. Therefore, all testing activities should be accompanied by a plan for follow-up care of persons with LTBI or TB disease. A decision to test for infection with *M. tuberculosis* should be based

on a commitment to treat LTBI after a medical examination (*39*). Health-care agencies or other settings should consult with the local or state health department before starting a program to test HCWs for *M. tuberculosis* infection. This step ensures that adequate provisions are in place for the evaluation and treatment of persons whose test results are positive, including the medical supervision of the course of treatment for those who are treated for LTBI or TB disease.

Groups that are not at high risk for LTBI or TB disease should not be tested routinely because testing in populations at low risk diverts resources from other priority activities. In addition, testing persons at low risk for *M. tuberculosis* infection is discouraged because a substantial proportion of persons from populations at low risk who have positive TST results might actually have false-positive TST results and might not represent true infection with *M. tuberculosis* (*39,316*). Testing for infection with *M. tuberculosis* should be performed for well-defined groups at high risk. These groups can be divided into two categories: 1) persons at higher risk for exposure to and infection with *M. tuberculosis* and 2) persons at higher risk for progression from LTBI to TB disease (see TB Infection-Control Program for Settings in Which Patients with Suspected or Confirmed TB Disease Are Expected To Be Encountered; and TB Infection-Control Program for Settings in Which Patients with Suspected or Confirmed TB Disease Are Not Expected To Be Encountered).

Flexibility is needed in defining high-priority groups for TB screening. The changing epidemiology of TB indicates that the risk for TB among groups currently considered as high priority might decrease over time, and groups currently not identified originally as being at high risk might be considered as high priority.

Baseline Testing with BAMT

For the purposes of establishing a baseline, a single negative BAMT result is sufficient evidence that the HCW is probably not infected with *M. tuberculosis* (Box 2). However, cautions regarding making medical care decisions for persons whose conditions are at increased risk for progressing to TB disease from *M. tuberculosis* infection have been presented (Box 4).

If BAMT is used for baseline testing of HCWs, including those in settings that are low risk, one negative BAMT result is sufficient to demonstrate that the HCW is not infected with *M. tuberculosis* (Box 2). Perform and document the baseline BAMT result preferably within 10 days of starting employment. HCWs with positive baseline results should be referred for a medical and diagnostic evaluation to exclude TB disease and then treatment for LTBI should be considered in accordance with CDC guidelines. Persons with a positive BAMT result do not need to be tested again for surveillance. For HCWs who have indeterminate test results, providers should consult the responsible laboratorian for advice on interpreting the result and making additional decisions (*383*).

Serial Testing with BAMT for Infection-Control Surveillance

When using BAMT for serial testing, a conversion for administrative purposes is a change from a negative to a positive result (Box 3). For HCWs who have indeterminate test results, providers should consult the responsible laboratorian for advice on interpreting the result and making additional decisions (*383*). Persons with indeterminate results should not be counted for administrative calculations of conversion rates.

Exposure of HCWs and Patients to *M. tuberculosis*

Known and Presumed Exposure

For HCWs with known and presumed exposure to *M. tuberculosis*, administer a symptom screen and obtain the BAMT result. A BAMT conversion probably indicates recent *M. tuberculosis* infection; therefore, TB disease must be excluded. Experience with BAMT in contact investigations is limited. Specific attention is needed in the management of certain populations (e.g., infants and children aged <4 years and immunocompromised persons, including those who are HIV-infected) (Box 4).

If the symptom screen or the BAMT result is positive, the exposed person should be evaluated for TB disease promptly, which includes a chest radiograph. If TB disease is excluded, additional medical and diagnostic evaluation for LTBI is needed, which includes a judgment regarding the extent of exposure.

BOX 4. Conditions requiring caution in interpreting negative QuantiFERON®-TB Gold test results

- Human immunodeficiency virus infection or acquired immunodeficiency syndrome
- Immunosuppressive drugs, including those used for managing organ transplantation
- TNF*-α
- Diabetes mellitus
- Silicosis
- Chronic renal failure
- Certain hematological disorders (e.g., leukemias and lymphomas)
- Other specific malignancies (e.g., carcinoma of the head, neck, or lung)

* Tumor necrosis factor.

Performing QFT-G

The QFT-G should be performed as described in the product insert provided with the BAMT kit. This insert is also available from the manufacturer's website (http://www.cellestis.com).

