RISK ASSESSMENT TOWARDS TUBERCULOSIS AMONG HOSPITAL PERSONNEL: ADMINISTRATIVE CONTROL, RISK EXPOSURE, USE OF PROTECTIVE BARRIERS AND MICROBIAL AIR QUALITY

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Abstract. A recent increase in the rate of tuberculosis among hospital personnel has led to a greater concern about the risk of *Mycobacterium tuberculosis* transmission in the hospital. A cross-sectional study was conducted to assess the risk of tuberculosis infection among hospital personnel of a governmental hospital in Bangkok by applying hospital tuberculosis control strategies, including administrative control, risk exposure, use of protective barriers when in contact with TB patients, and microbial air quality in the studied wards. Fourteen members of the infection control committee (ICC) and 118 hospital personnel were interviewed regarding the infection control policy and its implementation. The history of TB exposure at work and the use of protective barriers when in contact with TB patients were recorded for the studied hospital personnel. Air samples in the studied wards were collected to investigate bacterial and fungal counts. The results reveal that all the studied ICC members and more than 85% of studied hospital personnel knew the infection control policy and attempted to implement it. However, 35.71, 37.50, 80.90, 93.93, and 88.46% of personnel working in ER, OPD, ICU, female medical ward, and male medical ward, respectively, implemented the TB isolation policy. More than 80% of studied personnel had histories of exposure to TB patients, but only 52.73% (31.57% in OPD to 80.00% in ICU) used the appropriate barriers (N95) when in contact with TB patients. Air samples collected from the studied wards, except ICU, had high bacterial and fungal counts (> 500 cfu/m^3). These findings show that hospital personnel working in the studied wards, except ICU, were at risk for tuberculosis infection. The hospital ICC should advertise the use of TB standard precautions to hospital personnel and provide a ventilation system for reducing the microbial counts in the air of the studied wards.

INTRODUCTION

Tuberculosis is an important global public health problem. It is estimated that 2 billion persons have been infected with *Mycobacterium tuberculosis*; 8 million persons have had active tuberculosis and tuberculosis causes 3 million deaths per year or 8,000 deaths per day (Raviglione *et al*, 1995). The pandemic of human immunodeficiency virus (HIV) infection and its association with tuberculosis has caused a marked increase in the incidence of tuberculosis in several countries (Sepkowitz *et al*, 1995). Approximately 8-10% of HIV infected individuals develop active tuberculosis per year. HIV has emerged as the most important risk factor for progression to clinical tuberculosis. In many developing countries, tuberculosis has emerged as the most common opportunistic disease associated with HIV infection; up to 54% of AIDS patients in Africa, 24-28% in Brazil and Mexico, and about 40% in Thailand (Dooley *et al*,1992; Raviglione *et al*, 1995; Sepkowitz *et al*, 1995; Wongsaheam, 1999).

People with a higher prevalence of tuberculosis infection include contacts of patients with active tuberculosis, the elderly, and persons with

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impaired immune systems (Sepkowitz *et al,* 1995; Evenson, 1999). A recent increase in the rate of tuberculosis among health care workers, as well as hospital-based outbreaks of multi-drug resistant *M. tuberculosis* among HIV patients, have led to greater concern about the risk of tuberculosis transmission in health care settings in many countries, including Thailand (Kantor *et al,*1988; Dooley *et al,* 1992; Sepkowitz, 1995; Harries *et al,*1997; Ubolsa-ard and Nakkroun, 1997; WHO, 1999; Chutimanukul *et al,*1999). The risk may be higher in areas where patients with tuberculosis are cared for before diagnosis or initiation of tuberculosis treatment, where diagnostic or treatment procedures that stimulate coughing are performed, and where there is inadequate ventilation. Many studies report that hospital personnel working in HIV units, internal medicine wards, emergency rooms, medical intensive care units, and outpatient departments have a higher proportion of positive purified protein derivative (PPD) tests than other groups (Kantor *et al,* 1988; Dooley *et al,* 1992; Sepkowitz, 1995; Ubolsa-ard and Nakkroun, 1997; WHO, 1999).

