

**Recommendations for Preventing the
Transmission of *Mycobacterium tuberculosis* at
Chiang Rai Hospital, Thailand, 1997**

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Centers for Disease Control and Prevention (CDC)
Atlanta, Georgia 30333
USA

Prepared by:

Denise O. Garrett, MD
Hospital Infections Program
National Center for Infectious Diseases

Paul A. Jensen, Ph.D.
Division of Physical Sciences and Engineering
National Institute for Occupational Safety and Health

Patrick A. Zuber, MD
Division of Tuberculosis Elimination
National Center for HIV, STD and TB Prevention

William R. Jarvis, MD
Hospital Infections Program
National Center for Infectious Diseases

Nancy J. Binkin, MD
Division of Tuberculosis Elimination
National Center for HIV, STD and TB Prevention

Submitted through:

Timothy D. Mastro, MD, Director
The HIV/AIDS Collaboration

Khanchit Limpakarnjanarat, MD, Adjunct Director
The HIV/AIDS Collaboration

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I. Background and purpose

After decades of declining incidence, tuberculosis (TB) is once again a major public health problem.¹ The annual number of TB patients has increased in several countries, reversing a long-established downward trend.² A similar trend in TB incidence also has been observed in Chiang Rai Province. Following a steady decline in reported TB from 1982 through 1991, the incidence of TB increased sharply from 1991 through 1993. From 1990 through 1994, the annual number of patients with TB at Chiang Rai Hospital increased from 257 to 455 largely related to an increase in HIV+ TB cases.³ From 1989-1996, numerous nosocomial *Mycobacterium tuberculosis* outbreaks were reported in the United States (U.S.).⁴⁻¹⁰ They included both patient to patient and patient to health care worker (HCW) *M. tuberculosis* transmission. In these outbreaks, several HCWs have developed active TB and many patients and some HCWs have died of nosocomially-acquired multidrug-resistant *M. tuberculosis*.

Because of concern about possible nosocomial/occupational *M. tuberculosis* transmission in hospitals in developing countries, the HIV/AIDS Collaboration, a joint activity of the Ministry of Public Health of Thailand and the U. S. Centers for Diseases Control and Prevention (CDC), in collaboration with the Hospital Infections Program, the Division of Tuberculosis Elimination, CDC, and Chiang Rai Hospital, initiated a study to ascertain whether there was increased risk of *M. tuberculosis* infection among HCWs at the Chiang Rai Hospital associated with occupational exposure. The first phase of this study, conducted from February through March 1996, had as its main objective to examine the prevalence of predictive risk factors for tuberculin skin test (TST) positivity and TST positivity among HCWs in this hospital setting, where there have been few TB-specific infection control measures. All participants, 911 HCWs, were interviewed to determine age, educational level, history of TB in the family, job title, location of work and duration of employment in the hospital. HCWs also were examined for smallpox and Bacillus of Calmette and Guérin (BCG) vaccination scars. A two-step TST was used to measure the prevalence of boosted reaction

by the initial skin test. Of the 911 HCWs tested, 623 (69%) had an initial positive TST (≥ 10 mm) and 288 HCW who were TST negative were asked to have a second step TST. 123 (53%) of the 233 HCWs who completed the second step TST had induration ≥ 10 mm. Accounting for the incomplete second TST, the overall TST positivity is estimated at 85%. TST positivity was not associated with age, education level, history of TB in a family member, or working in hospital locations with different risks of exposure. TST positivity (TST reaction ≥ 10 mm) was associated with being male (173/220 [79%] vs 450/691 [65%], OR=2), having a BCG scar (503/705 [71%] vs 120/206 [58%], OR=1.8), or having major duties involving patient contact (259/361 [72%] for direct contact with patients (e.g., nurses), 94/121 [78%] for working in patient care areas (e.g., maintenance), vs 270/429 [63%] for rare or never contact with patients (e.g., clerk), OR=1.5 and 2.1, respectively). Higher TST positivity also was associated with employment duration ≥ 1 year [599/863 (69%) vs 24/48 (50%), OR=2.3, $p < 0.01$]. Similar associations were observed when TST positivity was defined by a ≥ 15 mm cutoff with the exception of having a BCG scar, which no longer predicted TST positivity.

In summary, results of this first phase showed a pattern of higher TST positivity among persons: a) working in direct contact with patients and b) who had been employed for ≥ 1 year. These results suggest that HCWs at Chiang Rai Hospital are at risk of *M. tuberculosis* infection (i.e., TST positivity) that may be related to occupational exposure. The second phase of this project will focus on implementing interventions to reduce the risk of nosocomial transmission of *M. tuberculosis* and the development of active TB disease among HCWs at the Chiang Rai Hospital.