Interpretation of BAMT Results and Referral for Evaluation

HCWs who meet the criteria for referral should have a medical and diagnostic evaluation (see Supplements, Estimating the Infectiousness of a TB Patient; Diagnostic Procedures for LTBI and TB Disease; and Treatment Procedures for LTBI and TB Disease). The factors affecting treatment decisions during medical and diagnostic evaluation by risk for infection with *M. tuberculosis* have been presented (Box 5). In addition, because BAMT and other indirect tests for *M. tuberculosis* infection are diagnostic aids, the test results must be interpreted in the context of epidemiologic, historical, physical, and diagnostic findings. A higher likelihood of infection, as estimated from historical or epidemiologic details (e.g., exposure to *M. tuberculosis*) or because of the presence of an illness consistent with TB disease, increases the predictive value of a positive result. Setting-based risk factors (e.g., the prevalence of TB disease in the setting) should be considered when making decisions regarding the diagnosis and treatment of LTBI.

Medical conditions that impair or alter immune function (Box 4) decrease the predictive value of a negative result, and additional diagnostic methods (e.g., bacteriology, radiography, and histology) are required as evidence before excluding *M. tuberculosis* infection when the BAMT result is negative. Medical evaluations can occur in different settings, including an occupational health clinic, local or state health department, hospital, or private medical clinic.

Indeterminate QFT-G results are reported for either of two test conditions.

- The IFN-γ responses to all antigens (ESAT-6, CFP-10, and mitogen) are below a cut-off threshold. The weak response to mitogen could be caused by nonstandard storage or transportation of the blood sample, by laboratory errors, or by lymphocytic insensitivity caused by immune dysfunction.

OR,

- The IFN-γ response to the Nil exceeds a specified threshold, and the responses to both ESAT-6 and CFP-10 do not exceed the response to Nil by at least 50%. This response could be caused by nonstandard storage or transportation, laboratory errors, or circulating IFN-γ, which can be increased in ill HCWs or patients. For HCWs who have indeterminate test results, providers should consult the responsible laboratorian for advice on interpreting the result and making further decisions (*383*).

Interpreting the BAMT Result for Infection Control and Surveillance

BAMT conversion rates should be determined routinely. The precision of the BAMT conversion rate will depend, in part, on the number of HCWs tested, which should be considered when establishing a regular interval for evaluation and monitoring of HCWs with BAMT. Health-care settings with a substantial number of HCWs might have testing schedules that can accurately determine the BAMT conversion rate each month (i.e., from annual results of an HCW cohort tested within the given month), if testing is staggered throughout the year. BAMT conversion rates are more difficult to calculate in settings with fewer test results.

QC Program for the BAMT

Multiple processes are necessary to assure quality BAMT results: specimen collection, transport and handling, and conducting the test in the laboratory. BAMT must meet performance parameters for a valid test result to be achieved. QC is an ongoing laboratory issue. The infection-control team should assist the laboratory in assuring that all requisite conditions are present. The laboratory performing the BAMT will be required to validate its performance of the test before processing clinical samples. State and federal laboratory requirements regulate laboratory-testing procedures.

Additional Considerations

An indeterminate QFT-G result does not mean that the test has failed; it indicates that the specimen has inadequate responsiveness for the test to be performed. This result might reflect the condition of the HCW or patient, who, for example, might be immunosuppressed. Alternatively, the specimen might have been handled incorrectly. For HCWs who have indeterminate test results, providers should consult the responsible laboratorian for advice on interpreting the result and making further decisions (*383*). Skin testing for cutaneous anergy is not useful in screening for asymptomatic LTBI or for diagnosing TB disease (*339*).

QFT-G use with HIV-infected persons taking ART. The effect of HIV infection and of ART on the performance of the QFT-G have not been fully evaluated.

Persons aged <17 years or pregnant women. The use of the QFT-G has not been evaluated in persons aged <17 years or pregnant women (*35*).

Booster phenomenon and BAMT. BAMT does not involve the injection of any substance into the persons being tested and is not affected by the booster phenomenon.

