- failure to cover the mouth and nose when coughing;
- incorrect, lack of, or short duration of antituberculosis treatment; and
- undergoing cough-inducing or aerosol-generating procedures (e.g., bronchoscopy, sputum induction, and administration of aerosolized medications) (*29*).

Environmental Factors That Increase the Risk for Probability of Transmission of *M. tuberculosis*

The probability of the risk for transmission of *M. tuberculosis* is increased as a result of various environmental factors.

- Exposure to TB in small, enclosed spaces.
- Inadequate local or general ventilation that results in insufficient dilution or removal of infectious droplet nuclei.
- Recirculation of air containing infectious droplet nuclei.
- Inadequate cleaning and disinfection of medical equipment.
- Improper procedures for handling specimens.

Risk for Health-Care–Associated Transmission of *M. tuberculosis*

Transmission of *M. tuberculosis* is a risk in health-care settings (*57,61–79*). The magnitude of the risk varies by setting, occupational group, prevalence of TB in the community, patient population, and effectiveness of TB infection-control measures. Health-care–associated transmission of *M. tuberculosis* has been linked to close contact with persons with TB disease during aerosol-generating or aerosol-producing procedures, including bronchoscopy (*29,63,80–82*), endotracheal intubation, suctioning (*66*), other respiratory procedures (*8,9,83–86*), open abscess irrigation (*69,83*), autopsy (*71,72,77*), sputum induction, and aerosol treatments that induce coughing (*87–90*).

Of the reported TB outbreaks in health-care settings, multiple outbreaks involved transmission of MDR TB strains to both patients and HCWs (*56,57,70,87,91–94*). The majority of the patients and certain HCWs were HIV-infected, and progression to TB and MDR TB disease was rapid. Factors contributing to these outbreaks included delayed diagnosis of TB disease, delayed initiation and inadequate airborne precautions, lapses in AII practices and precautions for cough-inducing and aerosol-generating procedures, and lack of adequate respiratory protection. Multiple studies suggest that the decline in health-care–associated transmission observed in specific institutions is associated with the rigorous implementation of infection-control measures (*11,12,18–20,23,95–97*). Because various interventions were implemented simultaneously, the effectiveness of each intervention could not be determined.

After the release of the 1994 CDC infection-control guidelines, increased implementation of recommended infection-control measures occurred and was documented in multiple national surveys (*13,15,98,99*). In a survey of approximately 1,000 hospitals, a TST program was present in nearly all sites, and 70% reported having an AII room (*13*). Other surveys have documented improvement in the proportion of AII rooms meeting CDC criteria and proportion of HCWs using CDC-recommended respiratory protection and receiving serial TST (*15,98*). A survey of New York City hospitals with high caseloads of TB disease indicated 1) a decrease in the time that patients with TB disease spent in EDs before being transferred to a hospital room, 2) an increase in the proportion of patients initially placed in AII rooms, 3) an increase in the proportion of patients started on recommended antituberculosis treatment and reported to the local or state health department, and 4) an increase in the use of recommended respiratory protection and environmental controls (*99*). Reports of increased implementation of recommended TB infection controls combined with decreased reports of outbreaks of TB disease in health-care settings suggest that the recommended controls are effective in reducing and preventing health-care–associated transmission of *M. tuberculosis* (*28*).

Less information is available regarding the implementation of CDC-recommended TB infection-control measures in settings other than hospitals. One study identified major barriers to implementation that contribute to the costs of a TST program in health departments and hospitals, including personnel costs, HCWs' time off from work for TST administration and reading, and training and education of HCWs (*100*). Outbreaks have occurred in outpatient settings (i.e., private physicians' offices and pediatric settings) where the guidelines were not followed (*101–103*). CDC-recommended TB infection-control measures are implemented in correctional facilities, and certain variations might relate to resources, expertise, and oversight (*104–106*).

