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Guidelines for Preventing the Transmission of *Mycobacterium tuberculosis* in Health-Care Facilities, 1994

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Guidelines for Preventing the Transmission of *Mycobacterium tuberculosis* in Health-Care Facilities, 1994

Executive Summary

This document updates and replaces all previously published guidelines for the prevention of *Mycobacterium tuberculosis* transmission in health-care facilities. The purpose of this revision is to emphasize the importance of a) the hierarchy of control measures, including administrative and engineering controls and personal respiratory protection; b) the use of risk assessments for developing a written tuberculosis (TB) control plan; c) early identification and management of persons who have TB; d) TB screening programs for health-care workers (HCWs); e) HCW training and education; and f) the evaluation of TB infection-control programs.

Transmission of *M. tuberculosis* is a recognized risk to patients and HCWs in health-care facilities. Transmission is most likely to occur from patients who have unrecognized pulmonary or laryngeal TB, are not on effective anti-TB therapy, and have not been placed in TB isolation. Several recent TB outbreaks in health-care facilities, including outbreaks of multidrug-resistant TB, have heightened concern about nosocomial transmission. Patients who have multidrug-resistant TB can remain infectious for prolonged periods, which increases the risk for nosocomial and/or occupational transmission of *M. tuberculosis*. Increases in the incidence of TB have been observed in some geographic areas; these increases are related partially to the high risk for TB among immunosuppressed persons, particularly those infected with human immunodeficiency virus (HIV). Transmission of *M. tuberculosis* to HIV-infected persons is of particular concern because these persons are at high risk for developing active TB if they become infected with the bacteria. Thus, health-care facilities should be particularly alert to the need for preventing transmission of *M. tuberculosis* in settings in which HIV-infected persons work or receive care.

Supervisory responsibility for the TB infection-control program should be assigned to a designated person or group of persons who should be given the authority to implement and enforce TB infection-control policies. An effective TB infection-control program requires early identification, isolation, and treatment of persons who have active TB. The primary emphasis of TB infection-control plans in health-care facilities should be achieving these three goals by the application of a hierarchy of control measures, including a) the use of administrative measures to reduce the risk for exposure to persons who have infectious TB, b) the use of engineering controls to prevent the spread and reduce the concentration of infectious droplet nuclei, and c) the use of personal respiratory protective equipment in areas where there is still a risk for exposure to *M. tuberculosis* (e.g., TB isolation rooms). Implementation of a TB infection-control program requires risk assessment and development of a TB infection-control plan; early identification, treatment, and isolation of infectious TB patients; effective

engineering controls; an appropriate respiratory protection program; HCW TB training, education, counseling, and screening; and evaluation of the program's effectiveness.

Although completely eliminating the risk for transmission of *M. tuberculosis* in all health-care facilities may not be possible at the present time, adherence to these guidelines should reduce the risk to persons in these settings. Recently, nosocomial TB outbreaks have demonstrated the substantial morbidity and mortality among patients and HCWs that have been associated with incomplete implementation of CDC's *Guidelines for Preventing the Transmission of Tuberculosis in Health-Care Facilities, with Special Focus on HIV-Related Issues* published in 1990.* Follow-up investigations at some of these hospitals have documented that complete implementation of measures similar or identical to those in the *1990 TB Guidelines* significantly reduced or eliminated nosocomial transmission of *M. tuberculosis* to patients and/or HCWs.

I. Introduction

A. Purpose of Document

In April 1992, the National MDR-TB Task Force published the *National Action Plan to Combat Multidrug-Resistant Tuberculosis* (*1*). The publication was a response to reported nosocomial outbreaks of tuberculosis (TB), including outbreaks of multidrug-resistant TB (MDR-TB), and the increasing incidence of TB in some geographic areas. The plan called for the update and revision of the guidelines for preventing nosocomial transmission of *Mycobacterium tuberculosis* published December 7, 1990 (*2*).

Public meetings were held in October 1992 and January 1993 to discuss revision of the *1990 TB Guidelines* (*2*). CDC received considerable input on various aspects of infection control, including health-care worker (HCW) education; administrative controls (e.g., having protocols for the early identification and management of patients who have TB); the need for more specific recommendations regarding ventilation; and clarification on the use of respiratory protection in health-care settings. On the basis of these events and the input received, on October 12, 1993, CDC published in the *Federal Register* the *Draft Guidelines For Preventing the Transmission of Tuberculosis in Health-Care Facilities, Second Edition* (*3*). During and after the 90-day comment period following publication of this draft, CDC's TB Infection-Control Guidelines Work Group received and reviewed more than 2,500 comments.

The purpose of this document is to make recommendations for reducing the risk for transmitting *M. tuberculosis* to HCWs, patients, volunteers, visitors, and other persons in these settings. The information also may serve as a useful resource for educating HCWs about TB.

* CDC. *Guidelines for Preventing the Transmission of Tuberculosis in Health-Care Facilities, with Special Focus on HIV-Related Issues*. MMWR 1990;39(No. RR-17).

These recommendations update and replace all previously published CDC recommendations for TB infection control in health-care facilities (*2,4*). The recommendations in this document are applicable primarily to inpatient facilities in which health care is provided (e.g., hospitals, medical wards in correctional facilities, nursing homes, and hospices). Recommendations applicable to ambulatory-care facilities, emergency departments, home-health–care settings, emergency medical services, medical offices, dental settings, and other facilities or residential settings that provide medical care are provided in separate sections, with cross-references to other sections of the guidelines if appropriate.

Designated personnel at health-care facilities should conduct a risk assessment for the entire facility and for each area* and occupational group, determine the risk for nosocomial or occupational transmission of *M. tuberculosis*, and implement an appropriate TB infection-control program. The extent of the TB infection-control program may range from a simple program emphasizing administrative controls in settings where there is minimal risk for exposure to *M. tuberculosis*, to a comprehensive program that includes administrative controls, engineering controls, and respiratory protection in settings where the risk for exposure is high. In all settings, administrative measures should be used to minimize the number of HCWs exposed to *M. tuberculosis* while still providing optimal care for TB patients. HCWs providing care to patients who have TB should be informed about the level of risk for transmission of *M. tuberculosis* and the appropriate control measures to minimize that risk.

In this document, the term "HCWs" refers to all the paid and unpaid persons working in health-care settings who have the potential for exposure to *M. tuberculosis*. This may include, but is not limited to, physicians; nurses; aides; dental workers; technicians; workers in laboratories and morgues; emergency medical service (EMS) personnel; students; part-time personnel; temporary staff not employed by the health-care facility; and persons not involved directly in patient care but who are potentially at risk for occupational exposure to *M. tuberculosis* (e.g., volunteer workers and dietary, housekeeping, maintenance, clerical, and janitorial staff).

Although the purpose of this document is to make recommendations for reducing the risk for transmission of *M. tuberculosis* in health-care facilities, the process of implementing these recommendations must safeguard, in accordance with applicable state and federal laws, the confidentiality and civil rights of persons who have TB.

* Area: a structural unit (e.g., a hospital ward or laboratory) or functional unit (e.g., an internal medicine service) in which HCWs provide services to and share air with a specific patient population or work with clinical specimens that may contain viable *M. tuberculosis* organisms. The risk for exposure to *M. tuberculosis* in a given area depends on the prevalence of TB in the population served and the characteristics of the environment.

B. Epidemiology, Transmission, and Pathogenesis of TB

The prevalence of TB is not distributed evenly throughout all segments of the U.S. population. Some subgroups or persons have a higher risk for TB either because they are more likely than other persons in the general population to have been exposed to and infected with *M. tuberculosis* or because their infection is more likely to progress to active TB after they have been infected (*5*). In some cases, both of these factors may be present. Groups of persons known to have a higher prevalence of TB infection include contacts of persons who have active TB, foreign-born persons from areas of the world with a high prevalence of TB (e.g., Asia, Africa, the Caribbean, and Latin America), medically underserved populations (e.g., some African-Americans, Hispanics, Asians and Pacific Islanders, American Indians, and Alaskan Natives), homeless persons, current or former correctional-facility inmates, alcoholics, injecting-drug users, and the elderly. Groups with a higher risk for progression from latent TB infection to active disease include persons who have been infected recently (i.e., within the previous 2 years), children <4 years of age, persons with fibrotic lesions on chest radiographs, and persons with certain medical conditions (i.e., human immunodeficiency virus [HIV] infection, silicosis, gastrectomy or jejuno-ileal bypass, being ≥10% below ideal body weight, chronic renal failure with renal dialysis, diabetes mellitus, immunosuppression resulting from receipt of high-dose corticosteroid or other immunosuppressive therapy, and some malignancies) (*5*).

M. tuberculosis is carried in airborne particles, or droplet nuclei, that can be generated when persons who have pulmonary or laryngeal TB sneeze, cough, speak, or sing (*6*). The particles are an estimated 1–5 μm in size, and normal air currents can keep them airborne for prolonged time periods and spread them throughout a room or building (*7*). Infection occurs when a susceptible person inhales droplet nuclei containing *M. tuberculosis*, and these droplet nuclei traverse the mouth or nasal passages, upper respiratory tract, and bronchi to reach the alveoli of the lungs. Once in the alveoli, the organisms are taken up by alveolar macrophages and spread throughout the body. Usually within 2–10 weeks after initial infection with *M. tuberculosis*, the immune response limits further multiplication and spread of the tubercle bacilli; however, some of the bacilli remain dormant and viable for many years. This condition is referred to as latent TB infection. Persons with latent TB infection usually have positive purified protein derivative (PPD)-tuberculin skin-test results, but they do not have symptoms of active TB, and they are not infectious.

In general, persons who become infected with *M. tuberculosis* have approximately a 10% risk for developing active TB during their lifetimes. This risk is greatest during the first 2 years after infection. Immunocompromised persons have a greater risk for the progression of latent TB infection to active TB disease; HIV infection is the strongest known risk factor for this progression. Persons with latent TB infection who become coinfected with HIV have approximately an 8%–10% risk per year for developing active TB (*8*).

HIV-infected persons who are already severely immunosuppressed and who become newly infected with *M. tuberculosis* have an even greater risk for developing active TB (*9–12*).

The probability that a person who is exposed to *M. tuberculosis* will become infected depends primarily on the concentration of infectious droplet nuclei in the air and the duration of exposure. Characteristics of the TB patient that enhance transmission include a) disease in the lungs, airways, or larynx; b) presence of cough or other forceful expiratory measures; c) presence of acid-fast bacilli (AFB) in the sputum; d) failure of the patient to cover the mouth and nose when coughing or sneezing; e) presence of cavitation on chest radiograph; f) inappropriate or short duration of chemotherapy; and g) administration of procedures that can induce coughing or cause aerosolization of *M. tuberculosis* (e.g., sputum induction). Environmental factors that enhance the likelihood of transmission include a) exposure in relatively small, enclosed spaces; b) inadequate local or general ventilation that results in insufficient dilution and/or removal of infectious droplet nuclei; and c) recirculation of air containing infectious droplet nuclei. Characteristics of the persons exposed to *M. tuberculosis* that may affect the risk for becoming infected are not as well defined. In general, persons who have been infected previously with *M. tuberculosis* may be less susceptible to subsequent infection. However, reinfection can occur among previously infected persons, especially if they are severely immunocompromised. Vaccination with Bacille of Calmette and Guérin (BCG) probably does not affect the risk for infection; rather, it decreases the risk for progressing from latent TB infection to active TB (*13*). Finally, although it is well established that HIV infection increases the likelihood of progressing from latent TB infection to active TB, it is unknown whether HIV infection increases the risk for becoming infected if exposed to *M. tuberculosis*.

C. Risk for Nosocomial Transmission of *M. tuberculosis*

Transmission of *M. tuberculosis* is a recognized risk in health-care facilities (*14–22*). The magnitude of the risk varies considerably by the type of health-care facility, the prevalence of TB in the community, the patient population served, the HCW's occupational group, the area of the health-care facility in which the HCW works, and the effectiveness of TB infection-control interventions. The risk may be higher in areas where patients with TB are provided care before diagnosis and initiation of TB treatment and isolation precautions (e.g., in clinic waiting areas and emergency departments) or where diagnostic or treatment procedures that stimulate coughing are performed. Nosocomial transmission of *M. tuberculosis* has been associated with close contact with persons who have infectious TB and with the performance of certain procedures (e.g., bronchoscopy [*17*], endotracheal intubation and suctioning [*18*], open abscess irrigation [*20*], and autopsy [*21,22*]). Sputum induction and aerosol treatments that induce coughing may also increase the potential for transmission of *M. tuberculosis* (*23,24*). Personnel of health-care facilities

should be particularly alert to the need for preventing transmission of *M. tuberculosis* in those facilities in which immunocompromised persons (e.g., HIV-infected persons) work or receive care—especially if cough-inducing procedures, such as sputum induction and aerosolized pentamidine treatments, are being performed.

Several TB outbreaks among persons in health-care facilities have been reported recently (*11,24–28* ; CDC, unpublished data). Many of these outbreaks involved transmission of multidrug-resistant strains of *M. tuberculosis* to both patients and HCWs. Most of the patients and some of the HCWs were HIV-infected persons in whom new infection progressed rapidly to active disease. Mortality associated with those outbreaks was high (range: 43%–93%). Furthermore, the interval between diagnosis and death was brief (range of median intervals: 4–16 weeks). Factors contributing to these outbreaks included delayed diagnosis of TB, delayed recognition of drug resistance, and delayed initiation of effective therapy—all of which resulted in prolonged infectiousness, delayed initiation and inadequate duration of TB isolation, inadequate ventilation in TB isolation rooms, lapses in TB isolation practices and inadequate precautions for cough-inducing procedures, and lack of adequate respiratory protection. Analysis of data collected from three of the health-care facilities involved in the outbreaks indicates that transmission of *M. tuberculosis* decreased significantly or ceased entirely in areas where measures similar to those in the *1990 TB Guidelines* were implemented (*2,29–32*). However, several interventions were implemented simultaneously, and the effectiveness of the separate interventions could not be determined.

D. Fundamentals of TB Infection Control

An effective TB infection-control program requires early identification, isolation, and effective treatment of persons who have active TB. The primary emphasis of the TB infection-control plan should be on achieving these three goals. In all health-care facilities, particularly those in which persons who are at high risk for TB work or receive care, policies and procedures for TB control should be developed, reviewed periodically, and evaluated for effectiveness to determine the actions necessary to minimize the risk for transmission of *M. tuberculosis*.

The TB infection-control program should be based on a hierarchy of control measures. The first level of the hierarchy, and that which affects the largest number of persons, is using administrative measures intended primarily to reduce the risk for exposing uninfected persons to persons who have infectious TB. These measures include a) developing and implementing effective written policies and protocols to ensure the rapid identification, isolation, diagnostic evaluation, and treatment of persons likely to have TB; b) implementing effective work practices among HCWs in the health-care facility (e.g., correctly wearing respiratory protection and keeping doors to isolation rooms closed); c) educating, training, and counseling HCWs about TB; and d) screening HCWs for TB infection and disease.

The second level of the hierarchy is the use of engineering controls to prevent the spread and reduce the concentration of infectious droplet nuclei. These controls include a) direct source control using local exhaust ventilation, b) controlling direction of airflow to prevent contamination of air in areas adjacent to the infectious source, c) diluting and removing contaminated air via general ventilation, and d) air cleaning via air filtration or ultraviolet germicidal irradiation (UVGI).

The first two levels of the hierarchy minimize the number of areas in the health-care facility where exposure to infectious TB may occur, and they reduce, but do not eliminate, the risk in those few areas where exposure to *M. tuberculosis* can still occur (e.g., rooms in which patients with known or suspected infectious TB are being isolated and treatment rooms in which cough-inducing or aerosol-generating procedures are performed on such patients). Because persons entering such rooms may be exposed to *M. tuberculosis*, the third level of the hierarchy is the use of personal respiratory protective equipment in these and certain other situations in which the risk for infection with *M. tuberculosis* may be relatively higher.

Specific measures to reduce the risk for transmission of *M. tuberculosis* include the following:

- Assigning to specific persons in the health-care facility the supervisory responsibility for designing, implementing, evaluating, and maintaining the TB infection-control program (Section II.A).
- Conducting a risk assessment to evaluate the risk for transmission of *M. tuberculosis* in all areas of the health-care facility, developing a written TB infection-control program based on the risk assessment, and periodically repeating the risk assessment to evaluate the effectiveness of the TB infection-control program (Section II.B).
- Developing, implementing, and enforcing policies and protocols to ensure early identification, diagnostic evaluation, and effective treatment of patients who may have infectious TB (Section II.C; Suppl. 2).
- Providing prompt triage for and appropriate management of patients in the outpatient setting who may have infectious TB (Section II.D).
- Promptly initiating and maintaining TB isolation for persons who may have infectious TB and who are admitted to the inpatient setting (Section II.E; Suppl. 1).
- Effectively planning arrangements for discharge (Section II.E).
- Developing, installing, maintaining, and evaluating ventilation and other engineering controls to reduce the potential for airborne exposure to *M. tuberculosis* (Section II.F; Suppl. 3).
- Developing, implementing, maintaining, and evaluating a respiratory protection program (Section II.G; Suppl. 4).
- Using precautions while performing cough-inducing procedures (Section II.H; Suppl. 3).

- Educating and training HCWs about TB, effective methods for preventing transmission of *M. tuberculosis*, and the benefits of medical screening programs (Section II.I).
- Developing and implementing a program for routine periodic counseling and screening of HCWs for active TB and latent TB infection (Section II.J; Suppl. 2).
- Promptly evaluating possible episodes of *M. tuberculosis* transmission in health-care facilities, including PPD skin-test conversions among HCWs, epidemiologically associated cases among HCWs or patients, and contacts of patients or HCWs who have TB and who were not promptly identified and isolated (Section II.K).
- Coordinating activities with the local public health department, emphasizing reporting, and ensuring adequate discharge follow-up and the continuation and completion of therapy (Section II.L).

II. Recommendations

A. Assignment of Responsibility

- Supervisory responsibility for the TB infection-control program should be assigned to a designated person or group of persons with expertise in infection control, occupational health, and engineering. These persons should be given the authority to implement and enforce TB infection-control policies.
- If supervisory responsibility is assigned to a committee, one person should be designated as the TB contact person. Questions and problems can then be addressed to this person.

B. Risk Assessment, Development of the TB Infection-Control Plan, and Periodic Reassessment

1. Risk assessment

a. General

- TB infection-control measures for each health-care facility should be based on a careful assessment of the risk for transmission of *M. tuberculosis* in that particular setting. The first step in developing the TB infection-control program should be to conduct a baseline risk assessment to evaluate the risk for transmission of *M. tuberculosis* in each area and occupational group in the facility (Table 1, Figure 1). Appropriate infection-control interventions can then be developed on the basis of actual risk. Risk assessments should be performed for all inpatient and outpatient settings (e.g., medical and dental offices).
- Regardless of risk level, the management of patients with known or suspected infectious TB should not vary. However, the index of suspicion for infectious TB among patients, the frequency of HCW PPD skin testing, the number of TB isolation rooms, and other factors will depend on whether the risk for transmission of *M. tuberculosis* in the

facility, area, or occupational group is high, intermediate, low, very low, or minimal.

- The risk assessment should be conducted by a qualified person or group of persons (e.g., hospital epidemiologists, infectious disease specialists, pulmonary disease specialists, infection-control practitioners, health-care administrators, occupational health personnel, engineers, HCWs, or local public health personnel).
- The risk assessment should be conducted for the entire facility and for specific areas within the facility (e.g., medical, TB, pulmonary, or HIV wards; HIV, infectious disease, or pulmonary clinics; and emergency departments or other areas where TB patients might receive

TABLE 1. Elements of a risk assessment for tuberculosis (TB) in health-care facilities

1. Review the community TB profile (from public health department data).
2. Review the number of TB patients who were treated in each area of the facility (both inpatient and outpatient). (This information can be obtained by analyzing laboratory surveillance data and by reviewing discharge diagnoses or medical and infection-control records.)
3. Review the drug-susceptibility patterns of TB isolates of patients who were treated at the facility.
4. Analyze purified protein derivative (PPD)-tuberculin skin-test results of health-care workers (HCWs), by area or by occupational group for HCWs not assigned to a specific area (e.g., respiratory therapists).
5. To evaluate infection-control parameters, review medical records of a sample of TB patients seen at the facility.

   Calculate intervals from:
   - admission until TB suspected;
   - admission until TB evaluation performed;
   - admission until acid-fast bacilli (AFB) specimens ordered;
   - AFB specimens ordered until AFB specimens collected;
   - AFB specimens collected until AFB smears performed and reported;
   - AFB specimens collected until cultures performed and reported;
   - AFB specimens collected until species identification conducted and reported;
   - AFB specimens collected until drug-susceptibility tests performed and reported;
   - admission until TB isolation initiated;
   - admission until TB treatment initiated; and
   - duration of TB isolation.

   Obtain the following additional information:
   - Were appropriate criteria used for discontinuing isolation?
   - Did the patient have a history of prior admission to the facility?
   - Was the TB treatment regimen adequate?
   - Were follow-up sputum specimens collected properly?
   - Was appropriate discharge planning conducted?

6. Perform an observational review of TB infection control practices.
7. Review the most recent environmental evaluation and maintenance procedures.

FIGURE 1. Protocol for conducting a tuberculosis (TB) risk assessment in a health-care facility

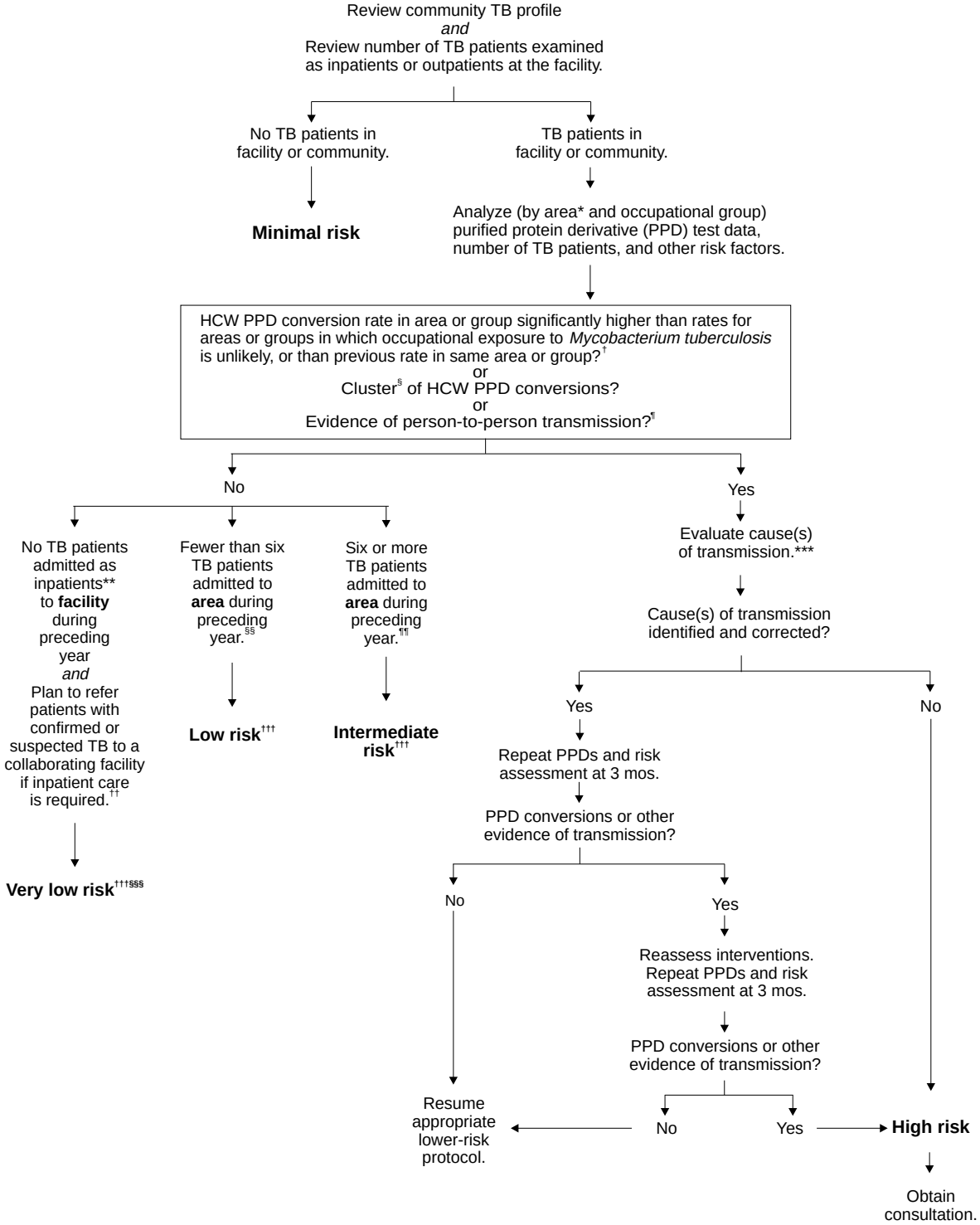


FIGURE 1. Protocol for conducting a TB risk assessment in a health-care facility — Continued

* Area: a structural unit (e.g., a hospital ward or laboratory) or functional unit (e.g., an internal medicine service) in which HCWs provide services to and share air with a specific patient population or work with clinical specimens that may contain viable *M. tuberculosis* organisms. The risk for exposure to *M. tuberculosis* in a given area depends on the prevalence of TB in the population served and the characteristics of the environment.

† With epidemiologic evaluation suggestive of occupational (nosocomial) transmission (see Problem Evaluation section in the text).

§ Cluster: two or more PPD skin-test conversions occurring within a 3-month period among HCWs in a specific area or occupational group, and epidemiologic evidence suggests occupational (nosocomial) transmission.

¶ For example, clusters of *M. tuberculosis* isolates with identical DNA fingerprint (RFLP) patterns or drug-resistance patterns, with epidemiologic evaluation suggestive of nosocomial transmission (see Problem Evaluation section in the text).

** Does not include patients identified in triage system and referred to a collaborating facility or patients being managed in outpatient areas.

†† To prevent inappropriate management and potential loss to follow-up of patients identified in the triage system of a very low-risk facility as having suspected TB, an agreement should exist for referral between the referring and receiving facilities.

§§ Or, for occupational groups, exposure to fewer than six TB patients for HCWs in the particular occupational group during the preceding year.

¶¶ Or, for occupational groups, exposure to six or more TB patients for HCWs in the particular occupational group during the preceding year.

*** See Problem Evaluation section in the text.

††† Occurrence of drug-resistant TB in the facility or community, or a relatively high prevalence of HIV infection among patients or HCWs in the area, may warrant a higher risk rating.

§§§ For outpatient facilities, if TB cases have been documented in the community but no TB patients have been examined in the outpatient area during the preceding year, the area can be designated as very low risk.

care or where cough-inducing procedures are performed). This should include both inpatient and outpatient areas. In addition, risk assessments should be conducted for groups of HCWs who work throughout the facility rather than in a specific area (e.g., respiratory therapists; bronchoscopists; environmental services, dietary, and maintenance personnel; and students, interns, residents, and fellows).

- Classification of risk for a facility, for a specific area, and for a specific occupational group should be based on a) the profile of TB in the community; b) the number of infectious TB patients admitted to the area or ward, or the estimated number of infectious TB patients to whom HCWs in an occupational group may be exposed; and c) the results of analysis of HCW PPD test conversions (where applicable) and possible person-to-person transmission of *M. tuberculosis* (Figure 1).
- All TB infection-control programs should include periodic reassessments of risk. The frequency of repeat risk assessments should be based on the results of the most recent risk assessment (Table 2, Figure 1).
- The "minimal-risk" category applies only to an entire facility. A "minimal-risk" facility does not admit TB patients to inpatient or outpatient areas and is not located in a community with TB (i.e.,

TABLE 2. Elements of a tuberculosis (TB) infection-control program

Element	Risk categories				
	Minimal	Very low	Low	Intermediate	High
Assigning responsibility (Section II.A)					
Designated TB control officer or committee	R	R	R	R	R
Conducting a risk assessment (Section II.B.1)					
Baseline risk assessment	R	R	R	R	R
Community TB profile: incidence, prevalence, and drug-susceptibility patterns	Y	Y	Y	Y	Y
Facility case surveillance (laboratory- and discharge-diagnosis–based)	C	C	C	C	C
Analysis of purified protein derivative (PPD) test results among health-care workers (HCWs)	N/A	V*	Y	every 6–12 mos	every 3 mos
Review of TB patient medical records	N/A	O†	Y	every 6–12 mos	every 3 mos
Observation of infection-control practices	N/A	N/A	Y	every 6–12 mos	every 3 mos
Evaluation of engineering control maintenance	O§	O§	Y	every 6–12 mos	every 3 mos
Developing a TB infection control plan (Section II.B.2)					
Written TB infection control plan	R	R	R	R	R
Periodically reassessing risk (Section II.B.3)					
Reassessment of risk	Y	Y	Y	every 6–12 mos	every 3 mos
Identifying, evaluating, and initiating treatment for patients who may have active TB (Section II.C)					
Protocol (clinical prediction rules)¶ for identifying patients who may have active TB	R	R	R	R	R
Protocol for diagnostic evaluation of patients who may have active TB**	N/A	R	R	R	R

R=recommended; Y=yearly; C=continual; N/A=not applicable; O=optional; V=variable.

TABLE 2. Elements of a TB infection-control program — Continued

Element	Risk categories				
	Minimal	**Very low**	**Low**	**Intermediate**	**High**
Protocol for reporting laboratory results to clinicians, infection-control practitioners, collaborating referral facilities, and appropriate health department(s)	N/A	R	R	R	R
Protocol for initiating treatment of patients who may have active TB**	N/A	R	R	R	R
Managing patients who may have TB in ambulatory-care settings and emergency departments (Section II.D)					
Triage system for identifying patients who have active TB in emergency departments and ambulatory-care settings	R	R	R	R	R
Protocol for managing patients who may have active TB in emergency departments and ambulatory-care settings	R	R	R	R	R
Protocol for referring patients who may have active TB to collaborating facility	R	R	N/A††	N/A††	N/A††
Managing hospitalized patients who may have TB (Section II.E)					
Appropriate number of TB isolation rooms§§	N/A	N/A	R	R	R
Protocol for initiating TB isolation	N/A	N/A	R	R	R
Protocol for TB isolation practices	N/A	N/A	R	R	R
Protocol for discontinuing TB isolation	N/A	N/A	R	R	R
Protocol for discharge planning	N/A	N/A	R	R	R
Engineering controls (Suppl. 3, Section II.F)					
Protocol(s) for maintenance of engineering controls	O§	O§	R	R	R
Respiratory protection (Suppl. 4, Section II.G)					
Respiratory protection program	N/A	V*	R	R	R

R=recommended; Y=yearly; C=continual; N/A=not applicable; O=optional; V=variable.