BCG vaccination. In the United States, vaccination with BCG is not routinely recommended (*227*). However, BCG is the most commonly used vaccine in the world. Foreign-born

BOX 5. Factors affecting treatment decisions during the medical and diagnostic evaluation, by tuberculin skin test (TST) result

TST result ≥5 mm is positive	TST result ≥10 mm is positive	TST result ≥15 mm is positive*
• Persons infected with HIV†	• Recent immigrants (i.e., within the previous 5 years) from countries with a high incidence of TB disease	• Persons with no known risk factors for TB disease
• Recent contacts of a person with tuberculosis (TB) disease	• Persons who inject illicit drugs	• HCWs who are otherwise at low risk for TB disease and who received baseline testing at the beginning of employment as part of a TB screening program**
• Persons with fibrotic changes on chest radiograph consistent with previous TB disease	• Residents and employees (including health-care workers [HCWs])** of the following congregate settings — hospitals and other health-care facilities — long-term–care facilities (e.g., hospices and skilled nursing facilities) — residential facilities for patients with AIDS†† or other immunocompromising conditions — correctional facilities — homeless shelters	
• Organ transplant recipients and other immunosuppressed persons (e.g., persons receiving ≥15 mg/day of prednisone for ≥1 month)§	• Mycobacteriology laboratory personnel	
• TB suspects¶	• Persons with any of the following clinical conditions or immunocompromising conditions that place them at high risk for TB disease — diabetes mellitus — silicosis — chronic renal failure — certain hematologic disorders (e.g., leukemias and lymphomas) — other specific malignancies (e.g., carcinoma of the head, neck, or lung) — unexplained weight loss of ≥10% of ideal body weight — gastrectomy — jejunoileal bypass	
	• Persons living in areas with high incidence of TB disease	
	• Children aged <4 years	
	• Infants, children, and adolescents exposed to adults at high risk for developing TB disease	
	• Locally identified groups at high risk	

* TST results ≥15 mm is positive in anyone. These persons should receive a symptom screen and do not need be tested again. They should be evaluated for TB disease, and if disease is excluded, they should be offered treatment for latent TB infection (LTBI) if they have no contraindication to treatment.

† Human immunodeficiency virus.

§ The risk for TB disease in persons treated with corticosteroids increases with higher doses and longer duration of corticosteroid use.

¶ Persons with suspected TB disease can be treated based on the medical and diagnostic evaluation, regardless of the TST results.

** For HCWs who are otherwise at low risk for LTBI and progression to TB disease if infected and who received baseline testing at the beginning of employment as part of a TB infection-control screening program, a TST result of ≥15 mm (instead of ≥10 mm) is considered to be positive. Although a result of ≥10 mm on baseline or follow-up testing is considered a positive result for HCWs for the purposes of referral for medical and diagnostic evaluation, if the TST result is 10–14 mm on baseline or follow-up testing, the referring clinician might not recommend treatment of LTBI. **SOURCE:** Marsh BJ, SanVicente J, vonReyn F. Utility of dual skin tests to evaluate tuberculin skin test reactions of 10 to 14 mm in health-care workers. Infect Control Hosp Epidemiol 2003;24:821–4.

†† Acquired immunodeficiency syndrome.

persons are commonly employed in the United States as HCWs. Previous BCG vaccination is not a contraindication to having a BAMT performed. BCG does not influence BAMT results with the version of the test approved in 2005 (i.e., QFT-G). HCWs who have received BCG vaccination should receive a baseline BAMT in the same manner as those without BCG vaccination, and the test result should be interpreted without reference to BCG.

Environmental Controls

Overview

Environmental controls include the following technologies to remove or inactivate *M. tuberculosis*: local exhaust ventilation, general ventilation, HEPA filtration, and UVGI. These controls help to prevent the spread and reduce the concentration of airborne infectious droplet nuclei. Environmental controls are the second line of defense in the TB infection-control program, and they work in harmony with administrative controls.

The reduction of exposures to *M. tuberculosis* can be facilitated through the effective use of environmental controls at the source of exposure (e.g., coughing patient or laboratory specimen) or in the general workplace environment. Source control is amenable to situations where the source has been identified and the generation of the contaminant is localized. Source-control techniques can prevent or reduce the spread of infectious droplet nuclei into the air by collecting infectious particles as they are released. These techniques are especially critical during procedures that will probably generate infectious aerosols (e.g., bronchoscopy, sputum induction, endotracheal intubation, suctioning, irrigating TB abscesses, aerosol treatments, autopsies on cadavers with untreated TB disease, and certain laboratory specimen manipulations) and when patients with infectious TB disease are coughing or sneezing.