A recent survey (1996) on TB knowledge, attitudes and practices among nursing staff (N=127) at Chiang Rai Hospital showed that nursing staff have a high level of concern about TB transmission and that there are opportunities for prevention. According to this survey, 61% of nursing personnel think TB prevention for HCWs should be improved, 72% had concern about TB transmission from patient to HCWs, 73% had concern about TB transmission from undiagnosed patients, 83% agreed with the statement that "if there were an isolation ward, I would be protected", 83% think that TB transmission will be reduced by a TB isolation ward and, 97% felt they need further training about caring for infectious TB patients. However, only 20% said they would be willing to work on a TB isolation ward, while 57% were willing to take care of TB patients.

In October 1996, a team from the CDC - Drs. Denise Garrett (Hospital Infections Program), Paul Jensen (National Institute for Occupational Safety and Health) and Patrick Zuber (Division of TB Elimination)- visited the Chiang Rai Hospital to assess the hospital's facilities and make

recommendations for preventing the transmission of *M. tuberculosis*. During this visit, a small group discussed potential TB infection control measures which could be implemented by the hospital. Participants in this discussion were:

Dr. Wat Uthaivorawit

Chiang Rai Hospital

Dr. Pacharee Khantipongs

Chiang Rai Hospital

Ms. Udomsiri Panrat

Division of Provincial Hospitals, Ministry of Public Health (MOPH)

Dr. Srivanna Phoonsapasith

Division of Provincial Hospitals, MOPH

Dr. Tapanok Ratanadilok Na Phuket

Division of TB, MOPH

Dr. Timothy Mastro

HIV/AIDS Collaboration

Dr. Khanchit Limpakarnjanarat

HIV/AIDS Collaboration

Dr. Peter Kilmarx

Chiang Rai Health Club, HIV/AIDS Collaboration

Ms. Supaporn Korattana

Chiang Rai Health Club, HIV/AIDS Collaboration

Dr. Denise Garrett

Hospital Infections Program (HIP), CDC

Dr. Paul Jensen

National Institute for Occupational Safety and Health (NIOSH), CDC

Dr. Patrick Zuber

Division of TB Elimination (DTBE), CDC

Dr. Takashi Yoshiyama

Research Institute of Tuberculosis (RIT), Japan

This report is based upon what was discussed at this meeting, the results of the study of the risk of nosocomial/occupational transmission of *M. tuberculosis* at Chiang Rai Hospital, a review of the Hospital's facilities, and input from HIP, DTBE and NIOSH experts. **These recommendations for reducing the risk of *M. tuberculosis* transmission to HCWs and other patients are specifically intended for Chiang Rai Hospital; not all recommendations are intended to be generalized to other settings. It is suggested that officials of the Ministry of Public Health of Thailand and other public health officials consider these recommendations as an example to be adapted to other hospital settings following consideration of other relevant information and opinions.**

II. TB Infection Control Strategy

The main objective of a TB infection control strategy is to prevent persons exposed to infectious TB patients in a health care setting from developing *M. tuberculosis* infection or disease. Little is known about the respective efficacy of existing infection control interventions in places with high prevalence of TB, like Chiang Rai Hospital. Therefore, it is important that any intervention implemented be prospectively evaluated for feasibility and impact. The notion of continuous evaluation or management has been central to infection control strategies developed in the U.S. In order for personnel at Chiang Rai Hospital to determine the short- or long-term benefit of its investment in a *M. tuberculosis* infection control, it will be critical that adequate evaluation of the intervention be an integral part of the infection control program. Information about the health status of hospital employees should be collected on an ongoing basis, and these data should be systematically analyzed at regular intervals. These evaluations will allow prospective quantification of the impact of the interventions and the resources used. Furthermore, since Chiang Rai Hospital will be a pioneer in the field of applying TB control measures in the developing world setting, the experience gathered will be extremely beneficial for other institutions throughout the world.

The approach to *M. tuberculosis* infection control should focus on three levels:

- 1) Hospital employees (i.e., training and education, tuberculin skin testing, preventive therapy, voluntary counseling and testing for human immunodeficiency virus [HIV] infection, and personal respiratory protection).
- 2) Patients (i.e., early identification of patients suspected to have infectious TB, prompt diagnostic evaluation, isolation, and appropriate treatment).

- 3) Environment (i.e., use of local exhaust ventilation, control of airflow direction, air cleaning by filtration or ultraviolet germicidal irradiation [UVGI]).

III. Specific Recommendations

As discussed above, continuous management of all implemented interventions is an absolute priority to the infection control program. For all three levels of intervention, we have tried to adapt our recommendations to Chiang Rai Hospital's setting. Prioritized summaries of the proposed interventions are presented in tables at the end of the report.