TABLE 2. Elements of a TB infection-control program — Continued

Element	Risk categories				
	Minimal	**Very low**	**Low**	**Intermediate**	**High**
Cough-inducing and aerosol-generating procedures (Section II.H)					
Protocol(s) for performing cough-inducing or aerosol-generating procedures	O	O¶¶	R	R	R
Engineering controls for performing cough-inducing or aerosol-generating procedures	O§	O¶¶	R	R	R
Educating and Training HCWs (Section II.I)					
Educating and training HCWs regarding TB	R	R	R	R	R
Counseling and screening HCWs (Section II.J)					
Counseling HCWs regarding TB	R	R	R	R	R
Protocol for identifying and evaluating HCWs who have signs or symptoms of active TB	R	R	R	R	R
Baseline PPD testing of HCWs	O***	R	R	R	R
Routine periodic PPD screening of HCWs for latent TB infection	N/A	V*	Y	every 6–12 mos	every 3 mos
Protocol for evaluating and managing HCWs who have positive PPD tests	R	R	R	R	R
Protocol for managing HCWs who have active TB	R	R	R	R	R
Conducting a problem evaluation (Section II.K)					
Protocol for investigating PPD conversions and active TB in HCWs	R	R	R	R	R
Protocol for investigating possible patient-to-patient transmission of *Mycobacterium tuberculosis*	R	R	R	R	R

R=recommended; Y=yearly; C=continual; N/A=not applicable; O=optional; V=variable.

TABLE 2. Elements of a TB infection-control program — Continued

Element	Risk categories				
	Minimal	Very low	Low	Intermediate	High
Protocol for investigating possible contacts of TB patients who were not diagnosed initially as having TB and were not placed in isolation	R	R	R	R	R
Coordination with the public health department (Section II.L)					
Effective system for reporting patients who have suspected or confirmed TB to appropriate health department(s)	R	R	R	R	R

R=recommended; Y=yearly; C=continual; N/A=not applicable; O=optional; V=variable.

* Because very low-risk facilities do not admit patients who may have active TB to inpatient areas, most HCWs in such facilities do not need routine follow-up PPD screening after baseline PPD testing is done. However, those who are involved in the initial assessment and diagnostic evaluation of patients in the ambulatory-care, emergency, and admitting departments of such facilities or in the outpatient management of patients with active TB could be exposed potentially to a patient who has active TB. These HCWs may need to receive routine periodic PPD screening. Similarly, these HCWs may need to be included in a respiratory protection program.

† Because very low-risk facilities do not admit patients suspected of having active TB, review of TB patient medical records is not applicable. However, follow-up of patients who were identified during triage as possibly having active TB and referred to another institution for further evaluation and management may be useful in evaluating the effectiveness of the triage system.

§ Some minimal or very low-risk facilities may elect to use engineering controls (e.g., booths for cough-inducing procedures, portable high-efficiency particulate [HEPA] filtration units, ultraviolet germicidal irradiation units) in triage/waiting areas. In such situations, appropriate protocols for maintaining this equipment should be in place, and this maintenance should be evaluated periodically.

¶ The criteria used in clinical prediction rules will probably vary from facility to facility depending on the prevalence of TB in the population served by the facility and on the clinical, radiographic, and laboratory characteristics of TB patients examined in the facility.

** The protocols should be consistent with CDC/American Thoracic Society recommendations (*33*).

†† Protocols for referring patients who require specialized treatment (e.g., patients with multidrug-resistant TB) may be appropriate.

§§ Based on maximum daily number of patients requiring TB isolation for suspected or confirmed active TB. Isolation rooms should meet the performance criteria specified in these guidelines.

¶¶ If such procedures are used in the triage protocol(s) for identifying patients who may have active TB.

*** Minimal-risk facilities do not need to maintain an ongoing PPD skin-testing program. However, baseline PPD testing of HCWs may be advisable so that if an unexpected exposure does occur, conversions can be distinguished from positive PPD test results caused by previous exposures.

counties or communities in which TB cases have not been reported during the previous year). Thus, there is essentially no risk for exposure to TB patients in the facility. This category may also apply to many outpatient settings (e.g., many medical and dental offices).

- The "very low-risk" category generally applies only to an entire facility. A very low-risk facility is one in which a) patients with active TB are not admitted to inpatient areas but may receive initial assessment and diagnostic evaluation or outpatient management in outpatient areas (e.g., ambulatory-care and emergency departments) and b) patients who may have active TB and need inpatient care are promptly referred to a collaborating facility. In such facilities, the outpatient areas in which exposure to patients with active TB could occur should be assessed and assigned to the appropriate low-, intermediate-, or high-risk category. Categorical assignment will depend on the number of TB patients examined in the area during the preceding year and whether there is evidence of nosocomial transmission of *M. tuberculosis* in the area. If TB cases have been reported in the community, but no patients with active TB have been examined in the outpatient area during the preceding year, the area can be designated as very low risk (e.g., many medical offices).

  The referring and receiving facilities should establish a referral agreement to prevent inappropriate management and potential loss to follow-up of patients suspected of having TB during evaluation in the triage system of a very low-risk facility.

  In some facilities in which TB patients are admitted to inpatient areas, a very low-risk protocol may be appropriate for areas (e.g., administrative areas) or occupational groups that have only a very remote possibility of exposure to *M. tuberculosis*.

  The very low-risk category may also be appropriate for outpatient facilities that do not provide initial assessment of persons who may have TB, but do screen patients for active TB as part of a limited medical screening before undertaking specialty care (e.g., dental settings).

- "Low-risk" areas or occupational groups are those in which a) the PPD test conversion rate is not greater than that for areas or groups in which occupational exposure to *M. tuberculosis* is unlikely or than previous conversion rates for the same area or group, b) no clusters* of PPD test conversions have occurred, c) person-to-person transmission of *M. tuberculosis* has not been detected, and d) fewer than six TB patients are examined or treated per year.

- "Intermediate-risk" areas or occupational groups are those in which a) the PPD test conversion rate is not greater than that for areas or groups in which occupational exposure to *M. tuberculosis* is unlikely or than previous conversion rates for the same area or group, b) no clusters of PPD test conversions have occurred, c) person-to-person transmission of *M. tuberculosis* has not been detected, and d) six or

*Cluster: two or more PPD skin-test conversions occurring within a 3-month period among HCWs in a specific area or occupational group, and epidemiologic evidence suggests occupational (nosocomial) transmission.

more patients with active TB are examined or treated each year. Survey data suggest that facilities in which six or more TB patients are examined or treated each year may have an increased risk for transmission of *M. tuberculosis* (CDC, unpublished data); thus, areas in which six or more patients with active TB are examined or treated each year (or occupational groups in which HCWs are likely to be exposed to six or more TB patients per year) should be classified as "intermediate risk."

- "High-risk" areas or occupational groups are those in which a) the PPD test conversion rate is significantly greater than for areas or groups in which occupational exposure to *M. tuberculosis* is unlikely or than previous conversion rates for the same area or group, and epidemiologic evaluation suggests nosocomial transmission; **or** b) a cluster of PPD test conversions has occurred, and epidemiologic evaluation suggests nosocomial transmission of *M. tuberculosis*; **or** c) possible person-to-person transmission of *M. tuberculosis* has been detected.
- If no data or insufficient data for adequate determination of risk have been collected, such data should be compiled, analyzed, and reviewed expeditiously.

b. Community TB profile

- A profile of TB in the community that is served by the facility should be obtained from the public health department. This profile should include, at a minimum, the incidence (and prevalence, if available) of active TB in the community and the drug-susceptibility patterns of *M. tuberculosis* isolates (i.e., the antituberculous agents to which each isolate is susceptible and those to which it is resistant) from patients in the community.

c. Case surveillance

- Data concerning the number of suspected and confirmed active TB cases among patients and HCWs in the facility should be systematically collected, reviewed, and used to estimate the number of TB isolation rooms needed, to recognize possible clusters of nosocomial transmission, and to assess the level of potential occupational risk. The number of TB patients in specific areas of a facility can be obtained from laboratory surveillance data on specimens positive for AFB smears or *M. tuberculosis* cultures, from infection-control records, and from databases containing information about hospital discharge diagnoses.
- Drug-susceptibility patterns of *M. tuberculosis* isolates from TB patients treated in the facility should be reviewed to identify the frequency and patterns of drug resistance. This information may indicate a need to modify the initial treatment regimen or may suggest possible nosocomial transmission or increased occupational risk.

d. Analysis of HCW PPD test screening data

- Results of HCW PPD testing should be recorded in the individual HCW's employee health record and in a retrievable aggregate data-

base of all HCW PPD test results. Personal identifying information should be handled confidentially. PPD test conversion rates should be calculated at appropriate intervals to estimate the risk for PPD test conversions for each area of the facility and for each specific occupational group not assigned to a specific area (Table 2). To calculate PPD test conversion rates, the total number of previously PPD-negative HCWs tested in each area or group (i.e., the denominator) and the number of PPD test conversions among HCWs in each area or group (the numerator) must be obtained.

- PPD test conversion rates for each area or occupational group should be compared with rates for areas or groups in which occupational exposure to *M. tuberculosis* is unlikely and with previous conversion rates in the same area or group to identify areas or groups where the risk for occupational PPD test conversions may be increased. A low number of HCWs in a specific area may result in a greatly increased rate of conversion for that area, although the actual risk may not be significantly greater than that for other areas. Testing for statistical significance (e.g., Fisher's exact test or chi square test) may assist interpretation; however, lack of statistical significance may not rule out a problem (i.e., if the number of HCWs tested is low, there may not be adequate statistical power to detect a significant difference). Thus, interpretation of individual situations is necessary.
- An epidemiologic investigation to evaluate the likelihood of nosocomial transmission should be conducted if PPD test conversions are noted (Section II.K.1).
- The frequency and comprehensiveness of the HCW PPD testing program should be evaluated periodically to ensure that all HCWs who should be included in the program are being tested at appropriate intervals. For surveillance purposes, earlier detection of transmission may be enhanced if HCWs in a given area or occupational group are tested on different scheduled dates rather than all being tested on the same date (Section II.J.3).

e. Review of TB patient medical records

- The medical records of a sample of TB patients examined at the facility can be reviewed periodically to evaluate infection-control parameters (Table 1). Parameters to examine may include the intervals from date of admission until a) TB was suspected, b) specimens for AFB smears were ordered, c) these specimens were collected, d) tests were performed, and e) results were reported. Moreover, the adequacy of the TB treatment regimens that were used should be evaluated.
- Medical record reviews should note previous hospital admissions of TB patients before the onset of TB symptoms. Patient-to-patient transmission may be suspected if active TB occurs in a patient who had a prior hospitalization during which exposure to another TB patient occurred or if isolates from two or more TB patients have identical characteristic drug-susceptibility or DNA fingerprint patterns.

- Data from the case review should be used to determine if there is a need to modify a) protocols for identifying and isolating patients who may have infectious TB, b) laboratory procedures, c) administrative policies and practices, or d) protocols for patient management.

f. Observation of TB infection-control practices

- Assessing adherence to the policies of the TB infection-control program should be part of the evaluation process. This assessment should be performed on a regular basis and whenever an increase occurs in the number of TB patients or HCW PPD test conversions. Areas at high risk for transmission of *M. tuberculosis* should be monitored more frequently than other areas. The review of patient medical records provides information on HCW adherence to some of the policies of the TB infection-control program. In addition, work practices related to TB isolation (e.g., keeping doors to isolation rooms closed) should be observed to determine if employers are enforcing, and HCWs are adhering to, these policies and if patient adherence is being enforced. If these policies are not being enforced or adhered to, appropriate education and other corrective action should be implemented.

g. Engineering evaluation

- Results of engineering maintenance measures should be reviewed at regular intervals (Table 3). Data from the most recent evaluation and from maintenance procedures and logs should be reviewed carefully as part of the risk assessment.

2. Development of the TB Infection-Control Plan

- Based on the results of the risk assessment, a written TB infection-control plan should be developed and implemented for each area of the facility and for each occupational group of HCWs not assigned to a specific area of the facility (Table 2; Table 3).
- The occurrence of drug-resistant TB in the facility or the community, or a relatively high prevalence of HIV infection among patients or HCWs in the community, may increase the concern about transmission of *M. tuberculosis* and may influence the decision regarding which protocol to follow (i.e., a higher-risk classification may be selected).
- Health-care facilities are likely to have a combination of low-, intermediate-, and high-risk areas or occupational groups during the same time period. The appropriate protocol should be implemented for each area or group.
- Areas in which cough-inducing procedures are performed on patients who may have active TB should, at the minimum, implement the intermediate-risk protocol.

3. Periodic Reassessment

- Follow-up risk assessment should be performed at the interval indicated by the most recent risk assessment (Figure 1; Table 2). Based on

TABLE 3. Characteristics of an effective tuberculosis (TB) infection-control program*

I. Assignment of responsibility

A. Assign responsibility for the TB infection-control program to qualified person(s).

B. Ensure that persons with expertise in infection control, occupational health, and engineering are identified and included.

II. Risk assessment, TB infection-control plan, and periodic reassessment

A. Initial risk assessments
   1. Obtain information concerning TB in the community.
   2. Evaluate data concerning TB patients in the facility.
   3. Evaluate data concerning purified protein derivative (PPD)-tuberculin skin-test conversions among health-care workers (HCWs) in the facility.
   4. Rule out evidence of person-to-person transmission.

B. Written TB infection-control program
   1. Select initial risk protocol(s).
   2. Develop written TB infection-control protocols.

C. Repeat risk assessment at appropriate intervals.
   1. Review current community and facility surveillance data and PPD-tuberculin skin-test results.
   2. Review records of TB patients.
   3. Observe HCW infection-control practices.
   4. Evaluate maintenance of engineering controls.

III. Identification, evaluation, and treatment of patients who have TB

A. Screen patients for signs and symptoms of active TB:
   1. On initial encounter in emergency department or ambulatory-care setting.
   2. Before or at the time of admission.

B. Perform radiologic and bacteriologic evaluation of patients who have signs and symptoms suggestive of TB.

C. Promptly initiate treatment.

IV. Managing outpatients who have possible infectious TB

A. Promptly initiate TB precautions.

B. Place patients in separate waiting areas or TB isolation rooms.

C. Give patients a surgical mask, a box of tissues, and instructions regarding the use of these items.

V. Managing inpatients who have possible infectious TB

A. Promptly isolate patients who have suspected or known infectious TB.

B. Monitor the response to treatment.

C. Follow appropriate criteria for discontinuing isolation.

VI. Engineering recommendations

A. Design local exhaust and general ventilation in collaboration with persons who have expertise in ventilation engineering.

B. Use a single-pass air system or air recirculation after high-efficiency particulate air (HEPA) filtration in areas where infectious TB patients receive care.

C. Use additional measures, if needed, in areas where TB patients may receive care.

*A program such as this is appropriate for health-care facilities in which there is a high risk for transmission of *Mycobacterium tuberculosis.*

TABLE 3. Characteristics of an effective TB infection-control program — Continued

D. Design TB isolation rooms in health-care facilities to achieve ≥6 air changes per hour (ACH) for existing facilities and ≥12 ACH for new or renovated facilities.

E. Regularly monitor and maintain engineering controls.

F. TB isolation rooms that are being used should be monitored daily to ensure they maintain negative pressure relative to the hallway and all surrounding areas.

G. Exhaust TB isolation room air to outside or, if absolutely unavoidable, recirculate after HEPA filtration.

VII. Respiratory protection

A. Respiratory protective devices should meet recommended performance criteria.

B. Repiratory protection should be used by persons entering rooms in which patients with known or suspected infectious TB are being isolated, by HCWs when performing cough-inducing or aerosol-generating procedures on such patients, and by persons in other settings where administrative and engineering controls are not likely to protect them from inhaling infectious airborne droplet nuclei.

C. A respiratory protection program is required at all facilities in which respiratory protection is used.

VIII. Cough-inducing procedures

A. Do not perform such procedures on TB patients unless absolutely necessary.

B. Perform such procedures in areas that have local exhaust ventilation devices (e.g., booths or special enclosures) or, if this is not feasible, in a room that meets the ventilation requirements for TB isolation.

C. After completion of procedures, TB patients should remain in the booth or special enclosure until their coughing subsides.

IX. HCW TB training and education

A. All HCWs should receive periodic TB education appropriate for their work responsibilities and duties.

B. Training should include the epidemiology of TB in the facility.

C. TB education should emphasize concepts of the pathogenesis of and occupational risk for TB.

D. Training should describe work practices that reduce the likelihood of transmitting *M. tuberculosis.*

X. HCW counseling and screening

A. Counsel all HCWs regarding TB and TB infection.

B. Counsel all HCWs about the increased risk to immunocompromised persons for developing active TB.

C. Perform PPD skin tests on HCWs at the beginning of their employment, and repeat PPD tests at periodic intervals.

D. Evaluate symptomatic HCWs for active TB.

XI. Evaluate HCW PPD test conversions and possible nosocomial transmission of *M. tuberculosis.*

XII. Coordinate efforts with public health department(s)

the results of the follow-up assessment, problem evaluation may need to be conducted or the protocol may need to be modified to a higher- or lower-risk level.

- After each risk assessment, the staff responsible for TB control, in conjunction with other appropriate HCWs, should review all TB control policies to ensure that they are effective and meet current needs.

4. Examples of Risk Assessment

Examples of six hypothetical situations and the means by which surveillance data are used to select a TB control protocol are described as follows:

Hospital A. The overall HCW PPD test conversion rate in the facility is 1.6%. No areas or HCW occupational groups have a significantly greater PPD test conversion rate than areas or groups in which occupational exposure to *M. tuberculosis* is unlikely (or than previous rates for the same area or group). No clusters of PPD test conversions have occurred. Patient-to-patient transmission has not been detected. Patients who have TB are admitted to the facility, but no area admits six or more TB patients per year. The low-risk protocol will be followed in all areas.

Hospital B. The overall HCW PPD test conversion rate in the facility is 1.8%. The PPD test conversion rate for the medical intensive-care unit rate is significantly higher than all other areas in the facility. The problem identification process is initiated (Section II.K). It is determined that all TB patients have been isolated appropriately. Other potential problems are then evaluated, and the cause for the higher rate is not identified. After consulting the public health department TB infection-control program, the high-risk protocol is followed in the unit until the PPD test conversion rate is similar to areas of the facility in which occupational exposure to TB patients is unlikely. If the rate remains significantly higher than other areas, further evaluation, including environmental and procedural studies, will be performed to identify possible reasons for the high conversion rate.

Hospital C. The overall HCW PPD test conversion rate in the facility is 2.4%. Rates range from 0 to 2.6% for the individual areas and occupational groups. None of these rates is significantly higher than rates for areas in which occupational exposure to *M. tuberculosis* is unlikely. No particular HCW group has higher conversion rates than the other groups. No clusters of HCW PPD test conversions have occurred. In two of the areas, HCWs cared for more than six TB patients during the preceding year. These two areas will follow the intermediate-risk protocol, and all other areas will follow the low-risk protocol. This hospital is located in the southeastern United States, and these conversion rates may reflect cross-reactivity with nontuberculous mycobacteria.

Hospital D. The overall HCW PPD test conversion rate in the facility is 1.2%. In no area did HCWs care for six or more TB patients during the preceding

year. Three of the 20 respiratory therapists tested had PPD conversions, for a rate of 15%. The respiratory therapists who had PPD test conversions had spent all or part of their time in the pulmonary function laboratory, where induced sputum specimens were obtained. A low-risk protocol is maintained for all areas and occupational groups in the facility except for respiratory therapists. A problem evaluation is conducted in the pulmonary function laboratory (Section II.K). It is determined that the ventilation in this area is inadequate. Booths are installed for sputum induction. PPD testing and the risk assessment are repeated 3 months later. If the repeat testing at 3 months indicates that no more conversions have occurred, the respiratory therapists will return to the low-risk protocol.

Hospital E. Hospital E is located in a community that has a relatively low incidence of TB. To optimize TB services in the community, the four hospitals in the community have developed an agreement that one of them (e.g., Hospital G) will provide all inpatient services to persons who have suspected or confirmed TB. The other hospitals have implemented protocols in their ambulatory-care clinics and emergency departments to identify patients who may have active TB. These patients are then transferred to Hospital G for inpatient care if such care is considered necessary. After discharge from Hospital G, they receive follow-up care in the public health department's TB clinic. During the preceding year, Hospital E has identified fewer than six TB patients in its ambulatory-care and emergency departments and has had no PPD test conversions or other evidence of *M. tuberculosis* transmission among HCWs or patients in these areas. These areas are classified as low risk, and all other areas are classified as very low risk.

Hospital F. Hospital F is located in a county in which no TB cases have been reported during the preceding 2 years. A risk assessment conducted at the facility did not identify any patients who had suspected or confirmed TB during the preceding year. The facility is classified as minimal risk.

C. Identifying, Evaluating, and Initiating Treatment for Patients Who May Have Active TB

The most important factors in preventing transmission of *M. tuberculosis* are the early identification of patients who may have infectious TB, prompt implementation of TB precautions for such patients, and prompt initiation of effective treatment for those who are likely to have TB.

1. Identifying patients who may have active TB

- Health-care personnel who are assigned responsibility for TB infection control in ambulatory-care and inpatient settings should develop, implement, and enforce protocols for the early identification of patients who may have infectious TB.

- The criteria used in these protocols should be based on the prevalence and characteristics of TB in the population served by the specific facility. These protocols should be evaluated periodically and revised according to the results of the evaluation. Review of medical records of patients who were examined in the facility and diagnosed as having TB may serve as a guide for developing or revising these protocols.
- A diagnosis of TB may be considered for any patient who has a persistent cough (i.e., a cough lasting for ≥3 weeks) or other signs or symptoms compatible with active TB (e.g., bloody sputum, night sweats, weight loss, anorexia, or fever). However, the index of suspicion for TB will vary in different geographic areas and will depend on the prevalence of TB and other characteristics of the population served by the facility. The index of suspicion for TB should be very high in geographic areas or among groups of patients in which the prevalence of TB is high (Section I.B). Appropriate diagnostic measures should be conducted and TB precautions implemented for patients in whom active TB is suspected.

2. Diagnostic evaluation for active TB

- Diagnostic measures for identifying TB should be conducted for patients in whom active TB is being considered. These measures include obtaining a medical history and performing a physical examination, PPD skin test, chest radiograph, and microscopic examination and culture of sputum or other appropriate specimens (*6,34,35*). Other diagnostic procedures (e.g., bronchoscopy or biopsy) may be indicated for some patients (*36,37*).
- Prompt laboratory results are crucial to the proper treatment of the TB patient and to early initiation of infection control. To ensure timely results, laboratories performing mycobacteriologic tests should be proficient at both the laboratory and administrative aspects of specimen processing. Laboratories should use the most rapid methods available (e.g., fluorescent microscopy for AFB smears; radiometric culture methods for isolation of mycobacteria; ρ-nitro-α-acetylamino-β-hydroxy-proprophenone [NAP] test, nucleic acid probes, or high-pressure liquid chromatography [HPLC] for species identification; and radiometric methods for drug-susceptibility testing). As other more rapid or sensitive tests become available, practical, and affordable, such tests should be incorporated promptly into the mycobacteriology laboratory. Laboratories that rarely receive specimens for mycobacteriologic analysis should refer the specimens to a laboratory that more frequently performs these tests.
- Results of AFB sputum smears should be available within 24 hours of specimen collection (*38*).
- The probability of TB is greater among patients who have positive PPD test results or a history of positive PPD test results, who have previously had TB or have been exposed to *M. tuberculosis*, or who belong to a group at high risk for TB (Section I.B). Active TB is strongly suggested if the diagnostic evaluation reveals AFB in sputum, a chest radiograph suggestive of TB, or symptoms highly suggestive of TB. TB can occur

simultaneously in immunosuppressed persons who have pulmonary infections caused by other organisms (e.g., *Pneumocystis carinii* or *Mycobacterium avium* complex) and should be considered in the diagnostic evaluation of all patients who have symptoms compatible with TB (Suppl. 1; Suppl. 2).

- TB may be more difficult to diagnose among persons who have HIV infection (or other conditions associated with severe suppression of cell-mediated immunity) because of a nonclassical clinical or radiographic presentation and/or the simultaneous occurrence of other pulmonary infections (e.g., *P. carinii* pneumonia and *M. avium* complex). The difficulty in diagnosing TB in HIV-infected persons may be further compounded by impaired responses to PPD skin tests (*39,40*), the possibly lower sensitivity of sputum smears for detecting AFB (*41*), or the overgrowth of cultures with *M. avium* complex in specimens from patients infected with both *M. avium* complex and *M. tuberculosis* (*42*).
- Immunosuppressed patients who have pulmonary signs or symptoms that are ascribed initially to infections or conditions other than TB should be evaluated initially for coexisting TB. The evaluation for TB should be repeated if the patient does not respond to appropriate therapy for the presumed cause(s) of the pulmonary abnormalities (Suppl. 1; Suppl. 2).
- Patients with suspected or confirmed TB should be reported immediately to the appropriate public health department so that standard procedures for identifying and evaluating TB contacts can be initiated.

3. Initiation of treatment for suspected or confirmed TB

- Patients who have confirmed active TB or who are considered highly likely to have active TB should be started promptly on appropriate treatment in accordance with current guidelines (Suppl. 2) (*43*). In geographic areas or facilities that have a high prevalence of MDR-TB, the initial regimen used may need to be enhanced while the results of drug-susceptibility tests are pending. The decision should be based on analysis of surveillance data.
- While the patient is in the health-care facility, anti-TB drugs should be administered by directly observed therapy (DOT), the process by which an HCW observes the patient swallowing the medications. Continuing DOT after the patient is discharged should be strongly considered. This decision and the arrangements for providing outpatient DOT should be made in collaboration with the public health department.

D. Management of Patients Who May Have Active TB in Ambulatory-Care Settings and Emergency Departments

- Triage of patients in ambulatory-care settings and emergency departments should include vigorous efforts to promptly identify patients who have active TB. HCWs who are the first points of contact in facilities that serve populations at risk for TB should be trained to ask questions that will facilitate identification of patients with signs and symptoms suggestive of TB.

- Patients with signs or symptoms suggestive of TB should be evaluated promptly to minimize the amount of time they are in ambulatory-care areas. TB precautions should be followed while the diagnostic evaluation is being conducted for these patients.
- TB precautions in the ambulatory-care setting should include a) placing these patients in a separate area apart from other patients, and not in open waiting areas (ideally, in a room or enclosure meeting TB isolation requirements); b) giving these patients surgical masks* to wear and instructing them to keep their masks on; and c) giving these patients tissues and instructing them to cover their mouths and noses with the tissues when coughing or sneezing.
- TB precautions should be followed for patients who are known to have active TB and who have not completed therapy until a determination has been made that they are noninfectious (Suppl. 1).
- Patients with active TB who need to attend a health-care clinic should have appointments scheduled to avoid exposing HIV-infected or otherwise severely immunocompromised persons to *M. tuberculosis*. This recommendation could be accomplished by designating certain times of the day for appointments for these patients or by treating them in areas where immunocompromised persons are not treated.
- Ventilation in ambulatory-care areas where patients at high risk for TB are treated should be designed and maintained to reduce the risk for transmission of *M. tuberculosis*. General-use areas (e.g., waiting rooms) and special areas (e.g., treatment or TB isolation rooms in ambulatory areas) should be ventilated in the same manner as described for similar inpatient areas (Sections II.E.3, II.F; Suppl. 3). Enhanced general ventilation or the use of air-disinfection techniques (e.g., UVGI or recirculation of air within the room through high-efficiency particulate air [HEPA] filters) may be useful in general-use areas of facilities where many infectious TB patients receive care (Section II.F; Suppl. 3).
- Ideally, ambulatory-care settings in which patients with TB are frequently examined or treated should have a TB isolation room(s) available. Such rooms are not necessary in ambulatory-care settings in which patients who have confirmed or suspected TB are seen infrequently. However, these facilities should have a written protocol for early identification of patients with TB symptoms and referral to an area or a collaborating facility where the patient can be evaluated and managed appropriately. These protocols should be reviewed on a regular basis and revised as necessary. The additional guidelines in Section II.H should be followed in ambulatory-care settings where cough-inducing procedures are performed on patients who may have active TB.

*Surgical masks are designed to prevent the respiratory secretions of the person wearing the mask from entering the air. When not in a TB isolation room, patients suspected of having TB should wear surgical masks to reduce the expulsion of droplet nuclei into the air. These patients do not need to wear particulate respirators, which are designed to filter the air before it is inhaled by the person wearing the mask. Patients suspected of having or known to have TB should never wear a respirator that has an exhalation valve, because the device would provide no barrier to the expulsion of droplet nuclei into the air.

E. Management of Hospitalized Patients Who Have Confirmed or Suspected TB

1. Initiation of isolation for TB

- In hospitals and other inpatient facilities, any patient suspected of having or known to have infectious TB should be placed in a TB isolation room that has currently recommended ventilation characteristics (Section II.E.3; Suppl. 3). Written policies for initiating isolation should specify a) the indications for isolation, b) the person(s) authorized to initiate and discontinue isolation, c) the isolation practices to follow, d) the monitoring of isolation, e) the management of patients who do not adhere to isolation practices, and f) the criteria for discontinuing isolation.
- In rare circumstances, placing more than one TB patient together in the same room may be acceptable. This practice is sometimes referred to as "cohorting." Because of the risk for patients becoming superinfected with drug-resistant organisms, patients with TB should be placed in the same room only if all patients involved a) have culture-confirmed TB, b) have drug-susceptibility test results available on a current specimen obtained during the present hospitalization, c) have identical drug-susceptibility patterns on these specimens, and d) are on effective therapy. Having isolates with identical DNA fingerprint patterns is not adequate evidence for placing two TB patients together in the same room, because isolates with the same DNA fingerprint pattern can have different drug-susceptibility patterns.
- Pediatric patients with suspected or confirmed TB should be evaluated for potential infectiousness according to the same criteria as are adults (i.e., on the basis of symptoms, sputum AFB smears, radiologic findings, and other criteria) (Suppl. 1). Children who may be infectious should be placed in isolation until they are determined to be noninfectious. Pediatric patients who may be infectious include those who have laryngeal or extensive pulmonary involvement, pronounced cough, positive sputum AFB smears, or cavitary TB or those for whom cough-inducing procedures are performed (*44*).
- The source of infection for a child with TB is often a member of the child's family (*45*). Therefore, parents and other visitors of all pediatric TB patients should be evaluated for TB as soon as possible. Until they have been evaluated, or the source case is identified, they should wear surgical masks when in areas of the facility outside of the child's room, and they should refrain from visiting common areas in the facility (e.g., the cafeteria or lounge areas).
- TB patients in intensive-care units should be treated the same as patients in noncritical-care settings. They should be placed in TB isolation and have respiratory secretions submitted for AFB smear and culture if they have undiagnosed pulmonary symptoms suggestive of TB.
- If readmitted to a health-care facility, patients who are known to have active TB and who have not completed therapy should have TB

precautions applied until a determination has been made that they are noninfectious (Suppl. 1).

