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Original article

Improving tuberculosis infection control practice and microbial air quality in a general hospital after intervention

Pipat Luksamijarulkul[1], Jiraporn Khumsri[2], Pisit Vatthanasomboon[3], Pornapa Aiumlaor[2]

[1] *Department of Microbiology, Faculty of Public Health, Mahidol University, Bangkok* 10400, *Thailand*
[2] *Center for Nosocomial Infection Control, Nopparatjathanee Hospital, Bangkok, Thailand*
[3] *Department of Environmental Health, Faculty of Public Health, Mahidol University, Bangkok* 10400, *Thailand*

Abstract

Objective: Hospital personnel, especially nurses are at risk for tuberculosis (TB) infection and the intervention for reducing the risk should be established. **Methods**: To compare the TB infection control practices and standard precaution in 154 registered nurses and auxiliary nurses working in risk wards. Additionally, microbial air quality in the studied wards was investigated before and after implementation of an intervention including two-day training program on TB infection control and standard precaution practices and managing the ward environments. **Results**: Post-intervention, the percentage of studied nurses who always practiced increased in every item of TB infection control practice (6 items) and standard precaution (9 items) when compared with the pre-intervention period. Both mean scores were significantly higher than those before intervention (5.0 ± 1.0 vs 4.4 ± 1.1, and 7.6 ± 1.3 vs 6.7 ± 1.5, $P < 0.001$, respectively). As well as, bacterial and fungal counts in air samples collected from every studied ward decreased after implementing the intervention, for example, mean of bacterial counts in OPD decreased from 387.8 ± 249.5 cfu/m^3 to 194.4 ± 134.3 cfu/m^3. Additionally, there was no air sample with high level of bacterial and fungal counts, whereas, 3.7 – 22.2% of air samples collected before intervention had high level of bacterial counts (> 500 cfu/m^3). **Conclusion**: Two-day training program and management of the ward environment could improve the scores of TB infection control practices and the standard precaution among studied nurses and reduce the microbial counts in air samples collected from the studied wards.

Keywords: Tuberculosis; Infection control; Standard precaution; Microbial air quality

INTRODUCTION

Development of drug for tuberculosis treatment has been progressed and can cure the disease in six months, but the pandemic of human immunodeficiency virus (HIV) infection causes marked increase to incidence of tuberculosis[1,2]. 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; 24 – 28% of AIDS patients in Brazil and Mexico, over 50% in Africa and about 40% in Thailand[1,3-5]. Recently, *Mycobacterium tuberculosis* (*M. tuberculosis*) has infected one-third of the world's population[2,4]. It is also estimated that 8 million people exposed to the infection and 2 to 3 million developed tuberculosis (TB) and died annually. Approximately 95% of new cases and 98% of deaths occur in developing countries where the resource for treatment was limited and HIV infection was common[2,4,6-8].

People who are at high risk for tuberculosis in-

Correspondence to: Pipat Luksamijarulkul, Department of Microbiology, Faculty of Public Health, Mahidol University, 420/1 Ratchavithi Road, Phayathai, Ratchathevi, Bangkok 10400, Thailand.
Tel: 66(0)2245 – 5525
E-mail: luksamijarulkul@hotmail.com, phpls@mahidol.ac.th

fection include contacts of patients with active tuberculosis, the elderly, and persons with impaired immune systems[1,9]. A recent increase in tuberculosis infection rate among health care workers, as well as hospital-based outbreaks of multi-drug resistant *M. tuberculosis* (MDR-TB) among HIV patients, have led to greater concern about the risk of tuberculosis transmission in health care settings in many countries[3,6,7,10]. Several reports showed the risk for tuberculosis transmission in health care personnel, because TB is spread through the air from TB patient to health care personnel. Transmission of TB is most likely to occur from patients with unrecognized pulmonary or laryngeal TB or non-effective treatment[3,11,12]. A recent study in a general hospital in Bangkok showed that only 25.5% of personnel who exposed to TB patients used the appropriate barrier (N-95 mask) and the high levels of total bacterial and fungal counts were found in studied wards except the medical intensive care unit[5]. Nurses were at risk for acquiring nosocomial tuberculosis due to their responsibility: taking care patients, exposing to TB patients, processing patients´specimens, and exposing hospital environments[5,13]. These evidences supported that hospital personnel, especially nurses are at risk for TB infection and the intervention for reducing the risk should be established. This study attempted to develop the potential intervention in the TB risk wards for reducing risk opportunity to TB infection among nurses.