A. Continuous management

Using periodic health evaluations, a surveillance system should be developed to assess:

- a) The risk of *M. tuberculosis* infection among HCWs. This relies on a baseline two-step tuberculin skin test (TST) (on all new employees and current staff who have not had a two-step TST) and periodical evaluation of persons with a negative TST as discussed in the section on hospital employees. Surveillance should include information about the main risk factors, e.g., workplace, occupation, and history of recent exposure to TB patients at work or outside the workplace. The specific information to be included in the surveillance system should depend on the interventions selected by Chiang Rai Hospital.
- b) Standardized surveillance of active TB among hospital employees. The Chiang Rai Hospital's Department of Preventive and Social Medicine keeps track of morbidity among employees. In order to allow for systematic surveillance of HCWs with active TB, it would be important to develop a standardized case-definition and to include all the important risk factors for TB.
- c) Standardized surveillance of active TB among patients. A simple form, including diagnostic criteria, dates of admission and positive smear or culture, and place of stay at the hospital, should be developed.

CDC can assist in developing the instruments for surveillance systems which meet the criteria of simplicity, flexibility, acceptability, sensitivity, and timeliness.¹¹

B) Specific interventions

The three levels of specific interventions have different objectives. For hospital employees,

objectives are to increase their awareness of the risk related to occupational transmission of *M. tuberculosis*, to educate them about TB prevention, and to protect them from *M. tuberculosis* infection or disease. For hospital patients, objectives are to minimize chances that persons with active pulmonary TB disseminate *M. tuberculosis* in the hospital environment. Finally, environmental or engineering interventions help reduce the concentration of infectious droplet nuclei and prevent their spread. The latter two levels are not only beneficial to hospital employees, but also to all persons hospitalized or visiting the hospital, since they contribute to reducing the general level of exposure to *M. tuberculosis*.

1) Hospital employees

1.1. HCW training and education

All HCWs should receive in-service education about the basic concepts of *M. tuberculosis* transmission and pathogenesis, the signs and symptoms of TB, TB infection control practices, the importance of participating in the HCW TST program, and the particular risk of *M. tuberculosis* infection for persons with HIV infection. Training of HCWs should include the epidemiology of TB in the facility and should describe work practices that reduce the likelihood of transmitting *M. tuberculosis*. It should also educate employees about the hospital policy for reducing the risk of *M. tuberculosis* infection and the role of personal respiratory protection.

Ideally, training should be conducted before initial assignment, and continuing education should be provided to all employees (e.g., once a year). During our discussions of the TB infection control measures, representatives of the Division of TB, MOPH, mentioned that their division would be willing to participate in this activity through the development of brochures and teaching materials to be used by trainers for the education of HCWs. If such a training package is prepared, it may be expanded to other health care facilities in Chiang Rai or Thailand.

1.2. Tuberculin skin testing

All HCWs should be included in a TST screening and TB prevention program. All HCWs should receive a two-step Mantoux TST upon employment together with a chest radiograph. Those who test negative (two-step tuberculin skin test reaction <15 mm) should be reevaluated with a one step TST at intervals determined by their risk of exposure (every 6 months for persons working in patient care areas and every year for other employees could be a reasonable initial approach).

Conversion to a positive TST, as defined below, should be followed as soon as possible, by appropriate physical, laboratory, and radiographic evaluation to determine whether the employee has active TB and to offer preventive therapy (if no active TB) or treatment (if active TB). It must be pointed out that successful employee health evaluation programs require occupational health professionals to conduct active follow-up. Passive systems are notoriously incomplete.

1.3. Prevention of active TB

Since it is unlikely that patient management and environmental interventions will totally eliminate potential HCW exposure to *M. tuberculosis* in the hospital, it is to be expected that HCW with TST conversions will be detected. The following measures should be considered in order to diminish the risk of progressing from *M. tuberculosis* infection to active disease in HCWs: evaluation of TST converters to exclude active TB, follow-up of TST converters, and consideration of preventive therapy and voluntary HIV counseling and testing. A recent TST conversion is defined as an increase of ≥ 10 mm of the size of induration (e.g., an increase from 7 mm to 17 mm).¹²

a) It is usually considered that immunocompetent persons with recent *M. tuberculosis* infection have a 5% risk of developing active TB within two years, and another 5% risk for the rest of their life.¹³ This is in contrast to a 10% annual risk of developing active TB in immunocompromised persons. Thus, in immunocompromised HCWs, a thorough clinical evaluation to exclude active TB is essential. The investigation should include history taking and physical examination to identify classical symptoms and signs of TB (weight loss, persistent cough, fever), and a chest x-ray.