2. TB isolation practices

- Patients who are placed in TB isolation should be educated about the mechanisms of *M. tuberculosis* transmission and the reasons for their being placed in isolation. They should be taught to cover their mouths and noses with a tissue when coughing or sneezing, even while in the isolation room, to contain liquid drops and droplets before they are expelled into the air (*46*).
- Efforts should be made to facilitate patient adherence to isolation measures (e.g., staying in the TB isolation room). Such efforts might include the use of incentives (e.g., providing them with telephones, televisions, or radios in their rooms or allowing special dietary requests). Efforts should also be made to address other problems that could interfere with adherence to isolation (e.g., management of the patient's withdrawal from addictive substances [including tobacco]).
- Patients placed in isolation should remain in their isolation rooms with the door closed. If possible, diagnostic and treatment procedures should be performed in the isolation rooms to avoid transporting patients through other areas of the facility. If patients who may have infectious TB must be transported outside their isolation rooms for medically essential procedures that cannot be performed in the isolation rooms, they should wear surgical masks that cover their mouths and noses during transport. Persons transporting the patients do not need to wear respiratory protection outside the TB isolation rooms. Procedures for these patients should be scheduled at times when they can be performed rapidly and when waiting areas are less crowded.
- Treatment and procedure rooms in which patients who have infectious TB or who have an undiagnosed pulmonary disease and are at high risk for active TB receive care should meet the ventilation recommendations for isolation rooms (Section II.E.3; Suppl. 3). Ideally, facilities in which TB patients are frequently treated should have an area in the radiology department that is ventilated separately for TB patients. If this is not possible, TB patients should wear surgical masks and should stay in the radiology suite the minimum amount of time possible, then be returned promptly to their isolation rooms.
- The number of persons entering an isolation room should be minimal. All persons who enter an isolation room should wear respiratory protection (Section II.G; Suppl. 4). The patient's visitors should be given respirators to wear while in the isolation room, and they should be given general instructions on how to use their respirators.
- Disposable items contaminated with respiratory secretions are not associated with transmission of *M. tuberculosis*. However, for general infection-control purposes, these items should be handled and transported in a manner that reduces the risk for transmitting other microorganisms to patients, HCWs, and visitors and that decreases environmental contamination in the health-care facility. Such items

should be disposed of in accordance with hospital policy and applicable regulations (Suppl. 5).

3. The TB isolation room

- TB isolation rooms should be single-patient rooms with special ventilation characteristics appropriate for the purposes of isolation (Suppl. 3). The primary purposes of TB isolation rooms are to a) separate patients who are likely to have infectious TB from other persons; b) provide an environment that will allow reduction of the concentration of droplet nuclei through various engineering methods; and c) prevent the escape of droplet nuclei from the TB isolation room and treatment room, thus preventing entry of *M. tuberculosis* into the corridor and other areas of the facility.
- To prevent the escape of droplet nuclei, the TB isolation room should be maintained under negative pressure (Suppl. 3). Doors to isolation rooms should be kept closed, except when patients or personnel must enter or exit the room, so that negative pressure can be maintained.
- Negative pressure in the room should be monitored daily while the room is being used for TB isolation.
- The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) (*47*), the American Institute of Architects (AIA) (*48*), and the Health Resources and Services Administration (*49*) recommend a minimum of 6 air changes per hour (ACH) for TB isolation and treatment rooms. This ventilation rate is based on comfort and odor control considerations. The effectiveness of this level of airflow in reducing the concentration of droplet nuclei in the room, thus reducing the transmission of airborne pathogens, has not been evaluated directly or adequately.

  Ventilation rates of >6 ACH are likely to produce an incrementally greater reduction in the concentration of bacteria in a room than are lower rates (*50–52*). However, accurate quantitation of decreases in risk that would result from specific increases in general ventilation levels has not been performed and may not be possible.

  For the purposes of reducing the concentration of droplet nuclei, TB isolation and treatment rooms in existing health-care facilities should have an airflow of ≥6 ACH. Where feasible, this airflow rate should be increased to ≥12 ACH by adjusting or modifying the ventilation system or by using auxiliary means (e.g., recirculation of air through fixed HEPA filtration systems or portable air cleaners) (Suppl. 3, Section II.B.5.a) (*53*). New construction or renovation of existing health-care facilities should be designed so that TB isolation rooms achieve an airflow of ≥12 ACH.
- Air from TB isolation rooms and treatment rooms used to treat patients who have known or suspected infectious TB should be exhausted to the outside in accordance with applicable federal, state, and local regulations. The air should not be recirculated into the general ventilation. In some instances, recirculation of air into the general ventilation system from such rooms is unavoidable (i.e., in existing facilities in which the

ventilation system or facility configuration makes venting the exhaust to the outside impossible). In such cases, HEPA filters should be installed in the exhaust duct leading from the room to the general ventilation system to remove infectious organisms and particulates the size of droplet nuclei from the air before it is returned to the general ventilation system (Section II.F; Suppl. 3). Air from TB isolation and treatment rooms in new or renovated facilities should not be recirculated into the general ventilation system.

- Although not required, an anteroom may increase the effectiveness of the isolation room by minimizing the potential escape of droplet nuclei into the corridor when the door is opened. To work effectively, the anteroom should have positive air pressure in relation to the isolation room. The pressure relationship between the anteroom and the corridor may vary according to ventilation design.
- Upper-room air UVGI may be used as an adjunct to general ventilation in the isolation room (Section II.F; Suppl. 3). Air in the isolation room may be recirculated within the room through HEPA filters or UVGI devices to increase the effective ACH and to increase thermal efficiency.
- Health-care facilities should have enough isolation rooms to appropriately isolate all patients who have suspected or confirmed active TB. This number should be estimated using the results of the risk assessment of the health-care facility. Except for minimal- and very low-risk health-care facilities, all acute-care inpatient facilities should have at least one TB isolation room (Section II.B).
- Grouping isolation rooms together in one area of the facility may reduce the possibility of transmitting *M. tuberculosis* to other patients and may facilitate care of TB patients and the installation and maintenance of optimal engineering (particularly ventilation) controls.

4. Discontinuation of TB isolation

- TB isolation can be discontinued if the diagnosis of TB is ruled out. For some patients, TB can be ruled out when another diagnosis is confirmed. If a diagnosis of TB cannot be ruled out, the patient should remain in isolation until a determination has been made that the patient is noninfectious. However, patients can be discharged from the health-care facility while still potentially infectious if appropriate postdischarge arrangements can be ensured (Section II.E.5).
- The length of time required for a TB patient to become noninfectious after starting anti-TB therapy varies considerably (Suppl. 1). Isolation should be discontinued only when the patient is on effective therapy, is improving clinically, and has had three consecutive negative sputum AFB smears collected on different days.
- Hospitalized patients who have active TB should be monitored for relapse by having sputum AFB smears examined regularly (e.g., every 2 weeks). Nonadherence to therapy (i.e., failure to take medications as prescribed) and the presence of drug-resistant organisms are the two most common reasons why patients remain infectious despite treat-

ment. These reasons should be considered if a patient does not respond clinically to therapy within 2–3 weeks.

- Continued isolation throughout the hospitalization should be strongly considered for patients who have MDR-TB because of the tendency for treatment failure or relapse (i.e., difficulty in maintaining noninfectiousness) that has been observed in such cases.

5. Discharge planning

- Before a TB patient is discharged from the health-care facility, the facility's staff and public health authorities should collaborate to ensure continuation of therapy. Discharge planning in the health-care facility should include, at a minimum, a) a confirmed outpatient appointment with the provider who will manage the patient until the patient is cured, b) sufficient medication to take until the outpatient appointment, and c) placement into case management (e.g., DOT) or outreach programs of the public health department. These plans should be initiated and in place before the patient's discharge.
- Patients who may be infectious at the time of discharge should only be discharged to facilities that have isolation capability or to their homes. Plans for discharging a patient who will return home must consider whether all the household members were infected previously and whether any uninfected household members are at very high risk for active TB if infected (e.g., children <4 years of age or persons infected with HIV or otherwise severely immunocompromised). If the household does include such persons, arrangements should be made to prevent them from being exposed to the TB patient until a determination has been made that the patient is noninfectious.

F. Engineering Control Recommendations

1. General ventilation

This section deals only with engineering controls for general-use areas of health-care facilities (e.g., waiting-room areas and emergency departments). Recommendations for engineering controls for specific areas of the facility (e.g., TB isolation rooms) are contained in the sections encompassing those areas. Details regarding ventilation design, evaluation, and supplemental approaches are described in Supplement 3.

- Health-care facilities should either a) include as part of their staff an engineer or other professional with expertise in ventilation or b) have this expertise available from a consultant who is an expert in ventilation engineering and who also has hospital experience. These persons should work closely with infection-control staff to assist in controlling airborne infections.
- Ventilation system designs in health-care facilities should meet any applicable federal, state, and local requirements.

- The direction of airflow in health-care facilities should be designed, constructed, and maintained so that air flows from clean areas to less-clean areas.
- Health-care facilities serving populations that have a high prevalence of TB may need to supplement the general ventilation or use additional engineering approaches (i.e., HEPA filtration or UVGI) in general-use areas where TB patients are likely to go (e.g., waiting-room areas, emergency departments, and radiology suites). A single-pass, nonrecirculating system that exhausts air to the outside, a recirculation system that passes air through HEPA filters before recirculating it to the general ventilation system, or upper air UVGI may be used in such areas.

2. Additional engineering control approaches

a. HEPA filtration

HEPA filters may be used in a number of ways to reduce or eliminate infectious droplet nuclei from room air or exhaust (Suppl. 3). These methods include placement of HEPA filters a) in exhaust ducts discharging air from booths or enclosures into the surrounding room; b) in ducts or in ceiling- or wall-mounted units, for recirculation of air within an individual room (fixed recirculation systems); c) in portable air cleaners; d) in exhaust ducts to remove droplet nuclei from air being discharged to the outside, either directly or through ventilation equipment; and e) in ducts discharging air from the TB isolation room into the general ventilation system. In any application, HEPA filters should be installed carefully and maintained meticulously to ensure adequate functioning.

The manufacturers of in-room air cleaning equipment should provide documentation of the HEPA filter efficiency and the efficiency of the device in lowering room air contaminant levels.

b. UVGI

For general-use areas in which the risk for transmission of *M. tuberculosis* is relatively high, UVGI lamps may be used as an adjunct to ventilation for reducing the concentration of infectious droplet nuclei (Suppl. 3), although the effectiveness of such units has not been evaluated adequately. Ultraviolet (UV) units can be installed in a room or corridor to irradiate the air in the upper portion of the room (i.e., upper-room air irradiation), or they can be installed in ducts to irradiate air passing through the ducts. UV units installed in ducts should not be substituted for HEPA filters in ducts that discharge air from TB isolation rooms into the general ventilation system. However, UV units can be used in ducts that recirculate air back into the same room.

To function properly and decrease hazards to HCWs and others in the health-care facility, UV lamps should be installed properly and maintained adequately, which includes the monitoring of irradiance levels.

UV tubes should be changed according to the manufacturer's instructions or when meter readings indicate tube failure. An employee trained in the use and handling of UV lamps should be responsible for these measures and for keeping maintenance records. Applicable safety guidelines should be followed. Caution should be exercised to protect HCWs, patients, visitors, and others from excessive exposure to UV radiation.

G. Respiratory Protection

- Personal respiratory protection should be used by a) persons entering rooms in which patients with known or suspected infectious TB are being isolated, b) persons present during cough-inducing or aerosol-generating procedures performed on such patients, and c) persons in other settings where administrative and engineering controls are not likely to protect them from inhaling infectious airborne droplet nuclei (Suppl. 4). These other settings include transporting patients who may have infectious TB in emergency transport vehicles and providing urgent surgical or dental care to patients who may have infectious TB before a determination has been made that the patient is noninfectious (Suppl. 1).
- Respiratory protective devices used in health-care settings for protection against *M. tuberculosis* should meet the following standard performance criteria:

  1. The ability to filter particles 1 μm in size in the unloaded* state with a filter efficiency of ≥95% (i.e., filter leakage of ≤5%), given flow rates of up to 50 L per minute.

  2. The ability to be qualitatively or quantitatively fit tested in a reliable way to obtain a face-seal leakage of ≤10% (*54,55*).

  3. The ability to fit the different facial sizes and characteristics of HCWs, which can usually be met by making the respirators available in at least three sizes.

  4. The ability to be checked for facepiece fit, in accordance with standards established by the Occupational Safety and Health Administration (OSHA) and good industrial hygiene practice, by HCWs each time they put on their respirators (*54,55*).

- The facility's risk assessment may identify a limited number of selected settings (e.g., bronchoscopy performed on patients suspected of having TB or autopsy performed on deceased persons suspected of having had active TB at the time of death) where the estimated risk for transmission of *M. tuberculosis* may be such that a level of respiratory protection exceeding the standard performance criteria is appropriate. In such circumstances, a level of respiratory protection exceeding the standard criteria and compatible with patient-care delivery (e.g., more protective negative-pressure respirators; powered air-purifying particulate respirators [PAPRs]; or positive-pressure air-line, half-mask respirators) should be

*Some filters become more efficient as they become loaded with dust. Health-care settings do not have enough dust in the air to load a filter on a respirator. Therefore, the filter efficiency for respirators used in health-care settings must be determined in the unloaded state.

provided by employers to HCWs who are exposed to *M. tuberculosis*. Information on these and other respirators is in the *NIOSH Guide to Industrial Respiratory Protection* (*55*) and in Supplement 4 of this document.

- In some settings, HCWs may be at risk for two types of exposure: a) inhalation of *M. tuberculosis* and b) mucous membrane exposure to fluids that may contain bloodborne pathogens. In these settings, protection against both types of exposure should be used.

- When operative procedures (or other procedures requiring a sterile field) are performed on patients who may have infectious TB, respiratory protection worn by the HCW should serve two functions: a) it should protect the surgical field from the respiratory secretions of the HCW, and b) it should protect the HCW from infectious droplet nuclei that may be expelled by the patient or generated by the procedure. Respirators with exhalation valves and most positive-pressure respirators do not protect the sterile field.

- Health-care facilities in which respiratory protection is used to prevent inhalation of *M. tuberculosis* are required by OSHA to develop, implement, and maintain a respiratory protection program (Suppl. 4). All HCWs who use respiratory protection should be included in this program. Visitors to TB patients should be given respirators to wear while in isolation rooms, and they should be given general instructions on how to use their respirators.

- Facilities that do not have isolation rooms and do not perform cough-inducing procedures on patients who may have TB may not need to have a respiratory protection program for TB. However, such facilities should have written protocols for the early identification of patients who have signs or symptoms of TB and procedures for referring these patients to a facility where they can be evaluated and managed appropriately. These protocols should be evaluated regularly and revised as needed.

- Surgical masks are designed to prevent the respiratory secretions of the person wearing the mask from entering the air. To reduce the expulsion of droplet nuclei into the air, patients suspected of having TB should wear surgical masks when not in TB isolation rooms. These patients do not need to wear particulate respirators, which are designed to filter the air before it is inhaled by the person wearing the respirator. Patients suspected of having or known to have TB should never wear a respirator that has an exhalation valve, because this type of respirator does not prevent expulsion of droplet nuclei into the air.

H. Cough-Inducing and Aerosol-Generating Procedures

1. General guidelines

Procedures that involve instrumentation of the lower respiratory tract or induce coughing can increase the likelihood of droplet nuclei being expelled into the air. These cough-inducing procedures include endotracheal

intubation and suctioning, diagnostic sputum induction, aerosol treatments (e.g., pentamidine therapy), and bronchoscopy. Other procedures that can generate aerosols (e.g., irrigation of tuberculous abscesses, homogenizing or lyophilizing tissue, or other processing of tissue that may contain tubercle bacilli) are also covered by these recommendations.

- Cough-inducing procedures should not be performed on patients who may have infectious TB unless the procedures are absolutely necessary and can be performed with appropriate precautions.
- All cough-inducing procedures performed on patients who may have infectious TB should be performed using local exhaust ventilation devices (e.g., booths or special enclosures) or, if this is not feasible, in a room that meets the ventilation requirements for TB isolation.
- HCWs should wear respiratory protection when present in rooms or enclosures in which cough-inducing procedures are being performed on patients who may have infectious TB.
- After completion of cough-inducing procedures, patients who may have infectious TB should remain in their isolation rooms or enclosures and not return to common waiting areas until coughing subsides. They should be given tissues and instructed to cover their mouths and noses with the tissues when coughing. If TB patients must recover from sedatives or anesthesia after a procedure (e.g, after a bronchoscopy), they should be placed in separate isolation rooms (and not in recovery rooms with other patients) while they are being monitored.
- Before the booth, enclosure, or room is used for another patient, enough time should be allowed to pass for at least 99% of airborne contaminants to be removed. This time will vary according to the efficiency of the ventilation or filtration used (Suppl. 3, Table S3-1).

2. Special considerations for bronchoscopy

- If performing bronchoscopy in positive-pressure rooms (e.g., operating rooms) is unavoidable, TB should be ruled out as a diagnosis before the procedure is performed. If the bronchoscopy is being performed for the purpose of diagnosing pulmonary disease and that diagnosis could include TB, the procedure should be performed in a room that meets TB isolation ventilation requirements.

3. Special considerations for the administration of aerosolized pentamidine

- Patients should be screened for active TB before prophylactic therapy with aerosolized pentamidine is initiated. Screening should include obtaining a medical history and performing skin testing and chest radiography.
- Before each subsequent treatment with aerosolized pentamidine, patients should be screened for symptoms suggestive of TB (e.g., development of a productive cough). If such symptoms are elicited, a diagnostic evaluation for TB should be initiated.

- Patients who have suspected or confirmed active TB should take, if clinically practical, oral prophylaxis for *P. carinii* pneumonia.

I. Education and Training of HCWs

All HCWs, including physicians, should receive education regarding TB that is relevant to persons in their particular occupational group. Ideally, training should be conducted before initial assignment, and the need for additional training should be reevaluated periodically (e.g., once a year). The level and detail of this education will vary according to the HCW's work responsibilities and the level of risk in the facility (or area of the facility) in which the HCW works. However, the program may include the following elements:

- The basic concepts of *M. tuberculosis* transmission, pathogenesis, and diagnosis, including information concerning the difference between latent TB infection and active TB disease, the signs and symptoms of TB, and the possibility of reinfection.
- The potential for occupational exposure to persons who have infectious TB in the health-care facility, including information concerning the prevalence of TB in the community and facility, the ability of the facility to properly isolate patients who have active TB, and situations with increased risk for exposure to *M. tuberculosis*.
- The principles and practices of infection control that reduce the risk for transmission of *M. tuberculosis*, including information concerning the hierarchy of TB infection-control measures and the written policies and procedures of the facility. Site-specific control measures should be provided to HCWs working in areas that require control measures in addition to those of the basic TB infection-control program.
- The purpose of PPD skin testing, the significance of a positive PPD test result, and the importance of participating in the skin-test program.
- The principles of preventive therapy for latent TB infection. These principles include the indications, use, effectiveness, and the potential adverse effects of the drugs (Suppl. 2).
- The HCW's responsibility to seek prompt medical evaluation if a PPD test conversion occurs or if symptoms develop that could be caused by TB. Medical evaluation will enable HCWs who have TB to receive appropriate therapy and will help to prevent transmission of *M. tuberculosis* to patients and other HCWs.
- The principles of drug therapy for active TB.
- The importance of notifying the facility if the HCW is diagnosed with active TB so that contact investigation procedures can be initiated.
- The responsibilities of the facility to maintain the confidentiality of the HCW while ensuring that the HCW who has TB receives appropriate therapy and is noninfectious before returning to duty.
- The higher risks associated with TB infection in persons who have HIV infection or other causes of severely impaired cell-mediated immunity, including a) the more frequent and rapid development of clinical TB after

infection with *M. tuberculosis*, b) the differences in the clinical presentation of disease, and c) the high mortality rate associated with MDR-TB in such persons.

- The potential development of cutaneous anergy as immune function (as measured by CD4+ T-lymphocyte counts) declines.
- Information regarding the efficacy and safety of BCG vaccination and the principles of PPD screening among BCG recipients.
- The facility's policy on voluntary work reassignment options for immunocompromised HCWs.

J. HCW Counseling, Screening, and Evaluation

A TB counseling, screening, and prevention program for HCWs should be established to protect both HCWs and patients. HCWs who have positive PPD test results, PPD test conversions, or symptoms suggestive of TB should be identified, evaluated to rule out a diagnosis of active TB, and started on therapy or preventive therapy if indicated (*5*). In addition, the results of the HCW PPD screening program will contribute to evaluation of the effectiveness of current infection-control practices.

1. Counseling HCWs regarding TB

- Because of the increased risk for rapid progression from latent TB infection to active TB in HIV-infected or otherwise severely immunocompromised persons, all HCWs should know if they have a medical condition or are receiving a medical treatment that may lead to severely impaired cell-mediated immunity. HCWs who may be at risk for HIV infection should know their HIV status (i.e., they should be encouraged to voluntarily seek counseling and testing for HIV antibody status). Existing guidelines for counseling and testing should be followed routinely (*56*). Knowledge of these conditions allows the HCW to seek the appropriate preventive measures outlined in this document and to consider voluntary work reassignments. Of particular importance is that HCWs need to know their HIV status if they are at risk for HIV infection and they work in settings where patients who have drug-resistant TB may be encountered.
- All HCWs should be informed about the need to follow existing recommendations for infection control to minimize the risk for exposure to infectious agents; implementation of these recommendations will greatly reduce the risk for occupational infections among HCWs (*57*). All HCWs should also be informed about the potential risks to severely immunocompromised persons associated with caring for patients who have some infectious diseases, including TB. It should be emphasized that limiting exposure to TB patients is the most protective measure that severely immunosuppressed HCWs can take to avoid becoming infected with *M. tuberculosis*. HCWs who have severely impaired cell-mediated immunity and who may be exposed to *M. tuberculosis* may consider a change in job setting to avoid such exposure. HCWs should be advised of the option that severely immunocompromised

HCWs can choose to transfer voluntarily to areas and work activities in which there is the lowest possible risk for exposure to *M. tuberculosis*. This choice should be a personal decision for HCWs after they have been informed of the risks to their health.

- Employers should make reasonable accommodations (e.g., alternative job assignments) for employees who have a health condition that compromises cell-mediated immunity and who work in settings where they may be exposed to *M. tuberculosis.* HCWs who are known to be immunocompromised should be referred to employee health professionals who can individually counsel the employees regarding their risk for TB. Upon the request of the immunocompromised HCW, employers should offer, but not compel, a work setting in which the HCW would have the lowest possible risk for occupational exposure to *M. tuberculosis*. Evaluation of these situations should also include consideration of the provisions of the Americans With Disabilities Act of 1990* and other applicable federal, state, and local laws.
- All HCWs should be informed that immunosuppressed HCWs should have appropriate follow-up and screening for infectious diseases, including TB, provided by their medical practitioner. HCWs who are known to be HIV-infected or otherwise severely immunosuppressed should be tested for cutaneous anergy at the time of PPD testing (Suppl. 2). Consideration should be given to retesting, at least every 6 months, those immunocompromised HCWs who are potentially exposed to *M. tuberculosis* because of the high risk for rapid progression to active TB if they become infected.
- Information provided by HCWs regarding their immune status should be treated confidentially. If the HCW requests voluntary job reassignment, the confidentiality of the HCW should be maintained. Facilities should have written procedures on confidential handling of such information.

2. Screening HCWs for active TB

- Any HCW who has a persistent cough (i.e., a cough lasting ≥3 weeks), especially in the presence of other signs or symptoms compatible with active TB (e.g., weight loss, night sweats, bloody sputum, anorexia, or fever), should be evaluated promptly for TB. The HCW should not return to the workplace until a diagnosis of TB has been excluded or until the HCW is on therapy and a determination has been made that the HCW is noninfectious.

3. Screening HCWs for latent TB infection

- The risk assessment should identify which HCWs have potential for exposure to *M. tuberculosis* and the frequency with which the exposure may occur. This information is used to determine which HCWs to include in the skin-testing program and the frequency with which they should be tested (Table 2).

*Americans With Disabilities Act of 1990. PL 101-336, 42 U.S.C. 12101 et seq.

- If HCWs are from risks groups with increased prevalence of TB, consideration may be given to including them in the skin-testing program, even if they do not have potential occupational exposure to *M. tuberculosis*, so that converters can be identified and preventive therapy offered.
- Administrators of health-care facilities should ensure that physicians and other personnel not paid by, but working in, the facility receive skin testing at appropriate intervals for their occupational group and work location.
- During the pre-employment physical or when applying for hospital privileges, HCWs who have potential for exposure to *M. tuberculosis* (Table 2), including those with a history of BCG vaccination, should have baseline PPD skin testing performed (Suppl. 2). For HCWs who have not had a documented negative PPD test result during the preceding 12 months, the baseline PPD testing should employ the two-step method; this will detect boosting phenomena that might be misinterpreted as a skin-test conversion. Decisions concerning the use of the two-step procedure for baseline testing in a particular facility should be based on the frequency of boosting in that facility.
- HCWs who have a documented history of a positive PPD test, adequate treatment for disease, or adequate preventive therapy for infection, should be exempt from further PPD screening unless they develop signs or symptoms suggestive of TB.
- PPD-negative HCWs should undergo repeat PPD testing at regular intervals as determined by the risk assessment (Section II.B). In addition, these HCWs should be tested whenever they have been exposed to a TB patient and appropriate precautions were not observed at the time of exposure (Section II.K.3). Performing PPD testing of HCWs who work in the same area or occupational group on different scheduled dates (e.g., test them on their birthdays or on their employment anniversary dates), rather than testing all HCWs in the area or group on the same day, may lead to earlier detection of *M. tuberculosis* transmission.
- All PPD tests should be administered, read, and interpreted in accordance with current guidelines by specified trained personnel (Suppl. 2). At the time their test results are read, HCWs should be informed about the interpretation of both positive and negative PPD test results. This information should indicate that the interpretation of an induration that is 5–9 mm in diameter depends on the HCW's immune status and history of exposure to persons who have infectious TB. Specifically, HCWs who have indurations of 5–9 mm in diameter should be advised that such results may be considered positive for HCWs who are contacts of persons with infectious TB or who have HIV infection or other causes of severe immunosuppression (e.g., immunosuppressive therapy for organ transplantation).
- When an HCW who is not assigned regularly to a single work area has a PPD test conversion, appropriate personnel should identify the areas where the HCW worked during the time when infection was likely to have occurred. This information can then be considered in analyzing the risk for transmission in those areas.

- In any area of the facility where transmission of *M. tuberculosis* is known to have occurred, a problem evaluation should be conducted (Section II.K), and the frequency of skin testing should be determined according to the applicable risk category (Section II.B).
- PPD test results should be recorded confidentially in the individual HCW's employee health record and in an aggregate database of all HCW PPD test results. The database can be analyzed periodically to estimate the risk for acquiring new infection in specific areas or occupational groups in the facility.

4. Evaluation and management of HCWs who have positive PPD test results or active TB

a. Evaluation

- All HCWs with newly recognized positive PPD test results or PPD test conversions should be evaluated promptly for active TB. This evaluation should include a clinical examination and a chest radiograph. If the history, clinical examination, or chest radiograph is compatible with active TB, additional tests should be performed (Section II.C.2). If symptoms compatible with TB are present, the HCW should be excluded from the workplace until either a) a diagnosis of active TB is ruled out or b) a diagnosis of active TB was established, the HCW is being treated, and a determination has been made that the HCW is noninfectious (Suppl. 2). HCWs who do not have active TB should be evaluated for preventive therapy according to published guidelines (Suppl. 2).
- If an HCW's PPD test result converts to positive, a history of confirmed or suspected TB exposure should be obtained in an attempt to determine the potential source. When the source of exposure is known, the drug-susceptibility pattern of the *M. tuberculosis* isolated from the source should be identified so that the correct curative or preventive therapy can be initiated for the HCW with the PPD test conversion. The drug-susceptibility pattern should be recorded in the HCW's medical record, where it will be available if the HCW subsequently develops active TB and needs therapy specific for the drug-susceptibility pattern.
- All HCWs, including those with histories of positive PPD test results, should be reminded periodically about the symptoms of TB and the need for prompt evaluation of any pulmonary symptoms suggestive of TB.

b. Routine and follow-up chest radiographs

- Routine chest radiographs are not required for asymptomatic, PPD-negative HCWs. HCWs with positive PPD test results should have a chest radiograph as part of the initial evaluation of their PPD test; if negative, repeat chest radiographs are not needed unless symptoms develop that could be attributed to TB (*58*). However, more frequent monitoring for symptoms of TB may be considered for recent converters and other PPD-positive HCWs who are at increased risk for

developing active TB (e.g., HIV-infected or otherwise severely immunocompromised HCWs).

c. Workplace restrictions

1) Active TB

- HCWs with pulmonary or laryngeal TB pose a risk to patients and other HCWs while they are infectious, and they should be excluded from the workplace until they are noninfectious. The same work restrictions apply to all HCWs regardless of their immune status.
- Before the HCW who has TB can return to the workplace, the health-care facility should have documentation from the HCW's health-care provider that the HCW is receiving adequate therapy, the cough has resolved, and the HCW has had three consecutive negative sputum smears collected on different days. After work duties are resumed and while the HCW remains on anti-TB therapy, facility staff should receive periodic documentation from the HCW's health-care provider that the HCW is being maintained on effective drug therapy for the recommended time period and that the sputum AFB smears continue to be negative.
- HCWs with active laryngeal or pulmonary TB who discontinue treatment before they are cured should be evaluated promptly for infectiousness. If the evaluation determines that they are still infectious, they should be excluded from the workplace until treatment has been resumed, an adequate response to therapy has been documented, and three more consecutive sputum AFB smears collected on different days have been negative.
- HCWs who have TB at sites other than the lung or larynx usually do not need to be excluded from the workplace if a diagnosis of concurrent pulmonary TB has been ruled out.

2) Latent TB infection

- HCWs receiving preventive treatment for latent TB infection should not be restricted from their usual work activities.
- HCWs with latent TB infection who cannot take or who do not accept or complete a full course of preventive therapy should not be excluded from the workplace. These HCWs should be counseled about the risk for developing active TB and instructed regularly to seek prompt evaluation if signs or symptoms develop that could be caused by TB.

K. Problem Evaluation

Epidemiologic investigations may be indicated for several situations. These include, but are not limited to, a) the occurrence of PPD test conversions or active TB in HCWs; b) the occurrence of possible person-to-person transmission of *M. tuberculosis*; and c) situations in which patients or HCWs with active TB are not promptly identified and isolated, thus exposing other

persons in the facility to *M. tuberculosis*. The general objectives of the epidemiologic investigations in these situations are as follows:

1) to determine the likelihood that transmission of and infection with *M. tuberculosis* has occurred in the facility;

2) to determine the extent to which *M. tuberculosis* has been transmitted;

3) to identify those persons who have been exposed and infected, enabling them to receive appropriate clinical management;

4) to identify factors that could have contributed to transmission and infection and to implement appropriate interventions; and

5) to evaluate the effectiveness of any interventions that are implemented and to ensure that exposure to and transmission of *M. tuberculosis* have been terminated.

The exact circumstances of these situations are likely to vary considerably, and the associated epidemiologic investigations should be tailored to the individual circumstances. The following sections provide general guidance for conducting these investigations.

1. Investigating PPD test conversions and active TB in HCWs

a. Investigating PPD test conversions in HCWs

PPD test conversions may be detected in HCWs as a result of a contact investigation, in which case the probable source of exposure and transmission is already known (Section II.K.3.), or as a result of routine screening, in which case the probable source of exposure and infection is not already known and may not be immediately apparent.

If a skin-test conversion in an HCW is identified as part of routine screening, the following steps should be considered (Figure 2):

- The HCW should be evaluated promptly for active TB. The initial evaluation should include a thorough history, physical examination, and chest radiograph. On the basis of the initial evaluation, other diagnostic procedures (e.g., sputum examination) may be indicated.
- If appropriate, the HCW should be placed on preventive or curative therapy in accordance with current guidelines (Suppl. 2) (*5*).
- A history of possible exposure to *M. tuberculosis* should be obtained from the HCW to determine the most likely source of infection. When the source of infection is known, the drug-susceptibility pattern of the *M. tuberculosis* isolate from the source patient should be identified to determine appropriate preventive or curative therapy regimens.

