Nosocomial Tuberculosis Risk Assessment and Management Recommendation for an Emergency Department in a University Hospital

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Objectives: *To assess the nosocomial TB risk and recommend appropriate risk management procedure for the trauma ward of the emergency department at a university hospital in Bangkok.*
Material and Method*: The risk assessment procedure includes: (1) estimating the number of healthcare visits of the TB patients at the trauma ward of emergency department in 2004; (2) determining the TB incidence rate among the healthcare workers (HCWs) of the trauma ward during 2004-2005; and (3) surveying the indoor environment (particularly concerning the ventilation condition) of the targeting ward. Appropriate risk management procedures were then recommended based on the guidelines provided by The World Health Organization (WHO) and The Centers for Disease Control and Prevention (CDC) of the United States.*
Results: *The estimated number of healthcare visits of the TB patient at the trauma ward in 2004 was 20. During 2004-2005, there were 4 out of 57 HCWs at the trauma ward who developed tuberculosis; among these were two registered nurses and two nursing auxiliaries. The TB incidence rates among these HCWs were 3,509 per 100,000 person-year overall (or 2,632 per 100,000 person-year for confirmed TB cases only) and 3,333 (or 1,667 for confirmed TB cases only) and 4,761 per 100,000 person-year for registered nurse and nursing auxiliary. The ventilation in the trauma inpatient ward had 1.43 air changes per hour, which was below the recommended standard value. Turbulence pattern of airflow, which promotes airborne TB spreading in this area, was also detected.*
Conclusion: *The risk assessment results showed that the trauma ward of the emergency department at this university hospital has a high risk for nosocomial tuberculosis. Appropriate risk management procedures, which are in accord with the standard guidelines, should be urgently implemented.*

Keywords: *Risk assessment, Nosocomial tuberculosis, Emergency department*

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The emergency department (ED) is an area with high nosocomial TB risk in the hospital. It is the point of entry into the medical system for many high risk patients (such as the homeless, the indigent patients, the drug abusers, and the patients with HIV), some of which before their TB statuses are unrecognized and appropriate treatments are administered[1]. Emergency procedures such as intubation and suctioning, which promote droplet nuclei formation, pose particular risk to ED staff serving high-risk populations[2]. In addition, significant numbers of HIV-positive and HIV-negative patients may present with atypical clinical findings, and these patients tend to be identified late in their hospital course.

A recent study reported a very high TB risk among the ED personnel at a university hospital in Bangkok between 1988 and 2002[3]. The TB incidence rate among the ER personnel was 1,610 per 100,000 person-years(PYs), which were 17.2 times higher than the non-occupationally exposed workers (clerks, whose TB incidence rate during the same period was 94 per 100,000 PYs). Furthermore, an additional four TB cases

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were detected between October 2004 and August 2005 among 57 personnel in the trauma inpatient ward, which is a section of the hospital emergency department.

This article reported the nosocomial TB risk assessment result for the trauma inpatient ward at this university hospital. Relevant risk management was also recommended.

Material and Method

The risk assessment was conducted in August 2005. It followed the procedures suggested by the US. Centers for Disease Control and Prevention (CDC) and included: (a) estimation of the number of potential TB infectious patients who had visited the study site during the past years (source identification); (b) examination of the indoor environment particularly the ventilation condition of the study site (path evaluation), and; (c) calculation of the TB incidence rate among the healthcare worker (HCW) of the study site (receiver evaluation)[2]. The details are as follows:

(a) Source identification

The total number of TB-diagnosed inpatients of the study ward during 2004 was enumerated. For those inpatients without overt TB-diagnosis, the probable number of undetected TB cases was also estimated. This was conducted separately for the AIDS/HIV-infected inpatients and those without such a condition. For the AIDS/HIV-infected inpatients, their probable number of undetected TB cases was calculated by multiplying the total number of AIDS/HIV-infected inpatients during January-December 2004 with the prevalence rate of TB among AIDS/HIV-infected persons in Thailand (or the probability of having TB among those with AIDS/HIV infection, which was 0.34)[4]. For those without AIDS/HIV-infection, the estimation procedure was more complicated, as there was no information about TB prevalence among the ER patients in Thailand. Their probability of having undetected TB, which was 2.7×10^{-2}, was estimated from the TB prevalence data for the ER patients in New York City (which was 2.7×10^{-3}), arbitrarily assuming 10 times higher TB risk among the ER patients in Bangkok than in New York City[5]. The possible number of undetected TB cases among the inpatients without AIDS/HIV-infection was calculated by multiplying the total number of inpatients without AIDS/HIV infection during 2004 with this estimated probability. The possible number of overall TB cases admitted into the study ward was then calculated by summing the number of TB diagnosed inpatients and the estimated probable numbers of TB cases among patients with and without AIDS/HIV-infection. The data is presented in Table 1.

(b) Path evaluation

The direction of air flow was predicted from the relative locations of doors, windows, air conditioners, exhaust fans, and physical structure of the ward. Air exchanges per hour were estimated by releasing pure CO_2 while a fan was operating to ensure thorough mixing[6]. The resultant CO_2 concentrations were measured every minute for the next 20 minutes by an infrared direct reading instrument. Air exchanges per hour were calculated by using the following formula[7]:

Air exchanges per hour = [(*LnCPEAK*)-(*LnCT*)]/[T/60]

Where *LnCPEAK* is the natural log of the peak concentration of CO_2, *LnCT* is the natural log of the concentration of CO_2 at time T, and T is the time in minutes from when the CO_2 concentration was at its peak until the end of the measurement period or the CO_2 concentration returned to the baseline value.

(c) Receiver evaluation

The TB incidence rate between 2004 and 2005 among the personnel of the study ward was calculated by person-time analysis, assuming each personnel contributed 2 years of observation during this period. The overall and occupation-specific incidence rates were then reported as number of TB cases per 100,000 person-years (PYs)[8].

Due to the small number of personnel in the study ward, the standardized morbidity ratio (SMR) was then used in the determination of their TB risk. The TB incidence rate of the 15-64 years age group of Bangkok population in 2002 (36.7 per 100,000) was used as the standard rate. The expected number of TB cases among the personnel was calculated by multiplying the number of personnel with the standard rate and the duration of observation (which was 2 years). The overall and occupation-specific SMRs were then estimated by the following: SMR = (observed TB cases/expected TB cases)[8].The 95 percent confidence intervals of the SMRs were calculated according to the method proposed by Rothman and Boice[9].

Relevant risk management was lastly recommended according to the standard guidelines of the CDC and the World Health Organization (WHO)[2,10].

Results

Source identification

The study ward was the inpatient ward for

trauma patients. It contained 23 beds, and had an occupancy rate of 100 percent all year. Totally 535 trauma patients were admitted in the ward during January-December 2004. Only one female patient had overt TB diagnosis. Her diagnosis was based on the compatible signs and symptoms, although the sputum examination and chest x-ray results were negative. The estimated numbers of probable TB cases among the inpatients with and without AIDS or HIV infection were 4.76 and 14.04. These accounted for the overall confirmed and probable TB cases of 20 (Table 1).

The TB prevalence among the Thai population was almost 69 times higher than among the American population (206 and 3 cases per 100,000 population respectively in 2003)[11]. As we assumed the TB prevalence among the ER patients in Bangkok to be only 10 times higher than among those in New York City, we may have underestimated the probable number of undetected TB cases among the inpatients without AIDS or HIV infection in this ward.

Path evaluation

The trauma ward occupied an area of 306 (18 x 17) square meters on the third floor of a three-storey building. It was 13 years old (Table 2). The layout of the ward is shown in Fig. 1(a). There were four air conditioners and four exhaust fans. All air conditioners were split-type. They worked by sucking-in the room air, cooling it, and then recirculating it back to the room. Only a small amount of indoor air is extracted to the outside by the exhaust fan, and replenished with fresh outside air. Measuring the result showed that the amount of ventilation was only about 1.4 air exchanges per hour, which was much below the recommended standard level of no less than 6 air exchange per hour for an inpatient ward[12,13]. This might have been due to the inadequate efficiency of the existing exhaust fans.