b) Preventive therapy with isoniazid is a recognized intervention for preventing the development of active TB among persons infected by *M. tuberculosis*. The most common regimen consists of 300 mg. of isoniazid daily for six months.¹⁴ For persons likely to have been infected by a strain resistant to isoniazid, rifampin is the most commonly recommended alternative.¹⁵

The main concern with preventive therapy is to ensure that active TB has been ruled out. Preventive therapy in a person with active disease may momentarily mask the presence of the disease without resulting in a cure and can significantly increase the risk of developing a form of disease resistant to isoniazid. Another challenge to preventive therapy is its feasibility, because of the relatively long duration of the treatment. However, there are no indications that an incomplete regimen of isoniazid could have a detrimental effect on the evolution of TB; it simply would be ineffective.

c) Because of the high risk presented during the first two years, all TST converters should be re-evaluated at regular intervals (every 6 months) to exclude the development of active TB. If preventive therapy is offered, follow-up may not be necessary once it has been ensured that the prescribed course has been completed.

Two situations must be distinguished: 1) persons with evidence of recent infection by *M. tuberculosis*; and 2) persons with past infection detected at baseline.

c.1.) Recent TST converters (an increase of ≥ 10 mm of the size of induration) benefit the most from preventive therapy because of the higher risk of TB in the first two years after infection.

c.2.) Latent *M. tuberculosis* infection may reactivate into active TB. However, among immunocompetent persons, the risk is lower than for recent converters. In the U.S., it is usually recommended that persons younger than 35 years of age with a high probability of latent *M. tuberculosis* infection also be offered preventive therapy. Because of a higher risk of isoniazid-associated hepatitis among older persons¹⁶, the benefit of preventive therapy is not as well established when the risk of developing active disease is less likely. Preventive therapy is therefore not usually recommended for latently infected persons aged 35 years or older, or for persons with evidence of liver disease or heavy alcohol consumption. In addition, because the risk for INH-associated hepatitis may be increased during the peripartum period, the use of preventive therapy for pregnant women should be delayed until after delivery.

Data from our study suggests that BCG vaccination also was a predictor of a positive TST. Thus, a TST reaction of 10 mm or larger could be found among non-infected persons because of a previous BCG vaccination. However, when a cutoff of 15 mm was used, a BCG scar was no longer associated with TST positivity. Therefore, when considering to initiate a program of preventive therapy at Chiang Rai Hospital for latently infected HCWs it would be reasonable to restrict it to those who have a TST reaction ≥ 15 mm. According to our study, there are 154 employees at Chiang Rai Hospital younger than 35 years of age who have a TST reaction ≥ 15 mm, that should be offered preventive therapy.

d) Persons with HIV are at increased risk of progressing to active TB disease after *M. tuberculosis* infection¹⁷, and TB-associated mortality is higher in this group.¹⁸ HCWs should be informed about the particular risk associated with TB and HIV and should be offered the possibility of confidential, voluntary HIV testing and counseling. Voluntary HIV testing should not affect their ability to be employed and for HIV+ employees concerned about their risk of occupational acquisition of TB, alternative work sites (i.e., areas with lower risk) should be considered and

discussed with the TB infection control committee.

HCWs offered preventive therapy should be monitored monthly for signs and symptoms consistent with adverse effects and for development of symptoms compatible with pulmonary and/or extrapulmonary tuberculosis. If signs and symptoms of toxicity appear, preventive therapy should be stopped immediately and the patient should be reevaluated. Laboratory monitoring of persons younger than 35 of age is not required. However, a transaminase level should be determined in case of signs and symptoms of toxicity. If any of these tests exceeds 3 times the upper limit of normal, discontinuation of INH should be strongly considered. If TB is confirmed, preventive therapy should be stopped and treatment commenced. **Preventive therapy should not be prescribed if monthly monitoring cannot be done.**

1.4. Personal respiratory protection

Personal respirators, such as the N95 (42CFR84), should be worn by HCWs while they stay in areas with increased risk of exposure to infectious TB patients, such as in TB isolation rooms.^{19,20,21} If TB patients are 'isolated' on large TB wards, then HCWs in these areas may need to wear respirators continuously. In areas of high risk of exposure such as autopsy suites (planned for the new building) or rooms where cough-inducing procedures are performed, a higher level of personal respiratory protection, such as powered air-purifying respirator (PAPR), may be needed. For example, if a cough-inducing procedure can't be conducted inside a booth or ventilation hood, then the HCW should wear respiratory protection when conducting or assisting with this procedure. In such instances, the donning of a PAPR may be appropriate. PAPRs are available with half-face pieces or hood that cover the entire head. A small number of such devices could be purchased and shared by HCWs in these areas (autopsy and bronchoscopy).

