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Environmental control measures for prevention of transmission of TB in hospital settings

P Kumar, S Anand[1], Hema Sundaram[2], K Reena[3]*

Summary

Diseases caused by Mycobacterium tuberculosis (M. tuberculosis) are some of the most important causes of mortality among adults in the world. Nosocomial transmission is a cause of concern as it affects not only other patients, but also health care workers (HCWs). Increased risk of nosocomial transmission has been documented in a variety of settings and there are varied contributing factors. The greatest risk of transmission occurs when patients remain undiagnosed and untreated. The key, therefore, to the reduction of nosocomial transmission of infection, is early diagnosis and prompt initiation of treatment of tuberculosis (TB) cases. Measures to prevent nosocomial transmission of *M. tuberculosis,* serve not only to conserve resources in terms of direct costs due to treatment of the HCWs, indirect costs in terms of loss of HCWs specializing in the management of TB patients but also, in reducing the burden due to TB. Non-existent or ineffective TB infection control (IC) measures facilitate the transmission of infection. These can be remedied with simple and in many instances inexpensive control measures. IC strategies include - administrative controls, environmental controls, personal protection methods and laboratory safety practices.

Key words: Nosocomial Transmission, Tuberculosis, Environmental Controls, Ventilation, Directional Airflow, Infection Control, Ultra Violet Germicidal Irradiation, Respirators.

Introduction

Diseases caused by *M. tuberculosis,* are some of the most important causes of mortality among adults in the world[1]. Populations in resource limited settings account for nearly 95% of the total pool of infected individuals in the world. Recent increase in the incidence of TB among health care workers as well as hospital-based outbreaks of multidrug resistant TB among the HIV infected patients[2], have led to a larger apprehension about the risk of *M. tuberculosis* transmission in health care settings (nosocomial transmission). Nosocomial transmission is of obvious concern because it affects not only other patients but also the personal health of HCWs and may result in either temporary or permanent loss of HCWs from the workforce.

Recent studies of the risk of nosocomial transmission of *M. tuberculosis* in developing countries have shown that HCWs providing services to infectious TB patients are at risk of *M. tuberculosis* infection and disease[3]. Non-existent or ineffective IC measures facilitate transmission of infection in these settings. Several of the TB control measures that are likely to have the greatest impact on reducing *M. tuberculosis* transmission (e.g., rapid diagnosis and triage of infectious TB patients) can be implemented with minimal additional financial resources[4, 5.]

The DOTS (the internationally recommended strategy for TB control), can cure nearly all cases of TB. One of the foundations of DOTS is to administer standard short-course chemotherapy (SCC) to TB patients under direct observation of health care workers (HCWs).

Several studies in developed countries has also revealed that HCWs and medical and nursing students are at higher risk for acquisition of TB infection and developing the disease thereafter [7, 8, 9 &10]. However till recently, data on risk of infection and disease among HCWs in developing countries has been limited.

* Director (Corresponding author),[1, 2] Consultant Microbiologists, [3] Jr. Bacteriologist, NTI, Bangalore

The assessment of occupational risk is complicated by difficulty in accumulating the incidence data of TB among HCWs. The high prevalence of tuberculosis infection in the general population and widespread use of BCG vaccination obscures the interpretation of tuberculin skin testing. Studies have been conducted to assess the risk of an active TB infection or risk of infection as measured by the tuberculin skin test (TST) positivity among HCWs and students in the health professions, in African, Asian and South American countries[7, 11, 9 & 10.] To date, an increased risk has been documented in a number of HCW groups such as nurses, physicians, nursing and medical students and laboratory workers. The risk factors for acquiring tuberculous infection include frequent and direct patient contact, long duration of employment, contact with underdiognosed and untreated TB patients, employment in facilities with no infection control measures and performing cough-inducing procedures on patients[10].

1.1 Infection control strategies:

There are three levels of infection control measures:

- Administrative (managerial) controls, which reduce HCW and patient exposure.
- Environmental control, which reduce the concentration of infectious droplet nuclei.
- Personal respiratory protection, which are useful in protecting the HCWs in areas where droplet nuclei concentration cannot be adequately reduced by administrative and environmental controls.

Administrative controls are the most important since environmental and personal controls, in the absence of robust administrative control measures are not effective. Each level operates at a different point in the process of transmission of infection. (Figure 1)

2.1 Administrative (managerial) controls:

These are the first and most important line of defense to significantly reduce and prevent generation of droplet nuclei. The control measures include:

- Early diagnosis
- Prompt separation/isolation
- Prompt initiation of appropriate anti-TB treatment
- Assessment of risk of transmission in the facility
- Development of an infection control strategy
- Adequate training of HCWs to implement the plan.