- If the history suggests that the HCW was exposed to and infected with *M. tuberculosis* outside the facility, no further epidemiologic investigation to identify a source in the facility is necessary.
- If the history does not suggest that the HCW was exposed and infected outside the facility but does identify a probable source of exposure in the facility, contacts of the suspected source patient should be identified and evaluated. Possible reasons for the exposure and transmission should be evaluated (Table 4), interventions should be implemented to correct these causes, and PPD testing of PPD-negative HCWs should be performed immediately and repeated after 3 months.

  If no additional PPD test conversions are detected on follow-up testing, the investigation can be terminated.

  If additional PPD test conversions are detected on follow-up testing, the possible reasons for exposure and transmission should be reassessed, the appropriateness of and degree of adherence to the interventions implemented should be evaluated, and PPD testing of PPD-negative HCWs should be repeated after another 3 months.

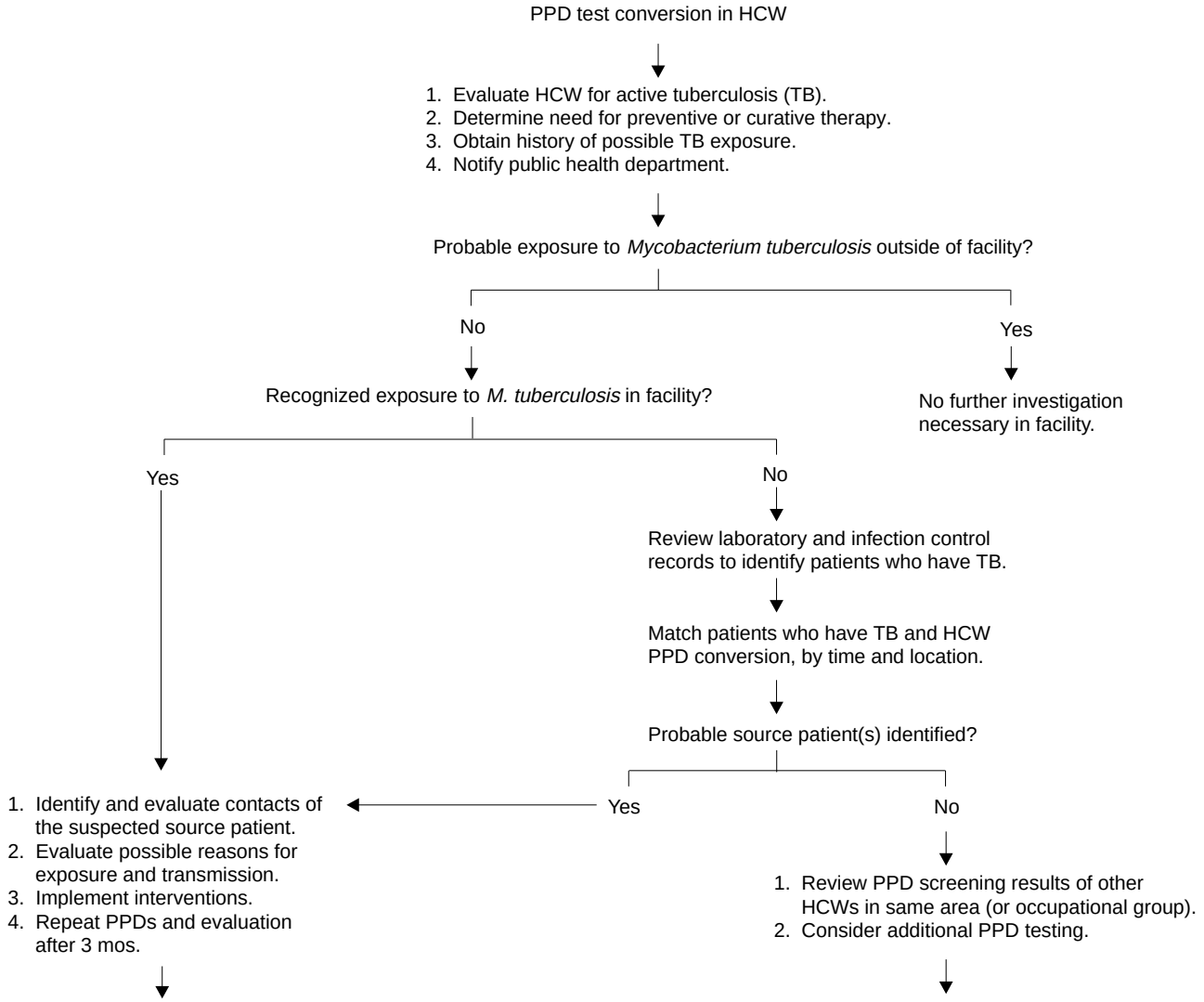
  If no additional PPD test conversions are detected on the second round of follow-up testing, the investigation can be terminated. However, if additional PPD conversions are detected on the second round of follow-up testing, a high-risk protocol should be implemented in the affected area or occupational group, and the public health department or other persons with expertise in TB infection control should be consulted.
- If the history does not suggest that the HCW was exposed to and infected with *M. tuberculosis* outside the facility and does not identify a probable source of exposure in the facility, further investigation to identify the probable source patient in the facility is warranted.

  The interval during which the HCW could have been infected should be estimated. Generally, this would be the interval from 10 weeks before the most recent negative PPD test through 2 weeks before the first positive PPD test (i.e., the conversion).

  Laboratory and infection-control records should be reviewed to identify all patients or HCWs who have suspected or confirmed infectious TB and who could have transmitted *M. tuberculosis* to the HCW.

  If this process does identify a likely source patient, contacts of the suspected source patient should be identified and evaluated, and possible reasons for the exposure and transmission should be evaluated (Table 4). Interventions should be implemented to correct these causes, and PPD testing of PPD-negative HCWs should be repeated after 3 months. However, if this process does not identify a probable source case, PPD screening results of other HCWs in the same area or occupational group should be reviewed for additional evidence of *M. tuberculosis* transmission. If sufficient additional PPD screening results are not available, appropriate personnel should consider conducting additional PPD screening of other HCWs in the same area or occupational group.

FIGURE 2. Protocol for investigating purified protein derivative (PPD)-tuberculin skin-test conversions in health-care workers (HCWs)



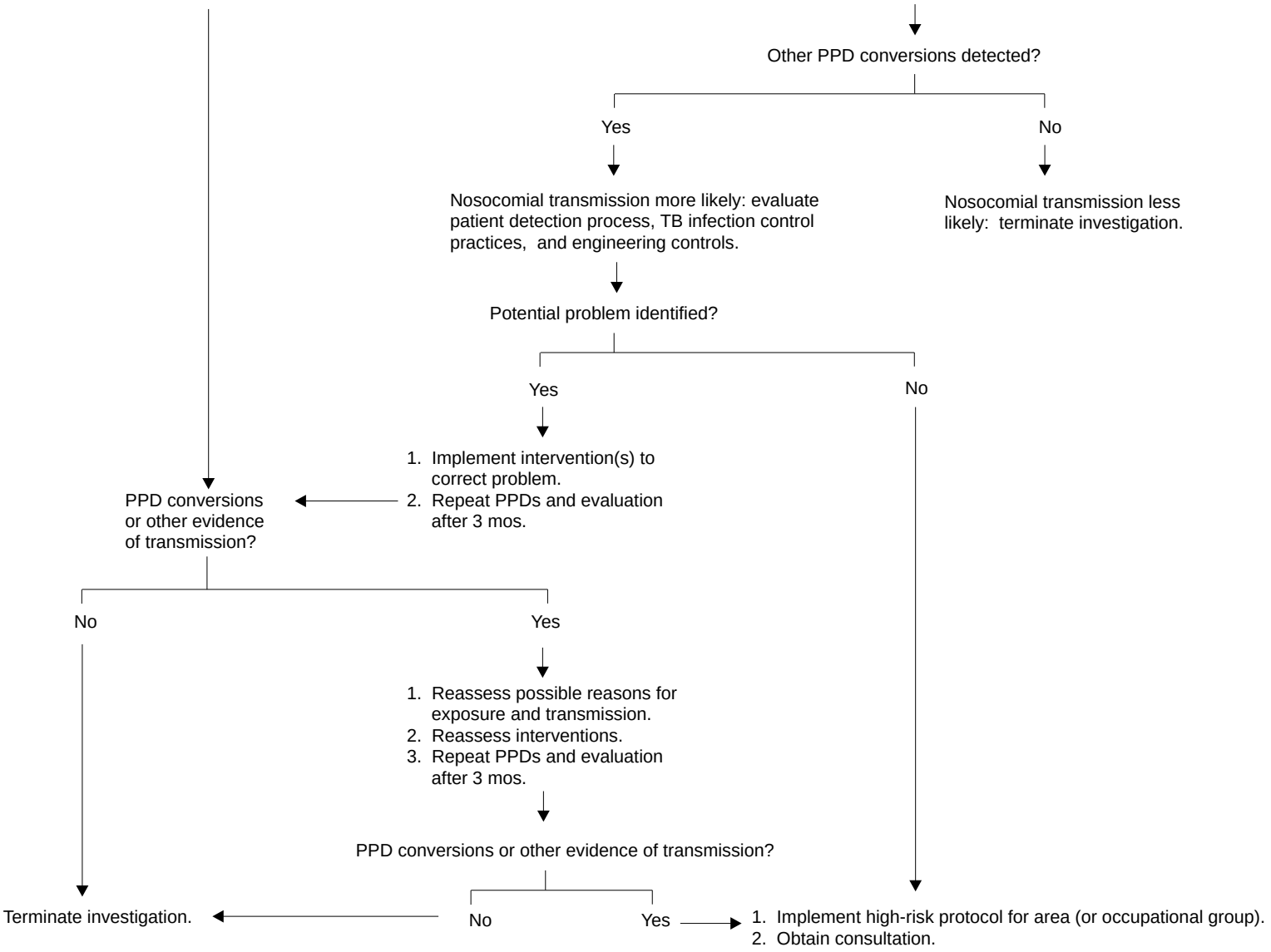

Other PPD conversions detected?
Yes
No
Nosocomial transmission more likely: evaluate patient detection process, TB infection control practices, and engineering controls.
Nosocomial transmission less likely: terminate investigation.
Potential problem identified?
Yes
No
1. Implement intervention(s) to correct problem.
2. Repeat PPDs and evaluation after 3 mos.
PPD conversions or other evidence of transmission?
No
Yes
1. Reassess possible reasons for exposure and transmission.
2. Reassess interventions.
3. Repeat PPDs and evaluation after 3 mos.
PPD conversions or other evidence of transmission?
Terminate investigation.
No
Yes
1. Implement high-risk protocol for area (or occupational group).
2. Obtain consultation.

TABLE 4. Examples of potential problems that can occur when identifying or isolating patients who may have infectious tuberculosis (TB)

Situation	Potential problem	Intervention
Patient identification during triage	Patient with signs or symptoms not identified.	Review triage procedures, facilities, and practices.
	Patient had no symptoms listed in triage protocol.	Reevaluate triage protocol.
During review of laboratory results	Positive smear: results available >24 hours* after submitted.	Change laboratory practices. Assess potential barriers. Explore alternatives.
	Positive smear: results available but action not taken promptly.	Educate appropriate personnel. Review protocol for management of positive smear results.
	Positive culture: results not available for >3 weeks.*	Change laboratory practices. Assess potential barriers. Explore alternatives.
	Positive culture: results available but action not taken promptly.	Educate appropriate personnel. Review protocol for management of positive culture results.
	Positive culture: susceptibility results not available for >6 weeks.*	Change laboratory practices. Assess potential barriers. Explore alternatives.
	Positive culture: susceptibility results available but action not taken promptly.	Educate appropriate personnel. Review protocol for management of positive culture susceptibility results.
At time of diagnosis and during isolation	Patient with signs/symptoms of TB: appropriate tests not ordered promptly.	Educate appropriate personnel. Evaluate protocols for TB detection.
	Isolation room unavailable.	Reassess need for number of isolation rooms.
	Isolation not ordered or discontinued too soon, or isolation policy not followed properly (e.g., patients going outside of room).	Educate patients and appropriate personnel. Evaluate institutional barriers to implementation of isolation policy.
	Personnel not properly using respiratory protection.	Educate appropriate personnel. Evaluate regularly scheduled re-education. Evaluate institutional barriers to use of respiratory protection.
	Isolation room or procedure room not at negative pressure relative to surrounding areas.	Make appropriate engineering modifications. Establish protocols for regularly monitoring and maintaining negative pressure.
	Inadequate air circulation.	Make appropriate engineering modifications.
	Door left open.	Educate appropriate personnel and patients. Evaluate self-closing doors, comfort levels in the room, and other measures to promote door closing.

*These time intervals are used as examples and should not be considered absolute standards.

If this review and/or screening does not identify additional PPD conversions, nosocomial transmission is less likely, and the contact investigation can probably be terminated. Whether the HCW's PPD test conversion resulted from occupational exposure and infection is uncertain; however, the absence of other data implicating nosocomial transmission suggests that the conversion could have resulted from a) unrecognized exposure to *M. tuberculosis* outside the facility; b) cross-reactivity with another antigen (e.g., nontuberculous mycobacteria); c) errors in applying, reading, or interpreting the test; d) false positivity caused by the normal variability of the test; or e) false positivity caused by a defective PPD preparation.

If this review and/or screening does identify additional PPD test conversions, nosocomial transmission is more likely. In this situation, the patient identification (i.e., triage) process, TB infection-control policies and practices, and engineering controls should be evaluated to identify problems that could have led to exposure and transmission (Table 4).

If no such problems are identified, a high-risk protocol should be implemented in the affected area or occupational group, and the public health department or other persons with expertise in TB infection control should be consulted.

If such problems are identified, appropriate interventions should be implemented to correct the problem(s), and PPD skin testing of PPD-negative HCWs should be repeated after 3 months.

If no additional PPD conversions are detected on follow-up testing, the investigation can be terminated.

If additional PPD conversions are detected on follow-up testing, the possible reasons for exposure and transmission should be reassessed, the appropriateness of and adherence to the interventions implemented should be evaluated, and PPD skin testing of PPD-negative HCWs should be repeated after another 3 months.

If no additional PPD test conversions are detected on this second round of follow-up testing, the investigation can be terminated. However, if additional PPD test conversions are detected on the second round of follow-up testing, a high-risk protocol should be implemented in the affected area or occupational group, and the public health department or other persons with expertise in TB infection control should be consulted.

b. Investigating cases of active TB in HCWs

If an HCW develops active TB, the following steps should be taken:

- The case should be evaluated epidemiologically, in a manner similar to PPD test conversions in HCWs, to determine the likelihood that it resulted from occupational transmission and to identify possible causes and implement appropriate interventions if the evaluation suggests such transmission.

- Contacts of the HCW (e.g., other HCWs, patients, visitors, and others who have had intense exposure to the HCW) should be identified and evaluated for TB infection and disease (Section II.K.3; Suppl. 2). The public health department should be notified immediately for consultation and to allow for investigation of community contacts who were not exposed in the health-care facility.
- The public health department should notify facilities when HCWs with TB are reported by physicians so that an investigation of contacts can be conducted in the facility. The information provided by the health department to facilities should be in accordance with state or local laws to protect the confidentiality of the HCW.

2. Investigating possible patient-to-patient transmission of *M. tuberculosis*

Surveillance of active TB cases in patients should be conducted. If this surveillance suggests the possibility of patient-to-patient transmission of *M. tuberculosis* (e.g., a high proportion of TB patients had prior admissions during the year preceding onset of their TB, the number of patients with drug-resistant TB increased suddenly, or isolates obtained from multiple patients had identical and characteristic drug-susceptibility or DNA fingerprint patterns), the following steps should be taken:

- Review the HCW PPD test results and patient surveillance data for the suspected areas to detect additional patients or HCWs with PPD test conversions or active disease.
- Look for possible exposures that patients with newly diagnosed TB could have had to other TB patients during previous admissions. For example, were the patients admitted to the same room or area, or did they receive the same procedure or go to the same treatment area on the same day?

If the evaluation thus far suggests transmission has occurred, the following steps should be taken:

- Evaluate possible causes of the transmission (e.g., problem with patient detection, institutional barriers to implementing appropriate isolation practices, or inadequate engineering controls) (Table 4).
- Ascertain whether other patients or HCWs could have been exposed; if so, evaluate these persons for TB infection and disease (Section II.K.3; Suppl. 2).
- Notify the public health department so they can begin a community contact investigation if necessary.

3. Investigating contacts of patients and HCWs who have infectious TB

If a patient who has active TB is examined in a health-care facility and the illness is not diagnosed correctly, resulting in failure to apply appropriate precautions, or if an HCW develops active TB and exposes other persons in the facility, the following steps should be taken when the illness is later diagnosed correctly:

- To identify other patients and HCWs who were exposed to the source patient before isolation procedures were begun, interview the source patient and all applicable personnel and review that patient's medical record. Determine the areas of the facility in which the source patient was hospitalized, visited, or worked before being placed in isolation (e.g., outpatient clinics, hospital rooms, treatment rooms, radiology and procedure areas, and patient lounges) and the HCWs who may have been exposed during that time (e.g., persons providing direct care, therapists, clerks, transportation personnel, housekeepers, and social workers).
- The contact investigation should first determine if *M. tuberculosis* transmission has occurred from the source patient to those persons with whom the source patient had the most intense contact.
- Administer PPD tests to the most intensely exposed HCWs and patients as soon as possible after the exposure has occurred. If transmission did occur to the most intensely exposed persons, then those persons with whom the patient had less contact should be evaluated. If the initial PPD test result is negative, a second test should be administered 12 weeks after the exposure was terminated.
- Those persons who were exposed to *M. tuberculosis* and who have either a PPD test conversion or symptoms suggestive of TB should receive prompt clinical evaluation and, if indicated, chest radiographs and bacteriologic studies should be performed (Suppl. 2). Those persons who have evidence of newly acquired infection or active disease should be evaluated for preventive or curative therapy (Suppl. 2). Persons who have previously had positive PPD test results and who have been exposed to an infectious TB patient do not require a repeat PPD test or a chest radiograph unless they have symptoms suggestive of TB.
- In addition to PPD testing those HCWs and patients who have been exposed to *M. tuberculosis* because a patient was not isolated promptly or an HCW with active TB was not identified promptly, the investigation should determine why the diagnosis of TB was delayed. If the correct diagnosis was made but the patient was not isolated promptly, the reasons for the delay need to be defined so that corrective actions can be taken.

L. Coordination with the Public Health Department

- As soon as a patient or HCW is known or suspected to have active TB, the patient or HCW should be reported to the public health department so that appropriate follow-up can be arranged and a community contact investigation can be performed. The health department should be notified well before patient discharge to facilitate follow-up and continuation of therapy. A discharge plan coordinated with the patient or HCW, the health department, and the inpatient facility should be implemented.
- The public health department should protect the confidentiality of the patient or HCW in accordance with state and local laws.

- Health-care facilities and health departments should coordinate their efforts to perform appropriate contact investigations on patients and HCWs who have active TB.
- In accordance with state and local laws and regulations, results of all AFB-positive sputum smears, cultures positive for *M. tuberculosis*, and drug-susceptibility results on *M. tuberculosis* isolates should be reported to the public health department as soon as these results are available.
- The public health department may be able to assist facilities with planning and implementing various aspects of a TB infection-control program (e.g., surveillance, screening activities, and outbreak investigations). In addition, the state health department may be able to provide names of experts to assist with the engineering aspects of TB infection control.

M. Additional Considerations for Selected Areas in Health-Care Facilities and Other Health-Care Settings

This section contains additional information for selected areas in health-care facilities and for other health-care settings.

1. Selected areas in health-care facilities

a. Operating rooms

- Elective operative procedures on patients who have TB should be delayed until the patient is no longer infectious.
- If operative procedures must be performed, they should be done, if possible, in operating rooms that have anterooms. For operating rooms without anterooms, the doors to the operating room should be closed, and traffic into and out of the room should be minimal to reduce the frequency of opening and closing the door. Attempts should be made to perform the procedure at a time when other patients are not present in the operative suite and when a minimum number of personnel are present (e.g., at the end of day).
- Placing a bacterial filter on the patient endotracheal tube (or at the expiratory side of the breathing circuit of a ventilator or anesthesia machine if these are used) when operating on a patient who has confirmed or suspected TB may help reduce the risk for contaminating anesthesia equipment or discharging tubercle bacilli into the ambient air.
- During postoperative recovery, the patient should be monitored and should be placed in a private room that meets recommended standards for ventilating TB isolation rooms.
- When operative procedures (or other procedures requiring a sterile field) are performed on patients who may have infectious TB, respiratory protection worn by the HCW must protect the field from the respiratory secretions of the HCW and protect the HCW from the infectious droplet nuclei generated by the patient. Valved or positive-pressure respirators do not protect the sterile field; therefore, a

respirator that does not have a valve and that meets the criteria in Section II.G should be used.

b. Autopsy rooms

- Because infectious aerosols are likely to be present in autopsy rooms, such areas should be at negative pressure with respect to adjacent areas (Suppl. 3), and the room air should be exhausted directly to the outside of the building. ASHRAE recommends that autopsy rooms have ventilation that provides an airflow of 12 ACH (*47*), although the effectiveness of this ventilation level in reducing the risk for *M. tuberculosis* transmission has not been evaluated. Where possible, this level should be increased by means of ventilation system design or by auxiliary methods (e.g., recirculation of air within the room through HEPA filters) (Suppl. 3).
- Respiratory protection should be worn by personnel while performing autopsies on deceased persons who may have had TB at the time of death (Section II.G; Suppl. 4).
- Recirculation of HEPA-filtered air within the room or UVGI may be used as a supplement to the recommended ventilation (Suppl. 3).

c. Laboratories

- Laboratories in which specimens for mycobacteriologic studies (e.g., AFB smears and cultures) are processed should be designed to conform with criteria specified by CDC and the National Institutes of Health (*59*).

2. Other health-care settings

TB precautions may be appropriate in a number of other types of health-care settings. The specific precautions that are applied will vary depending on the setting. At a minimum, a risk assessment should be performed yearly for these settings; a written TB infection-control plan should be developed, evaluated, and revised on a regular basis; protocols should be in place for identifying and managing patients who may have active TB; HCWs should receive appropriate training, education, and screening; protocols for problem evaluation should be in place; and coordination with the public health department should be arranged when necessary. Other recommendations specific to certain of these settings follow.

a. Emergency medical services

- When EMS personnel or others must transport patients who have confirmed or suspected active TB, a surgical mask should be placed, if possible, over the patient's mouth and nose. Because administrative and engineering controls during emergency transport situations cannot be ensured, EMS personnel should wear respiratory protection when transporting such patients. If feasible, the windows of the vehicle should be kept open. The heating and air-conditioning system should be set on a nonrecirculating cycle.

- EMS personnel should be included in a comprehensive PPD screening program and should receive a baseline PPD test and follow-up testing as indicated by the risk assessment. They should also be included in the follow-up of contacts of a patient with infectious TB.*

b. Hospices

- Hospice patients who have confirmed or suspected TB should be managed in the manner described in this document for management of TB patients in hospitals. General-use and specialized areas (e.g., treatment or TB isolation rooms) should be ventilated in the same manner as described for similar hospital areas.

c. Long-term care facilities

- Recommendations published previously for preventing and controlling TB in long-term care facilities should be followed (*60*).
- Long-term care facilities should also follow the recommendations outlined in this document.

d. Correctional facilities

- Recommendations published previously for preventing and controlling TB in correctional facilities should be followed (*61*).
- Prison medical facilities should also follow the recommendations outlined in this document.

e. Dental settings

In general, the symptoms for which patients seek treatment in a dental-care setting are not likely to be caused by infectious TB. Unless a patient requiring dental care coincidentally has TB, it is unlikely that infectious TB will be encountered in the dental setting. Furthermore, generation of droplet nuclei containing *M. tuberculosis* during dental procedures has not been demonstrated (*62*). Therefore, the risk for transmission of *M. tuberculosis* in most dental settings is probably quite low. Nevertheless, during dental procedures, patients and dental workers share the same air for varying periods of time. Coughing may be stimulated occasionally by oral manipulations, although no specific dental procedures have been classified as "cough-inducing." In some instances, the population served by a dental-care facility, or the HCWs in the facility, may be at relatively high risk for TB. Because the potential exists for transmission of *M. tuberculosis* in dental settings, the following recommendations should be followed:

- A risk assessment (Section II.B) should be done periodically, and TB infection-control policies for each dental setting should be based on the risk assessment. The policies should include provisions for detection and referral of patients who may have undiagnosed active

*The Ryan White Comprehensive AIDS Resource Emergency Act of 1990, P.L. 101-381, mandates notification of EMS personnel after they have been exposed to infectious pulmonary TB (42 U.S.C. §300ff-82.54 Fed. Reg. 13417 [March 21, 1994]).

TB; management of patients with active TB, relative to provision of urgent dental care; and employer-sponsored HCW education, counseling, and screening.

- While taking patients' initial medical histories and at periodic updates, dental HCWs should routinely ask all patients whether they have a history of TB disease and symptoms suggestive of TB.
- Patients with a medical history or symptoms suggestive of undiagnosed active TB should be referred promptly for medical evaluation of possible infectiousness. Such patients should not remain in the dental-care facility any longer than required to arrange a referral. While in the dental-care facility, they should wear surgical masks and should be instructed to cover their mouths and noses when coughing or sneezing.
- Elective dental treatment should be deferred until a physician confirms that the patient does not have infectious TB. If the patient is diagnosed as having active TB, elective dental treatment should be deferred until the patient is no longer infectious.
- If urgent dental care must be provided for a patient who has, or is strongly suspected of having, infectious TB, such care should be provided in facilities that can provide TB isolation (Sections II.E and G). Dental HCWs should use respiratory protection while performing procedures on such patients.
- Any dental HCW who has a persistent cough (i.e., a cough lasting ≥3 weeks), especially in the presence of other signs or symptoms compatible with active TB (e.g., weight loss, night sweats, bloody sputum, anorexia, and fever), should be evaluated promptly for TB. The HCW should not return to the workplace until a diagnosis of TB has been excluded or until the HCW is on therapy and a determination has been made that the HCW is noninfectious.
- In dental-care facilities that provide care to populations at high risk for active TB, it may be appropriate to use engineering controls similar to those used in general-use areas (e.g., waiting rooms) of medical facilities that have a similar risk profile.

f. Home-health–care settings

- HCWs who provide medical services in the homes of patients who have suspected or confirmed infectious TB should instruct such patients to cover their mouths and noses with a tissue when coughing or sneezing. Until such patients are no longer infectious, HCWs should wear respiratory protection when entering these patients' homes (Suppl. 4).
- Precautions in the home may be discontinued when the patient is no longer infectious (Suppl. 1).
- HCWs who provide health-care services in their patients' homes can assist in preventing transmission of *M. tuberculosis* by educating their patients regarding the importance of taking medications as prescribed and by administering DOT.

- Cough-inducing procedures performed on patients who have infectious TB should not be done in the patients' homes unless absolutely necessary. When medically necessary cough-inducing procedures (e.g., AFB sputum collection for evaluation of therapy) must be performed on patients who may have infectious TB, the procedures should be performed in a health-care facility in a room or booth that has the recommended ventilation for such procedures. If these procedures must be performed in a patient's home, they should be performed in a well-ventilated area away from other household members. If feasible, the HCW should consider opening a window to improve ventilation or collecting the specimen while outside the dwelling. The HCW collecting these specimens should wear respiratory protection during the procedure (Section II.G).
- HCWs who provide medical services in their patients' homes should be included in comprehensive employer-sponsored TB training, education, counseling, and screening programs. These programs should include provisions for identifying HCWs who have active TB, baseline PPD skin testing, and follow-up PPD testing at intervals appropriate to the degree of risk.
- Patients who are at risk for developing active TB and the HCWs who provide medical services in the homes of such patients should be reminded periodically of the importance of having pulmonary symptoms evaluated promptly to permit early detection of and treatment for TB.

g. Medical offices

In general, the symptoms of active TB are symptoms for which patients are likely to seek treatment in a medical office. Furthermore, the populations served by some medical offices, or the HCWs in the office, may be at relatively high risk for TB. Thus, it is likely that infectious TB will be encountered in a medical office. Because of the potential for *M. tuberculosis* transmission, the following recommendations should be observed:

- A risk assessment should be conducted periodically, and TB infection-control policies based on results of the risk assessment should be developed for the medical office. The policies should include provisions for identifying and managing patients who may have undiagnosed active TB; managing patients who have active TB; and educating, training, counseling, and screening HCWs.
- While taking patients' initial medical histories and at periodic updates, HCWs who work in medical offices should routinely ask all patients whether they have a history of TB disease or have had symptoms suggestive of TB.
- Patients with a medical history and symptoms suggestive of active TB should receive an appropriate diagnostic evaluation for TB and be evaluated promptly for possible infectiousness. Ideally, this evaluation should be done in a facility that has TB isolation capability. At a minimum, the patient should be provided with and asked to wear a

surgical mask, instructed to cover the mouth and nose with a tissue when coughing or sneezing, and separated as much as possible from other patients.

- Medical offices that provide evaluation or treatment services for TB patients should follow the recommendations for managing patients in ambulatory-care settings (Section II.D).
- If cough-inducing procedures are to be administered in a medical office to patients who may have active TB, appropriate precautions should be followed (Section II.H).
- Any HCW who has a persistent cough (i.e., a cough lasting ≥3 weeks), especially in the presence of other signs or symptoms compatible with active TB (e.g., weight loss, night sweats, bloody sputum, anorexia, or fever) should be evaluated promptly for TB. HCWs with such signs or symptoms should not return to the workplace until a diagnosis of TB has been excluded or until they are on therapy and a determination has been made that they are noninfectious.
- HCWs who work in medical offices in which there is a likelihood of exposure to patients who have infectious TB should be included in employer-sponsored education, training, counseling, and PPD testing programs appropriate to the level of risk in the office.
- In medical offices that provide care to populations at relatively high risk for active TB, use of engineering controls as described in this document for general-use areas (e.g., waiting rooms) may be appropriate (Section II.F; Suppl. 3).

Supplement 1: Determining the Infectiousness of a TB Patient

The infectiousness of patients with TB correlates with the number of organisms expelled into the air, which, in turn, correlates with the following factors: a) disease in the lungs, airways, or larynx; b) presence of cough or other forceful expiratory measures; c) presence of acid-fast bacilli (AFB) in the sputum; d) failure of the patient to cover the mouth and nose when coughing; e) presence of cavitation on chest radiograph; f) inappropriate or short duration of chemotherapy; and g) administration of procedures that can induce coughing or cause aerosolization of *M. tuberculosis* (e.g., sputum induction).

The most infectious persons are most likely those who have not been treated for TB and who have either a) pulmonary or laryngeal TB and a cough or are undergoing cough-inducing procedures, b) a positive AFB sputum smear, or c) cavitation on chest radiograph. Persons with extrapulmonary TB usually are not infectious unless they have a) concomitant pulmonary disease; b) nonpulmonary disease located in the respiratory tract or oral cavity; or c) 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 (*20,22*). Coinfection with HIV does not appear to affect the infectiousness of TB patients (*63–65*).