Strategies for TB infection control in the hospital include administrative control, environmental control, and personal respiratory protection (Blumberg *et al,* 1995; WHO, 1999). Administrative control reduces hospital personnel and patient exposure, whereas, environmental control reduces the amount of infectious droplets. Personal respiratory protection protects hospital personnel in areas where the number of infectious droplets cannot be adequately reduced by the other controls.

This study attempted to apply TB infection control strategies to the prevention of *M. tuberculosis* infection in hospital personnel working in different wards at a governmental hospital in Bangkok, by using administrative control (administrative policies and their implementation), reduces exposure to TB patients, use of protective barriers when in contact with TB patients, and evaluating microbial air quality on the wards.

MATERIALS AND METHODS

Study design and study samples

A cross-sectional study of 14 infection control committee (ICC) members and 118 hospital personnel in a governmental hospital in Bangkok was conducted between June 2001 and March 2002 to assess the perceptions of infection control policy and its implementation in the hospital, the history of exposure to tuberculosis patients, and the use of protective barriers when in contact with TB patients. In addition, air samples in TB at risk wards, including male and female medical wards, the medical intensive care unit (ICU), emergency room (ER), and out-patient department (OPD), were collected to assess air quality.

Study methods and research tools

Interviews were by structured questionnaire, which included open-ended and close-ended questions regarding general information, the knowledge of the infection control policy, and its implementation in the hospital, history of exposure to TB patients and the use of protective barriers when in contact with TB patients. The air quality study measured bacterial counts, fungal counts, and *Staphylococcus* spp counts. The total bacterial count was obtained using Plate Count Agar (PCA) or Tripticase Soy Agar (TSA). The total fungal count was obtained using Sabouraud Dextrose Agar (SDA). *Staphylococcus* spp was cultivated in Mannitol Salt Agar. Air samples in the studied wards were collected using the Anderson N6 Viable Particle Sampler with a fixed air flow rate of 28.3 liter/minute. The air was collected for 3 minutes. Triplicate air samples were collected from each area. Air flow direction was measured using a smoke tube. After incubation of the air samples, the total counts of culturable bacteria, fungi or *Staphylococcus* spp (cfu/m^3) were calculated with the formula:

$$\text{Microbial count (cfu/m}^3\text{)} = \frac{(\text{Total colony} \times 10^3)}{\text{air flow rate} \times \text{time}}$$

Interpretation of microbial air quality

If the total bacterial or fungal count was more than 500 cfu/m^3, it indicated poor ventilation or unhygienic conditions following the American Conference of Governmental Industrial Hygienist (ACGIH) committee recommendations (Seitz, 1989). There were no guidelines for *Staphylococcus* spp interpretation.

Data analysis

Data from the questionnaire and microbial

air quality assessment were analyzed by descriptive statistics, including percentages, means, and standard deviations.

RESULTS

General characteristics of studied hospital personnel

There were 191 hospital personnel in this study. Only 118 hospital personnel worked on TB at risk wards. Fourteen infection control committee (ICC) members were included in the study. Fourteen ICC members were involved only in administrative policy.

Among the 118 hospital personnel working in TB at risk wards, about 56% were 21-30 years of age, and 35% were 31-40 years. The majority of studied personnel were female (96%). Nearly 46% had finished undergraduate training or higher. About 65% were nurses or nurse aids. About 59% had worked 5 or more years. Data showed approximately 83% had a history of insufficient sleep, 26% had no exercise, 17% had chronic diseases, 12% had an above normal body mass index (BMI), 8% used alcohol, 1.7% smoked, and 0.8% used sedative drugs. The details are shown in Table 1.