Unsuspected and undiagnosed cases of infectious TB disease are believed to represent a substantial proportion of the current risk to HCWs (*10,85*). In such situations, source control is not a feasible option. Instead, general ventilation and air cleaning must be relied upon for control. General ventilation can be used to dilute the air and remove air contaminants and to control airflow patterns in rooms or in a health-care setting. Air-cleaning technologies include HEPA filtration to reduce the concentration of *M. tuberculosis* droplet nuclei and UVGI to kill or inactivate the microorganisms so that they no longer pose a risk for infection.

Ventilation systems for health-care settings should be designed, and modified when necessary, by ventilation engineers in collaboration with infection-control practitioners and occupational health staff. Recommendations for designing and operating ventilation systems have been published (*117,118,178*). The multiple types and conditions for use of ventilation systems in health-care settings and the needs of persons in these settings preclude the provision of extensive guidance in this document.

The information in this section is conceptual and intended to educate HCWs regarding environmental controls and how these controls can be used in the TB infection-control program. This information should not be used in place of consultation with experts who can give advice on ventilation system design, selection, installation, and maintenance. Because environmental controls will fail if they are not properly operated and maintained, routine training and education of staff are key components to a successful TB infection-control program. These guidelines do not specifically address mechanical ventilators in detail (see Intensive Care Units [ICUs]).

Local Exhaust Ventilation

Local exhaust ventilation captures airborne contaminants at or near their source and removes the contaminants without exposing persons in the area to infectious agents. This method is considered the most efficient way to remove airborne contaminants because it captures them before they can disperse. In local exhaust devices, hoods are typically used. Two types of hoods are 1) enclosing devices, in which the hood either partially or fully encloses the infectious source; and 2) exterior devices, in which the infectious source is near but outside the hood. Fully enclosed hoods, booths, or tents are always preferable to exterior devices because of their superior ability to prevent contaminants from escaping into the HCW's breathing space. Descriptions of both enclosing and exterior devices have been published (*178*).

Enclosing Devices

Enclosing devices for local exhaust ventilation include 1) booths for sputum induction or administration of aerosolized medications (Figure 2), 2) tents or hoods for enclosing and isolating a patient, and 3) BSCs (*165*). These devices are available in various configurations. The simplest device is a tent placed over the patient; the tent has an exhaust connection to the room-discharge exhaust system. The most complex device is an enclosure with a self-contained airflow and recirculation system (Figure 2).

Tents and booths should have sufficient airflow to remove at least 99% of airborne particles during the interval between the departure of one patient and the arrival of the next (Table 1). The time required to remove 99% or 99.9% of airborne particles from an enclosed space depends on 1) the number of ACH, which is a function of the volume (number of cubic feet of air) in the room or booth and the rate at which air is exiting the room or booth at the intake source; 2) the location of the ventilation inlet and outlet; and 3) the configuration of

the room or booth. The surfaces of tents and booths should be periodically cleaned in accordance with recommendations and guidance from the manufacturers (see Supplement, Cleaning, Disinfecting, and Sterilizing Patient-Care Equipment and Rooms).

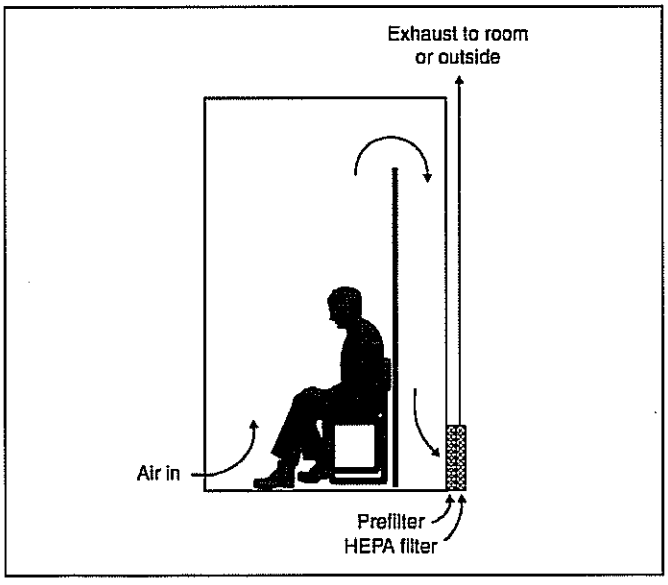
Exterior Devices

Exterior devices for local exhaust ventilation are usually hoods that are near to but not enclosing an infectious patient. The airflow produced by these devices should be sufficient to prevent cross-currents of air near the patient's face from allowing droplet nuclei to escape. Whenever possible, the patient should face directly into the opening of the hood to direct any coughing or sneezing into the hood. The device should maintain an air velocity of 200 feet per minute (fpm) at the patient's breathing zone to ensure the capture of droplet nuclei. Smoke tubes should be used to verify that the control velocity at the typical location of the patient's breathing zone is adequate to provide capture for the condition of highest expected cross-drafts and then the patient's breathing zone should be maintained at this location for the duration of the treatment.