2.2 Environmental control measures:

The exposure to infectious droplet nuclei is usually difficult to eliminate altogether. Environmental measures are hence used in high-risk areas to reduce concentration of droplet nuclei in the air. The control measures include:

- Maximizing natural ventilation
- Controlling directional airflow

These are the second line of defense against nosocomial transmission of TB among HCWs. When employed in conjunction with administrative controls, they can be used effectively to reduce concentration of infectious droplet nuclei, to which HCWs or patients may be exposed.

Many simple to complex environmental controls can be used to reduce the number of aerosolized infectious droplet nuclei in the work environment. The simplest and least expensive measure is the removal and dilution of air from TB patient areas, away from patients without TB, by maximizing natural ventilation. More complex and expensive methods include use of mechanical ventilation such as window fans, exhaust ventilation systems, etc. Isolation rooms or wards can be provided with negative pressure, which prevents contaminated air from escaping into hallways and other surrounding areas.

Additional, complex and expensive methods include air filtration to remove infectious particles and ultraviolet germicidal irradiation (UVGI) to kill *M. tuberculosis.*

2.2.1 Design and Evaluation:

Design of the facility, climate, number of TB patients catered to in the facility, resources available, and type of patient population served, dictate the type of environmental controls applicable to each facility. Regular evaluation of the adequate functioning of these controls is important and imperative.

Ventilation is the movement of air to achieve dilution and air exchange in a specific area to reduce concentration of aerosolized droplet nuclei. Ideally, fresh air should be constantly pulled into a room and the contaminated air exhausted outside, such that the air is changed several times every hour. The most common way to achieve this is by negative pressure ventilation.

3.1 Ventilation:

3.1.1 Natural Ventilation:

Waiting areas, sputum collection areas, examination rooms and wards should be established in areas with adequate natural ventilation and open windows, such that air moves to the outdoors and not into other wards or waiting areas. (window-window, window-door, etc.). When ceiling fans are used, windows should also be left open to achieve dilution and exchange of air, rather than mixing. The risk of transmission of infection is highest in a closed room containing air with aerosolized infectious droplet nuclei.

3.1.2 Mechanical Ventilation:

Mechanical ventilation can be used in patient rooms, waiting areas, examination rooms if natural ventilation is not feasible or is inadequate. The use of good quality equipment is important. Directional airflow should be maintained from a "clean" area, across the HCW, across the patient and to the outside. The area from where air is entering should be located away from the exhaust area to avoid re-entry of contaminated air (short-circuiting) (Fig. 2).

3.1.3 Monitoring of ventilation and ventilation systems:

Monitoring of the ventilation and ventilation systems requires regular evaluation for proper functioning. The simplest method for such evaluation is the smoke tube method, in which a smoking tube is inserted in the region of airflow. The smoke moves in the direction of airflow. Such evaluations should also be documented in a maintenance record.

3.1.4 Special areas:

Certain areas of the health care facility should be considered high risk and a priority, if environmental controls are implemented:

- TB isolation rooms
- TB wards
- ICUs where TB patients are housed
- Sputum induction rooms
- Bronchoscopy suites, OTs and autopsy suites, mechanical ventilation during and after procedures, is strongly recommended in these areas.

4.1 Ultraviolet germicidal irradiation (UVGI):

Ultraviolet germicidal irradiation (UVGI) is a less expensive alternative to other measures requiring structural alterations of the facility. It is particularly useful in larger wards, TB clinic waiting areas or inpatient areas, such as recreation rooms, where TB patients congregate.

UVGI may be applied in sputum collection booths. Bare bulbs can be used to irradiate the entire booth when not occupied. If HCWs and patients are in the room, continuous upper air irradiation can be used, in which shielding placed below the sources prevents injury to the occupants. Portable floor units may also be used in such settings. Continuous upper air irradiation is the most applicable in resource-limited settings. The advantage of upper air being continuously irradiated, is that it provides protection to the HCW while the infectious patient is in the room.

In UVGI installations, meant for continuous upper air irradiation to be effective, air mixing should be good. Structural features such as ceiling height, may limit feasibility and usefulness of this method. If portable floor units are used, lamp placement requires attention, as corners may not receive the required radiation. Cleaning and monitoring of the lamps is important[12] .

5.1 High Efficiency Particulate Air (HEPA) Filtration:

HEPA filters can be used for small rooms, with a limited number of patients, small-enclosed areas, etc. These units may be free-standing/ permanently attached to the floors or ceilings to minimize tampering. Alternately, they could also be exhausted outdoors, creating a negative pressure isolation room. If portable units are used, unrestricted airflow is essential. Placing the unit close to furniture or putting items on top of the units can compromise their performance. Careful monitoring is essential for optimal performance of these systems[13].