Administrative policy and implementation

There were 14 ICC members in the studied hospital. All the studied ICC members knew about the infection control policy. More than 85% of studied hospital personnel working on the wards knew the policy. Most studied personnel (64-100%) implemented the policy while working on the wards, as shown in Table 2. However, 36, 37,

Table 1
General characteristics of 118 studied hospital personnel.

General characteristics	No.	%
Age groups (years)		
21-30	67	56.78
31-40	42	35.59
41-50	7	5.93
51-60	2	1.70
Sex		
Male	4	3.39
Female	114	96.61
Education		
Secondary level and lower	33	27.97
Vocational level	31	26.27
Undergraduate and higher	54	45.76
Type of personnel		
Registration nurse	53	44.92
Technical nurse and nurse aid	24	20.34
Workers	41	34.74
Studied wards		
Male medical ward	26	22.03
Female medical ward	33	27.97
Medical intensive care unit	21	17.80
Outpatient department	24	20.34
Emergency room	14	11.86
Duration of working (years)		
< 5	48	40.68
5-10	40	33.90
>10	30	25.42
Some medical history		
Insufficient sleep	98	83.05
No exercise	31	26.27
Having chronic disease	20	16.95
High Body Mass Index (≥ 25)	14	11.86
Alcohol drinking	10	8.47
Smoking	2	1.69
Sedative drug taking	1	0.85

Table 2
Perception of 118 studied hospital personnel towards the infection prevention and control policy in the hospital.

Studied wards	No. (%) of personnel aware		No. (%) of personnel who implemented policy	
Male medical ward	25	96.15	23	88.46
Female medical ward	33	100.00	31	93.93
Medical intensive care unit	21	100.00	21	100.00
Outpatient department	24	100.00	24	100.00
Emergency room	12	85.71	9	64.28
Total	115	97.46	108	91.53

Table 3
Use of the isolation policy among 118 studied hospital personnel, classified by wards.

Studied wards	No. of studied personnel	No. and % of studied personnel who used the isolation policy	
Male medical ward	26	23	88.46
Female medical ward	33	31	93.93
Medical intensive care unit	21	17	80.90
Outpatient department	24	9	37.50
Emergency room	14	5	35.71
Total	118	85	72.03

81, 94, and 88% of studied personnel working in the ER, OPD, ICU, female medical ward, and male medical ward, respectively, implemented the isolation policy for TB patients. The details are shown in Table 3.

History of TB exposure while working on the studied wards

Most hospital personnel working on the studied wards had a history of TB exposure while working. On the female medical ward and in the ER, all studied personnel (100%) had a history of TB exposure while working. Whereas, 95, 92, and 79% of those working in the ICU, on the male

Table 4
History of TB exposure while working on the wards among the 118 studied hospital personnel (One person can answer more than 1 item).

Risk event	% of studied personnel exposed to TB patients				
	Male Med	Female Med	ICU	OPD	ER
1. Collected specimens contaminated with *M. tuberculosis*	84.62	90.91	76.19	87.50	100.00
2. Nebulizer	84.62	90.91	80.95	20.83	100.00
3. Suction	84.62	84.85	85.71	20.83	100.00
4. Taking care of patients on a respirator	84.62	87.88	80.95	16.67	71.43
5. Doing a physical examination on a TB suspected case	61.54	81.82	33.33	70.83	85.71
6. Admitted or referred TB patients	65.38	54.55	71.43	45.83	85.71
7. Cleaned the isolation room	57.69	54.55	95.24	12.50	50.00
8. Intubation	76.92	60.61	33.33	8.33	78.57
9. Dressing wound of TB patients	42.31	42.42	23.81	12.50	64.29
10. Tracheostomy	15.38	15.15	4.76	12.50	7.14
11. Bronchoscopy	11.54	9.09	0.00	0.00	0.00
% of hospital personnel who had at least 1 item of exposure	92.31	100.00	95.24	79.17	100.00

Table 5
Use of TB protective barriers among studied hospital personnel when in contact with suspected TB patients.