Worker education and respirator training are important for an effective infection control program. With the implementation of the use of respirators, a standard operating procedure should be developed to address the following issues:

- a. Permissible practices for respirator use
- b. Respiratory program administration
- c. Respirator selection
- d. Inspection of respirators
- e. Cleaning and maintenance of respirators

- f. Storage of respirators
- g. Training in respiratory protection
- h. Fit testing of respirators
- i. Respiratory program evaluation
- j. Medical surveillance of respirators users

Respirators should be replaced whenever soiled, moistened or misshapen. If used over days, weeks, or months, they should be stored in a clean dry location until the next shift. Before reuse, the respirator should be visually inspected for structural integrity, cleanliness and evidence of moisture.

2) Patients

2.1. Identification of infectious TB Patients

Clinicians at Chiang Rai Hospital report a high index of suspicion for TB in any patient with symptoms suggestive of TB (e.g., persistent cough, bloody sputum, night sweats, fever, weight loss, or loss of appetite). We encourage the HCWs to maintain this high index of suspicion, particularly among patients in whom the risk of TB is high, such as HIV-infected patients. For the outpatient and inpatient settings, a designated person or personnel should develop a written protocol for the early detection of persons with active TB, based on the prevalence and characteristics of the TB population in Chiang Rai. This will help insure that all patients with suspected TB will be evaluated in a standard and comprehensive manner. A review of the Chiang Rai Hospital TB patient database may be useful in outlining which patient populations are at greatest risk of TB.

2.2. Management of Suspected TB Patients

- a) All suspected TB patients should be placed in TB isolation, until after TB is excluded or the patient is considered non-infectious. TB isolation rooms should be single-patient rooms with special ventilation characteristics (see engineering control section).
- b) Once identified, potentially infectious TB patients should be given a surgical mask to wear or they should be given tissues and asked to cover their nose and mouth when coughing, sneezing or speaking while not in an isolation area.
- c) All HCWs evaluating known or suspected TB patients in the HIV and TB counseling areas should wear personal respiratory protection.

- d) Prompt therapy should be initiated in patients who are considered highly likely to have active TB.

2.3. Diagnostic evaluation

a) Acid fast bacilli (AFB) sputum smears

Patients suspected of having TB should undergo prompt diagnostic evaluation. To ensure prompt results, the laboratory performing AFB smears should be proficient at both the laboratory and administrative aspects of specimen processing. It is essential that sputum collection and delivery of sputum to the laboratory be done in a timely manner. One possible option to avoid delays in the wards would be to have a designated person responsible for all aspects of sputum collection. It also is essential that laboratory technician(s) be available, so that AFB smears can be obtained, performed, and read in a timely manner, and results can be available within 24 hours of specimen collection.²²

b) Chest radiograph

It was noticed during our visit to the Chiang Rai Hospital, that suspected and confirmed TB patients wait for chest x-rays in a common patient waiting area. In order to minimize exposure of other patients, chest x-rays in suspected and/or confirmed infectious TB patients should be performed immediately, minimizing their wait-time. If possible, such patients should be masked and wait in an area separate from other non TB patients.

2.4. Management of Confirmed TB Patients

a) If TB is confirmed, the TB patient should remain in the TB isolation room or be moved to a TB ward. For the most optimal condition, TB wards should provide an environment that will allow for the reduction in the concentration of airborne droplet nuclei through various engineering controls which would prevent the escape of infectious TB droplet nuclei from the TB ward into other areas of the facility. The number of TB wards necessary at the Chiang Rai Hospital should be based on either the average or maximum number of TB patients admitted to the hospital and can range from one (for all TB patients), two (if men and women have to be separated), or three (if an isolated area for monks is desired) wards.

The grouping of all infectious TB patients on TB wards has several benefits over having separate isolation facilities throughout the entire hospital. First, it reduces the risk of HCW (and patient) exposure to infectious TB patients throughout the hospital. Second, the HCW education is

more feasible when applied to a limited number of wards, with a limited number of HCWs rather than the entire facility. Third, the implementation of environmental controls and HCW respiratory protection is easier and less costly in a smaller area with a smaller number of HCWs. Fourth, applying these controls in a smaller well-defined area simplifies observation and monitoring of HCWs for their degree of compliance and function of environmental controls. With limited numbers of personnel to implement and monitor any TB infection control program, the TB ward approach focuses their efforts on one or more specific areas and a limited number of personnel.

b) Patients placed in TB isolation should remain in their isolation rooms. If transportation of these patients for essential medical procedures is necessary, the patient should wear a surgical mask that covers the mouth and nose during transport. Essential medical procedures for these patients should be scheduled at times when they can be performed rapidly and when waiting areas are least crowded, for instance at the end of the day.