In general, children who have TB may be less likely than adults to be infectious; however, transmission from children can occur. Therefore, children with TB should be evaluated for infectiousness using the same parameters as for adults (i.e., pulmonary or laryngeal TB, presence of cough or cough-inducing procedures, positive sputum AFB smear, cavitation on chest radiograph, and adequacy and duration of therapy). Pediatric patients who may be infectious include those who a) are not on therapy, b) have just been started on therapy, or c) are on inadequate therapy, *and* who a) have laryngeal or extensive pulmonary involvement, b) have pronounced cough or are undergoing cough-inducing procedures, c) have positive sputum AFB smears, or d) have cavitary TB. Children who have typical primary tuberculous lesions and do not have any of the indicators of infectiousness listed previously usually do not need to be placed in isolation. Because the source case for pediatric TB patients often occurs in a member of the infected child's family (*45*), parents and other visitors of all pediatric TB patients should be evaluated for TB as soon as possible.

Infection is most likely to result from exposure to persons who have unsuspected pulmonary TB and are not receiving anti-TB therapy or from persons who have diagnosed TB and are not receiving adequate therapy. Administration of effective anti-TB therapy has been associated with decreased infectiousness among persons who have active TB (*66*). Effective therapy reduces coughing, the amount of sputum produced, and the number of organisms in the sputum. However, the period of time a patient must take effective therapy before becoming noninfectious varies between patients (*67*). For example, some TB patients are never infectious, whereas those with unrecognized or inadequately treated drug-resistant TB may remain infectious for weeks or months (*24*). Thus, decisions about infectiousness should be made on an individual basis.

In general, patients who have suspected or confirmed active TB should be considered infectious if they a) are coughing, b) are undergoing cough-inducing procedures, or c) have positive AFB sputum smears, *and* if they a) are not on chemotherapy, b) have just started chemotherapy, or c) have a poor clinical or bacteriologic response to chemotherapy. A patient who has drug-susceptible TB and who is on adequate chemotherapy and has had a significant clinical and bacteriologic response to therapy (i.e., reduction in cough, resolution of fever, and progressively decreasing quantity of bacilli on smear) is probably no longer infectious. However, because drug-susceptibility results are not usually known when the decision to discontinue isolation is made, all TB patients should remain in isolation while hospitalized until they have had three consecutive negative sputum smears collected on different days and they demonstrate clinical improvement.

Supplement 2: Diagnosis and Treatment of Latent TB Infection and Active TB

I. Diagnostic Procedures for TB Infection and Disease

A diagnosis of TB may be considered for any patient who has a persistent cough (i.e., a cough lasting ≥3 weeks) or other signs or symptoms compatible with TB (e.g., bloody sputum, night sweats, weight loss, anorexia, or fever). However, the index of suspicion for TB will vary in different geographic areas and will depend on the prevalence of TB and other characteristics of the population served by the facility. The index of suspicion for TB should be very high in areas or among groups of patients in which the prevalence of TB is high (Section I.B). Persons for whom a diagnosis of TB is being considered should receive appropriate diagnostic tests, which may include PPD skin testing, chest radiography, and bacteriologic studies (e.g., sputum microscopy and culture).

A. PPD Skin Testing and Anergy Testing

1. Application and reading of PPD skin tests

The PPD skin test is the only method available for demonstrating infection with *M. tuberculosis*. Although currently available PPD tests are <100% sensitive and specific for detection of infection with *M. tuberculosis*, no better diagnostic methods have yet been devised. Interpretation of PPD test results requires knowledge of the antigen used, the immunologic basis for the reaction to this antigen, the technique used to administer and read the test, and the results of epidemiologic and clinical experience with the test (*2,5,6*). The PPD test, like all medical tests, is subject to variability, but many of the variations in administering and reading PPD tests can be avoided by proper training and careful attention to details.

The intracutaneous (Mantoux) administration of a measured amount of PPD-tuberculin is currently the preferred method for doing the test. One-tenth milliliter of PPD (5 TU) is injected just beneath the surface of the skin on either the volar or dorsal surface of the forearm. A discrete, pale elevation of the skin (i.e., a wheal) that is 6–10 mm in diameter should be produced.

PPD test results should be read by designated, trained personnel between 48 and 72 hours after injection. Patient or HCW self-reading of PPD test results should not be accepted (*68*). The result of the test is based on the presence or absence of an induration at the injection site. Redness or erythema should not be measured. The transverse diameter of induration should be recorded in millimeters.

2. Interpretation of PPD skin tests

a. General

The interpretation of a PPD reaction should be influenced by the purpose for which the test was given (e.g., epidemiologic versus diagnostic purposes), by the prevalence of TB infection in the population being tested, and by the consequences of false classification. Errors in classification can be minimized by establishing an appropriate definition of a positive reaction (Table S2-1).

The positive-predictive value of PPD tests (i.e, the probability that a person with a positive PPD test is actually infected with *M. tuberculosis*) is dependent on the prevalence of TB infection in the population being tested and the specificity of the test (*69,70*). In populations with a low prevalence of TB infection, the probability that a positive PPD test represents true infection with *M. tuberculosis* is very low if the cut-point is set too low (i.e., the test is not adequately specific). In populations with a high prevalence of TB infection, the probability that a positive PPD test using the same cut-point represents true infection with *M. tuberculosis* is much higher. To ensure that few persons infected with tubercle bacilli will be misclassified as having negative reactions and few persons not infected with tubercle bacilli will be misclassified as having positive reactions, different cut-points are used to separate positive reactions from negative reactions for different populations, depending on the risk for TB infection in that population.

A lower cut-point (i.e., 5 mm) is used for persons in the highest risk groups, which include HIV-infected persons, recent close contacts of persons with TB (e.g., in the household or in an unprotected occupational exposure similar in intensity and duration to household contact), and persons who have abnormal chest radiographs with fibrotic changes consistent with inactive TB. A higher cut-point (i.e., 10 mm) is used for persons who are not in the highest risk group but who have other risk factors (e.g., injecting-drug users known to be HIV seronegative; persons with certain medical conditions that increase the risk for progression from latent TB infection to active TB [Table S2-1]); medically underserved, low-income populations; persons born in foreign countries that have a high prevalence of TB; and residents of correctional institutions and nursing homes). An even higher cut-point (i.e., 15 mm) is used for all other persons who have none of the above risk factors.

Recent PPD converters are considered members of a high-risk group. A ≥10 mm increase in the size of the induration within a 2-year period is classified as a conversion from a negative to a positive test result for persons <35 years of age. An increase of induration of ≥15 mm within a

2-year period is classified as a conversion for persons ≥35 years of age (*5*).

b. HCWs

In general, HCWs should have their skin-test results interpreted according to the recommendations in this supplement and in sections 1, 2, 3, and 5 of Table S2-1. However, the prevalence of TB in the facility should be considered when choosing the appropriate cut-point for defining a positive PPD reaction. In facilities where there is essentially no risk for exposure to TB patients (i.e., minimal- or very low-risk facilities [Section II.B]), an induration ≥15 mm may be an appropriate cut-point for HCWs who have no other risk factors. In other facilities where TB patients receive care, the appropriate cut-point for HCWs who have no other risk factors may be ≥10 mm.

A recent PPD test conversion in an HCW should be defined generally as an increase of ≥10 mm in the size of induration within a 2-year period. For HCWs in facilities where exposure to TB is very unlikely (e.g., minimal-risk facilities), an increase of ≥15 mm within a 2-year period may be more appropriate for defining a recent conversion because of the lower positive-predictive value of the test in such groups.

3. Anergy testing

HIV-infected persons may have suppressed reactions to PPD skin tests because of anergy, particularly if their CD4+ T-lymphocyte counts decline (*71*). Persons with anergy will have a negative PPD test regardless of infection with *M. tuberculosis*. HIV-infected persons should be evaluated for anergy in conjunction with PPD testing (*72*). Two companion antigens (e.g., *Candida* antigen and tetanus toxoid) should be administered in addition to PPD. Persons with ≥3 mm of induration to any of the skin tests (including tuberculin) are considered not anergic. Reactions of ≥5 mm to PPD are considered to be evidence of TB infection in HIV-infected persons regardless of the reactions to the companion antigens. If there is no reaction (i.e., <3 mm induration) to any of the antigens, the person being tested is considered anergic. Determination of whether such persons are likely to be infected with *M. tuberculosis* must be based on other epidemiologic factors (e.g., the proportion of other persons with the same level of exposure who have positive PPD test results and the intensity or duration of exposure to infectious TB patients that the anergic person experienced).

4. Pregnancy and PPD skin testing

Although thousands (perhaps millions) of pregnant women have been PPD skin tested since the test was devised, thus far no documented episodes of fetal harm have resulted from use of the tuberculin test (*73*). Pregnancy should not exclude a female HCW from being skin tested as part of a contact investigation or as part of a regular skin-testing program.

TABLE S2-1. Summary of interpretation of purified protein derivative (PPD)-tuberculin skin-test results

1. An induration of ≥5 mm is classified as positive in:
   - persons who have human immunodeficiency virus (HIV) infection or risk factors for HIV infection but unknown HIV status;
   - persons who have had recent close contact* with persons who have active tuberculosis (TB);
   - persons who have fibrotic chest radiographs (consistent with healed TB).

2. An induration of ≥10 mm is classified as positive in all persons who do not meet any of the criteria above but who have other risk factors for TB, including:

   High-risk groups —
   - injecting-drug users known to be HIV seronegative;
   - persons who have other medical conditions that reportedly increase the risk for progressing from latent TB infection to active TB (e.g., silicosis; gastrectomy or jejuno-ileal bypass; being ≥10% below ideal body weight; chronic renal failure with renal dialysis; diabetes mellitus; high-dose corticosteroid or other immunosuppressive therapy; some hematologic disorders, including malignancies such as leukemias and lymphomas; and other malignancies);
   - children <4 years of age.

   High-prevalence groups —
   - persons born in countries in Asia, Africa, the Caribbean, and Latin America that have high prevalence of TB;
   - persons from medically underserved, low-income populations;
   - residents of long-term–care facilities (e.g., correctional institutions and nursing homes);
   - persons from high-risk populations in their communities, as determined by local public health authorities.

3. An induration of ≥15 mm is classified as positive in persons who do not meet any of the above criteria.

4. Recent converters are defined on the basis of both size of induration and age of the person being tested:
   - ≥10 mm increase within a 2-year period is classified as a recent conversion for persons <35 years of age;
   - ≥15 mm increase within a 2-year period is classified as a recent conversion for persons ≥35 years of age.

5. PPD skin-test results in health-care workers (HCWs)
   - In general, the recommendations in sections 1, 2, and 3 of this table should be followed when interpreting skin-test results in HCWs.

     However, the prevalence of TB in the facility should be considered when choosing the appropriate cut-point for defining a positive PPD reaction. In facilities where there is essentially no risk for exposure to *Mycobacterium tuberculosis* (i.e., minimal- or very low-risk facilities [Section II.B]), an induration ≥15 mm may be a

*Recent close contact implies either household or social contact or unprotected occupational exposure similar in intensity and duration to household contact.

TABLE S2-1. Summary of interpretation of PPD skin-test results — Continued

suitable cut-point for HCWs who have no other risk factors. In facilities where TB patients receive care, the cut-point for HCWs with no other risk factors may be ≥10 mm.

- A recent conversion in an HCW should be defined generally as a ≥10 mm increase in size of induration within a 2-year period. For HCWs who work in facilities where exposure to TB is very unlikely (e.g., minimal-risk facilities), an increase of ≥15 mm within a 2-year period may be more appropriate for defining a recent conversion because of the lower positive-predictive value of the test in such groups.

5. BCG vaccination and PPD skin testing

BCG vaccination may produce a PPD reaction that cannot be distinguished reliably from a reaction caused by infection with *M. tuberculosis*. For a person who was vaccinated with BCG, the probability that a PPD test reaction results from infection with *M. tuberculosis* increases a) as the size of the reaction increases, b) when the person is a contact of a person with TB, c) when the person's country of origin has a high prevalence of TB, and d) as the length of time between vaccination and PPD testing increases. For example, a PPD test reaction of ≥10 mm probably can be attributed to *M. tuberculosis* infection in an adult who was vaccinated with BCG as a child and who is from a country with a high prevalence of TB (*74,75*).

6. The booster phenomenon

The ability of persons who have TB infection to react to PPD may gradually wane. For example, if tested with PPD, adults who were infected during their childhood may have a negative reaction. However, the PPD could boost the hypersensitivity, and the size of the reaction could be larger on a subsequent test. This boosted reaction may be misinterpreted as a PPD test conversion from a newly acquired infection. Misinterpretation of a boosted reaction as a new infection could result in unnecessary investigations of laboratory and patient records in an attempt to identify the source case and in unnecessary prescription of preventive therapy for HCWs. Although boosting can occur among persons in any age group, the likelihood of the reaction increases with the age of the person being tested (*6,76*).

When PPD testing of adults is to be repeated periodically (as in HCW skin-testing programs), two-step testing can be used to reduce the likelihood that a boosted reaction is misinterpreted as a new infection. Two-step testing should be performed on all newly employed HCWs who have an initial negative PPD test result at the time of employment and have not had a documented negative PPD test result during the 12 months preceding the initial test. A second test should be performed 1–3 weeks after the first test. If the second test result is positive, this is most likely a boosted reaction,

and the HCW should be classified as previously infected. If the second test result remains negative, the HCW is classified as uninfected, and a positive reaction to a subsequent test is likely to represent a new infection with *M. tuberculosis*.

B. Chest Radiography

Patients who have positive skin-test results or symptoms suggestive of TB should be evaluated with a chest radiograph regardless of PPD test results. Radiographic abnormalities that strongly suggest active TB include upper-lobe infiltration, particularly if cavitation is seen (*77*), and patchy or nodular infiltrates in the apical or subapical posterior upper lobes or the superior segment of the lower lobe. If abnormalities are noted, or if the patient has symptoms suggestive of extrapulmonary TB, additional diagnostic tests should be conducted.

The radiographic presentation of pulmonary TB in HIV-infected patients may be unusual (*78*). Typical apical cavitary disease is less common among such patients. They may have infiltrates in any lung zone, a finding that is often associated with mediastinal and/or hilar adenopathy, or they may have a normal chest radiograph, although this latter finding occurs rarely.

C. Bacteriology

Smear and culture examination of at least three sputum specimens collected on different days is the main diagnostic procedure for pulmonary TB (*6*). Sputum smears that fail to demonstrate AFB do not exclude the diagnosis of TB. In the United States, approximately 60% of patients with positive sputum cultures have positive AFB sputum smears. HIV-infected patients who have pulmonary TB may be less likely than immunocompetent patients to have AFB present on sputum smears, which is consistent with the lower frequency of cavitary pulmonary disease observed among HIV-infected persons (*39,41*).

Specimens for smear and culture should contain an adequate amount of expectorated sputum but not much saliva. If a diagnosis of TB cannot be established from sputum, a bronchoscopy may be necessary (*36,37*). In young children who cannot produce an adequate amount of sputum, gastric aspirates may provide an adequate specimen for diagnosis.

A culture of sputum or other clinical specimen that contains *M. tuberculosis* provides a definitive diagnosis of TB. Conventional laboratory methods may require 4–8 weeks for species identification; however, the use of radiometric culture techniques and nucleic acid probes facilitates more rapid detection and identification of mycobacteria (*79,80*). Mixed mycobacterial infection, either simultaneous or sequential, can obscure the identification of *M. tuberculosis* during the clinical evaluation and the laboratory analysis (*42*). The use of nucleic acid probes for both *M. avium* complex and *M. tuberculosis*

may be useful for identifying mixed mycobacterial infections in clinical specimens.

II. Preventive Therapy for Latent TB Infection and Treatment of Active TB

A. Preventive Therapy for Latent TB Infection

Determining whether a person with a positive PPD test reaction or conversion is a candidate for preventive therapy must be based on a) the likelihood that the reaction represents true infection with *M. tuberculosis* (as determined by the cut-points), b) the estimated risk for progression from latent infection to active TB, and c) the risk for hepatitis associated with taking isoniazid (INH) preventive therapy (as determined by age and other factors).

HCWs with positive PPD test results should be evaluated for preventive therapy regardless of their ages if they a) are recent converters, b) are close contacts of persons who have active TB, c) have a medical condition that increases the risk for TB, d) have HIV infection, or e) use injecting drugs (*5*). HCWs with positive PPD test results who do not have these risk factors should be evaluated for preventive therapy if they are <35 years of age.

Preventive therapy should be considered for anergic persons who are known contacts of infectious TB patients and for persons from populations in which the prevalence of TB infection is very high (e.g., a prevalence of >10%).

Because the risk for INH-associated hepatitis may be increased during the peripartum period, the decision to use preventive therapy during pregnancy should be made on an individual basis and should depend on the patient's estimated risk for progression to active disease. In general, preventive therapy can be delayed until after delivery. However, for pregnant women who were probably infected recently or who have high-risk medical conditions, especially HIV infection, INH preventive therapy should begin when the infection is documented (*81–84*). No evidence suggests that INH poses a carcinogenic risk to humans (*85–87*).

The usual preventive therapy regimen is oral INH 300 mg daily for adults and 10 mg/kg/day for children (*88*). The recommended duration of therapy is 12 months for persons with HIV infection and 9 months for children. Other persons should receive INH therapy for 6–12 months. For persons who have silicosis or a chest radiograph demonstrating inactive fibrotic lesions and who have no evidence of active TB, acceptable regimens include a) 4 months of INH plus rifampin or b) 12 months of INH, providing that infection with INH-resistant organisms is unlikely (*33*). For persons likely to be infected with MDR-TB, alternative multidrug preventive therapy regimens should be considered (*89*).

All persons placed on preventive therapy should be educated regarding the possible adverse reactions associated with INH use, and they should be questioned carefully at monthly intervals by qualified personnel for signs or symptoms consistent with liver damage or other adverse effects (*81–84,88,90,91*). Because INH-associated hepatitis occurs more frequently among persons >35 years of age, a transaminase measurement should be obtained from persons in this age group before initiation of INH therapy and then obtained monthly until treatment has been completed. Other factors associated with an increased risk for hepatitis include daily alcohol use, chronic liver disease, and injecting-drug use. In addition, postpubertal black and Hispanic women may be at greater risk for hepatitis or drug interactions (*92*). More careful clinical monitoring of persons with these risk factors and possibly more frequent laboratory monitoring should be considered. If any of these tests exceeds three to five times the upper limit of normal, discontinuation of INH should be strongly considered. Liver function tests are not a substitute for monthly clinical evaluations or for the prompt assessment of signs or symptoms of adverse reactions that could occur between the regularly scheduled evaluations (*33*).

Persons who have latent TB infection should be advised that they can be reinfected with another strain of *M. tuberculosis* (*93*).

B. Treatment of Patients Who Have Active TB

Drug-susceptibility testing should be performed on all initial isolates from patients with TB. However, test results may not be available for several weeks, making selection of an initial regimen difficult, especially in areas where drug-resistant TB has been documented. Current recommendations for therapy and dosage schedules for the treatment of drug-susceptible TB should be followed (Table S2-2; Table S2-3) (*43*). Streptomycin is contraindicated in the treatment of pregnant women because of the risk for ototoxicity to the fetus. In geographic areas or facilities in which drug-resistant TB is highly prevalent, the initial treatment regimen used while results of drug-susceptibility tests are pending may need to be expanded. This decision should be based on analysis of surveillance data.

When results from drug-susceptibility tests become available, the regimen should be adjusted appropriately (*94–97*). If drug resistance is present, clinicians unfamiliar with the management of patients with drug-resistant TB should seek expert consultation.

For any regimen to be effective, adherence to the regimen must be ensured. The most effective method of ensuring adherence is the use of DOT after the patient has been discharged from the hospital (*43,91*). This practice should be coordinated with the public health department.

TABLE S2-2. Regimen options for the treatment of tuberculosis (TB) in children and adults

Option	Indication	Total duration of therapy	Initial treatment phase		Continuation treatment phase		Comments
			Drugs*	Interval and duration	Drugs*	Interval and duration	
1	Pulmonary and extrapulmonary TB in adults and children	6 mos	INH RIF PZA EMB or SM	Daily for 8 wks	INH RIF	Daily or two or three times wkly† for 16 wks§	• EMB or SM should be continued until susceptibility to INH and RIF is demonstrated. • In areas where primary INH resistance is <4%, EMB or SM may not be necessary for patients with no individual risk factors for drug resistance.
2	Pulmonary and extrapulmonary TB in adults and children	6 mos	INH RIF PZA EMB or SM	Daily for 2 wks, then Two times wkly† for 6 wks	INH RIF	Two times wkly† for 16 wks§	• Regimen should be directly observed. • After the initial phase, EMB or SM should be continued until susceptibility to INH and RIF is demonstrated, unless drug resistance is unlikely.
3	Pulmonary and extrapulmonary TB in adults and children	6 mos	INH RIF PZA EMB or SM	3 times wkly† for 6 mos§			• Regimen should be directly observed. • Continue all four drugs for 6 mos.¶ • This regimen has been shown to be effective for INH-resistant TB.
4	Smear- and culture-negative pulmonary TB in adults	4 mos	INH RIF PZA EMB or SM	Follow option 1, 2, or 3 for 8 wks	INH RIF PZA EMB or SM	Daily or two or three times wkly† for 8 wks	• Continue all four drugs for 4 mos. • If drug resistance is unlikely (primary INH resistance <4% and patient has no individual risk factors for drug resistance), EMB or SM may not be necessary and PZA may be discontinued after 2 mos.
5	Pulmonary and extrapulmonary TB in adults and children when PZA is contraindicated	9 mos	INH RIF EMB or SM**	Daily for 8 wks	INH RIF	Daily or two times wkly† for 24 wks§	• EMB or SM should be continued until susceptibility to INH and RIF is demonstrated. • In areas where primary INH resistance is <4%, EMB or SM may not be necessary for patients with no individual risk factors for drug resistance.

***** EMB=ethambutol; INH=isoniazid; PZA=pyrazinamide; RIF=rifampin; SM=streptomycin.

† All regimens administered intermittently should be directly observed.

§ For infants and children with miliary TB, bone and joint TB, or TB meningitis, treatment should last at least 12 months. For adults with these forms of extrapulmonary TB, response to therapy should be monitored closely. If response is slow or suboptimal, treatment may be prolonged on a case-by-case basis.

¶ Some evidence suggests that SM may be discontinued after 4 months if the isolate is susceptible to all drugs.

** Avoid treating pregnant women with SM because of the risk for ototoxicity to the fetus.

Note: For all patients, if drug-susceptibility results show resistance to any of the first-line drugs, or if the patient remains symptomatic or smear- or culture-positive after 3 months, consult a TB medical expert.

TABLE S2-3. Dosage recommendations for the initial treatment of tuberculosis in children* and adults

Drug	Dosage schedule					
	Daily dose (maximum dose)		Two doses per week (maximum dose)		Three doses per week (maximum dose)	
	Children	Adults	Children	Adults	Children	Adults
Isoniazid	10–20 mg/kg (300 mg)	5 mg/kg (300 mg)	20–40 mg/kg (900 mg)	15 mg/kg (900 mg)	20–40 mg/kg (900 mg)	15 mg/kg (900 mg)
Rifampin	10–20 mg/kg (600 mg)	10 mg/kg (600 mg)	10–20 mg/kg (600 mg)	10 mg/kg (600 mg)	10–20 mg/kg (600 mg)	10 mg/kg (600 mg)
Pyrazinamide	15–30 mg/kg (2 gm)	15–30 mg/kg (2 gm)	50–70 mg/kg (4 gm)	50–70 mg/kg (4 gm)	50–70 mg/kg (3 gm)	50–70 mg/kg (3 gm)
Ethambutol	15–25 mg/kg	15–25 mg/kg	50 mg/kg	50 mg/kg	25–30 mg/kg	25–30 mg/kg
Streptomycin	20–40 mg/kg (1 gm)	15 mg/kg (1 gm)	20–40 mg/kg (1.5 gm)	20–40 mg/kg (1.5 gm)	20–40 mg/kg (1.5 gm)	20–40 mg/kg (1.5 gm)

*Persons ≤12 years of age.

Supplement 3: Engineering Controls

I. Introduction

This supplement provides information regarding the use of ventilation (Section II) and UVGI (Section III) for preventing the transmission of *M. tuberculosis* in health-care facilities. The information provided is primarily conceptual and is intended to educate staff in the health-care facility concerning engineering controls and how these controls can be used as part of the TB infection-control program. This supplement should not be used in place of consultation with experts, who can assume responsibility for advising on ventilation system design and selection, installation, and maintenance of equipment.

The recommendations for engineering controls include a) local exhaust ventilation (i.e., source control), b) general ventilation, and c) air cleaning. General ventilation considerations include a) dilution and removal of contaminants, b) airflow patterns within rooms, c) airflow direction in facilities, d) negative pressure in rooms, and e) TB isolation rooms. Air cleaning or disinfection can be accomplished by filtration of air (e.g., through HEPA filters) or by UVGI.

II. Ventilation

Ventilation systems for health-care facilities should be designed, and modified when necessary, by ventilation engineers in collaboration with infection-control and occupational health staff. Recommendations for designing and operating ventilation systems have been published by ASHRAE (*47*), AIA (*48*), and the American Conference of Governmental Industrial Hygienists, Inc. (*98*).

As part of the TB infection-control plan, health-care facility personnel should determine the number of TB isolation rooms, treatment rooms, and local exhaust devices (i.e., for cough-inducing or aerosol-generating procedures) that the facility needs. The locations of these rooms and devices will depend on where in the facility the ventilation conditions recommended in this document can be achieved. Grouping isolation rooms together in one area of the facility may facilitate the care of TB patients and the installation and maintenance of optimal engineering controls (particularly ventilation).

Periodic evaluations of the ventilation system should review the number of TB isolation rooms, treatment rooms, and local exhaust devices needed and the regular maintenance and monitoring of the local and general exhaust systems (including HEPA filtration systems if they are used).

The various types and conditions of ventilation systems in health-care facilities and the individual needs of these facilities preclude the ability to provide specific instructions regarding the implementation of these recommendations. Engineering control methods must be tailored to each facility on the basis of need and the feasibility of using the ventilation and air-cleaning concepts discussed in this supplement.

A. Local Exhaust Ventilation

Purpose: To capture airborne contaminants at or near their source (i.e., the source control method) and remove these contaminants without exposing persons in the area to infectious agents (*98*).

Source control techniques can prevent or reduce the spread of infectious droplet nuclei into the general air circulation by entrapping infectious droplet nuclei as they are being emitted by the patient (i.e., the source). These techniques are especially important when performing procedures likely to generate aerosols containing infectious particles and when infectious TB patients are coughing or sneezing.

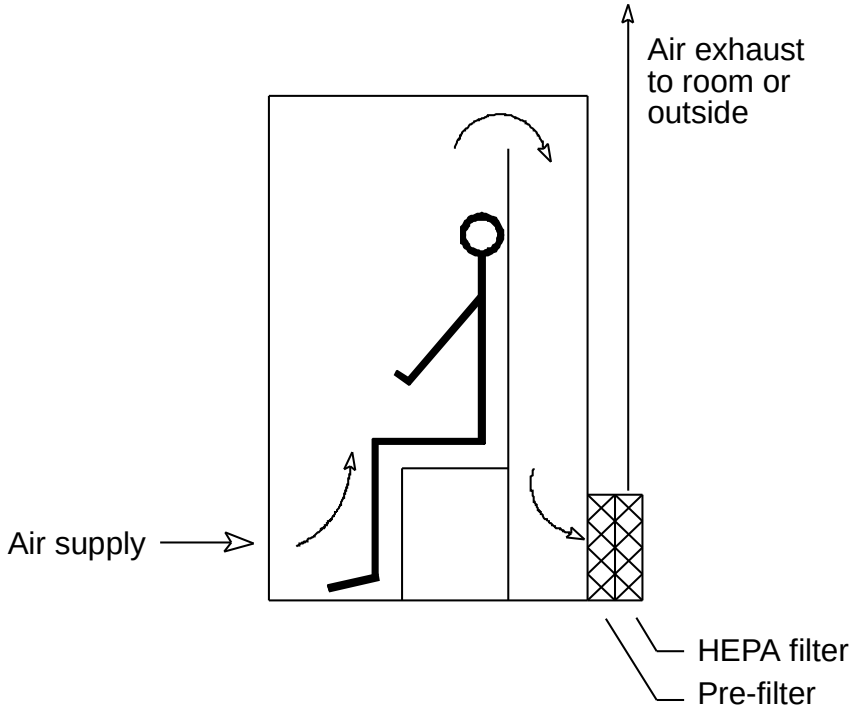
Local exhaust ventilation is a preferred source control technique, and it is often the most efficient way to contain airborne contaminants because it captures these contaminants near their source before they can disperse. Therefore, the technique should be used, if feasible, wherever aerosol-generating procedures are performed. Two basic types of local exhaust devices use hoods: a) the enclosing type, in which the hood either partially or fully encloses the infectious source; and b) the exterior type, in which the infectious source is near but outside the hood. Fully enclosed hoods, booths, or tents are always preferable to exterior types because of their superior ability to prevent contaminants from escaping into the HCW's breathing zone. Descriptions of both enclosing and exterior devices have been published previously (*98*).

1. Enclosing devices

The enclosing type of local exhaust ventilation device includes laboratory hoods used for processing specimens that could contain viable infectious organisms, booths used for sputum induction or administration of aerosolized medications (e.g., aerosolized pentamidine) (Figure S3-1), and tents or hoods made of vinyl or other materials used to enclose and isolate a patient. These devices are available in various configurations. The most simple of these latter devices is a tent that is placed over the patient; the tent has an exhaust connection to the room discharge exhaust system. The most complex device is an enclosure that has a sophisticated self-contained airflow and recirculation system.

Both 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 (*99*). The time required for removing a given percentage of airborne particles from an enclosed space depends on several factors. These factors include the number of ACH, which is determined by the number of cubic feet of air in the room or booth and the rate at which air is entering the room or booth at the intake source; the location of the ventilation inlet and outlet; and the physical configuration of the room or booth (Table S3-1).

FIGURE S3-1. An enclosing booth designed to sweep air past a patient who has active tuberculosis and entrap the infectious droplet nuclei in a high-efficiency particulate air (HEPA) filter



*Passage of air directly from the air supply to the exhaust (i.e., short-circuiting of air) is prevented by the structure on which patients sit and the wall on which patients rest their backs.

2. Exterior devices

The exterior type of local exhaust ventilation device is usually a hood very near, but not enclosing, the infectious patient. The airflow produced by these devices should be sufficient to prevent cross-currents of air near the patient's face from causing escape of droplet nuclei. Whenever possible, the patient should face directly into the hood opening so that any coughing or sneezing is directed into the hood, where the droplet nuclei are captured. The device should maintain an air velocity of ≥200 feet per minute at the patient's breathing zone to ensure capture of droplet nuclei.