Discharge of Exhaust from Booths, Tents, and Hoods

Air from booths, tents, and hoods is either discharged into the room in which the device is located or to the outside. If the exhaust air is discharged into the room, a HEPA filter should be incorporated at the discharge duct or vent of the device. The exhaust fan should be located on the discharge side of the HEPA filter to ensure that the air pressure in the filter housing and booth is negative compared with adjacent areas. Uncontaminated air from the room will flow into the booth through all openings, preventing infectious droplet nuclei in the booth from escaping into the room. Additional information on the installation, maintenance, and monitoring of HEPA filters is included in this report (Appendix A).

FIGURE 2. An enclosing booth designed to sweep air past a patient with tuberculosis disease and collect the infectious droplet nuclei on a high efficiency particular air (HEPA) filter



The majority of commercially available booths, tents, and hoods are fitted with HEPA filters; additional HEPA filtration is not needed with these devices. If a device does not incorporate a HEPA filter, the air from the device should be exhausted directly to the outside and away from air-intake vents, persons, and animals, in accordance with applicable federal, state, and local regulations on environmental discharges.

General Ventilation

General ventilation is used to 1) dilute and remove contaminated air, 2) control the direction of airflow in a health-care setting, and 3) control airflow patterns in rooms.

Dilution and Removal of Contaminated Air

General ventilation maintains air quality by both air dilution and removal of airborne contaminants. Uncontaminated supply air mixes with contaminated room air (dilution), and air is subsequently removed from the room by the exhaust system (removal). These processes reduce the concentration of droplet nuclei in the room air.

Ventilation systems for air dilution and removal. Two types of general ventilation systems are used to dilute and remove contaminated air: single-pass air systems and recirculating air systems.

In a single-pass air system, the supply air is either outside air that has been heated or cooled or air that is uncontaminated from a central system that supplies multiple areas. After air passes through the room or area, 100% of the air is exhausted to the outside. A single-pass system is the preferred choice for an AII room because the system prevents contaminated air from being recirculated to other areas of the health-care setting. In a recirculating air system, a limited portion of the exhaust air is discharged directly to the outside and replaced with fresh outside air, which mixes with the portion of exhaust air that was not discharged. If the resulting air mixture is not treated, it can contain a substantial proportion of contaminated air when it is recirculated to areas serviced by the system. This air mixture can be recirculated into the general ventilation, and infectious particles can be carried from contaminated areas to uncontaminated areas. Alternatively, the air mixture could be recirculated in a specific room or area so that other areas are not affected. The use of air-cleaning technologies for removing or inactivating infectious particles in recirculated air systems has been discussed (Appendix A).

Delivery of general ventilation. General ventilation is delivered by either constant air volume (CAV) systems or VAV systems. In general, CAV systems are best for AII rooms and other negative-pressure rooms because the negative-pressure differential is easier to maintain. VAV systems are acceptable if provisions are made to maintain the minimum mechanical and outside ACH and a negative pressure ≥0.01 inch of water gauge compared with adjacent areas at all times.

Ventilation rates. Recommended ventilation rates (air change rates) for health-care settings are usually expressed in numbers of ACH, which is the ratio of the volume of air entering the room per hour to the room volume. ACH equals the exhaust airflow (Q cubic feet per minute [cfm]) divided by the room volume (V cubic feet) multiplied by 60.

$$ACH = (Q \div V) \times 60$$

Ventilation recommendations for selected areas in new or renovated health-care settings have been presented (Table 2). These recommendations have been adapted from those published by AIA (*118*). The feasibility of achieving a specific ventilation rate depends on the construction and operational requirements of the ventilation system and might differ for retrofitted and newly constructed facilities. The expense and effort of achieving a high ventilation rate might be reasonable for new construction but less reasonable when retrofitting an existing setting.

In existing settings, air-cleaning technologies (e.g., fixed or portable room-air recirculation units [also called portable air cleaners] or UVGI) can be used to increase the equivalent ACH. This equivalent ventilation concept has been used to compare microbial inactivation by UVGI with particle-removal by mechanical ventilation (*384,385*) and to compare particle removal by HEPA filtration of recirculated air with particle removal by mechanical ventilation. The equivalent ventilation approach does not, however, negate the requirement to provide sufficient fresh outside air for occupant comfort (Table 2).