c) Although this is common practice at Chiang Rai Hospital, it is important to emphasize that the length of hospitalization of TB patients should always be kept as short as possible. Directly observed therapy (DOT) is recognized as the best available method to ensure that TB patients will rapidly become non-infectious, which also is an important consideration for protecting all persons exposed to them outside of the hospital.

d) TB isolation can be discontinued when the patient is no longer considered infectious. Patients are not considered infectious if they meet all the following criteria:

- they have received effective therapy for 2 to 3 weeks
- they have a favorable clinical response to therapy
- they have had three consecutive negative sputum smear results from sputum collected on different days.

e) Patients with known MDR-TB (i.e., resistant to isoniazid and rifampin), whether newly developed or readmitted after initiated therapy, should be considered infectious; they should be placed in TB isolation on each admission until proven to be noninfectious. It must be noted, however, that culture for *M. tuberculosis* is not performed for most patients in Chiang Rai. It could therefore be helpful to include a clinical algorithm for suspecting drug resistant cases as part of the protocol for the detection of persons with active TB.

2.5. Patient TB training and education

To improve patient compliance with TB infection control measures, all TB patients should

be educated about the modes of transmission of *M. tuberculosis*, the reasons for TB isolation, and the importance of staying in their rooms while they are infectious.

3) Engineering Control Measures (Please see Table 2 for suggested priorities)

In general, recommendations for engineering controls include: (a) local exhaust ventilation (i.e., control at the generation point); (b) general ventilation; and (c) air cleaning. General ventilation considerations include: (a) dilution and removal of airborne contaminants; (b) airflow patterns within the room; (c) airflow direction in the facility; (d) negative pressure in rooms; and (e) TB isolation rooms. Air cleaning or disinfection can be accomplished by filtration of air (e.g., high efficiency particulate air [HEPA] filtration or 95% ASHRAE efficiency filtration) or inactivation of microorganisms by UVGI.

During our briefing on October 1996, five room ventilation configurations were discussed. The first configuration (i.e., open) is used in many of the medical wards (Figure 1a). In these, the medical ward is of open construction with free-flow of ambient air in one side of the building through the open windows and out the other side of the ward through open windows. The second configuration (i.e., neutral) is similar to the meeting room (Figure 1b). In these, the room is at neutral pressure relative to the surrounding area and has neither an air supply nor exhaust air; however, a recirculating air conditioner was used for temperature control. In the third configuration (i.e., positive - Figure 1c), outside air is supplied to the room (Figure 1b). This room is at positive pressure relative to the surrounding area. In the fourth configuration (i.e., negative - Figure 1d), air is exhausted out of the room (Figure 1a or 1b). This room is at a negative pressure relative to the surrounding area. Finally, the fifth configuration (i.e., ideal - Figure 1e), not present in Chiang Rai Hospital, is the ideal situation. In this system, fresh air is supplied to the room and a greater amount of air is exhausted. To be specific, the flow differential (exhaust minus supply) in a well-sealed negative pressure isolation room should be $\geq 10\%$ of the supply or $1.4 \text{ m}^3/\text{min}$ ($50 \text{ ft}^3/\text{min}$), whichever is greater. As with Figure 1d, this room is at negative pressure relative to the surrounding area. As various engineering control recommendations are discussed, you will be referred back to these figures and further explanation will be given.

3.1. Male and female wards

A floor plan of the hospital and wards is shown in Figure 2. Note that all ceilings were at

least 4 m (12 ft). Other than a few recirculating air conditioning units in selected offices, meeting rooms, clinical laboratories, and operating rooms, no heating, ventilation and air conditioning system was observed. The "ventilation" of the hospital medical wards consisted of open construction with open windows and doors (Figure 1a). Solid-pane, immobile windows should be replaced with louvered windows (including those above the toilet area). Unrestricted open construction, such as this, will require no additional engineering controls as long as the windows remain open and there is natural air movement through the wards.

The two isolation rooms in the male ward, however, did not appear to be at negative pressure. Perhaps, this was a result of the 2 m length of window which was open to supply air to the room and/or an exhaust (we did not measure the flow rate) grille in the center of the ceiling. Better airflow patterns and negative pressure could be obtained by restricting the amount of supply air to the room (i.e., blocking a portion of the window) and moving the exhaust to a location low on the opposite wall. These isolation rooms are large enough to house two confirmed TB patients. During the March 1997 visit, the exhaust system in one of the two isolation rooms was not operational. The windows and door were left open. The exhaust flow rate in the other room was measured to be approximately 25 m³/min (900 ft³/min), resulting in 38 air changes per hour (ACH). Though this is a large air exchange rate, the exhaust inlet was near the large open window; thus, the air in the room was not being efficiently cleaned. The current area previously designated for ICU and currently used by the nursing staff for meetings, could be renovated into three or four single-patient negative pressure isolation rooms. Additional isolation rooms may be needed. Consideration should be given to engineering several rooms in the new HIV ward as negative pressure isolation rooms. These rooms could be used when the other isolation rooms are filled to capacity.