3. Discharge exhaust from booths, tents, and hoods

Air from booths, tents, and hoods may be discharged into the room in which the device is located or it may be exhausted to the outside. If the 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 with respect to adjacent areas. Uncontaminated air from the room will flow into the booth through all openings,

TABLE S3-1. Air changes per hour (ACH) and time in minutes required for removal efficiencies of 90%, 99%, and 99.9% of airborne contaminants*

ACH	Minutes required for a removal efficiency of:		
	90%	99%	99.9%
1	138	276	414
2	69	138	207
3	46	92	138
4	35	69	104
5	28	55	83
6	23	46	69
7	20	39	59
8	17	35	52
9	15	31	46
10	14	28	41
11	13	25	38
12	12	23	35
13	11	21	32
14	10	20	30
15	9	18	28
16	9	17	26
17	8	16	24
18	8	15	23
19	7	15	22
20	7	14	21
25	6	11	17
30	5	9	14
35	4	8	12
40	3	7	10
45	3	6	9
50	3	6	8

*This table has been adapted from the formula for the rate of purging airborne contaminants (*99*). Values have been derived from the formula $t_1 = [\ln (C_2 \div C_1) \div (Q \div V)] \times 60$, with $T_1 = 0$ and $C_2 \div C_1 -$ (removal efficiency $\div$ 100), and where:

t_1 = initial timepoint
C_1 = initial concentration of contaminant
C_2 = final concentration of contaminants
Q = air flow rate (cubic feet per hour)
V = room volume (cubic feet)
$Q \div V$ = ACH

The times given assume perfect mixing of the air within the space (i.e., mixing factor = 1). However, perfect mixing usually does not occur, and the mixing factor could be as high as 10 if air distribution is very poor (*98*). The required time is derived by multiplying the appropriate time from the table by the mixing factor that has been determined for the booth or room. The factor and required time should be included in the operating instructions provided by the manufacturer of the booth or enclosure, and these instructions should be followed.

thus preventing infectious droplet nuclei in the booth from escaping into the room. Most commercially available booths, tents, and hoods are fitted with HEPA filters, in which case additional HEPA filtration is not needed.

If the device does not incorporate a HEPA filter, the air from the device should be exhausted to the outside in accordance with recommendations for isolation room exhaust (Suppl. 3, Section II.B.5). (See Supplement 3, Section II.C, for information regarding recirculation of exhaust air.)

B. General Ventilation

General ventilation can be used for several purposes, including diluting and removing contaminated air, controlling airflow patterns within rooms, and controlling the direction of airflow throughout a facility. Information on these topics is contained in the following sections.

1. Dilution and removal

Purpose: To reduce the concentration of contaminants in the air.

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

a. Types of general ventilation systems

Two types of general ventilation systems can be used for dilution and removal of contaminated air: the single-pass system and the recirculating system. In a single-pass system, the supply air is either outside air that has been appropriately heated and cooled or air from a central system that supplies a number of areas. After air passes through the room (or area), 100% of that air is exhausted to the outside. The single-pass system is the preferred choice in areas where infectious airborne droplet nuclei are known to be present (e.g., TB isolation rooms or treatment rooms) because it prevents contaminated air from being recirculated to other areas of the facility.

In a recirculating system, a small portion of the exhaust air is discharged to the outside and is replaced with fresh outside air, which mixes with the portion of exhaust air that was not discharged to the outside. The resulting mixture, which can contain a large proportion of contaminated air, is then recirculated to the areas serviced by the system. This air mixture could be recirculated into the general ventilation, in which case contaminants may be carried from contaminated areas to uncontaminated areas. Alternatively, the air mixture could also be recir-

culated within a specific room or area, in which case other areas of the facility will not be affected (Suppl. 3, Section II.C.3).

b. Ventilation rates

Recommended general ventilation rates for health-care facilities are usually expressed in number of ACH. This number is the ratio of the volume of air entering the room per hour to the room volume and is equal to the exhaust airflow (Q [cubic feet per minute]) divided by the room volume (V [cubic feet]) multiplied by 60 (i.e., $ACH = Q \div V \times 60$).

The feasibility of achieving specific ventilation rates depends on the construction and operational requirements of the ventilation system (e.g., the energy requirements to move and to heat or cool the air). The feasibility of achieving specific ventilation rates may also be different for retrofitted facilities and newly constructed facilities. The expense and effort of achieving specific higher ventilation rates for new construction may be reasonable, whereas retrofitting an existing facility to achieve similar ventilation rates may be more difficult. However, achieving higher ventilation rates by using auxiliary methods (e.g., room-air recirculation) in addition to exhaust ventilation may be feasible in existing facilities (Suppl. 3, Section II.C).

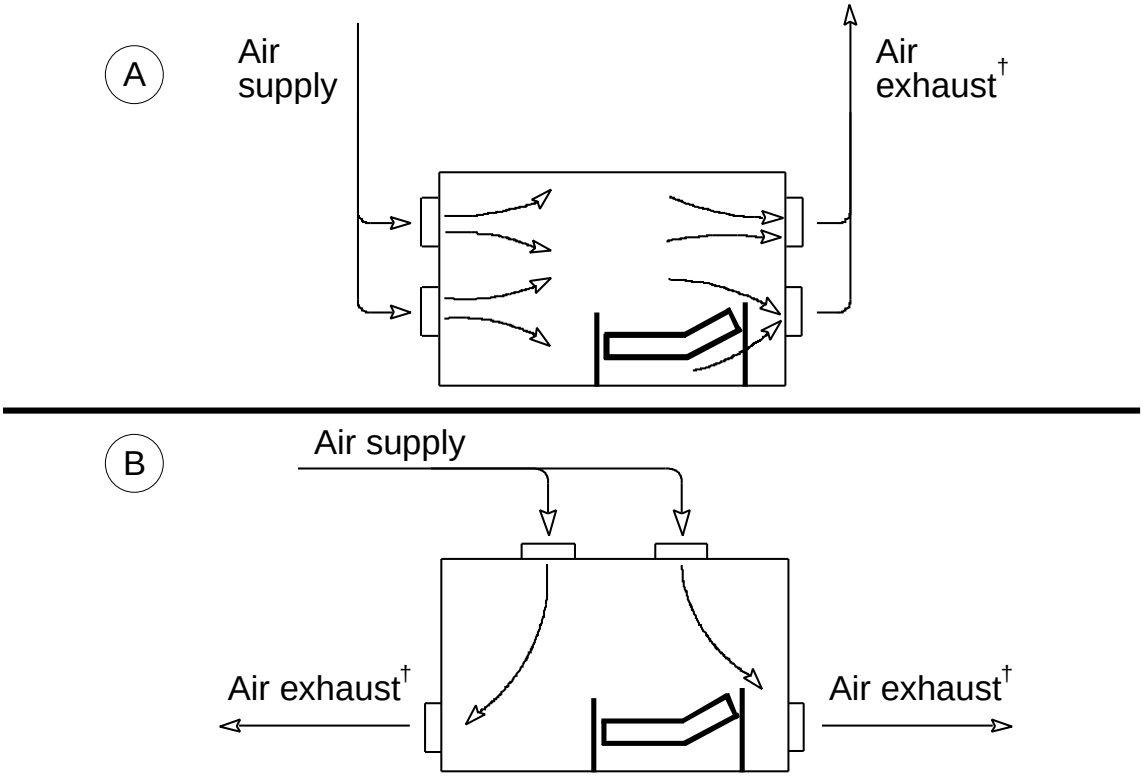
2. Airflow patterns within rooms (air mixing)

Purpose: To provide optimum airflow patterns and prevent both stagnation and short-circuiting of air.

General ventilation systems should be designed to provide optimal patterns of airflow within rooms and 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 air exhaust). To provide optimal airflow patterns, the air supply and exhaust should be located such that clean air first flows to parts of the room where HCWs are likely to work, and then flows across the infectious source and into the exhaust. In this way, the HCW is not positioned between the infectious source and the exhaust location. Although this configuration may not always be possible, it should be used whenever feasible. One way to achieve this 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. 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 S3-2). Airflow patterns are affected by large air temperature differentials, the precise location of the supply and exhausts, the location of furniture, the movement of HCWs and patients, and the physical configuration of the space. Smoke tubes can be used to visualize airflow patterns in a manner similar to that described for estimating room air mixing.

Adequate air mixing, which requires that an adequate number of ACH be provided to a room (Suppl. 3, Section II.B.1), must be ensured to prevent air stagnation within the room. However, the air will not usually be changed the calculated number of times per hour because the airflow patterns in the room may not permit complete mixing of the supply and room air in all parts of the room. This results in an "effective" airflow rate in which the supplied airflow may be less than required for proper ventilation. To account for this variation, a mixing factor (which ranges from 1 for perfect mixing to 10 for poor mixing) is applied as a multiplier to determine the actual supply airflow (i.e., the recommended ACH multiplied by the mixing factor equals the actual required ACH) (*51,98*). The room air supply and exhaust system should be designed to achieve the lowest mixing factor possible. The mixing factor is determined most accurately by experimentally testing each space configuration, but this procedure is complex and time-consuming. A reasonably good qualitative measure of mixing can be estimated by an experienced ventilation engineer who releases smoke from smoke tubes at a number of locations in the room and observes the movement of the smoke. Smoke movement in all areas of the room indicates good mixing. Stagnation of air in some areas of the room

FIGURE S3-2. Room airflow patterns designed to provide mixing of air and prevent passage of air directly from the air supply to the exhaust*



*Short-circuiting of air.
† Air should be exhausted to the outside (or through high-efficiency particulate air [HEPA] filters, if recirculated).

indicates poor mixing, and movement of the supply and exhaust openings or redirection of the supply air is necessary.

3. Airflow direction in the facility

Purpose: To contain contaminated air in localized areas in a facility and prevent its spread to uncontaminated areas.

a. Directional airflow

The general ventilation system should be designed and balanced so that air flows from less contaminated (i.e., more clean) to more contaminated (less clean) areas (*47,48*). For example, air should flow from corridors (cleaner areas) into TB isolation rooms (less clean areas) to prevent spread of contaminants to other areas. In some special treatment rooms in which operative and invasive procedures are performed, the direction of airflow is from the room to the hallway to provide cleaner air during these procedures. Cough-inducing or aerosol-generating procedures (e.g., bronchoscopy and irrigation of tuberculous abscesses) should not be performed in rooms with this type of airflow on patients who may have infectious TB.

b. 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. 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. The lower pressure area is described as being at negative* pressure relative to the higher pressure area. Negative pressure is attained by exhausting air from an area at a higher rate than air is being supplied. The level of negative pressure necessary to achieve the desired airflow will depend on the physical configuration of the ventilation system and area, including the airflow path and flow openings, and should be determined on an individual basis by an experienced ventilation engineer.

4. Achieving negative pressure in a room

Purpose: To control the direction of airflow between the room and adjacent areas, thereby preventing contaminated air from escaping from the room into other areas of the facility.

a. Pressure differential

The minimum pressure difference necessary to achieve and maintain negative pressure that will result in airflow into the room is very small (0.001 inch of water). Higher pressures (≥0.001 inch of water) are satisfactory; however, these higher pressures may be difficult to

*Negative is defined relative to the air pressure in the area from which air is to flow.

achieve. The actual level of negative pressure achieved will depend on the difference in the ventilation exhaust and supply flows and the physical configuration of the room, including the airflow path and flow openings. If the room is well sealed, negative pressures greater than the minimum of 0.001 inch of water may be readily achieved. However, if rooms are not well sealed, as may be the case in many facilities (especially older facilities), achieving higher negative pressures may require exhaust/supply flow differentials beyond the capability of the ventilation system.

To establish negative pressure in a room that has a normally functioning ventilation system, the room supply and exhaust airflows are first balanced to achieve an exhaust flow of either 10% or 50 cubic feet per minute (cfm) greater than the supply (whichever is the greater). In most situations, this specification should achieve a negative pressure of at least 0.001 inch of water. If the minimum 0.001 inch of water 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 (e.g., through doors, windows, plumbing, and equipment wall penetrations), and corrective action should be taken to seal the leaks.

Negative pressure in a room can be altered by changing the ventilation system operation or by the opening and closing of the room's doors, corridor doors, or windows. When an operating configuration has been established, it is essential that all doors and windows remain properly closed in the isolation room and other areas (e.g., doors in corridors that affect air pressure) except when persons need to enter or leave the room or area.

b. Alternate methods for achieving negative pressure

Although an anteroom is not a substitute for negative pressure in a room, it may be used to reduce escape of droplet nuclei during opening and closing of the isolation room door. Some anterooms have their own air supply duct, but others do not. The TB isolation room should have negative pressure relative to the anteroom, but the air pressure in the anteroom relative to the corridor may vary depending on the building design. This should be determined, in accordance with applicable regulations, by a qualified ventilation engineer.

If the existing ventilation system is incapable of achieving the desired negative pressure because the room lacks a separate ventilation system or the room's system cannot provide the proper airflow, steps should be taken to provide a means to discharge air from the room. The amount of air to be exhausted will be the same as discussed previously (Suppl. 3, Section II.B.4.a).

Fixed room-air recirculation systems (i.e., systems that recirculate the air in an entire room) may be designed to achieve negative pressure by discharging air outside the room (Suppl. 3, Section II.C.3).

Some portable room-air recirculation units (Suppl. 3, Section II.C.3.b.) are designed to discharge air to the outside to achieve negative pressure. Air cleaners that can accomplish this must be designed specifically for this purpose.

A small centrifugal blower (i.e., exhaust fan) can be used to exhaust air to the outside through a window or outside wall. This approach may be used as an interim measure to achieve negative pressure, but it provides no fresh air and suboptimal dilution.

Another approach to achieving the required pressure difference is to pressurize the corridor. Using this method, the corridor's general ventilation system is balanced to create a higher air pressure in the corridor than in the isolation room; the type of balancing necessary depends on the configuration of the ventilation system. Ideally, the corridor air supply rate should be increased while the corridor exhaust rate is not increased. If this is not possible, the exhaust rate should be decreased by resetting appropriate exhaust dampers. Caution should be exercised, however, to ensure that the exhaust rate is not reduced below acceptable levels. This approach requires that all settings used to achieve the pressure balance, including doors, be maintained. This method may not be desirable if the corridor being pressurized has rooms in which negative pressure is not desired. In many situations, this system is difficult to achieve, and it should be considered only after careful review by ventilation personnel.

c. Monitoring negative pressure

The negative pressure in a room can be monitored by visually observing the direction of airflow (e.g., using smoke tubes) or by measuring the differential pressure between the room and its surrounding area.

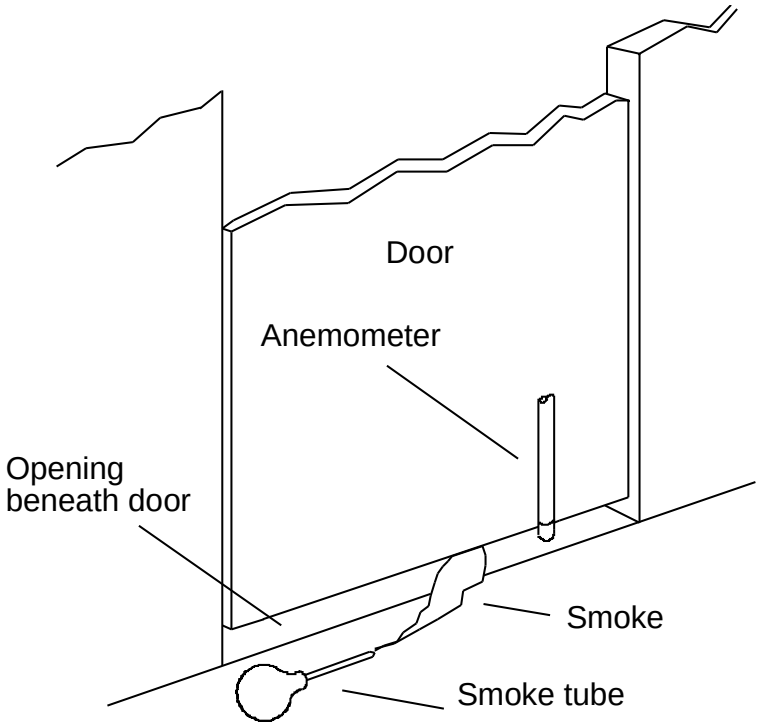
Smoke from a smoke tube can be used to observe airflow between areas or airflow patterns within an area. To check the negative pressure in a room by using a smoke tube, hold the smoke tube near the bottom of the door and approximately 2 inches in front of the door, or at the face of a grille or other opening if the door has such a feature, and generate a small amount of smoke by gently squeezing the bulb (Figure S3-3). The smoke tube should be held parallel to the door, and the smoke should be issued from the tube slowly to ensure the velocity of the smoke from the tube does not overpower the air velocity. The smoke will travel in the direction of airflow. If the room is at negative pressure, the smoke will travel under the door and into the room (e.g., from higher to lower pressure). If the room is not at negative pressure, the

smoke will be blown outward or will stay stationary. This test must be performed while the door is closed. If room air cleaners are being used in the room, they should be running. The smoke is irritating if inhaled, and care should be taken not to inhale it directly from the smoke tube. However, the quantity of smoke issued from the tube is minimal and is not detectable at short distances from the tube.

Differential pressure-sensing devices also can be used to monitor negative pressure; they can provide either periodic (noncontinuous) pressure measurements or continuous pressure monitoring. The continuous monitoring component may simply be a visible and/or audible warning signal that air pressure is low. In addition, it may also provide a pressure readout signal, which can be recorded for later verification or used to automatically adjust the facility's ventilation control system.

Pressure-measuring devices should sense the room pressure just inside the airflow path into the room (e.g., at the bottom of the door). Unusual airflow patterns within the room can cause pressure variations; for example, the air can be at negative pressure at the middle of a door and at

FIGURE S3-3. Smoke-tube testing and anemometer placement to determine the direction of airflow into and out of a room*



* Smoke flowing into the room indicates the room is at negative pressure relative to the corridor, and smoke flowing out of the room indicates the room is at positive pressure relative to the corridor. The anemometer, if used, is placed with the sensor in the airflow path at the bottom of the door.

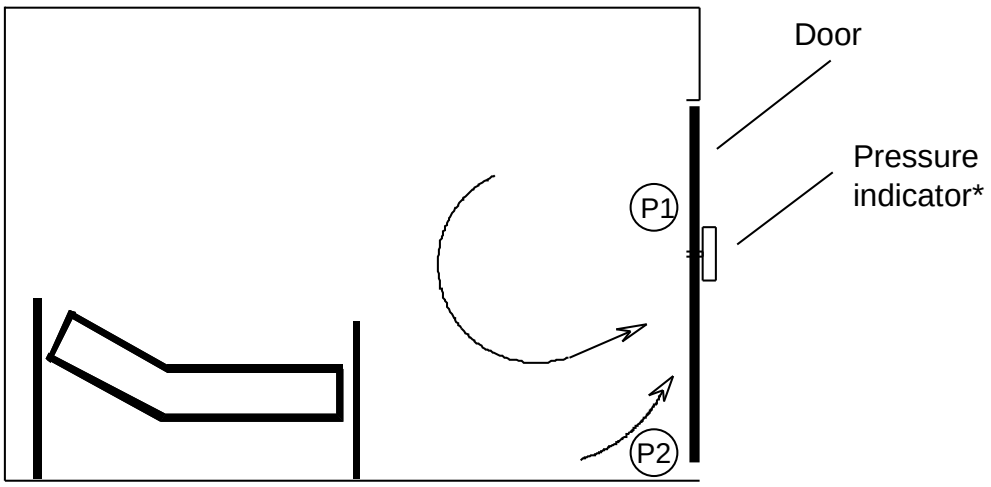
positive pressure at the bottom of the same door (Figure S3-4). If the pressure-sensing ports of the device cannot be located directly across the airflow path, it will be necessary to validate that the negative pressure at the sensing point is and remains the same as the negative pressure across the flow path.

Pressure-sensing devices should incorporate an audible warning with a time delay to indicate that a door is open. When the door to the room is opened, the negative pressure will decrease. The time-delayed signal should allow sufficient time for persons to enter or leave the room without activating the audible warning.

A potential problem with using pressure-sensing devices is that the pressure differentials used to achieve the low negative pressure necessitate the use of very sensitive mechanical devices, electronic devices, or pressure gauges to ensure accurate measurements. Use of devices that cannot measure these low pressures (i.e., pressures as low as 0.001 inch of water) will require setting higher negative pressures that may be difficult and, in some instances, impractical to achieve (Suppl. 3, Section II.B.4).

Periodic checks are required to ensure that the desired negative pressure is present and that the continuous monitoring devices, if used, are operating properly. If smoke tubes or other visual checks are used, TB isolation rooms and treatment rooms should be checked frequently for negative pressure. Rooms undergoing changes to the ventilation

FIGURE S3-4. Cross-sectional view of a room showing the location of negative pressure measurement



Airflow pressure at Position 1 may differ from Position 2.

Measure pressure at Position 2 to correctly identify negative pressure.

*Located on door frame.

system should be checked daily. TB isolation rooms should be checked daily for negative pressure while being used for TB isolation. If these rooms are not being used for patients who have suspected or confirmed TB but potentially could be used for such patients, the negative pressure in the rooms should be checked monthly. If pressure-sensing devices are used, negative pressure should be verified at least once a month by using smoke tubes or taking pressure measurements.

C. HEPA filtration

Purpose: To remove contaminants from the air.

HEPA filtration can be used as a method of air cleaning that supplements other recommended ventilation measures. For the purposes of these guidelines, HEPA filters are defined as air-cleaning devices that have a demonstrated and documented minimum removal efficiency of 99.97% of particles ≥0.3 μm in diameter. HEPA filters have been shown to be effective in reducing the concentration of *Aspergillus* spores (which range in size from 1.5 μm to 6 μm) to below measurable levels (*100–102*). The ability of HEPA filters to remove tubercle bacilli from the air has not been studied, but *M. tuberculosis* droplet nuclei probably range from 1 μm to 5 μm in diameter (i.e., approximately the same size as *Aspergillus* spores). Therefore, HEPA filters can be expected to remove infectious droplet nuclei from contaminated air. HEPA filters can be used to clean air before it is exhausted to the outside, recirculated to other areas of a facility, or recirculated within a room. If the device is not completely passive (e.g., it utilizes techniques such as electrostatics) and the failure of the electrostatic components permits loss of filtration efficiency to <99.97%, the device should not be used in systems that recirculate air back into the general facility ventilation system from TB isolation rooms and treatment rooms in which procedures are performed on patients who may have infectious TB (Suppl. 3, Section II.C.2).

HEPA filters can be used in a number of ways to reduce or eliminate infectious droplet nuclei from room air or exhaust. These methods include placement of HEPA filters a) in exhaust ducts to remove droplet nuclei from air being discharged to the outside, either directly or through ventilation equipment; b) in ducts discharging room air into the general ventilation system; and c) in fixed or portable room-air cleaners. The effectiveness of portable HEPA room-air cleaning units has not been evaluated adequately, and there is probably considerable variation in their effectiveness. HEPA filters can also be used in exhaust ducts or vents that discharge air from booths or enclosures into the surrounding room (Suppl. 3, Section II.A.3). In any application, HEPA filters should be installed carefully and maintained meticulously to ensure adequate function.

Manufacturers of room-air cleaning equipment should provide documentation of the HEPA filter efficiency and the efficiency of the installed device in lowering room-air contaminant levels.

1. Use of HEPA filtration when exhausting air to the outside

HEPA filters can be used as an added safety measure to clean air from isolation rooms and local exhaust devices (i.e., booths, tents, or hoods used for cough-inducing procedures) before exhausting it directly to the outside, but such use is unnecessary if the exhaust air cannot re-enter the ventilation system supply. The use of HEPA filters should be considered wherever exhaust air could possibly reenter the system.

In many instances, exhaust air is not discharged directly to the outside; rather, the air is directed through heat-recovery devices (e.g., heat wheels). Heat wheels are often used to reduce the costs of operating ventilation systems (*103*). If such units are used with the system, a HEPA filter should also be used. As the wheel rotates, energy is transferred into or removed from the supply inlet air stream. The HEPA filter should be placed upstream from the heat wheel because of the potential for leakage across the seals separating the inlet and exhaust chambers and the theoretical possibility that droplet nuclei could be impacted on the wheel by the exhaust air and subsequently stripped off into the supply air.

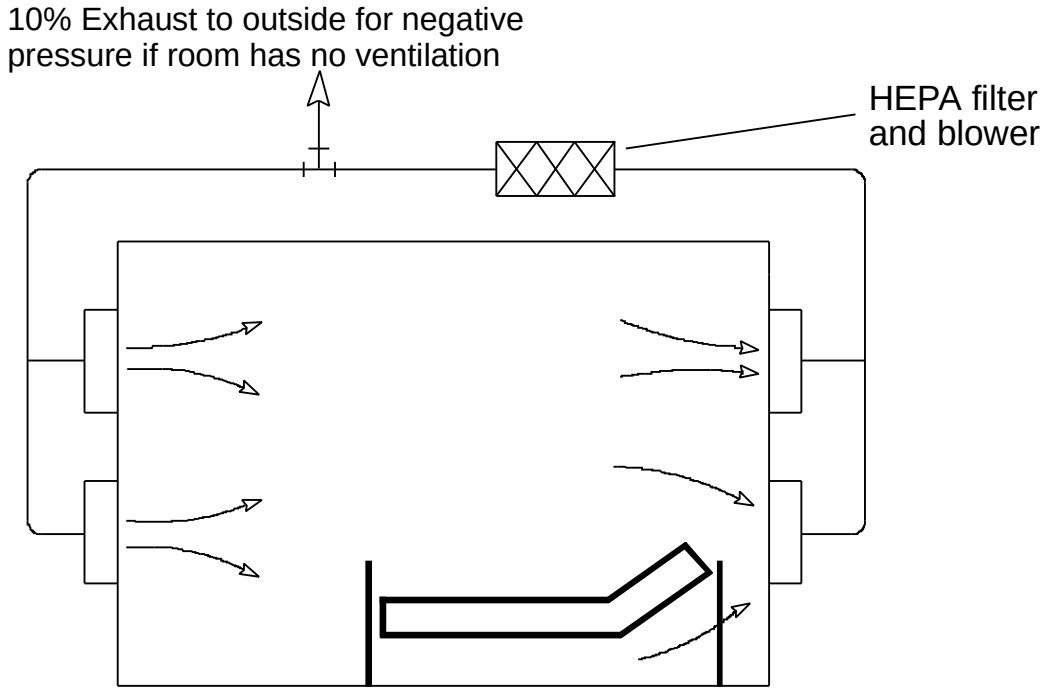
2. Recirculation of HEPA-filtered air to other areas of a facility

Air from TB isolation rooms and treatment rooms used to treat patients who have confirmed or suspected infectious TB should be exhausted to the outside in accordance with applicable federal, state, and local regulations. The air should not be recirculated into the general ventilation. In some instances, recirculation of air into the general ventilation system from such rooms is unavoidable (i.e., in existing facilities in which the ventilation system or facility configuration makes venting the exhaust to the outside impossible). In such cases, HEPA filters should be installed in the exhaust duct leading from the room to the general ventilation system to remove infectious organisms and particulates the size of droplet nuclei from the air before it is returned to the general ventilation system (Section II.F; Suppl. 3). Air from TB isolation rooms and treatment rooms in new or renovated facilities should not be recirculated into the general ventilation system.

3. Recirculation of HEPA-filtered air within a room

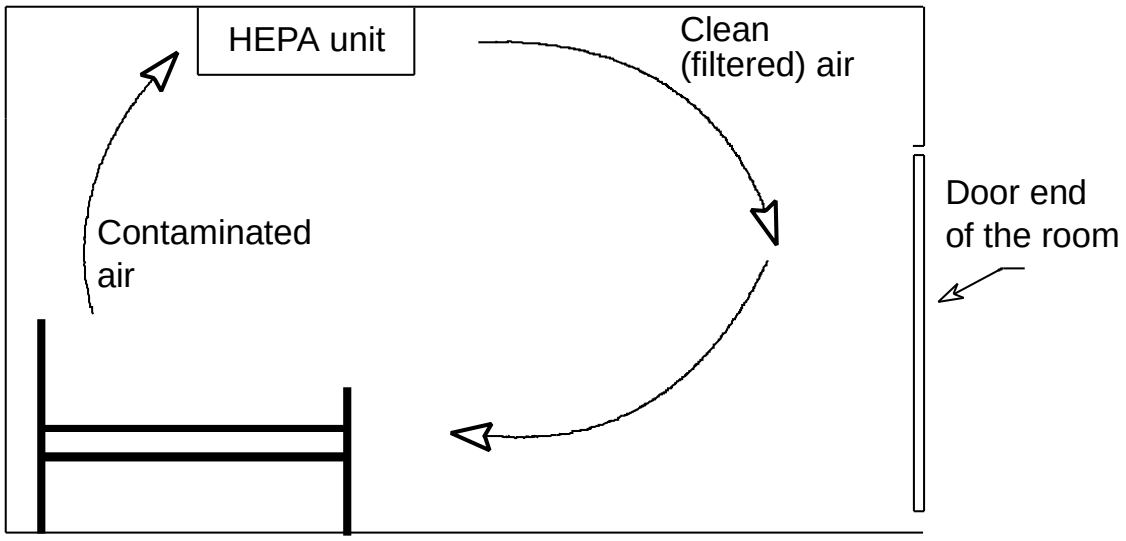
Individual room-air recirculation can be used in areas where there is no general ventilation system, where an existing system is incapable of providing adequate airflow, or where an increase in ventilation is desired without affecting the fresh air supply or negative pressure system already in place. Recirculation of HEPA-filtered air within a room can be achieved in several ways: a) by exhausting air from the room into a duct, filtering it through a HEPA filter installed in the duct, and returning it to the room (Figure S3-5); b) by filtering air through HEPA recirculation systems mounted on the wall or ceiling of the room (Figure S3-6); or c) by filtering air through portable HEPA recirculation systems. In this document, the first two of these

FIGURE S3-5. Fixed, ducted room-air recirculation system using a high-efficiency particulate air (HEPA) filter inside an air duct*



*Such a system can be used to increase the room ventilation rate.

FIGURE S3-6. Fixed ceiling-mounted room-air recirculation system using a high-efficiency particulate air (HEPA) filter*



*Such a system can be used to increase the room ventilation rate. Position the HEPA unit one third of the room's length from the patient's end of the room.

approaches are referred to as fixed room-air recirculation systems, because the HEPA filter devices are fixed in place and are not easily movable.

a. Fixed room-air recirculation systems

The preferred method of recirculating HEPA-filtered air within a room is a built-in system, in which air is exhausted from the room into a duct, filtered through a HEPA filter, and returned to the room (Figure S3-5). This technique may be used to add air changes in areas where there is a recommended minimum ACH that is difficult to meet with general ventilation alone. The air does not have to be conditioned, other than by the filtration, and this permits higher airflow rates than the general ventilation system can usually achieve. An alternative is the use of HEPA filtration units that are mounted on the wall or ceiling of the room (Figure S3-7). Fixed recirculation systems are preferred over portable (free-standing) units because they can be installed and maintained with a greater degree of reliability.

b. Portable room-air recirculation units

Portable HEPA filtration units may be considered for recirculating air within rooms in which there is no general ventilation system, where the system is incapable of providing adequate airflow, or where increased effectiveness in room airflow is desired. Effectiveness depends on circulating as much of the air in the room as possible through the HEPA filter, which may be difficult to achieve and evaluate. The effectiveness of a particular unit can vary depending on the room's configuration, the furniture and persons in the room, and placement of the HEPA filtration unit and the supply and exhaust grilles. Therefore, the effectiveness of the portable unit may vary considerably in rooms with different configurations or in the same room if moved from one location to another in the room. If portable units are used, caution should be exercised to ensure they can recirculate all or nearly all of the room air through the HEPA filter. Some commercially available units may not be able to meet this requirement because of design limitations or insufficient airflow capacity. In addition, units should be designed and operated to ensure that persons in the room cannot interfere with or otherwise compromise the functioning of the unit. Portable HEPA filtration units have not been evaluated adequately to determine their role in TB infection-control programs.