6.1 Role of Personal Respiratory Protection:

Personal respiratory protection forms the last line of defense for HCWs against nosocomial *M. tuberculosis* infections. Respirators serve as a valuable complement to administrative and environmental infection control measures. Such respiratory protection may not always be affordable, but is most appropriate for use in high-risk areas[4], [14].

Personal respiratory protection protects HCWs from inhaling infectious droplets by using devices designed to fit over the mouth and nose and filter out infectious TB particles. Surgical masks (cloth, paper) commonly used by HCWs, do not filter out infectious droplet nuclei, though if used by patients, can prevent their generation.

Use of surgical masks for patients, though not the highest priority among modes of intervention, can be used to reduce aerosols generated from potentially infectious TB patients-who leave isolation rooms for medically essential procedures. Education of patient and HCW regarding importance and appropriate use of masks should accompany their distribution[8].

A face mask (cloth/paper) prevents the spread of micro-organisms from the wearer to others by capturing the large wet particles near the nose and mouth. There is no protection to the wearer from inhaling infectious droplet nuclei in the air.

Widespread and constant use of respirators is impractical, and hence should be used on a limited basis in specified high risk areas, such as:

- Isolation rooms for patients with TB or MDR-TB
- During sputum induction or other cough-inducing procedures
- Bronchoscopy and autopsy suites
- Spirometry rooms
- During emergency surgery on potentially infectious TB patients, in conjunction with other administrative and environmental control measures.

All personnel entering high-risk areas should wear respirators. For protection of HCWs from airborne infectious droplet nuclei, a respiratory protective device with capacity to filter a 1-micron particle is needed that is closely fitted to the face to prevent leakage around the edges.

Respirators manufactured with at least 95% filter efficiency for particles of 0.3 micron in diameter are usually recommended for use by the HCWs[1]. They are disposable, but can be re-used repeatedly for several months if they are properly stored. The main factors responsible for deterioration of respirators are humidity, dirt and crushing. Respirators should be stored in a clean dry location, by folding a light sterile towel around the respirator and being careful not to crush it. Plastic bags should never be used to store respirators, as they retain humidity.

7.1 Laboratory safety:

7.1.1 AFB Smear Preparation:

Direct smear microscopy has not been documented to result in the transmission of TB (assuming centrifugation is not being used). Neither environmental controls nor personal respiratory protection are necessary during the preparation of smears. In laboratories performing only smear microscopy without the use of a centrifuge, the greatest threat to personnel, is contact with coughing patients. Administrative controls can limit this exposure[13].

7.1.2 Preparation of liquid suspensions of *M. tuberculosis* :

Personnel working in laboratories processing liquid preparations, as in centrifugation, culture and drug sensitivity testing (C & DST) are at a higher risk for nosocomial transmission. Their safety can be improved by following measure:

- Enhancing ventilation in C & DST areas.
- Reducing the number of laboratories handling concentrated specimens containing the Bacillus.
- Allowing only those laboratories with appropriate biosafety cabinets (BSCs : Class I or Class II) and experienced staff to work with liquid suspensions of *M. tuberculosis.*

8.1 Bio Safety Cabinets (BSC):

8.1.1 Class I:

The bio-safety cabinets protect the workers and work environment from exposure to aerosols by drawing air into the cabinet. They do not protect the specimen from contamination. Air is exhausted outside or filtered and re-circulated into the room. Ideally the air velocity in the cabinet should be measured periodically using a velometer (hot wire anemometer)

8.1.2 CLASS II:

They are more expensive and use laminar airflow in addition to the exhaust. These cabinets protect both specimen/culture and the HCW from contamination. Without proper maintenance of these instruments, the risk may actually increase, as the contaminated air would be pushed into the HCW's breathing zone from the BSC[4,13].

Conclusion:

HCWs are essential in the fight against TB and they should be protected. The HCW's role is integral to managing active cases and in preventing further transmission. Hence, infection control strategies, including administrative, environmental, personal protection methods and laboratory safety practices, gain significance. In low-income countries, the risk of patients and HCWs acquiring TB could be significantly reduced if governments, health authorities and HCWs themselves make infection control a high priority. HCWs are a valuable and often scarce resource, and their expertise cannot be easily replaced. Commitment to reduce the risk of nosocomial transmission of tuberculosis to HCWs is necessary to protect them from undue exposure, infection, disease, disability and death.

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Figure 1: Schematic representation of the three levels of controls in the infection control strategy.

1st Priority: Administrative Controls

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2nd Priority: Environmental Controls

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3rd Priority: Personal Respiratory Controls

Figure 2: Schematic representation of the directional airflow in a hospital setting.

Directional airflow: Fresh air → "Clean" area → HCW → Patient → Outside → Exhaust area