MATERIALS AND METHODS

Study design and study samples

The study design was an intervention study to assess the TB infection control practices and standard precaution in 154 registered nurses and auxiliary nurses working in 4 risk wards including 36 from female medical ward, 34 from male medical ward, 56 from emergency room (ER), and 28 from medical outpatient department (OPD) of a governmental hospital in Bangkok. All studied nurses who voluntarily participated were interviewed using a structured questionnaire before and after implementing an intervention program including training and managing the environment in the studied wards. The questionnaire included closed-end questions and open-end questions towards TB infection control and standard precaution practices adapting to the Guidelines for Preventing the Transmission of *Mycobacterium tuberculosis* in Health Care Facilities, WHO 1999[14]. The practices towards TB infection control and standard precaution consisted of 6 questions (total score = 6) and 9 questions (total score = 9), respectively. Additionally, microbial air quality in the studied wards was investigated before and after intervention and the outdoor air samples of the studied wards were also collected for comparison.

Air samples and methods of collection

Totally, 90 indoor air samples in the studied wards (27 from female medical ward, 27 from male medical ward, 18 from OPD and 18 from ER) were collected from patient rooms, and nurse stations before and after implementation of an intervention program. Seven outdoor air samples in each time were also collected. Bacterial and fungal counts were assessed by Millipore Air Tester. The system impacted micro-organisms onto an agar surface, which was the reference method for analyzing microbial air contamination (USP 24, p. 2099). Fast and reliable results with maximum recovery; large agar amount and unique micro-perforated sieve allowed air sampling of up to 1 cubic meter. Maximum sample volume was 1 000 L in less than 7 minutes. Air flow rate 140 L/min was set because this air flow rate was optimal for collecting indoor air samples volume of 250 L. Air-borne bacteria were cultivated in Plate count agar and incubated at 35-37℃ for 2 days. General fungi were cultivated in Sabouraud 4% glucose agar and incubated at room temperature for 5 days, but dairy observation.

Intervention program

Two-day training program included TB infection control practices and standard precaution and managing environment of the ward. Studied nurses were divided into 13 groups. Each group about 10-15 persons were trained at 13∶00-16∶00 pm in Tuesday and Thursday. Training and practicing about wearing the surgical mask and particulate respirators (N-95 mask) were emphasized. Surgical masks are designed to prevent the respiratory secretions of patients, whereas, N-95 masks are designed to filter the air from patients with suspected or known tuberculosis. Additionally, cleaning local exhaust fans, fans and air conditioners, and managing everything that blocked natural air from the window and the

door for improving the ward ventilation were also practiced.

After the training, all participants implemented TB infection control and standard precaution and managed their working wards for 1 to 2 months. The interview using the same questionnaire and microbial indoor air assessment were done again (post- intervention study).

Data analysis

Data were analyzed by descriptive and analytic statistics. The general characteristics of the studied subjects and studied air samples were shown by percentage, mean, and standard deviation (SD). An appropriate statistics, for example, paired *t*-test was used to compare means between before and after intervention. The *P*-value < 0.05 was considered statistical significance.

Ethical approval

This study protocol was approved by the Ethics Committee of Mahidol University and the studied hospital (Ref. No. 59/47).

RESULTS

General characteristics and personal health histories of the studied nurses

Of 154 studied nurses, 88.4% were 21-40 years of age and 93.5% were female. About 55.2% finished secondary school and diploma and 44.8% finished a bachelor's degree and higher. Approximately 62.3% were auxiliary nurses and 37.7% were registered nurses. The duration of working showed that 29.9% have worked less than and equal to 5 years. The mean of duration of working was 9.19 years. For health risk histories, 29.2% have a history of chronic diseases. About 15.6% had no history of BCG vaccination. Approximately 3.9% and 11.7% have a current smoking and alcohol drinking, respectively. Almost a half (47.4%) had insufficient resting, 53.2% had no exercise and 22.7% were over BMI. Details are presented in Table 1.