Portable HEPA filtration units should be designed to achieve the equivalent of ≥12 ACH. They should also be designed to ensure adequate air mixing in all areas of the hospital rooms in which they are used, and they should not interfere with the current ventilation system.

Some HEPA filtration units employ UVGI for disinfecting air after HEPA filtration. However, whether exposing the HEPA-filtered air to UV

irradiation further decreases the concentration of contaminants is not known.

c. Evaluation of room-air recirculation systems and units

Detailed and accurate evaluations of room-air recirculation systems and units require the use of sophisticated test equipment and lengthy test procedures that are not practical. However, an estimate of the unit's ability to circulate the air in the room can be made by visualizing airflow patterns as was described previously for estimating room air mixing (Suppl. 3, Section II.B.1). If the air movement is good in all areas of the room, the unit should be effective.

4. Installing, maintaining, and monitoring HEPA filters

Proper installation and testing and meticulous maintenance are critical if a HEPA filtration system is used (*104*), especially if the system used recirculates air to other parts of the facility. Improper design, installation, or maintenance could allow infectious particles to circumvent filtration and escape into the general ventilation system (*47*). HEPA filters should be installed to prevent leakage between filter segments and between the filter bed and its frame. A regularly scheduled maintenance program is required to monitor the HEPA filter for possible leakage and for filter loading. A quantitative leakage and filter performance test (e.g., the dioctal phthalate [DOP] penetration test [*105*]) should be performed at the initial installation and every time the filter is changed or moved. The test should be repeated every 6 months for filters in general-use areas and in areas with systems that exhaust air that is likely to be contaminated with *M. tuberculosis* (e.g, TB isolation rooms).

A manometer or other pressure-sensing device should be installed in the filter system to provide an accurate and objective means of determining the need for filter replacement. Pressure drop characteristics of the filter are supplied by the manufacturer of the filter. Installation of the filter should allow for maintenance that will not contaminate the delivery system or the area served. For general infection-control purposes, special care should be taken to not jar or drop the filter element during or after removal.

The scheduled maintenance program should include procedures for installation, removal, and disposal of filter elements. HEPA filter maintenance should be performed only by adequately trained personnel. Appropriate respiratory protection should be worn while performing maintenance and testing procedures. In addition, filter housing and ducts leading to the housing should be labelled clearly with the words "Contaminated Air" (or a similar warning).

When a HEPA filter is used, one or more lower efficiency disposable prefilters installed upstream will extend the useful life of the HEPA filter. A

disposable filter can increase the life of a HEPA filter by 25%. If the disposable filter is followed by a 90% extended surface filter, the life of the HEPA filter can be extended almost 900% (*98*). These prefilters should be handled and disposed of in the same manner as the HEPA filter.

D. TB Isolation Rooms and Treatment Rooms

Purpose: To separate patients who are likely to have infectious TB from other persons, to provide an environment that will allow reduction of the concentration of droplet nuclei through various engineering methods, and to prevent the escape of droplet nuclei from such rooms into the corridor and other areas of the facility using directional airflow.

A hierarchy of ventilation methods used to achieve a reduction in the concentration of droplet nuclei and to achieve directional airflow using negative pressure has been developed (Table S3-2). The methods are listed in order from the most desirable to the least desirable. The method selected will depend on the configuration of the isolation room and the ventilation system in the facility; the determination should be made in consultation with a ventilation engineer.

TABLE S3-2. Hierarchy of ventilation methods for tuberculosis (TB) isolation rooms and treatment rooms

Reducing concentration of airborne tubercle bacilli*	Achieving directional airflow using negative pressure†
1. Facility heating, ventilation, and air-conditioning (HVAC) system. 2. Fixed room-air high-efficiency particulate air (HEPA) recirculation system. 3. Wall- or ceiling-mounted room-air HEPA recirculation system. 4. Portable room-air HEPA recirculation unit.¶	1. Facility HVAC system. 2. Bleed air§ from fixed room-air HEPA recirculation system. 3. Bleed air from wall- or ceiling-mounted room-air HEPA recirculation system. 4. Bleed air from portable room-air HEPA recirculation unit.¶ 5. Exhaust air from room through window-mounted fan.**

*Ventilation methods are used to reduce the concentration of airborne tubercle bacilli. If the facility HVAC system cannot achieve the recommended ventilation rate, auxiliary room-air recirculation methods may be used. These methods are listed in order from the most desirable to the least desirable. Ultraviolet germicidal irradiation may be used as a supplement to any of the ventilation methods for air cleaning.

†Directional airflow using negative pressure can be achieved with the facility HVAC system and/or the auxiliary air-recirculation–cleaning systems. These methods are listed in order from the most desirable to the least desirable.

§To remove the amount of return air necessary to achieve negative pressure.

¶The effectiveness of portable room-air HEPA recirculation units can vary depending on the room's configuration, the furniture and persons in the room, the placement of the unit, the supply and exhaust grilles, and the achievable ventilation rates and air mixing. Units should be designed and operated to ensure that persons in the room cannot interfere with or otherwise compromise the function of the unit. Fixed recirculating systems are preferred over portable units in TB isolation rooms of facilities in which services are provided regularly to TB patients.

**This method simply achieves negative pressure and should be used only as a temporary measure.

1. Preventing the escape of droplet nuclei from the room

Rooms used for TB isolation should be single-patient rooms with negative pressure relative to the corridor or other areas connected to the room. Doors between the isolation room and other areas should remain closed except for entry into or exit from the room. The room's openings (e.g., windows and electrical and plumbing entries) should be sealed as much as possible. However, a small gap of ⅛ to ½ inch should be at the bottom of the door to provide a controlled airflow path. Proper use of negative pressure will prevent contaminated air from escaping the room.

2. Reducing the concentration of droplet nuclei in the room

ASHRAE (*47*), AIA (*48*), and the Health Resources and Services Administration (*49*) recommend a minimum of 6 ACH for TB isolation rooms and treatment rooms. This ventilation rate is based on comfort- and odor-control considerations. The effectiveness of this level of airflow in reducing the concentration of droplet nuclei in the room, thus reducing the transmission of airborne pathogens, has not been evaluated directly or adequately.

Ventilation rates >6 ACH are likely to produce an incrementally greater reduction in the concentration of bacteria in a room than are lower rates (*50–52*). However, accurate quantitation of decreases in risk that would result from specific increases in general ventilation levels has not been performed and may not be possible.

To reduce the concentration of droplet nuclei, TB isolation rooms and treatment rooms in existing health-care facilities should have an airflow of ≥6 ACH. Where feasible, this airflow rate should be increased to ≥12 ACH by adjusting or modifying the ventilation system or by using auxiliary means (e.g., recirculation of air through fixed HEPA filtration units or portable air cleaners) (Suppl. 3, Section II.C) (*53*). New construction or renovation of existing health-care facilities should be designed so that TB isolation rooms achieve an airflow of ≥12 ACH.

3. Exhaust from TB isolation rooms and treatment rooms

Air from TB isolation rooms and treatment rooms in which patients with infectious TB may be examined should be exhausted directly to the outside of the building and away from air-intake vents, persons, and animals in accordance with federal, state, and local regulations concerning environmental discharges. (See Suppl. 3, Section II.C, for information regarding recirculation of exhaust air.) Exhaust ducts should not be located near areas that may be populated (e.g., near sidewalks or windows that could be opened). Ventilation system exhaust discharges and inlets should be designed to prevent reentry of exhausted air. Wind blowing over a building creates a highly turbulent recirculation zone, which can cause exhausted air to reenter the building (Figure S3-7). Exhaust flow should be

discharged above this zone (Suppl. 3, Section II.C.1). Design guidelines for proper placement of exhaust ducts can be found in the 1989 *ASHRAE Fundamentals Handbook* (*106*). If recirculation of air from such rooms into the general ventilation system is unavoidable, the air should be passed through a HEPA filter before recirculation (Suppl. 3, Section II.C.2).

4. Alternatives to TB isolation rooms

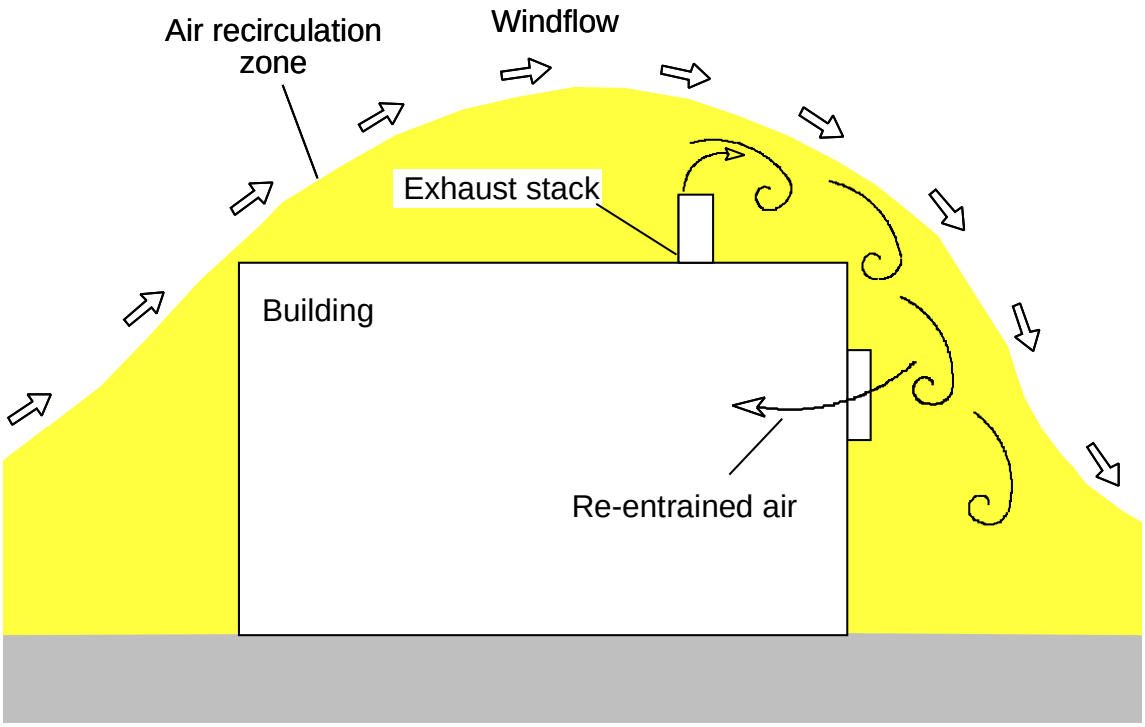
Isolation can also be achieved by use of negative-pressure enclosures (e.g, tents or booths) (Suppl. 3, Section II.A.1). These can be used to provide patient isolation in areas such as emergency rooms and medical testing and treatment areas and to supplement isolation in designated isolation rooms.

III. UVGI

Purpose: To kill or inactivate airborne tubercle bacilli.

Research has demonstrated that UVGI is effective in killing or inactivating tubercle bacilli under experimental conditions (*66,107–110*) and in reducing transmission of other infections in hospitals (*111*), military housing (*112*), and classrooms (*113–115*). Because of the results of numerous studies (*116–120*) and

FIGURE S3-7. Air recirculation zone* created by wind blowing over a building



*Height of air recirculation zone may be variable. Air should be exhausted above this zone to prevent re-entrainment.

the experiences of TB clinicians and mycobacteriologists during the past several decades, the use of UVGI has been recommended as a supplement to other TB infection-control measures in settings where the need for killing or inactivating tubercle bacilli is important (*2,4,121–125*).

UV radiation is defined as that portion of the electromagnetic spectrum described by wavelengths from 100 to 400 nm. For convenience of classification, the UV spectrum has been separated into three different wavelength bands: UV-A (long wavelengths, range: 320–400 nm), UV-B (midrange wavelengths, range: 290–320 nm), and UV-C (short wavelengths, range: 100–290 nm) (*126*). Commercially available UV lamps used for germicidal purposes are low-pressure mercury vapor lamps (*127*) that emit radiant energy in the UV-C range, predominantly at a wavelength of 253.7 nm (*128*).

A. Applications

UVGI can be used as a method of air disinfection to supplement other engineering controls. Two systems of UVGI can be used for this purpose: duct irradiation and upper-room air irradiation.

1. Duct irradiation

Purpose: To inactivate tubercle bacilli without exposing persons to UVGI.

In duct irradiation systems, UV lamps are placed inside ducts that remove air from rooms to disinfect the air before it is recirculated. When UVGI duct systems are properly designed, installed, and maintained, high levels of UV radiation may be produced in the duct work. The only potential for human exposure to this radiation occurs during maintenance operations.

Duct irradiation may be used:

- In a TB isolation room or treatment room to recirculate air from the room, through a duct containing UV lamps, and back into the room. This recirculation method can increase the overall room airflow but does not increase the supply of fresh outside air to the room.
- In other patients' rooms and in waiting rooms, emergency rooms, and other general-use areas of a facility where patients with undiagnosed TB could potentially contaminate the air, to recirculate air back into the general ventilation.

  Duct-irradiation systems are dependent on airflow patterns within a room that ensure that all or nearly all of the room air circulates through the duct.

2. Upper-room air irradiation

Purpose: To inactivate tubercle bacilli in the upper part of the room, while minimizing radiation exposure to persons in the lower part of the room.

In upper-room air irradiation, UVGI lamps are suspended from the ceiling or mounted on the wall. The bottom of the lamp is shielded to direct the radiation upward but not downward. The system depends on air mixing to take irradiated air from the upper to the lower part of the room, and non-irradiated air from the lower to the upper part. The irradiated air space is much larger than that in a duct system.

UVGI has been effective in killing bacteria under conditions where air mixing was accomplished mainly by convection. For example, BCG was atomized in a room that did not have supplemental ventilation (*120*), and in another study a surrogate bacteria, *Serratia marcesens*, was aerosolized in a room with a ventilation rate of 6 ACH (*129*). These reports estimated the effect of UVGI to be equivalent to 10 and 39 ACH, respectively, for the organisms tested, which are less resistant to UVGI than *M. tuberculosis* (*120*). The addition of fans or some heating/air conditioning arrangements may double the effectiveness of UVGI lamps (*130–132*). Greater rates of ventilation, however, may decrease the length of time the air is irradiated, thus decreasing the killing of bacteria (*117,129*). The optimal relationship between ventilation and UVGI is not known. Air irradiation lamps used in corridors have been effective in killing atomized *S. marcesens* (*133*). Use of UVGI lamps in an outpatient room has reduced culturable airborne bacteria by 14%–19%. However, the irradiation did not reduce the concentration of gram-positive, rod-shaped bacteria; although fast-growing mycobacteria were cultured, *M. tuberculosis* could not be recovered from the room's air samples because of fungal overgrowth of media plates (*134*).

Upper-room air UVGI irradiation may be used:

- In isolation or treatment rooms as a supplemental method of air cleaning.
- In other patients' rooms and in waiting rooms, emergency rooms, corridors, and other central areas of a facility where patients with undiagnosed TB could potentially contaminate the air.

  Determinants of UVGI effectiveness include room configuration, UV lamp placement, and the adequacy of airflow patterns in bringing contaminated air into contact with the irradiated upper-room space. Air mixing may be facilitated by supplying cool air near the ceiling in rooms where warmer air (or a heating device) is present below. The ceiling should be high enough for a large volume of upper-room air to be irradiated without HCWs and patients being overexposed to UV radiation.

B. Limitations

Because the clinical effectiveness of UV systems varies, and because of the risk for transmission of *M. tuberculosis* if a system malfunctions or is maintained improperly, UVGI is not recommended for the following specific applications:

1. Duct systems using UVGI are not recommended as a substitute for HEPA filters if air from isolation rooms must be recirculated to other areas of a facility.

2. UVGI alone is not recommended as a substitute for HEPA filtration or local exhaust of air to the outside from booths, tents, or hoods used for cough-inducing procedures.

3. UVGI is not a substitute for negative pressure.

The use of UV lamps and HEPA filtration in a single unit would not be expected to have any infection-control benefits not provided by use of the HEPA filter alone.

The effectiveness of UVGI in killing airborne tubercle bacilli depends on the intensity of UVGI, the duration of contact the organism has with the irradiation, and the relative humidity (*66,108,111*). Humidity can have an adverse effect on UVGI effectiveness at levels >70% relative humidity for *S. marcescens* (*135*). The interaction of these factors has not been fully defined, however, making precise recommendations for individual UVGI installations difficult to develop.

Old lamps or dust-covered UV lamps are less effective; therefore, regular maintenance of UVGI systems is crucial.

C. Safety Issues

Short-term overexposure to UV radiation can cause erythema and keratoconjunctivitis (*136,137*). Broad-spectrum UV radiation has been associated with increased risk for squamous and basal cell carcinomas of the skin (*138*). UV-C was recently classified by the International Agency for Research on Cancer as "probably carcinogenic to humans (Group 2A)" (*138*). This classification is based on studies suggesting that UV-C radiation can induce skin cancers in animals; DNA damage, chromosomal aberrations and sister chromatid exchange and transformation in human cells in vitro; and DNA damage in mammalian skin cells in vivo. In the animal studies, a contribution of UV-B to the tumor effects could not be excluded, but the effects were greater than expected for UV-B alone (*138*). Although some recent studies have demonstrated that UV radiation can activate HIV gene promoters (i.e., the genes in HIV that prompt replication of the virus) in laboratory samples of human cells (*139–144*), the implications of these in vitro findings for humans are unknown.

In 1972, the National Institute for Occupational Safety and Health (NIOSH) published a recommended exposure limit (REL) for occupational exposure to UV radiation (*136*). The REL is intended to protect workers from the acute effects of UV exposure (e.g., erythema and photokeratoconjunctivitis). However, photosensitive persons and those exposed concomitantly to photoactive chemicals may not be protected by the recommended standard.

If proper procedures are not followed, HCWs performing maintenance on such fixtures are at risk for exposure to UV radiation. Because UV fixtures used for upper-room air irradiation are present in rooms, rather than hidden in ducts, safety may be much more difficult to achieve and maintain. Fixtures must be designed and installed to ensure that UV exposure to persons in the room (including HCWs and inpatients) are below current safe exposure levels. Recent health hazard evaluations conducted by CDC have noted problems with overexposure of HCWs to UVGI and with inadequate maintenance, training, labelling, and use of personal protective equipment (*145–147*).

The current number of persons who are properly trained in UVGI system design and installation is limited. CDC strongly recommends that a competent UVGI system designer be consulted to address safety considerations before such a system is procured and installed. Experts who might be consulted include industrial hygienists, engineers, and health physicists. Principles for the safe installation of UV lamp fixtures have been developed and can be used as guidelines (*148,149*).

If UV lamps are being used in a facility, the general TB education of HCWs should include:

1. The basic principles of UVGI systems (i.e., how they work and what their limitations are).

2. The potential hazardous effects of UVGI if overexposure occurs.

3. The potential for photosensitivity associated with certain medical conditions or use of some medications.

4. The importance of general maintenance procedures for UVGI fixtures.

Exposure to UV intensities above the REL should be avoided. Lightweight clothing made of tightly woven fabric and UV-absorbing sunscreens with solar-protection factors (SPFs) ≥15 may help protect photosensitive persons. HCWs should be advised that any eye or skin irritation that develops after UV exposure should be examined by occupational health staff.

D. Exposure Criteria for UV Radiation

The NIOSH REL for UV radiation is wavelength dependent because different wavelengths of UV radiation have different adverse effects on the skin and eyes (*136*). Relative spectral effectiveness (S_λ) is used to compare various UV sources with a source producing UV radiation at 270 nm, the wavelength of maximum ocular sensitivity. For example, the S_λ at 254 nm is 0.5; therefore, twice as much energy is required at 254 nm to produce an identical biologic effect at 270 nm (*136*). Thus, at 254 nm, the NIOSH REL is 0.006 joules per square centimeter (J/cm^2); and at 270 nm, it is 0.003 J/cm^2.

For germicidal lamps that emit radiant energy predominantly at a wavelength of 254 nm, proper use of the REL requires that the measured irradiance level (E) in microwatts per square centimeter ($\mu W/cm^2$) be multiplied by the relative spectral effectiveness at 254 nm (0.5) to obtain the effective irradiance (E_{eff}). The maximum permissible exposure time can then be determined for selected values of E_{eff} (Table S3-3), or it can be calculated (in seconds) by dividing 0.003 J/cm^2 (the NIOSH REL at 270 nm) by E_{eff} in $\mu W/cm^2$ (*136,150*).

To protect HCWs who are exposed to germicidal UV radiation for 8 hours per workday, the measured irradiance (E) should be $\leq 0.2\ \mu W/cm^2$. This is calculated by obtaining E_{eff} ($0.1\ \mu W/cm^2$) (Table S3-3) and then dividing this value by S_λ (0.5).

E. Maintenance and Monitoring

1. Labelling and posting

Warning signs should be posted on UV lamps and wherever high-intensity (i.e., UV exposure greater than the REL) germicidal UV irradiation is present (e.g., upper-room air space and accesses to ducts [if duct irradiation is

TABLE S3-3. Maximum permissible exposure times* for selected values of effective irradiance

Permissible exposure time per day	Effective irradiance (E_{eff})† ($\mu W/cm^2$)
8 hrs	0.1
4 hrs	0.2
2 hrs	0.4
1 hr	0.8
30 min	1.7
15 min	3.3
10 min	5.0
5 min	10.0
1 min	50.0
30 sec	100.0

*Permissible exposure times are designed to prevent acute effects of irradiation to skin and eyes (*136*). These recommended limits are wavelength dependent because different wavelengths of ultraviolet (UV) radiation have different adverse effects on these organs.

†Relative spectral effectiveness (S_λ) is used to compare various UV sources with a source producing UV radiation at 270 nm, the wavelength of maximum ocular sensitivity. For example, the relative spectral effectiveness at 254 nm is 0.5; therefore, twice as much energy is required at 254 nm to produce an identical biologic effect at 270 nm. At 254 nm, the NIOSH REL is 0.006 joules per square centimeter (J/cm^2); and at 270 nm, it is 0.003 J/cm^2. For germicidal lamps that emit radiant energy predominantly at a wavelength of 254 nm, proper use of the REL requires that the measured irradiance level (E) in microwatts per square centimeter ($\mu W/cm^2$) be multiplied by the relative spectral effectiveness at 254 nm (0.5) to obtain E_{eff}. The maximum permissible exposure time can be calculated (in seconds) by dividing 0.003 J/cm^2 (the NIOSH REL at 270 nm) by E_{eff} in $\mu W/cm^2$ (*136,150*). To protect health-care workers who are exposed to germicidal UV radiation for 8 hours per work day, the measured irradiance (E) should be $\leq 0.2\ \mu W/cm^2$, which is calculated by obtaining E_{eff} ($0.1\ \mu W/cm^2$), then dividing this value by S_λ (0.5).

used]) to alert maintenance staff or other HCWs of the hazard. Some examples are shown below:

CAUTION
ULTRAVIOLET ENERGY:
TURN OFF LAMPS BEFORE
ENTERING UPPER ROOM

CAUTION
ULTRAVIOLET ENERGY:
PROTECT EYES & SKIN

2. Maintenance

Because the intensity of UV lamps fluctuates as they age, a schedule for replacing the lamps should be developed. The schedule can be determined from either a time/use log or a system based on cumulative time. The tube should be checked periodically for dust build-up, which lessens the output of UVGI. If the tube is dirty, it should be allowed to cool, then cleaned with a damp cloth. Tubes should be replaced if they stop glowing or if they flicker to an objectionable extent. Maintenance personnel must turn off all UV tubes before entering the upper part of the room or before accessing ducts for any purpose. Only a few seconds of direct exposure to the intense UV radiation in the upper-room air space or in ducts can cause burns. Protective equipment (e.g., gloves and goggles [and/or face shields]) should be worn if exposure greater than the recommended standard is anticipated.

Banks of UVGI tubes can be installed in ventilating ducts. Safety devices should be used on access doors to eliminate hazard to maintenance personnel. For duct irradiation systems, the access door for servicing the lamps should have an inspection window* through which the lamps are checked periodically for dust build-up and malfunctioning. The access door should have a warning sign written in languages appropriate for maintenance personnel to alert them to the health hazard of looking directly at bare tubes. The lock for this door should have an automatic electric switch or other device that turns off the lamps when the door is opened.

Two types of fixtures are used in upper-room air irradiation: wall-mounted fixtures that have louvers to block downward radiation and ceiling-mounted fixtures that have baffles to block radiation below the horizontal plane of the UV tube. The actual UV tube in either type of fixture must not be visible from any normal position in the room. Light switches that can be locked should be used, if possible, to prevent injury to personnel who might unintentionally turn the lamps on during maintenance procedures.

*Ordinary glass (not quartz) is sufficient to filter out UV radiation.

In most applications, properly shielding the UV lamps to provide protection from most, if not all, of the direct UV radiation is not difficult. However, radiation reflected from glass, polished metal, and high-gloss ceramic paints can be harmful to persons in the room, particularly if more than one UV lamp is in use. Surfaces in irradiated rooms that can reflect UVGI into occupied areas of the room should be covered with non-UV reflecting material.

3. Monitoring

A regularly scheduled evaluation of the UV intensity to which HCWs, patients, and others are exposed should be conducted.

UV measurements should be made in various locations within a room using a detector designed to be most sensitive at 254 nm. Equipment used to measure germicidal UV radiation should be maintained and calibrated on a regular schedule.

A new UV installation must be carefully checked for hot spots (i.e., areas of the room where the REL is exceeded) by an industrial hygienist or other person knowledgeable in making UV measurements. UV radiation levels should not exceed those in the recommended guidelines.

Supplement 4: Respiratory Protection

I. Considerations for Selection of Respirators

Personal respiratory protection should be used by a) persons entering rooms where patients with known or suspected infectious TB are being isolated, b) persons present during cough-inducing or aerosol-generating procedures performed on such patients, and c) persons in other settings where administrative and engineering controls are not likely to protect them from inhaling infectious airborne droplet nuclei. These other settings should be identified on the basis of the facility's risk assessment.

Although data regarding the effectiveness of respiratory protection from many hazardous airborne materials have been collected, the precise level of effectiveness in protecting HCWs from *M. tuberculosis* transmission in health-care settings has not been determined. Information concerning the transmission of *M. tuberculosis* is incomplete. Neither the smallest infectious dose of *M. tuberculosis* nor the highest level of exposure to *M. tuberculosis* at which transmission will not occur has been defined conclusively (*59,151,152*). Furthermore, the size distribution of droplet nuclei and the number of particles containing viable *M. tuberculosis* that are expelled by infectious TB patients have not been defined adequately, and accurate methods of measuring the concentration of infectious droplet nuclei in a room have not been developed.

Nevertheless, in certain settings the administrative and engineering controls may not adequately protect HCWs from airborne droplet nuclei (e.g., in TB isolation rooms, treatment rooms in which cough-inducing or aerosol-generating procedures are performed, and ambulances during the transport of infectious TB patients). Respiratory protective devices used in these settings should have characteristics that are suitable for the organism they are protecting against and the settings in which they are used.

A. Performance Criteria for Personal Respirators for Protection Against Transmission of *M. tuberculosis*

Respiratory protective devices used in health-care settings for protection against *M. tuberculosis* should meet the following standard criteria. These criteria are based on currently available information, including a) data on the effectiveness of respiratory protection against noninfectious hazardous materials in workplaces other than health-care settings and on an interpretation of how these data can be applied to respiratory protection against *M. tuberculosis*; b) data on the efficiency of respirator filters in filtering biological aerosols; c) data on face-seal leakage; and d) data on the characteristics of respirators that were used in conjunction with administrative and engineering controls in outbreak settings where transmission to HCWs and patients was terminated.

1. The ability to filter particles 1 μm in size in the unloaded state with a filter efficiency of ≥95% (i.e., filter leakage of ≤5%), given flow rates of up to 50 L per minute.

Available data suggest that infectious droplet nuclei range in size from 1 μm to 5 μm; therefore, respirators used in health-care settings should be able to efficiently filter the smallest particles in this range. Fifty liters per minute is a reasonable estimate of the highest airflow rate an HCW is likely to achieve during breathing, even while performing strenuous work activities.

2. The ability to be qualitatively or quantitatively fit tested in a reliable way to obtain a face-seal leakage of ≤10% (*54,55*).

3. The ability to fit the different facial sizes and characteristics of HCWs, which can usually be met by making the respirators available in at least three sizes.

4. The ability to be checked for facepiece fit, in accordance with OSHA standards and good industrial hygiene practice, by HCWs each time they put on their respirators (*54,55*).

In some settings, HCWs may be at risk for two types of exposure: a) inhalation of *M. tuberculosis* and b) mucous membrane exposure to fluids that may contain bloodborne pathogens. In these settings, protection against both types of exposure should be used.

When operative procedures (or other procedures requiring a sterile field) are performed on patients who may have infectious TB, respiratory protection worn by the HCW should serve two functions: a) it should protect the surgical field from the respiratory secretions of the HCW and b) it should protect the HCW from infectious droplet nuclei that may be expelled by the patient or generated by the procedure. Respirators with expiration valves and positive-pressure respirators do not protect the sterile field; therefore, a respirator that does not have a valve and that meets the criteria in Supplement 4, Section I.A, should be used.

B. Specific Respirators

The OSHA respiratory protection standard requires that all respiratory protective devices used in the workplace be certified by NIOSH.* NIOSH-approved HEPA respirators are the only currently available air-purifying respirators that meet or exceed the standard performance criteria stated above. However, the NIOSH certification procedures are currently being revised (*153*). Under the proposed revision, filter materials would be tested at a flow rate of 85 L/min for penetration by particles with a median aerodynamic diameter of 0.3 μm and, if certified, would be placed in one of the following categories: type A, which has ≥99.97% efficiency (similar to current HEPA filter media); type B, ≥99% efficiency; or type C, ≥95% efficiency. According to this proposed scheme, type C filter material would meet or exceed the standard performance criteria specified in this document.

*29 CFR Part 1910.134.

The facility's risk assessment may identify a limited number of selected settings (e.g., bronchoscopy performed on patients suspected of having TB or autopsy performed on deceased persons suspected of having had active TB at the time of death) where the estimated risk for transmission of *M. tuberculosis* may be such that a level of respiratory protection exceeding the standard criteria is appropriate. In such circumstances, a level of respiratory protection exceeding the standard criteria and compatible with patient-care delivery (e.g., negative-pressure respirators that are more protective; powered air-purifying particulate respirators [PAPRs]; or positive-pressure airline, half-mask respirators) should be provided by employers to HCWs who are exposed to *M. tuberculosis*. Information on these and other respirators may be found in the *NIOSH Guide to Industrial Respiratory Protection* (*55*).

C. The Effectiveness of Respiratory Protective Devices

The following information, which is based on experience with respiratory protection in the industrial setting, summarizes the available data about the effectiveness of respiratory protection against hazardous airborne materials. Data regarding protection against transmission of *M. tuberculosis* are not available.