When taking into account the relative location of the air conditioners and exhaust fans, the indoor airflow of the area was predicted to be turbulent rather than laminar pattern. This was due to the airflow from the air conditioners being multidirectional, often from opposite sides of the room. This type of airflow pattern was considered inappropriate because it promotes the spread of airborne infectious organisms including TB. However, the nurse's office was separated from the rest of the room by glass walls. So HCWs - who worked inside the office most of the time - were exposed to the contaminated air only when they did patient care activities in the patient care area.

Receiver evaluation

There were 57 HCWs in the ward: among these were 30 registered nurses, 21 Nursing auxiliaries, and six custodians (Table 3). During the past 2 years, one registered nurse and one nursing auxiliary had both pulmonary and lymph node TB, one nursing auxiliary had confirmed pulmonary TB, and one nurse had suspected pulmonary TB (Table 4). Among these, one case was multi-drug resistant TB. These accounted for the overall confirmed TB incidence rate of 2,632 per 100,000 person-years, and the occupation-specific incidence rates of 1,667 and 4,761 per 100,000 person-years respectively for a registered nurse and nurse auxiliary (Table 3). This magnitude of TB risk is considered very high when compared to those rates in the general population, which were 36.67 per 100,000 person-years for the adult population (15-64 years age group) in Bangkok in 2003[4]. The SMR calculation revealed that TB risk of the trauma ward personnel was more than 70 times that of the adult population in Bangkok (the overall SMR[95%CI]= 71.7[14.36-208.70], Table 5).

Discussion

Although there was no evidence of DNA fingerprint patterns to link the transmission of M. tuberculosis from patient(s) to the diseased HCWs,

Table 1. Estimated annual number of TB patients admitting in the trauma ward between January-December 2004

Type of Patient	Number (cases)	Probability of TB	Estimated Number of TB cases
Known TB cases	1	1.0	1
Known HIV-infected patients	14	0.34	4.76
Patients without overt TB or HIV infection	520	0.027*	14.04
Total	535		~ 20 (19.8)

* Calculated from (the prevalence of TB among ER patient in a hospital in New York City, which was 2.7 x 10^{-3}) x10[5]

Table 2. Physical characteristics of trauma ward

Characteristics	Description
Volume (Cubic meter)	1139.25 (21 x 15.5 x 3.5)
Space (Square meter)	325.5 (21 x 15.5)
Type of place	Inpatient ward
Year built	1992
Air conditioning system	Split-type (recirculating ventilation system)
Air exchange per hour*	1.43
Air flow pattern	Turbulent
Direction of air flow**	Inappropriate
Isolation room?	No
HEPA filtration?	No
UV light?	No

* Standard air change rate per hour according to the ANSI/ASHRAE 62.1-2004 for the inpatient ward was no less than 6 complete air change per hour[7]
** The appropriate direction of air flow is from personnel office to the contaminated area and then to the outside[2]

Table 3. TB incidence rates (IRs) among the personnel in trauma ward during 2004-2005

	Occupation			
	Registered nurse	Auxillary nurse	Custodian	Total
Number of personnel (persons)	30	21	6	57
Confirmed TB (cases)	1	2	-	3
Confirm + suspected TB (cases)	2	2	-	4
IR per 100000 person-years*	1,667	4,761	-	2,632
IR per 100000 person-years**	3,333	4,761	-	3,509

IR = incidence rate
* Confirmed TB cases only
** Confirmed and suspected TB cases

Table 4. Detailed information of the healthcare personnel in trauma ward with TB diagnosis during 2004-2005