Infection control and standard precaution practices towards TB infection before and after intervention

Before intervention, 63.6 – 82.5% of the studied nurses always practised TB infection control, for example, 82.5% always admitted TB patients in the isolation room and 79.9% always suggested the TB patient to close his mouth or nose when he coughed or sneezed. However, only 63.6% always used the N-95 mask for protecting TB infection. After intervention, 75.3-91.6% of the studied nurses always practised TB infection control. The percentage of studied nurses who always practised increased in every item of TB infection control practice (6 items), Table 2. The mean of practice scores after intervention was significantly higher than that before intervention (5.0 ± 1.0 vs 4.4 ± 1.1, $P < 0.001$). When we classified the practice scores by studied wards, it showed that the mean scores after intervention were significantly higher than those before intervention in every studied ward ($P < 0.05$). Details are shown in Table 2.

For standard precaution, before intervention, 43.5-99.4% of the studied nurses practised standard precaution, for example 99.4% practised handwashing after caring pulmonary TB patients. Only 64.9% practised wearing the surgical mask for TB patients when they were removed from the isolation room to another place and 46.8% practised wearing the N-95 mask for caring pulmonary TB patient. After intervention, 74-100% of the studied nurses practised standard precaution. The percentage of studied nurses who always practised increased in every item of standard precaution practice (9 items), Table 3. The mean of practice scores after intervention was significantly higher than that before intervention (7.6 ± 1.3 vs 6.7 ± 1.5, $P < 0.001$). When we classified the practice scores by studied wards, it showed that the mean scores after intervention were significantly higher than those before intervention in every studied ward ($P < 0.05$). Details are shown in Table 3.

Microbial counts in indoor air samples collected from the studied wards before and after intervention

A total of 90 indoor air samples collected from the studied wards including the female medical ward (27 samples), the male medical ward (27 samples), the OPD (18 samples), and the ER (18 samples) were investigated for bacterial and fungal counts. Results revealed that, before intervention, the OPD had the highest average bacterial count (387.8 ± 249.5 cfu/m^3), whereas, the ER had the highest

average fungal count (132. 8 ± 76. 1 cfu/m^3). When the microbial counts were compared with the level of guideline of the American Conference of Governmental Industrial Hygienists (ACGIH) [15] , it was found that 22. 2% of air samples collected from the OPD and 11. 1% of air samples collected from the ER had bacterial counts more than the recommended level (> 500 cfu/m^3), Table 4. As well as, data from interviews showed 53. 6% of studied nurses working in the OPD and 78. 6% of studied nurses working in the ER felt the poor ventilation in their wards (Table 5). After implementation of an intervention program, both bacterial and fungal counts in air samples collected from every studied ward decreased, for example, the bacterial count in the OPD and the ER remained 194. 4 ± 134. 3 and 146. 7 ± 68. 8 cfu/m^3, and the fungal count remained 81. 1 ± 58. 5 and 56. 7 ± 24. 5 cfu/m^3, respectively. Additionally, there was no air samples collected from the studied wards with high level of bacterial or fungal counts (Table 4). As well as, data from interviews showed only 35. 7% of studied nurses working in the OPD and 67. 8% of studied nurses working in the ER felt the poor ventilation in their wards, which were relatively lower percentage than those in the period of before implementation of the intervention program (Table 5).

Table 1 Some socio-demographic factors and health risk histories among studied personnel (n = 154).

Socio-demographic factors &health risk histories		No .	%
Some socio-demographic factors			
Age group (years)	21 – 40	136	88. 4
	41 – 60	18	11. 6
Gender	Male	10	6. 5
	Female	144	93. 5
Marital status	Single/ Widow/Separated	73	47. 4
	Married	81	52. 6
Education	Secondary level/ diploma	85	55. 2
	Undergraduate and higher	69	44. 8
Position	Auxiliary nurses	96	62. 3
	Registered nurses.	58	37. 7
Duration of working (years)	≤5	46	29. 9
	6 – 10	46	29. 9
	> 10	62	40. 2
Some health risk histories			
Body mass index (BMI)	Over (> 24. 5)	35	22. 7
History of BCG vaccination	No	24	15. 6
History of chronic diseases	Yes (DM, ect.)	45	29. 2
Current smoking	Yes	6	3. 9
Current alcohol consumption	Yes	18	11. 7
Exercise	No	82	53. 2
Resting	Insufficient	73	47. 4
Annually health check-up	No	23	14. 9

Table 2 Comparison of the practice towards TB infection control policy in the studied hospital personnel by each item and practice scores of studied wards.