The parameters used to determine the effectiveness of a respiratory protective device are face-seal efficacy and filter efficacy.

1. Face-seal leakage

Face-seal leakage compromises the ability of particulate respirators to protect HCWs from airborne materials (*154–156*). A proper seal between the respirator's sealing surface and the face of the person wearing the respirator is essential for effective and reliable performance of any negative-pressure respirator. This seal is less critical, but still important, for positive-pressure respirators. Face-seal leakage can result from various factors, including incorrect facepiece size or shape, incorrect or defective facepiece sealing-lip, beard growth, perspiration or facial oils that can cause facepiece slippage, failure to use all the head straps, incorrect positioning of the facepiece on the face, incorrect head strap tension or position, improper respirator maintenance, and respirator damage.

Every time a person wearing a negative-pressure particulate respirator inhales, a negative pressure (relative to the workplace air) is created inside the facepiece. Because of this negative pressure, air containing contaminants can take a path of least resistance into the respirator—through leaks at the face-seal interface—thus avoiding the higher-resistance filter material. Currently available, cup-shaped, disposable particulate respirators have from 0 to 20% face-seal leakage (*55,154*). This face-seal leakage results from the variability of the human face and from limitations in the respirator's design, construction, and number of sizes available. The face-

seal leakage is probably higher if the respirator is not fitted properly to the HCW's face, tested for an adequate fit by a qualified person, and then checked for fit by the HCW every time the respirator is put on. Face-seal leakage may be reduced to <10% with improvements in design, a greater variety in available sizes, and appropriate fit testing and fit checking.

In comparison with negative-pressure respirators, positive-pressure respirators produce a positive pressure inside the facepiece under most conditions of use. For example, in a PAPR, a blower forcibly draws ambient air through HEPA filters, then delivers the filtered air to the facepiece. This air is blown into the facepiece at flow rates that generally exceed the expected inhalation flow rates. The positive pressure inside the facepiece reduces face-seal leakage to low levels, particularly during the relatively low inhalation rates expected in health-care settings. PAPRs with a tight-fitting facepiece have <2% face-seal leakage under routine conditions (*55*). Powered-air respirators with loose-fitting facepieces, hoods, or helmets have <4% face-seal leakage under routine conditions (*55*). Thus, a PAPR may offer lower levels of face-seal leakage than nonpowered, half-mask respirators. Full facepiece, nonpowered respirators have the same leakage (i.e., <2%) as PAPRs.

Another factor contributing to face-seal leakage of cup-shaped, disposable respirators is that some of these respirators are available in only one size. A single size may produce higher leakage for persons who have smaller or difficult-to-fit faces (*157*). The facepieces used for some reusable (including HEPA and replaceable filter, negative-pressure) and all positive-pressure particulate air-purifying respirators are available in as many as three different sizes.

2. Filter leakage

Aerosol leakage through respirator filters depends on at least five independent variables: a) the filtration characteristics for each type of filter, b) the size distribution of the droplets in the aerosol, c) the linear velocity through the filtering material, d) the filter loading (i.e., the amount of contaminant deposited on the filter), and e) any electrostatic charges on the filter and on the droplets in the aerosol (*158*).

When HEPA filters are used in particulate air-purifying respirators, filter efficiency is so high (i.e., effectively 100%) that filter leakage is not a consideration. Therefore, for all HEPA-filter respirators, virtually all inward leakage of droplet nuclei occurs at the respirator's face seal.

3. Fit testing

Fit testing is part of the respiratory protection program required by OSHA for all respiratory protective devices used in the workplace. A fit test determines whether a respiratory protective device adequately fits a particular HCW. The HCW may need to be fit tested with several devices to determine

which device offers the best fit. However, fit tests can detect only the leakage that occurs at the time of the fit testing, and the tests cannot distinguish face-seal leakage from filter leakage.

Determination of facepiece fit can involve qualitative or quantitative tests (*55*). A qualitative test relies on the subjective response of the HCW being fit tested. A quantitative test uses detectors to measure inward leakage.

Disposable, negative-pressure particulate respirators can be qualitatively fit tested with aerosolized substances that can be tasted, although the results of this testing are limited because the tests depend on the subjective response of the HCW being tested. Quantitative fit testing of disposable negative-pressure particulate respirators can best be performed if the manufacturer provides a test respirator with a probe for this purpose.

Replaceable filter, negative-pressure particulate respirators and all positive-pressure particulate respirators can be fit tested reliably, both qualitatively and quantitatively, when fitted with HEPA filters.

4. Fit checking

A fit check is a maneuver that an HCW performs before each use of the respiratory protective device to check the fit. The fit check can be performed according to the manufacturer's facepiece fitting instructions by using the applicable negative-pressure or positive-pressure test.

Some currently available cup-shaped, disposable negative-pressure particulate respirators cannot be fit checked reliably by persons wearing the devices because occluding the entire surface of the filter is difficult. Strategies for overcoming these limitations are being developed by respirator manufacturers.

5. Reuse of respirators

Conscientious respirator maintenance should be an integral part of an overall respirator program. This maintenance applies both to respirators with replaceable filters and respirators that are classified as disposable but that are reused. Manufacturers' instructions for inspecting, cleaning, and maintaining respirators should be followed to ensure that the respirator continues to function properly (*55*).

When respirators are used for protection against noninfectious aerosols (e.g., wood dust), which may be present in the air in heavy concentrations, the filter material may become occluded with airborne material. This occlusion may result in an uncomfortable breathing resistance. In healthcare settings where respirators are used for protection against biological aerosols, the concentration of infectious particles in the air is probably low; thus, the filter material in a respirator is very unlikely to become occluded with airborne material. In addition, there is no evidence that

particles impacting on the filter material in a respirator are re-aerosolized easily. For these reasons, the filter material used in respirators in the health-care setting should remain functional for weeks to months. Respirators with replaceable filters are reusable, and a respirator classified as disposable may be reused by the same HCW as long as it remains functional.

Before each use, the outside of the filter material should be inspected. If the filter material is physically damaged or soiled, the filter should be changed (in the case of respirators with replaceable filters) or the respirator discarded (in the case of disposable respirators). Infection-control personnel should develop standard operating procedures for storing, reusing, and disposing of respirators that have been designated as disposable and for disposing of replaceable filter elements.

II. Implementing a Personal Respiratory Protection Program

If personal respiratory protection is used in a health-care setting, OSHA requires that an effective personal respiratory protection program be developed, implemented, administered, and periodically reevaluated (*54,55*).

All HCWs who need to use respirators for protection against infection with *M. tuberculosis* should be included in the respiratory protection program. Visitors to TB patients should be given respirators to wear while in isolation rooms, and they should be given general instructions on how to use their respirators.

The number of HCWs included in the respiratory protection program in each facility will vary depending on a) the number of potentially infectious TB patients, b) the number of rooms or areas to which patients with suspected or confirmed infectious TB are admitted, and c) the number of HCWs needed in these rooms or areas. Where respiratory protection programs are required, they should include enough HCWs to provide adequate care for a patient with known or suspected TB should such a patient be admitted to the facility. However, administrative measures should be used to limit the number of HCWs who need to enter these rooms or areas, thus limiting the number of HCWs who need to be included in the respiratory protection program.

Information regarding the development and management of a respiratory protection program is available in technical training courses that cover the basics of personal respiratory protection. Such courses are offered by various organizations, such as NIOSH, OSHA, and the American Industrial Hygiene Association. Similar courses are available from private contractors and universities.

To be effective and reliable, respiratory protection programs must contain at least the following elements (*55,154*):

1. *Assignment of responsibility.* Supervisory responsibility for the respiratory protection program should be assigned to designated persons who have

expertise in issues relevant to the program, including infectious diseases and occupational health.

2. *Standard operating procedures.* Written standard operating procedures should contain information concerning all aspects of the respiratory protection program.

3. *Medical screening.* HCWs should not be assigned a task requiring use of respirators unless they are physically able to perform the task while wearing the respirator. HCWs should be screened for pertinent medical conditions at the time they are hired, then rescreened periodically (*55*). The screening could occur as infrequently as every 5 years. The screening process should begin with a general screening (e.g., a questionnaire) for pertinent medical conditions, and the results of the screening should then be used to identify HCWs who need further evaluation. Routine physical examination or testing with chest radiographs or spirometry is not necessary or required.

Few medical conditions preclude the use of most negative-pressure particulate respirators. HCWs who have mild pulmonary or cardiac conditions may report discomfort with breathing when wearing negative-pressure particulate respirators, but these respirators are unlikely to have adverse health effects on the HCWs. Those HCWs who have more severe cardiac or pulmonary conditions may have more difficulty than HCWs with similar but milder conditions if performing duties while wearing negative-pressure respirators. Furthermore, these HCWs may be unable to use some PAPRs because of the added weight of these respirators.

4. *Training.* HCWs who wear respirators and the persons who supervise them should be informed about the necessity for wearing respirators and the potential risks associated with not doing so. This training should also include at a minimum:

- The nature, extent, and specific hazards of *M. tuberculosis* transmission in their respective health-care facility.
- A description of specific risks for TB infection among persons exposed to *M. tuberculosis*, of any subsequent treatment with INH or other chemoprophylactic agents, and of the possibility of active TB disease.
- A description of engineering controls and work practices and the reasons why they do not eliminate the need for personal respiratory protection.
- An explanation for selecting a particular type of respirator, how the respirator is properly maintained and stored, and the operation, capabilities, and limitations of the respirator provided.
- Instruction in how the HCW wearing the respirator should inspect, put on, fit check, and correctly wear the provided respirator (i.e., achieve and maintain proper face-seal fit on the HCW's face).

- An opportunity to handle the provided respirator and learn how to put it on, wear it properly, and check the important parts.
- Instruction in how to recognize an inadequately functioning respirator.

5. *Face-seal fit testing and fit checking.* HCWs should undergo fit testing to identify a respirator that adequately fits each individual HCW. The HCW should receive fitting instructions that include demonstrations and practice in how the respirator should be worn, how it should be adjusted, and how to determine if it fits properly. The HCW should be taught to check the facepiece fit before each use.

6. *Respirator inspection, cleaning, maintenance, and storage.* Conscientious respirator maintenance should be an integral part of an overall respirator program. This maintenance applies both to respirators with replaceable filters and respirators that are classified as disposable but that are reused. Manufacturers' instructions for inspecting, cleaning, and maintaining respirators should be followed to ensure that the respirator continues to function properly (*55*).

7. *Periodic evaluation of the personal respiratory protection program.* The program should be evaluated completely at least once a year, and both the written operating procedures and program administration should be revised as necessary based on the results of the evaluation. Elements of the program that should be evaluated include work practices and employee acceptance of respirator use (i.e., subjective comments made by employees concerning comfort during use and interference with duties).

Supplement 5: Decontamination—Cleaning, Disinfecting, and Sterilizing of Patient-Care Equipment

Equipment used on patients who have TB is usually not involved in the transmission of *M. tuberculosis*, although transmission by contaminated bronchoscopes has been demonstrated (*159,160*). Guidelines for cleaning, disinfecting, and sterilizing equipment have been published (*161,162*). The rationale for cleaning, disinfecting, or sterilizing patient-care equipment can be understood more readily if medical devices, equipment, and surgical materials are divided into three general categories. These categories—critical, semicritical, and noncritical items—are defined by the potential risk for infection associated with their use (*163,164*).

Critical items are instruments that are introduced directly into the bloodstream or into other normally sterile areas of the body (e.g., needles, surgical instruments, cardiac catheters, and implants). These items should be sterile at the time of use.

Semicritical items are those that may come in contact with mucous membranes but do not ordinarily penetrate body surfaces (e.g., noninvasive flexible and rigid fiberoptic endoscopes or bronchoscopes, endotracheal tubes, and anesthesia breathing circuits). Although sterilization is preferred for these instruments, high-level disinfection that destroys vegetative microorganisms, most fungal spores, tubercle bacilli, and small nonlipid viruses may be used. Meticulous physical cleaning of such items before sterilization or high-level disinfection is essential.

Noncritical items are those that either do not ordinarily touch the patient or touch only the patient's intact skin (e.g., crutches, bedboards, blood pressure cuffs, and various other medical accessories). These items are not associated with direct transmission of *M. tuberculosis*, and washing them with detergent is usually sufficient.

Health-care facility policies should specify whether cleaning, disinfecting, or sterilizing an item is necessary to decrease the risk for infection. Decisions about decontamination processes should be based on the intended use of the item, not on the diagnosis of the patient for whom the item was used. Selection of chemical disinfectants depends on the intended use, the level of disinfection required, and the structure and material of the item to be disinfected.

Although microorganisms are ordinarily found on walls, floors, and other environmental surfaces, these surfaces are rarely associated with transmission of infections to patients or HCWs. This is particularly true with organisms such as *M. tuberculosis*, which generally require inhalation by the host for infection to occur. Therefore, extraordinary attempts to disinfect or sterilize environmental surfaces are not indicated. If a detergent germicide is used for routine cleaning, a hospital-grade, EPA-approved germicide/disinfectant that is not tuberculocidal can be used. The same routine daily cleaning procedures used in other rooms in the facility should be used to clean TB isolation rooms, and personnel should follow isolation practices while cleaning these rooms. For final cleaning of the isolation room after a patient has been discharged,

personal protective equipment is not necessary if the room has been ventilated for the appropriate amount of time (Table S3-1).

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Glossary

This glossary contains many of the terms used in the guidelines, as well as others that are encountered frequently by persons who implement TB infection-control programs. The definitions given are not dictionary definitions but are those most applicable to usage relating to TB.

Acid-fast bacilli (AFB): Bacteria that retain certain dyes after being washed in an acid solution. Most acid-fast organisms are mycobacteria. When AFB are seen on a stained smear of sputum or other clinical specimen, a diagnosis of TB should be suspected; however, the diagnosis of TB is not confirmed until a culture is grown and identified as *M. tuberculosis*.

Adherence: Refers to the behavior of patients when they follow all aspects of the treatment regimen as prescribed by the medical provider, and also refers to the behavior of HCWs and employers when they follow all guidelines pertaining to infection control.

Aerosol: The droplet nuclei that are expelled by an infectious person (e.g., by coughing or sneezing); these droplet nuclei can remain suspended in the air and can transmit *M. tuberculosis* to other persons.

AIA: The American Institute of Architects, a professional body that develops standards for building ventilation.

Air changes: The ratio of the volume of air flowing through a space in a certain period of time (i.e., the airflow rate) to the volume of that space (i.e., the room volume); this ratio is usually expressed as the number of air changes per hour (ACH).

Air mixing: The degree to which air supplied to a room mixes with the air already in the room, usually expressed as a *mixing factor*. This factor varies from 1 (for perfect mixing) to 10 (for poor mixing), and it is used as a multiplier to determine the actual airflow required (i.e., the recommended ACH multiplied by the mixing factor equals the actual ACH required).

Alveoli: The small air sacs in the lungs that lie at the end of the bronchial tree; the site where carbon dioxide in the blood is replaced by oxygen from the lungs and where TB infection usually begins.

Anergy: The inability of a person to react to skin-test antigens (even if the person is infected with the organisms tested) because of immunosuppression.

Anteroom: A small room leading from a corridor into an isolation room; this room can act as an airlock, preventing the escape of contaminants from the isolation room into the corridor.

Area: A structural unit (e.g., a hospital ward or laboratory) or functional unit (e.g., an internal medicine service) in which HCWs provide services to and share air with a specific patient population or work with clinical specimens that may contain viable *M. tuberculosis* organisms. The risk for exposure to *M. tuberculosis* in a given area

depends on the prevalence of TB in the population served and the characteristics of the environment.

ASHRAE: The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., a professional body that develops standards for building ventilation.

Asymptomatic: Without symptoms, or producing no symptoms.

Bacillus of Calmette and Guérin (BCG) vaccine: A TB vaccine used in many parts of the world.

BACTEC®: One of the most often used radiometric methods for detecting the early growth of mycobacteria in culture. It provides rapid growth (in 7–14 days) and rapid drug-susceptibility testing (in 5–6 days). When BACTEC® is used with rapid species identification methods, *M. tuberculosis* can be identified within 10–14 days of specimen collection.

Booster phenomenon: A phenomenon in which some persons (especially older adults) who are skin tested many years after infection with *M. tuberculosis* have a negative reaction to an initial skin test, followed by a positive reaction to a subsequent skin test. The second (i.e., positive) reaction is caused by a boosted immune response. Two-step testing is used to distinguish new infections from boosted reactions (see Two-step testing).

Bronchoscopy: A procedure for examining the respiratory tract that requires inserting an instrument (a bronchoscope) through the mouth or nose and into the trachea. The procedure can be used to obtain diagnostic specimens.

Capreomycin: An injectable, second-line anti-TB drug used primarily for the treatment of drug-resistant TB.

Cavity: A hole in the lung resulting from the destruction of pulmonary tissue by TB or other pulmonary infections or conditions. TB patients who have cavities in their lungs are referred to as having cavitary disease, and they are often more infectious than TB patients without cavitary disease.

Chemotherapy: Treatment of an infection or disease by means of oral or injectable drugs.

Cluster: Two or more PPD skin-test conversions occurring within a 3-month period among HCWs in a specific area or occupational group, and epidemiologic evidence suggests occupational (nosocomial) transmission.

Contact: A person who has shared the same air with a person who has infectious TB for a sufficient amount of time to allow possible transmission of *M. tuberculosis*.

Conversion, PPD: See PPD test conversion.

Culture: The process of growing bacteria in the laboratory so that organisms can be identified.

Cycloserine: A second-line, oral anti-TB drug used primarily for treating drug-resistant TB.

Directly observed therapy (DOT): An adherence-enhancing strategy in which an HCW or other designated person watches the patient swallow each dose of medication.

DNA probe: A technique that allows rapid and precise identification of mycobacteria (e.g., *M. tuberculosis* and *M. bovis*) that are grown in culture. The identification can often be completed in 2 hours.

Droplet nuclei: Microscopic particles (i.e., 1–5 μm in diameter) produced when a person coughs, sneezes, shouts, or sings. The droplets produced by an infectious TB patient can carry tubercle bacilli and can remain suspended in the air for prolonged periods of time and be carried on normal air currents in the room.

Drug resistance, **acquired:** A resistance to one or more anti-TB drugs that develops while a patient is receiving therapy and which usually results from the patient's nonadherence to therapy or the prescription of an inadequate regimen by a health-care provider.

Drug resistance, primary: A resistance to one or more anti-TB drugs that exists before a patient is treated with the drug(s). Primary resistance occurs in persons exposed to and infected with a drug-resistant strain of *M. tuberculosis*.

Drug-susceptibility pattern: The anti-TB drugs to which the tubercle bacilli cultured from a TB patient are susceptible or resistant based on drug-susceptibility tests.

Drug-susceptibility tests: Laboratory tests that determine whether the tubercle bacilli cultured from a patient are susceptible or resistant to various anti-TB drugs.

Ethambutol: A first-line, oral anti-TB drug sometimes used concomitantly with INH, rifampin, and pyrazinamide.

Ethionamide: A second-line, oral anti-TB drug used primarily for treating drug-resistant TB.

Exposure: The condition of being subjected to something (e.g., infectious agents) that could have a harmful effect. A person exposed to *M. tuberculosis* does not necessarily become infected (see Transmission).

First-line drugs: The most often used anti-TB drugs (i.e., INH, rifampin, pyrazinamide, ethambutol, and streptomycin).

Fixed room-air HEPA recirculation systems: Nonmobile devices or systems that remove airborne contaminants by recirculating air through a HEPA filter. These may be built into the room and permanently ducted or may be mounted to the wall or ceiling within the room. In either situation, they are fixed in place and are not easily movable.

Fluorochrome stain: A technique for staining a clinical specimen with fluorescent dyes to perform a microscopic examination (smear) for mycobacteria. This technique is preferable to other staining techniques because the mycobacteria can be seen easily and the slides can be read quickly.

Fomites: Linens, books, dishes, or other objects used or touched by a patient. These objects are *not* involved in the transmission of *M. tuberculosis*.

Gastric aspirate: A procedure sometimes used to obtain a specimen for culture when a patient cannot cough up adequate sputum. A tube is inserted through the mouth or nose and into the stomach to recover sputum that was coughed into the throat and then swallowed. This procedure is particularly useful for diagnosis in children, who are often unable to cough up sputum.

High-efficiency particulate air (HEPA) filter: A specialized filter that is capable of removing 99.97% of particles ≥0.3 μm in diameter and that may assist in controlling the transmission of *M. tuberculosis*. Filters may be used in ventilation systems to remove particles from the air or in personal respirators to filter air before it is inhaled by the person wearing the respirator. The use of HEPA filters in ventilation systems requires expertise in installation and maintenance.

Human immunodeficiency virus (HIV) infection: Infection with the virus that causes acquired immunodeficiency syndrome (AIDS). HIV infection is the most important risk factor for the progression of latent TB infection to active TB.

Immunosuppressed: A condition in which the immune system is not functioning normally (e.g., severe cellular immunosuppression resulting from HIV infection or immunosuppressive therapy). Immunosuppressed persons are at greatly increased risk for developing active TB after they have been infected with *M. tuberculosis*. No data are available regarding whether these persons are also at increased risk for infection with *M. tuberculosis* after they have been exposed to the organism.

Induration: An area of swelling produced by an immune response to an antigen. In tuberculin skin testing or anergy testing, the diameter of the indurated area is measured 48–72 hours after the injection, and the result is recorded in millimeters.

Infection: The condition in which organisms capable of causing disease (e.g., *M. tuberculosis*) enter the body and elicit a response from the host's immune defenses. TB infection may or may not lead to clinical disease.

Infectious: Capable of transmitting infection. When persons who have clinically active pulmonary or laryngeal TB disease cough or sneeze, they can expel droplets containing *M. tuberculosis* into the air. Persons whose sputum smears are positive for AFB are probably infectious.

Injectable: A medication that is usually administered by injection into the muscle (intramuscular [IM]) or the bloodstream (intravenous [IV]).

Intermittent therapy: Therapy administered either two or three times per week, rather than daily. Intermittent therapy should be administered only under the direct supervision of an HCW or other designated person (see Directly observed therapy [DOT]).

Intradermal: Within the layers of the skin.

Isoniazid (INH): A first-line, oral drug used either alone as preventive therapy or in combination with several other drugs to treat TB disease.

Kanamycin: An injectable, second-line anti-TB drug used primarily for treatment of drug-resistant TB.

Latent TB infection: Infection with *M. tuberculosis*, usually detected by a positive PPD skin-test result, in a person who has no symptoms of active TB and who is not infectious.

Mantoux test: A method of skin testing that is performed by injecting 0.1 mL of PPD-tuberculin containing 5 tuberculin units into the dermis (i.e., the second layer of skin) of the forearm with a needle and syringe. This test is the most reliable and standardized technique for tuberculin testing (see Tuberculin skin test and Purified protein derivative [PPD]-tuberculin test).

Multidrug-resistant tuberculosis (MDR-TB): Active TB caused by *M. tuberculosis* organisms that are resistant to more than one anti-TB drug; in practice, often refers to organisms that are resistant to both INH and rifampin with or without resistance to other drugs (see Drug resistance, acquired and Drug resistance, primary).

***M. tuberculosis* complex:** A group of closely related mycobacterial species that can cause active TB (e.g., *M. tuberculosis, M. bovis*, and *M. africanum*); most TB in the United States is caused by *M. tuberculosis*.

Negative pressure: The relative air pressure difference between two areas in a health-care facility. A room that is at negative pressure has a lower pressure than adjacent areas, which keeps air from flowing out of the room and into adjacent rooms or areas.

Nosocomial: An occurrence, usually an infection, that is acquired in a hospital or as a result of medical care.

Para-aminosalicylic acid: A second-line, oral anti-TB drug used for treating drug-resistant TB.

Pathogenesis: The pathologic, physiologic, or biochemical process by which a disease develops.

Pathogenicity: The quality of producing or the ability to produce pathologic changes or disease. Some nontuberculous mycobacteria are pathogenic (e.g., *Mycobacterium kansasii*), and others are not (e.g., *Mycobacterium phlei*).

Portable room-air HEPA recirculation units: Free-standing portable devices that remove airborne contaminants by recirculating air through a HEPA filter.

Positive PPD reaction: A reaction to the purified protein derivative (PPD)-tuberculin skin test that suggests the person tested is infected with *M. tuberculosis*. The person interpreting the skin-test reaction determines whether it is positive on the basis of the size of the induration and the medical history and risk factors of the person being tested.

Preventive therapy: Treatment of latent TB infection used to prevent the progression of latent infection to clinically active disease.

Purified protein derivative (PPD)-tuberculin: A purified tuberculin preparation that was developed in the 1930s and that was derived from old tuberculin. The standard Mantoux test uses 0.1 mL of PPD standardized to 5 tuberculin units.

Purified protein derivative (PPD)-tuberculin test: A method used to evaluate the likelihood that a person is infected with *M. tuberculosis*. A small dose of tuberculin (PPD) is injected just beneath the surface of the skin, and the area is examined 48–72 hours after the injection. A reaction is measured according to the size of the induration. The classification of a reaction as positive or negative depends on the patient's medical history and various risk factors (see Mantoux test).

Purified protein derivative (PPD)-tuberculin test conversion: A change in PPD test results from negative to positive. A conversion within a 2-year period is usually interpreted as new *M. tuberculosis* infection, which carries an increased risk for progression to active disease. A booster reaction may be misinterpreted as a new infection (see Booster phenomenon and Two-step testing).

Pyrazinamide: A first-line, oral anti-TB drug used in treatment regimens.

Radiography: A method of viewing the respiratory system by using radiation to transmit an image of the respiratory system to film. A chest radiograph is taken to view the respiratory system of a person who is being evaluated for pulmonary TB. Abnormalities (e.g., lesions or cavities in the lungs and enlarged lymph nodes) may indicate the presence of TB.

Radiometric method: A method for culturing a specimen that allows for rapid detection of bacterial growth by measuring production of CO_2 by viable organisms; also a method of rapidly performing susceptibility testing of *M. tuberculosis*.

Recirculation: Ventilation in which all or most of the air that is exhausted from an area is returned to the same area or other areas of the facility.

Regimen: Any particular TB treatment plan that specifies which drugs are used, in what doses, according to what schedule, and for how long.

Registry: A record-keeping method for collecting clinical, laboratory, and radiographic data concerning TB patients so that the data can be organized and made available for epidemiologic study.

Resistance: The ability of some strains of bacteria, including *M. tuberculosis*, to grow and multiply in the presence of certain drugs that ordinarily kill them; such strains are referred to as drug-resistant strains.

Rifampin: A first-line, oral anti-TB drug that, when used concomitantly with INH and pyrazinamide, provides the basis for short-course therapy.

Room-air HEPA recirculation systems and units: Devices (either fixed or portable) that remove airborne contaminants by recirculating air through a HEPA filter.

Second-line drugs: Anti-TB drugs used when the first-line drugs cannot be used (e.g., for drug-resistant TB or because of adverse reactions to the first-line drugs). Examples are cycloserine, ethionamide, and capreomycin.

Single-pass ventilation: Ventilation in which 100% of the air supplied to an area is exhausted to the outside.

Smear (AFB smear): A laboratory technique for visualizing mycobacteria. The specimen is smeared onto a slide and stained, then examined using a microscope. Smear results should be available within 24 hours. In TB, a large number of mycobacteria seen on an AFB smear usually indicates infectiousness. However, a positive result is not diagnostic of TB because organisms other than *M. tuberculosis* may be seen on an AFB smear (e.g., nontuberculous mycobacteria).

Source case: A case of TB in an infectious person who has transmitted *M. tuberculosis* to another person or persons.

Source control: Controlling a contaminant at the source of its generation, which prevents the spread of the contaminant to the general work space.

Specimen: Any body fluid, secretion, or tissue sent to a laboratory where smears and cultures for *M. tuberculosis* will be performed (e.g., sputum, urine, spinal fluid, and material obtained at biopsy).

Sputum: Phlegm coughed up from deep within the lungs. If a patient has pulmonary disease, an examination of the sputum by smear and culture can be helpful in evaluating the organism responsible for the infection. Sputum should not be confused with saliva or nasal secretions.

Sputum induction: A method used to obtain sputum from a patient who is unable to cough up a specimen spontaneously. The patient inhales a saline mist, which stimulates a cough from deep within the lungs.

Sputum smear, positive: AFB are visible on the sputum smear when viewed under a microscope. Persons with a sputum smear positive for AFB are considered more infectious than those with smear-negative sputum.

Streptomycin: A first-line, injectable anti-TB drug.

Symptomatic: Having symptoms that may indicate the presence of TB or another disease (see Asymptomatic).

TB case: A particular episode of clinically active TB. This term should be used only to refer to the disease itself, not the patient with the disease. By law, cases of TB must be reported to the local health department.

TB infection: A condition in which living tubercle bacilli are present in the body but the disease is not clinically active. Infected persons usually have positive tuberculin reactions, but they have no symptoms related to the infection and are not infectious. However, infected persons remain at lifelong risk for developing disease unless preventive therapy is given.

Transmission: The spread of an infectious agent from one person to another. The likelihood of transmission is directly related to the duration and intensity of exposure to *M. tuberculosis* (see Exposure).

Treatment failures: TB disease in patients who do not respond to chemotherapy and in patients whose disease worsens after having improved initially.

Tubercle bacilli: *M. tuberculosis* organisms.

Tuberculin skin test: A method used to evaluate the likelihood that a person is infected with *M. tuberculosis*. A small dose of PPD-tuberculin is injected just beneath the surface of the skin, and the area is examined 48–72 hours after the injection. A reaction is measured according to the size of the induration. The classification of a reaction as positive or negative depends on the patient's medical history and various risk factors (see Mantoux test, PPD test).

Tuberculosis (TB): A clinically active, symptomatic disease caused by an organism in the *M. tuberculosis* complex (usually *M. tuberculosis* or, rarely, *M. bovis* or *M. africanum*).

Two-step testing: A procedure used for the baseline testing of persons who will periodically receive tuberculin skin tests (e.g., HCWs) to reduce the likelihood of mistaking a boosted reaction for a new infection. If the initial tuberculin-test result is classified as negative, a second test is repeated 1–3 weeks later. If the reaction to the second test is positive, it probably represents a boosted reaction. If the second test result is also negative, the person is classified as not infected. A positive reaction to a subsequent test would indicate new infection (i.e., a skin-test conversion) in such a person.

Ultraviolet germicidal irradiation (UVGI): The use of ultraviolet radiation to kill or inactivate microorganisms.

Ultraviolet germicidal irradiation (UVGI) lamps: Lamps that kill or inactivate microorganisms by emitting ultraviolet germicidal radiation, predominantly at a wavelength of 254 nm (intermediate light waves between visible light and X-rays). UVGI lamps can be used in ceiling or wall fixtures or within air ducts of ventilation systems.

Ventilation, dilution: An engineering control technique to dilute and remove airborne contaminants by the flow of air into and out of an area. Air that contains droplet nuclei is removed and replaced by contaminant-free air. If the flow is sufficient, droplet nuclei become dispersed, and their concentration in the air is diminished.

Ventilation, local exhaust: Ventilation used to capture and remove airborne contaminants by enclosing the contaminant source (i.e., the patient) or by placing an exhaust hood close to the contaminant source.

Virulence: The degree of pathogenicity of a microorganism as indicated by the severity of the disease produced and its ability to invade the tissues of a host. *M. tuberculosis* is a virulent organism.

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