Characteristics	Case #1	Case #2	Case #3	Case #4
Age (years)	34	32	30	23
Gender	Female	Female	Female	Female
Occupation	Nursing auxiliary	Registered nurse	Nursing auxiliary	Registered nurse
Work duration (years)				
At the hospital	13	11	10	2
At trauma ward	13	10	10	2
Date of TB diagnosis*	10/05/2004	11/23/2004	12/28/2004	8/02/2005
Type of TB	Pulmonary	Pulmonary/ lymph node	Pulmonary/ lymph node	Pulmonary (suspected)
Multi-drug resistant?	Yes	No	No	No
Evidence for diagnosis	Sputum culture, pathologic exam	pathologic exam	pathologic exam	Chest X-ray
Previous chest X-ray	normal	normal	normal	normal
Household TB contact?	no	no	no	no

* Month/day/year

Table 5. TB standardized morbidity ratios (SMRs) for the personnel in trauma ward during 2004-2005

Occupation	Number	Obs		Exp	SMR (95%CI)*	
		TB1	TB2		TB1	TB2
Registered nurse	30	1	2	0.022	45.42 (0.59-252.90)	90.88 (10.21-328.23)
Auxillary nurse	21	2	2	0.016	129.75 (14.04-451.31)	129.75 (14.04-451.31)
Custodian	6	-	-	0.004	0	0
Total	57	3	4	0.042	71.70 (14.36-208.70)	95.60 (25.62-243.83)

Obs = observed number of TB cases, Exp = expected number of TB cases
TB1 = confirmed TB cases, TB2 = confirmed and suspected TB cases
* The standard rate was the TB incidence rate of the 15-64 years age-group of Bangkok population in 2002, which was 36.7 per 100,000[4]

the epidemiological evidence described above strongly supports the likelihood that TB occurrence among the cases was occupationally acquired or at least work related. Previous investigation, which was mentioned previously in the Introduction, reported that HCWs at this work area also had a high TB risk during 15 years of observation between 1988 and 2002. Furthermore, the environmental survey result also showed the indoor condition of the area promoted TB spread.

Specific risk management recommendation

Measures to effectively reduce the TB risk among HCWs in this location are urgently needed. Although simultaneously multi-measures implementation targeting all aspects in the transmission from an infectious host to a susceptible receptor are highly suggested, the following measures are specifically recommended - in order of priority - for this trauma ward. These included (1) source control, (2) path modification, and (3) receiver(s) protection[2,10].

(1) Source control

(1.1) TB patient identification and initiation of effective treatment

Every patient admitted into the trauma ward should be assessed for tuberculosis. Two triage procedures for early TB case identification were suggested by Redd et al and Sokolove et al[1,5]. Patients with a high risk score from the triage procedure should be further investigated by chest x-ray and sputum examination. Those who have confirmed active TB or who are highly suspected to have active TB should be started promptly on appropriate treatment in accordance with current guidelines.

(1.2) TB patient isolation

Any patient suspected of having or known to have infectious TB should be placed in a TB isolation room that possesses currently recommended ventilation characteristics. There should be enough isolation rooms to appropriately isolate all patients who have suspected or confirmed active TB (Fig. 1(b)). TB isolation rooms should be single-patient rooms with special ventilation characteristics appropriate for the purposes of isolation. A minimum of six air changes per hour (ACH) is recommended for TB isolation and treatment rooms[2,12,13]. 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.