Items & Studied wards		Before intervention		After intervention	
Items(No,%)	1. You always admit the TB patient in the isolation room	127	82.5	136	88.3
	2. You always use the N-95 mask for protecting TB infection	98	63.6	116	75.3
	3. You always close the door after coming in and going out the isolation room	122	79.2	124	80.5
	4. When TB patients were removed from the isolation to other places, you always give the surgical mask for TB patients to wear	125	81.2	136	88.3
	5. You always suggest the TB patient to closed the mouth or nose when he coughs or sneezes	123	79.9	141	91.6
	6. You always remove TB patient from the isolation room after he is treated with anti-TB drug and has three-time sputum negative for AFB	104	67.5	123	79.9
Studied wards($\bar{x} \pm SD$)	female medical ward	4.6 ± 1.1		5.4 ± 0.6	
	medical ward	4.9 ± 0.8		5.5 ± 0.6	
	ODP	4.5 ± 0.8		5.3 ± 0.8	
	ER	3.9 ± 1.2		4.4 ± 1.1	
		4.4 ± 1.1 *		5.0 ± 1.0 *	

* Statistically significant difference by paired t-test, $P < 0.001$

Table 3 Comparison of practice towards standard precaution related to TB infection prevention and control in the hospital and practice scores of studied wards.

Items & Studied wards		Before intervention		After intervention	
Items(No,%)	1. Using the isolation room for admitting pulmonary TB patients	152	98.7	153	99.4
	2. Taking hand washing before caring pulmonary TB patients	143	92.9	150	97.4
	3. Taking hand washing after caring pulmonary TB patients	153	99.4	154	100.0
	4. Practice towards wearing the N-95mask for caring pulmonary TB patients	72	46.8	114	74.0
	5. Wearing the surgical mask for TB patients when they were removed from the isolation room to another place	100	64.9	122	79.2
	6. Using a wet mop to clean the floor.	134	87.0	137	89.0
	7. Giving cover garbage container to TB patients for splitting the sputum.	109	70.8	128	83.1
	8. Taking TB sputum into the infectious garbage container	148	96.1	151	98.1
	9. Using the detergent or washing power to clean equipments in isolation room.	67	43.5	114	74.0
Studied wards($\bar{x} \pm SD$)	female medical ward	6.9 ± 1.5		7.9 ± 1.0	
	medical ward	7.3 ± 1.3		8.1 ± 1.0	
	ODP	6.8 ± 1.5		8.2 ± 0.5	
	ER	6.2 ± 1.4		6.9 ± 1.4	
		6.7 ± 1.5 *		7.6 ± 1.3 *	

* Statistically significant difference by paired t-test, $P < 0.001$

Table 4 Microbial air quality in the studied wards, before and after intervention($\bar{x} \pm SD$, cfu/m^3).

Studied wards	No. of air samples	Before intervention		After intervention	
		Bacterial counts	Fungal counts	Bacterial counts	Fungal counts
Female medical ward	27	184.8 ± 111.9 (3.7%) *	120.7 ± 79.8 (0.0%) *	100.4 ± 45.4 (0.0%) *	104.4 ± 52.7 (0.0%) *
Male medical ward	27	203.1 ± 101.6 (7.4%) *	67.1 ± 54.2 (0.0%) *	86.3 ± 48.1 (0.0%) *	57.8 ± 28.1 (0.0%) *
Out-patient department (OPD)	18	387.8 ± 249.5 (22.2%) *	93.3 ± 60.1 (0.0%) *	194.4 ± 134.3 (0.0%) *	81.1 ± 58.5 (0.0%) *
Emergency room (ER)	18	237.8 ± 87.1 (11.1%) *	132.8 ± 76.1 (0.0%) *	146.7 ± 68.8 (0.0%) *	56.7 ± 24.5 (0.0%) *
Out-door	7	367 ± 133.7 (28.6%) *	175.1 ± 97.3 (0.0%) *	389.1 ± 132.4 (28.6%) *	189.4 ± 101.2 (0.0%) *

* % of air samples with high level (>500 cfu/m^3)

Table 5 Perception towards air ventilation in the working wards among studied nurses[No. (%)].