To dilute the concentration of normal room-air contaminants and minimize odors, a portion of the supply air should come from the outdoors (Table 2). Health-care settings should consult the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. (ASHRAE), Standard 62.1, Ventilation for Acceptable Indoor Air Quality, for outside air recommendations in areas not listed in this report (*386*).

Control of Airflow Direction in a Health-Care Setting

Airflow direction is controlled in health-care settings to contain contaminated air and prevent its spread to uncontaminated areas.

Directional airflow. The general ventilation system should be designed and balanced so that air flows from less contaminated (more clean) to more contaminated (less clean) areas (*118,117*). For example, air should flow from corridors (cleaner areas) into AII rooms (less clean areas) to prevent the spread of contaminants. In certain rooms in which surgical and invasive procedures are performed and in protective environment (PE) rooms, the direction of airflow should be from the room to the hallway. Environmental control recommendations for situations involving the care and treatment of patients with TB disease in ORs and PE rooms have been presented (see Other Selected Settings). Cough-inducing or aerosol-generating procedures should not be performed on patients with suspected or confirmed TB disease in rooms where air flows from the room to the hallway.

Negative pressure for achieving directional airflow. The direction of airflow is controlled by creating a lower (negative) pressure in the area into which the flow of air is desired. Negative pressure is the approximate air-pressure difference between two areas in a health-care setting. For air to flow from one area to another, the air pressure in the two areas must be different. Air will flow from a higher pressure area to a lower pressure area. A room that is under negative pressure has a lower pressure than adjacent areas, which keeps air flowing from the adjacent rooms or areas into the room. Negative pressure is achieved by exhausting air at a higher volumetric rate than the rate that the air is being supplied.

Control of Airflow Patterns in Rooms

General ventilation systems should be designed to provide controlled patterns of airflow in rooms and to prevent air stagnation or short-circuiting of air from the supply to the exhaust (i.e., passage of air directly from the air supply to the exhaust). To provide controlled airflow patterns, the air supply and exhaust should be located so that clean air flows first to parts of the room where HCWs probably work and then across the infectious source and into the exhaust. Therefore, HCWs are not positioned between the infectious source and the exhaust. This configuration is not always possible but should be used whenever feasible.

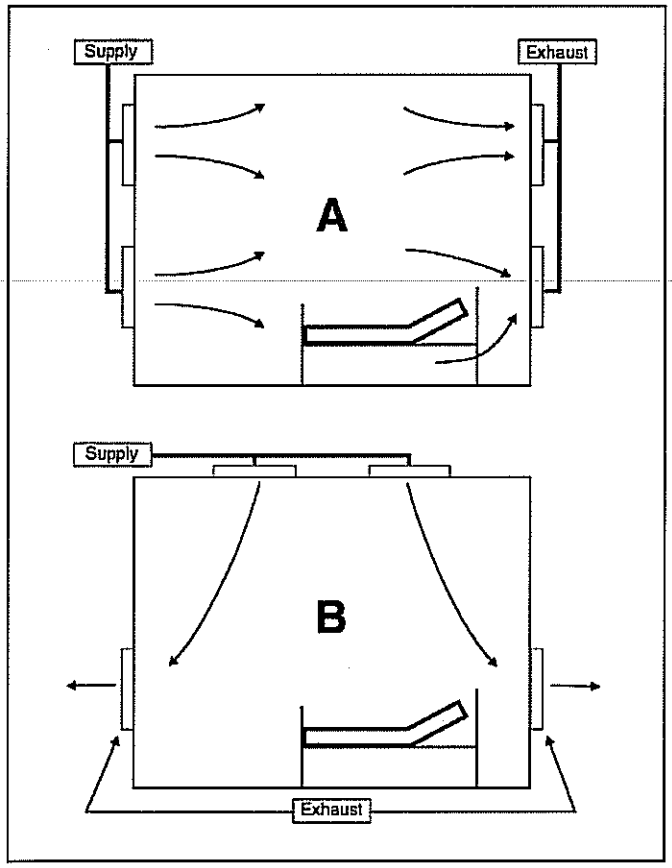
One way to achieve a controlled airflow pattern is to supply air at the side of the room opposite the patient and exhaust it from the side where the patient is located (Figure 3). Another method, which is most effective when the supply air is cooler than the room air, is to supply air near the ceiling and exhaust it near the floor (Figure 3). Care must be taken to ensure that furniture or moveable equipment does not block the low exhausts. Airflow patterns are affected by air temperature differentials, location of the supply diffusers and exhaust grilles,

location of furniture, movement of HCWs and patients, and the configuration of the space.