(1.3) High risk procedure

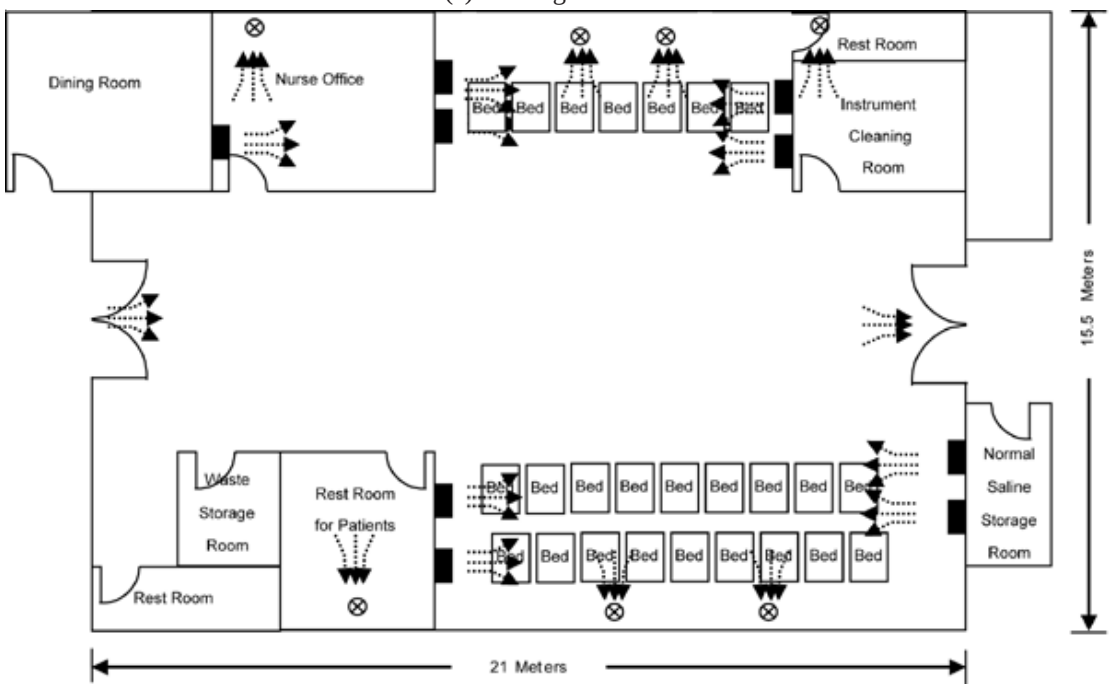
All cough-inducing procedures performed on patients who may have infectious TB should be performed using local exhaust ventilation devices (e.g., booths or special enclosures) or, if this is not feasible, in a room that meets the ventilation requirements for TB isolation. HCWs should wear respiratory protection when present in rooms or enclosures in which cough-inducing procedures are being performed on patients who may have infectious TB.

(2) Path modification

(2.1) Increase air exchange rate

As measures to early detection of TB cases and proper case management are not a hundred percent effective, undetected TB cases are still the potential source of TB spreading in the facility. Additional measures are then necessary to be implemented simultaneously in the trauma ward to decrease the probability