Fundamentals of TB Infection Control

One of the most critical risks for health-care–associated transmission of *M. tuberculosis* in health-care settings is from patients with unrecognized TB disease who are not promptly handled with appropriate airborne precautions (*56,57,93,104*) or who are moved from an AII room too soon (e.g., patients with unrecognized TB and MDR TB) (*94*). In the United States, the problem of MDR TB, which was amplified by health-care–associated transmission, has been substantially reduced by the use of standardized antituberculosis treatment regimens

in the initial phase of therapy, rapid drug-susceptibility testing, directly observed therapy (DOT), and improved infection-control practices (*1*). DOT is an adherence-enhancing strategy in which an HCW or other specially trained health professional watches a patient swallow each dose of medication and records the dates that the administration was observed. DOT is the standard of care for all patients with TB disease and should be used for all doses during the course of therapy for TB disease and for LTBI whenever feasible.

All health-care settings need a TB infection-control program designed to ensure prompt detection, airborne precautions, and treatment of persons who have suspected or confirmed TB disease (or prompt referral of persons who have suspected TB disease for settings in which persons with TB disease are not expected to be encountered). Such a program is based on a three-level hierarchy of controls, including administrative, environmental, and respiratory protection (*86,107,108*).

Administrative Controls

The first and most important level of TB controls is the use of administrative measures to reduce the risk for exposure to persons who might have TB disease. Administrative controls consist of the following activities:

- assigning responsibility for TB infection control in the setting;
- conducting a TB risk assessment of the setting;
- developing and instituting a written TB infection-control plan to ensure prompt detection, airborne precautions, and treatment of persons who have suspected or confirmed TB disease;
- ensuring the timely availability of recommended laboratory processing, testing, and reporting of results to the ordering physician and infection-control team;
- implementing effective work practices for the management of patients with suspected or confirmed TB disease;
- ensuring proper cleaning and sterilization or disinfection of potentially contaminated equipment (usually endoscopes);
- training and educating HCWs regarding TB, with specific focus on prevention, transmission, and symptoms;
- screening and evaluating HCWs who are at risk for TB disease or who might be exposed to *M. tuberculosis* (i.e., TB screening program);
- applying epidemiologic-based prevention principles, including the use of setting-related infection-control data;
- using appropriate signage advising respiratory hygiene and cough etiquette; and
- coordinating efforts with the local or state health department.

HCWs with TB disease should be allowed to return to work when they 1) have had three negative AFB sputum smear results (*109–112*) collected 8–24 hours apart, with at least one being an early morning specimen because respiratory secretions pool overnight; and 2) have responded to antituberculosis treatment that will probably be effective based on susceptibility results. In addition, HCWs with TB disease should be allowed to return to work when a physician knowledgeable and experienced in managing TB disease determines that HCWs are noninfectious (see Treatment Procedures for LTBI and TB Disease). Consideration should also be given to the type of setting and the potential risk to patients (e.g., general medical office versus HIV clinic) (see Supplements, Estimating the Infectiousness of a TB Patient; Diagnostic Procedures for LTBI and TB Disease; and Treatment Procedures for LTBI and TB Disease).

Environmental Controls

The second level of the hierarchy is the use of environmental controls to prevent the spread and reduce the concentration of infectious droplet nuclei in ambient air.

Primary environmental controls consist of controlling the source of infection by using local exhaust ventilation (e.g., hoods, tents, or booths) and diluting and removing contaminated air by using general ventilation.

Secondary environmental controls consist of controlling the airflow to prevent contamination of air in areas adjacent to the source (AII rooms) and cleaning the air by using high efficiency particulate air (HEPA) filtration or UVGI.

Respiratory-Protection Controls

The first two control levels minimize the number of areas in which exposure to *M. tuberculosis* might occur and, therefore, minimize the number of persons exposed. These control levels also reduce, but do not eliminate, the risk for exposure in the limited areas in which exposure can still occur. Because persons entering these areas might be exposed to *M. tuberculosis*, the third level of the hierarchy is the use of respiratory protective equipment in situations that pose a high risk for exposure. Use of respiratory protection can further reduce risk for exposure of HCWs to infectious droplet nuclei that have been expelled into the air from a patient with infectious TB disease (see Respiratory Protection). The following measures can be taken to reduce the risk for exposure:

- implementing a respiratory-protection program,
- training HCWs on respiratory protection, and
- training patients on respiratory hygiene and cough etiquette procedures.