The current female wards was similar to Figure 1a on one side; however, there was a center hallway with floor-to-ceiling walls. Across the hallway from the main ward, several two-person rooms are located. HIV-positive patients are housed in the hallway and in two of the rooms. The remaining two rooms are used as isolation rooms for TB and TB/HIV patients. This situation is adequate for worker and patient protection as long as the prevailing winds are from the ward toward the isolation rooms. If the wind is from the opposite direction, potentially TB-laden air could flow from the isolation room, past the HIV-positive patients, past the nurse's station, and into the general medical ward. If this ward is not moved to the new building, we would recommend making the isolation rooms negative pressure relative to the surrounding area (Figure 1d). After the new building opens in April, the women's wards will be relocated to second and third floors. See later

comments regarding the new building.

3.2. TB and outpatient clinic

The area used for the TB clinic on Wednesdays and Thursdays is a real challenge for providing effective engineering controls. The TB clinic area has a waiting room with six adjoining doors and one multi-panel window. One double-door is a public entrance (kept open), one open doorway leads to the OPD clinic area, one closed door to a storage room (near the window), one open door to an endoscopy room that is not used during TB clinic, one open to the double examining room, and one closed to the Medical Department staff office. The waiting room, Medical Department staff office, and examining room had windows.

As mentioned during the briefing, the major recommendation is both administrative and engineering--Isolate the TB clinic from the general Outpatient Department (OPD) clinic area. If safety and fire codes permit, the steel "roller" door could be lowered on TB Clinic days to prevent potentially contaminated air from reaching the OPD clinic area and prevent OPD patients from transitting through the waiting area for TB patients. As with the male medical wards, air freely flows across the waiting area (one window on one side, open doors on the other). We were told that the "cold" season is only 10°C cooler than the "hot" season; therefore, the doors and all six window panels should remain open all year. The examination room consists of a large room with two beds separated by curtains. The windows on one wall were open. Because of the limited effectiveness of ventilation in this room, additional engineering controls, such as supplemental air cleaners (forced air with HEPA, 95% ASHRAE, or UVGI) or upper air UVGI, may be necessary to reduce the risk of *M. tuberculosis* transmission in these areas.

The clinical effectiveness of UVGI systems varies because the intensity of UVGI, the duration of contact the organism has with the irradiation, and the relative humidity.^{23,24,25} Humidity can have an adverse effect on UVGI effectiveness at levels >70% relative humidity.²⁶ Temperature and relative humidity measurements taken on 12 March 1997 ranged from 22-27°C and 55-65% RH; thus, caution must be exercised in selecting UVGI. The month of March is considered the beginning of the hot season. Old lamps or dust-coated UVGI lamps are less effective; therefore, regular maintenance is crucial. In addition, UVGI measurements should be performed to verify the output of the UVGI lamps on a regular basis.

Safety also should be kept in mind whenever personnel are near UVGI fixtures. Short-term overexposure to UVGI can cause erythema and keratoconjunctivitis.^{27,28} UV-C (100 - 290 nm) has

been classified by the International Agency for Research on Cancer as probably carcinogenic to humans (group 2A).²⁹ Fixtures must be designed and installed to ensure that UVGI exposure to persons in the room (HCWs, patients, visitors, etc.) are below current safe exposure levels. The current National Institute for Occupational Safety and Health Recommended Exposure Limits and the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Values (TLVs) are listed in Table 3.³⁰ Note that the permissible levels are time and intensity dependent.

Attached to this clinic, is a room similar to Figure 1b, which is used as a Medicine Department staff room. One solution to the ventilation problem in these two areas would be to switch the activities in these two rooms. Then, the new medicine department room (old exam room) should have sufficient supply air to make it positive relative to the TB clinic (Figure 1c) and access to this room could be provided such that the HCWs could avoid walking through the TB Clinic waiting room.