(a) Existing condition



(b) Suggested modification

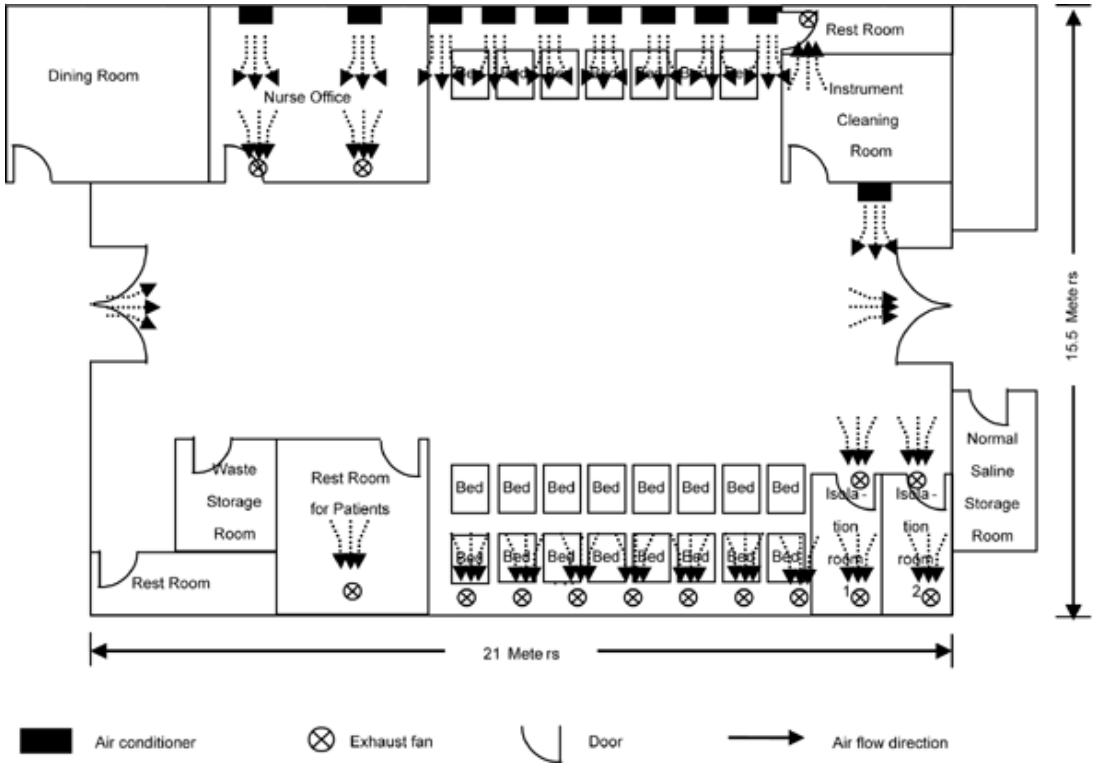


Fig. 1 Layouts of the trauma ward

of TB transmission from these undetected TB cases. Increased ventilation at very low levels can produce substantial improvement in protection. As the ventilation rate of this facility is very low (1.4 air exchange per hour), increased air exchange per hour, up to 6-12 air exchange per hour, is expected to reduce significantly the risk of TB spreading[14].

(2.2) Adjust the airflow direction

The direction of airflow in this area should be designed, constructed, and maintained so that air flows from clean areas to less-clean areas. The multidirectional, turbulent airflow in the room should then be corrected into the unidirectional, laminar flow to reduce spreading of infectious particles in the indoor environment. This is accomplished by reinstalling the existing air conditioners and exhaust fans at the proper locations as suggested in Fig. 1(b). Additional installation of inward and outward exhaust fans may be needed. Exhaust air should be disinfected before venting to the outside.

(3) Receiver protection

(3.1) Personal 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. Respiratory protective devices used in these settings should meet the recommended standard performance criteria.

(3.2) Health surveillance

The risk assessment should identify which HCWs have a potential for exposure to M. tuberculosis and the frequency with which the exposure may occur. The CDC and WHO recommended periodic PPD testing to detect TB infection among HCWs. However, the prevalence of positive baseline PPD tests among these HCWs was high (up to 86.0 or 82.5 percent for the wheal size at the cut-off points of 10 and 15 millimeters respectively)[15]. So periodic PPD testing might not be effective in the early detection of TB infection among these HCWs Health surveillance to early detect TB must then rely on the history of TB disease and periodic chest x-ray instead, until a more effective measure is available

(3.3) TB epidemic investigation system

Multi-drug resistant TB is the real threat for this area, since one HCW had already got this kind of TB. multi-drug resistant TB. A system should be established for detecting multi-drug resistant TB as well as other TB epidemics among the patients and HCWs. This requires collaboration among the ward, the microbiological laboratory, and the infection control committee of the hospital.

Conclusion

Although the DNA evidence was not available to link the transmission of M. tuberculosis from patient(s) to the diseased HCWs, the risk assessment results based on the epidemiological evidence strongly support that the trauma ward of the emergency department at this university hospital is at increased risk of nosocomial tuberculosis. Appropriate risk management procedures, which are in accord with the standard guidelines, should be urgently implemented.