Studied wards	No. of studied	Studied personnel who answered poor ventilation	
		Before intervention	After intervention
Female medical ward	36	15(44.4)	12(33.3)
Male medical ward	34	16(47.1)	11(32.4)
Out-patient Department (OPD)	28	15(53.6)	10(35.7)
Emergency room (ER)	56	42(78.6)	38(67.8)
Total	154	88(57.1)	71(46.1)

DISCUSSION

The prevention of tuberculosis transmission in health care settings requires 3 strategies: administrative control, environmental control and use of personal respiratory protection[14,16]. Administrative control reduces hospital personnel and patient exposure, whereas, environmental control reduces the amount of infectious droplets. Using of personal respiratory protection protects hospital personnel in areas where the number of infectious droplet cannot be adequately reduced by the other controls[14]. This intervention study attempted to compare the TB infection control practices, the standard precaution and microbial air quality in the wards between pre- and post-implementation of the TB infection control training and cleaning exhaust fans, air conditioning system, and managing some ward environments. Results revealed that, after intervention, the percentage of studied nurses who always practiced the TB infection control and standard precaution increased in every item, for example, 74% of studied nurses always wear N-95 mask for caring pulmonary TB patients after intervention compared with 46.8% in the period of before intervention. Evidences supported that TB is spread through the air from unrecognized pulmonary or laryngeal TB patients and TB patients with non-effective treatment[3,11,12]. The agent is carried in

airborne particles or droplet nuclei then it can spread quickly in people to be crowed. Most infections are due to inhalation of droplet nuclei in the 1 to 5 micron range[17,18]. The bacteria can settle in the lung and grow and to be infected. Another previous study reported that the surgical mask is insufficient to filter out particles of *M. tuberculosis*, whereas, the N-95 mask can filter particles to 0.3 in diameter by more than 95%[19].

The mean scores of TB infection control practice and standard precaution after intervention were significantly higher than those before intervention, $P < 0.001$. The authors reviewed several reports towards guidelines for preventing the transmission of *M. tuberculosis* or reducing the concentration of TB droplets[3,14,16] in order to develop the intervention program co-operated with infection control committee (ICC) of the studied hospital. This intervention program included 2 parts; the first part was the short education training towards TB transmission, risk for nasocomial transmission of *M. tuberculosis*, standard precaution and environmental control. The second was the training and practice about wearing the surgical mask for TB patients and protective respirators (N-95 mask) for hospital personnel. During the training, it was found that most of hospital personnel incorrectly practiced. After the training, most of them could practice correctly.

For microbial air quality, 90 air samples were collected from 4 studied wards. Before intervention, it was found that the medical out-patient department (OPD) had the highest average bacterial count. Some air samples (22%) had the bacterial concentrations more than the guideline of ACGIH (>500 cfu/m^3). As well as, the ER had the highest average fungal count and 11.1% of air samples had the bacterial counts more than the recommended level of ACGIH (>500 cfu/m^3). After intervention, both bacterial and fungal counts in every air sample collected from every studied wards decreased to the acceptable level of the guideline of ACGIH (<500 cfu/ m^3). This finding suggested that the cleaning of local exhaust fans, fans and air conditioners, and managing of everything that blocked natural air from the window and the door could improve the ward ventilation and reduce the microbial counts in indoor air. This supported the previous study on improving microbial air quality in air-conditioned mass transport buses by opening the bus exhaust ventilation fan[20]. Another study revealed that the rate of 6-12 air exchange per hour could reduce the risk of TB spreading[11]. Additionally, to prevent the microbial growth, the avoidance of wet surfaces, keeping relative humidity levels below 70%, effective filtration of particulates, proper HVAC system operation and maintenance, and good housekeeping should be included[21]. Previous studies found that indoor air pollution from tobacco and biomass fuel combustion and household poor ventilation increased TB risk[22-24]. These might be due to the effects of nicotine and pollutants from combustion on the immune response[25,26]. Therefore, the TB control programs might benefit from a focus on interventions aimed at reducing tobacco and the indoor air pollution responses, especially among those at high risk for exposure to TB[24]. In this study, the nurse plays a role in improving air ventilation in the ward which supported the study of Ayliffe *et al* (2000) who found that the nurse plays a major role in the prevention and control infections in the health-care environment[13]. Data from interviews after intervention showed only 35.7% of studied nurses working in the OPD and 67.8% of studied nurses working in the ER felt the poor ventilation in their wards, which were relatively lower percentage than those in the period of before the intervention (53.6% of studied nurses working in the OPD and 78.6% of studied nurses working in the ER).

In conclusion, two-day training program and management of the ward environment could improve the scores of TB infection control practices and the standard precaution among studied nurses and reduce the microbial counts in air samples collected from the studied wards.

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