Studied wards	No. of studied personnel	No. and % of studied personnel who used TB protective barriers when in contact with suspected TB patients	
Male medical ward	26	12	46.15
Female medical ward	33	17	51.52
Medical intensive care unit	21	17	80.95
Outpatient department	24	8	33.33
Emergency room	14	8	57.14
Total	118	62	52.54

Table 6
Microbial air quality of studied wards in the hospital.

Studied wards	Bacterial count $\bar{X}$ (cfu/m^3)	Fungal count $\bar{X}$ (cfu/m^3)	*Staph* spp count $\bar{X}$ (cfu/m^3)
Male medical ward (n = 45 samples)			
Patient room	755 ± 213[a]	553 ± 141[a]	61 ± 59
Isolation room	325 ± 112	807 ± 192[a]	45 ± 27
Nurse station	568 ± 44[a]	531 ± 16[a]	63 ± 54
Female medical ward (n = 45 samples)			
Patient room	672 ± 201[a]	654 ± 38[a]	60 ± 49
Isolation room	583 ± 231[a]	619 ± 74[a]	16 ± 12
Nurse station	568 ± 95[a]	531 ± 52[a]	20 ± 11
Intensive care unit (n = 18 samples)			
Patient room	346 ± 68	350 ± 104	8 ± 6
Nurse station	270 ± 51	313 ± 114	32 ± 18
Outpatient department (n = 36 samples)			
Examination room	3,177 ± 571[a]	575 ± 191[a]	275 ± 78
Nurse station	1,407 ± 484[a]	512 ± 178[a]	90 ± 55
Emergency room (n = 24 samples)			
Observation room	1,305 ± 334[a]	970 ± 129[a]	125 ± 71
Nurse station	1,303 ± 315[a]	1,311 ± 224[a]	67 ± 39

[a]Mean bacterial or fungal counts > 500 cfu/m^3, indicates the inadequate ventilation or unhygienic conditions of the air.

medical ward and in the OPD, respectively, had a history of TB exposure while working. The details are shown in Table 4. Only 52% of studied personnel used appropriate TB protective barriers (high efficiency filter masks or N95) when in contact with TB patients. The percentages of TB protective barrier usage ranged from 33% in the OPD to 81% in the medical ICU, shown in Table 5.

Microbial air quality of the studied wards

A total of 168 air samples, including 45 from the male medical ward, 45 from the female medical ward, 18 from the ICU, 36 from the OPD, and 24 from the ER were evaluated for bacterial, fungal, and *Staphylococcus* spp counts. The OPD and ER had the highest average bacterial, fungal, and *Staphylococcus* spp counts. The ICU had the lowest average bacterial, fungal, and *Staphylococcus* spp counts. Four studied wards, the male medical ward, the female medical ward, the OPD, and the ER had average bacterial and fungal counts of more than 500 cfu/m^3. This indicates that these 4 studied wards had unhygienic conditions, poor ventilation of air. The details are shown in Table 6.

Risk of TB infection among studied hospital personnel

A summary of the administrative policy, the risk of tuberculosis exposure, use of protective barriers and the microbial air quality in the studied wards is shown in Table 7. These findings suggest that hospital personnel working in the male and female medical wards, and in the OPD and ER were at high risk for acquiring TB infection (Table 7).

DISCUSSION

In general, people who become infected with *M. tuberculosis* have approximately a 10% risk for developing active tuberculosis during their lifetime. The risk is increased in immunocompromized people (Dooley *et al,* 1992; Selwyn *et al,* 1992; Bates and Stead, 1993). The tuberculin skin test is a TB risk screening method, but false negative results can occur and tested subjects frequently complain of adverse reactions (Chierakul and Damrongchokpipat, 1998). This study assessed the risk of TB infection by applying of the TB control strategy in the hospital. The studied hospital has an infection control committee (ICC)

Table 7
Comparison of the risks for TB infection among the studied hospital personnel classified by wards.