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การประเมินและข้อเสนอแนะการจัดการความเสี่ยงต่อการแพร่เชื้อวัณโรคในแผนกฉุกเฉินของโรงพยาบาลมหาวิทยาลัยแห่งหนึ่ง

วิโรจน์ เจียมจรัสรังษี, สราวุฒิ อยู่ฤทธิ์, วิศรุต ศรีสุนทร

วัตถุประสงค์: *เพื่อประเมินและกำหนดแนวทางการจัดการความเสี่ยงต่อการแพร่เชื้อวัณโรคในโรงพยาบาล ณ หอผู้ป่วยอุบัติเหตุ แผนกอุบัติเหตุฉุกเฉิน โรงพยาบาลมหาวิทยาลัยแห่งหนึ่ง*

วัสดุและวิธีการ: *การประเมินความเสี่ยงประกอบด้วยการสำรวจ **(1)** การประมาณการจำนวนผู้ป่วยวัณโรคที่มารับการตรวจรักษา ณ หอผู้ป่วยอุบัติเหตุ แผนกอุบัติเหตุฉุกเฉินใน 1 รอบปี (2) การคำนวณอัตราอุบัติการณ์การเป็นวัณโรคของบุคลากรที่ปฏิบัติงานอยู่ในหอผู้ป่วยดังกล่าวในรอบ 2 ปี ระหว่างปี พ.ศ. 2547 และ พ.ศ. 2548 และ (3) การสำรวจสภาพแวดล้อมภายในอาคาร (โดยเฉพาะระบบการระบายอากาศ) ของหอผู้ป่วยเป้าหมาย ส่วนการกำหนดแนวทางการจัดการความเสี่ยง อ้างอิงตามคู่มือแนวทางการควบคุมการแพร่เชื้อวัณโรคในโรงพยาบาลขององค์การอนามัยโลก และ The Centers for Disease Control and Prevention (CDC) แห่งประเทศสหรัฐอเมริกา*

ผลการศึกษา: *ประมาณการว่ามีผู้ป่วยวัณโรคมารับบริการตรวจรักษา ณ หอผู้ป่วยอุบัติเหตุ 20 รายในปี พ.ศ. 2547 และในช่วงเวลาระหว่างปี พ.ศ. 2547 - พ.ศ. 2548 มีบุคลากรในแผนกป่วยเป็นวัณโรค 4 ราย โดยเป็นพยาบาลวิชาชีพ 2 ราย เจ้าหน้าที่/ผู้ช่วยพยาบาล 2 ราย จากจำนวนบุคลากรทั้งหมด 57 คน คิดเป็นอัตราอุบัติการณ์รวมเท่ากับ 3,509 รายต่อแสนคน-ปี (หรือ 2,632 รายต่อแสนคน-ปีสำหรับวัณโรครายที่ยืนยัน) และอัตราอุบัติการณ์จำแนกตามวิชาชีพสำหรับพยาบาลวิชาชีพ และเจ้าหน้าที่/ผู้ช่วยพยาบาลเท่ากับ 3,333 (หรือ 1,667 รายสำหรับวัณโรครายที่ยืนยัน) และ 4,761 ราย ต่อแสนคน-ปีตามลำดับ โดยมีความเสี่ยงต่อวัณโรคสูงกว่าประชากรวัยผู้ใหญ่ในเขตกรุงเทพมหานครประมาณ 95.6 เท่า ส่วนผลการสำรวจสภาพแวดล้อมภายในอาคาร ณ หอผู้ป่วยอุบัติเหตุพบว่ามีปริมาณการไหลเวียนอากาศประมาณ 1.43 รอบต่อชั่วโมง ซึ่งต่ำกว่าค่ามาตรฐานที่กำหนด รวมทั้งมีทิศทางการไหลเวียนอากาศแบบวกวน ซึ่งเอื้ออำนวยต่อการแพร่เชื้อวัณโรคในโรงพยาบาล*

สรุป: *ผลการประเมินความเสี่ยงพบว่าหอผู้ป่วยอุบัติเหตุ แผนกอุบัติเหตุฉุกเฉิน โรงพยาบาลจุฬาลงกรณ์มีความเสี่ยงต่อการแพร่เชื้อวัณโรคในโรงพยาบาลสูง ดังนั้นจึงควรมีการดำเนินการเพื่อลดความเสี่ยงดังกล่าว โดยอาศัยแนวทางที่กำหนดไว้ในเอกสารคู่มือที่เกี่ยวข้องอันเป็นสากล*