If the room ventilation is not designed for a plug-flow type of airflow pattern (Figure 3), then adequate mixing must be maintained to minimize air stagnation. The majority of rooms with properly installed supply diffusers and exhaust grilles will have adequate mixing. A qualitative measure of mixing is the visualization of air movement with smoke tubes at multiple locations in the room. Smoke movement in all areas of the room indicates good mixing. Additional sophisticated studies can be conducted by using a tracer gas to quantify air-mixing and air-exchange rates.

If areas of air stagnation are present, air mixing can be improved by adding a circulating fan or repositioning the supply and exhaust vents. Room-air recirculation units positioned in the room or installed above the ceiling can also improve air mixing. If supply or exhaust vents, circulating fans, or room-air recirculation units are placed incorrectly, HCWs might not be adequately protected.

FIGURE 3. Room airflow patterns designed to provide mixing of air and prevent short-circuiting*



*Short-circuiting is the passage of air directly from the air supply to the exhaust.

Achieving Negative Pressure in Rooms

Negative pressure is needed to control the direction of airflow between selected rooms in a health-care setting and their adjacent spaces to prevent contaminated air from escaping from the room into other areas (*118*) (Figure 4). Control of a room's differential airflow and total leakage area is critical to achieving and maintaining negative pressure. Differential airflow, differential pressure, and leakage area are interrelated. This relation is illustrated (Figure 4) and is expressed in an empirical equation (*387*).

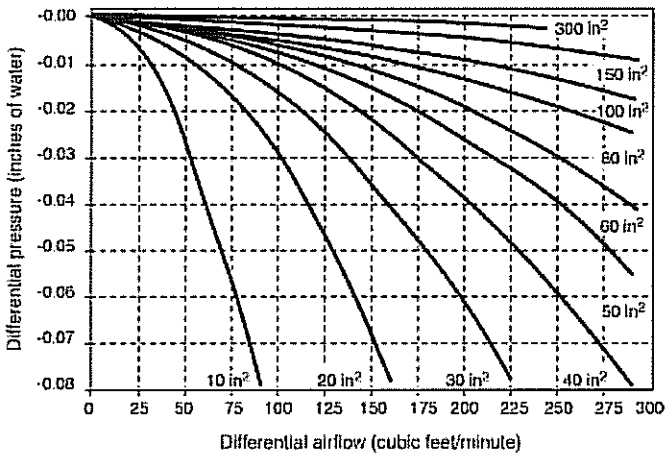
$$A_E = 0.01138 * (\Delta Q^{1.170}/\Delta P^{0.602})$$

In the equation, AE is the leakage area in square inches; ΔQ is the differential airflow rate in cfm; and ΔP is the differential pressure drop in inches of water gauge. This empirical equation was used (Figure 4), which indicates that changing one parameter will influence one or both of the other parameters. For example, the control of differential pressure can frequently be improved by increasing the air tightness or seal of a room, maintaining the HVAC system, and ensuring continuous monitoring. In a room that is already substantially tight (e.g., with 10 square inches of leakage), however, a small change in differential pressure will have a substantial effect on differential airflow. Similarly, a room with a more substantial leakage area (e.g., 300 square inches of leakage) requires a higher differential airflow rate to achieve a pressure differential of 0.01 inch of water gauge. Reducing the leakage in a room with 300 square inches of leakage can help achieve a pressure differential of 0.01 inch of water gauge (Figure 4). If the leakage area is reduced to approximately 40 square inches, a pressure differential of 0.01 inch of water gauge can be achieved by exhausting approximately 100 cubic feet per minute (cfm) more air from the room than is supplied to the room.

Room leakage can occur through cracks or spaces near doors, windows, ceiling, and utility connections. Steps should be taken to minimize these leaks. Changes in the performance of the HVAC system will affect the pressure differential in a room and can potentially cause a negative-pressure room to become positive-pressure. Therefore, each of these parameters requires close monitoring to ensure that minor changes in the performance of the HVAC system do not adversely affect the entire system (*388,389*).