Studied Wards	Percentage of 118 studied personnel who answered				Microbial counts in air samples (cfu/m^3)	Risk for TB infection
	Infection control policy implementation	Use of isolation on the ward	TB exposure	Use of protective barriers when in contact with TB patients		
Male Med	88.46	88.46	92.31	46.15	>500 [a]	High
Female Med	93.93	93.93	100.00	51.52	>500 [a]	High
ICU	100.00	80.95	95.24	80.95	<500	Low
OPD	100.00	37.50	79.17	33.33	>500 [a]	High
ER	64.28	35.71	100.00	57.14	>500 [a]	High

Male Med = Male medical ward; Female Med = Female medical ward; ICU = Intensive care unit; OPD = Outpatient department; ER = Emergency room
[a]Unhygienic condition or poor ventilation

which is responsible for the infection control policy, and surveillance system. All the studied ICC members and most of the studied hospital personnel (average of 97%) knew the policy. Approximately 72% used the isolation policy when admitting TB patients. Although there was no isolation room in the ER, 35% of hospital personnel in this section separated TB patients into a temporary observation area. Hospital personnel working in the ER expressed an opinion about this: "Most personnel working in this section know the diagnosis of patients after we have taken care them and we do not use efficient protective barriers, we wear surgical mask only." The guidelines of the WHO suggest that infectious TB patients should be isolated from other patients (WHO, 1999). If the isolation room is insufficient, TB patients can be separated in one part of the ward. The TB patients should wear surgical masks to prevent exposing other people.

Most studied hospital personnel had a history of exposure to TB patients while working on the ward, such as caring for TB patients, collecting TB specimens and respiratory therapy. A previous study reported that hospital personnel exposed to TB patients had a higher risk for TB infection than other persons, OR = 3.4 ($p < 0.001$) (Chanasit *et al*, 1999). Moreover, about 83, 26, 17, and 1.7% of studied hospital personnel had a history of insufficient sleep, no exercise, chronic disease and smoking, respectively. These conditions increase the risk for TB infection and disease progression (Sepkowitz, 1995; Wongsaheam, 1999).

Only 52.54% of hospital personnel used particulate respirators (N95) when giving respiratory therapy or nursing care to TB patients. The rest used surgical masks only. A study reported that the surgical mask is insufficient to filter out particles of *M. tuberculosis* (Willeke *et al*, 1996). The surgical mask prevents the spread of microorganisms from the wearer to others by capturing the large wet particles near the nose and mouth. The particulate respirator (N95) can filter particles to 0.3 μ in diameter by more than 95% (Willeke *et al*, 1996; WHO, 1999). The WHO advises strict adherence to barrier methods when caring for patients with severe acute respiratory syndrome (SARS), by using N95 masks and giving patients surgical masks to wear until SARS is excluded (WHO, 2003).

Air samples from 4 risk wards indicated over-crowding and inadequate ventilation (Seitz, 1989). A previous study reported that humans provide a major source of bioaerosal and respiratory pathogens by sneezing and coughing (Kodama and McGee, 1996). In Thailand, the Ministry of Public Health recommended 35-50 cfu/ft^3 or 388-555 cfu/m^3 (Ministry of Public Health, 1986). Results from the microbial assessment showed that only air samples from the medical intensive care unit had microbial counts at the recommended level. In the past year, 3 hospital personnel developed pulmonary tuberculosis at

the studied hospital. A male nurse's aid working in the emergency room, one of 3 personnel said he wore a surgical mask when exposed to TB and AIDS patients with TB. He thought that he was infected with TB by his patients.

Data from interviews regarding infection control, the use of isolation, a history of TB exposure, the use of TB protective barriers when in contact with TB patients, and the microbial air quality survey showed that hospital personnel in all the studied wards, except the ICU, are at high risk for acquiring TB infection from patients. The hospital ICC should campaign to use TB precautions among hospital personnel and provide a ventilation system for reducing the microbial concentration in the air. Health promoting behavior should be emphasized to the hospital personnel to enhance their immunity against infection.

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