Pressure differential. To achieve negative pressure in a room that has a normally functioning ventilation system, first measure and balance the supply and exhaust airflows to achieve an exhaust flow higher than the supply flow. Next, measure the pressure differential across the closed door. Although the minimum pressure difference needed for airflow into a room is substantially small (approximately 0.001 inch of water gauge), a pressure differential of ≥0.01 inch of water gauge

FIGURE 4. Empirical relation between differential airflow, differential pressure, and leakage areas*



*Black solid lines indicate leakage areas. **SOURCE:** Hayden II CS, Fischbach TJ, Johnston OE, Hughes RT, Jensen PA. A model for calculating leakage areas into negative pressure isolation rooms. Cincinnati, OH: US Department of Health and Human Services, CDC; 1996.

(≥2.5 Pascals [Pa]) is recommended. This higher pressure differential is easier to measure and offers a margin of safety for maintaining negative pressure as the pressure in surrounding areas changes because of the opening and closing of doors, operation of elevators, stack effect (rising of warm air, similar to a chimney), ventilation system fluctuations, and other factors. The higher pressurization value is consistent with the most recent AIA recommendations for airborne precautions in health-care settings (*118*) and is the generally accepted level of negative pressurization for microbiology and biomedical laboratories (*390*).

Opening doors and windows can substantially affect the negative pressure in an AII room. Infection-control criteria requires AII room windows and doors to remain closed, except when doors must be opened for persons to enter or leave the room. Keeping certain doors in the corridor outside the AII rooms closed might be necessary to maintain the negative-pressure differential between an AII room and the corridor. Pressurization cannot be maintained in rooms or spaces that are not enclosed.

If ≥0.01 inch of water gauge is not achieved and cannot be achieved by increasing the flow differential (within the limits of the ventilation system), the room should be inspected for leakage. The total room leakage is based on the previously measured pressure, and air flow differentials can be estimated (Figure 4). If the room leakage is too substantial (e.g., 300 square inches), maintaining a negative-pressure differential as high as 0.01 inch of water gauge might be difficult. A lower value is acceptable if air-pressure monitoring indicates that negative pressure is always maintained (or airflow indicators consistently demonstrate that air is flowing in the desired direction). If negative pressure cannot be maintained, the leakage area might need to be reduced by sealing cracks around windows or replacing porous suspended ceiling panels with gasketed or sealed solid panels.

Because negative pressure in an AII room can be affected by even minimal changes in the operation of the ventilation system, negative pressure can be difficult to maintain with a VAV ventilation system. To maintain negative pressure, a VAV supply system should be coupled with a compensating exhaust system that increases when the supply flow rate increases. Alternatively, the exhaust can be set at a fixed rate that ensures negative pressure throughout the VAV supply cycle. The VAV minimum flow rate must also be adequate to maintain the recommended minimum mechanical and outdoor ACH (Table 2).

Alternate methods for achieving negative pressure. An anteroom is not a substitute for negative pressure in an AII room. However, an anteroom can reduce the escape of droplet nuclei during the opening and closing of the door to an AII room and can buffer an AII room from pressure fluctuations in the corridor. To function properly, an anteroom must have more air exhausted from the room than supplied to remove *M. tuberculosis* that can enter from the AII room. An anteroom can also have its own supply diffuser, if needed, to balance the pressure with the corridor. If an anteroom is unventilated or not properly ventilated, it will function only as a lesser contaminated vestibule between the AII room and the corridor and might not prevent the escape of droplet nuclei into the corridor. To adjust airflow and pressure differentials, health-care settings should consult a ventilation engineer who is knowledgeable regarding all applicable regulations, including building fire codes.

If the desired negative pressure cannot be achieved because a room does not have a separate ventilation system or a system that can provide the proper airflow, steps should be taken to provide a method to discharge air from an AII room. One method to achieve negative pressure in a room is to add a supplemental exhaust unit. If an AII room has a window or an outside wall, a small exhaust fan can be used. An engineer should be consulted to evaluate the potential for negative effects on surrounding areas (e.g., disruption of exhaust airflow in adjoining bathrooms) and to ensure the provision of the recommended amounts of outdoor air. The exhaust must not be discharged where it can immediately re-enter the building or pose a hazard to persons outside.

Fixed room-air recirculation systems (i.e., systems that recirculate the air in an entire AII room) can be designed to achieve negative pressure by discharging a portion of the air to the outside. Some portable room-air recirculation units are