After reviewing the TB clinic area, we walked through the OPD clinic area and the pharmacy waiting area. The OPD clinic, where patients may be initially classified as suspected or confirmed TB is somewhat enclosed. The OPD area consists of eight examination rooms: three on the exterior wall, three exam rooms along the wall opposite the TB Clinic, and two exam rooms on an inside wall (backing up to pharmacy waiting area). The doorway to the TB clinic is in one corner of the OPD/orthopaedic waiting room. Part of the OPD waiting area opposite the examining rooms opens up into the pharmacy and pharmacy waiting area. Depending on the speed and direction of the prevailing wind outside the hospital, air enters/exits the waiting room after passing through the exam rooms located on the exterior wall with open windows. Air may then exit/enter the OPD waiting room from an outside door, the pharmacy waiting room, or the TB clinic. However, another room with three curtained exam areas has limited, if any, ventilation. Essentially, the only air exchange in this later examining room is through the openings near the ceiling on the waiting room side. This room could benefit greatly by adding engineering controls to remove contaminants. Since general ventilation is not feasible, an auxiliary air-cleaning unit may be appropriate. Since isolation is a primary engineering control, isolating the TB clinic from the other clinics/areas will reduce the potential for *M. tuberculosis* transmission. In addition, if antituberculous medications were dispensed on TB clinic days, from the TB clinic instead of the general pharmacy, additional TB patients would be isolated from the general population. The "ceiling" of the pharmacy waiting area is above the second floor; thus, dilution volume was great. No additional engineering controls are recommended for this area.

3.3. Laboratories

The mycobacteria and clinical laboratories appeared to be sealed rooms with no ventilation. The main mycobacteria laboratory, where AFB staining is performed, had a small fume hood used for the preparation of AFB slides, which had negligible air flow. Within this hood, the AFB slides were prepared. A small exhaust fan was observed in the rear of the hood. It was pulling air from the duct and pushing it into the hood. Reversing the fan direction did not appear to result in significant exhaust of air. After the fan, the hood was ducted outside and up; however, we were unable to trace the duct. It appears to exhaust in between the ceiling and the next floor. During the 12 March 1997 visit, the face velocity of the hood averaged 11 m/min (35 ft/min) with a flow rate into the hood of 0.81 m³/min (29 ft³/min). Further investigation and repairs of this hood exhaust are necessary. The UVGI within this hood was measured to be approximately 400 $\mu\text{W}/\text{cm}^2$ (permissible ultraviolet exposures are shown in Table 3). Approximately 40 cm from the hood opening, UVGI irradiance levels were measured as 1-5 $\mu\text{W}/\text{cm}^2$. The opening of the hood is at the same height above the floor (i.e., the laboratory person stands when working at this wooden hood) as the microscope station, located approximately 1.5 m away. An UVGI irradiance level of 0.1 $\mu\text{W}/\text{cm}^2$ was measured at this location. The laboratory technician was concerned about the UVGI killing the culturable mycobacteria in the sputum samples. UVGI transmission through the sputum collection bottles (both tops and bottoms) would be reduced by approximately 10^{-4} of the challenge UVGI. In other words, with a UVGI challenge of 400 $\mu\text{W}/\text{cm}^2$, less than 0.04 $\mu\text{W}/\text{cm}^2$ would be measurable on the opposite side of the sputum specimen jar (both top and bottom), a vinyl glove, or the outside of the glass near the UV lamp; this level of UVGI would not kill viable mycobacteria. The other mycobacteria laboratory, used for culturing sputum samples for mycobacteria, also had a hood where the agar slants were inoculated with sputum and transfers of culturable organisms were performed. This too, was a "fume-like" hood; however, it appeared to be operational and was ducted to the roof of this building. The UVGI emitted from this hood, with the front "door" open (the normal position), was measured at 1-2 $\mu\text{W}/\text{cm}^2$. UVGI measured at eye level, seated at the hood was approximately 7 $\mu\text{W}/\text{cm}^2$ (maximum exposure time of 8 min). As with any exhaust from this hood, which may contain airborne contaminants, the exhaust was directed away from open windows, air intakes, and persons (i.e., patients, HCWs, visitors). Without a means to measure velocity directly, a piece of tissue was used to demonstrate relative differences in velocity. With the doors to this hood closed with the exception of hand/arm access, the velocity appeared excessive. During the 12 March 1997 visit, the face velocity of the hood averaged 200 m/min (660 ft/min) with a flow

rate into the hood of 11 m³/min (390 ft³/min). Both hoods should be evaluated and modified as necessary to ensure the safety of the laboratory worker. As biosafety level 2 laboratories, these rooms should have limited/restricted access and be under negative pressure relative to surrounding areas. Perhaps, the exhaust from the large hood could be reduced to 4 m³/min (140 ft³/min), 3 m³/min (110 ft³/min) could be exhausted from the mycobacterial lab (making it negative pressure), and the small hood could be exhausted with the remaining fan capacity (up to 3 m³/min [110 ft³/min]).

One area of confusion and concern is the area used for the production of sputum samples. Some HCWs told us the patient brought them in from home, others thought it was done in the laboratory, some thought it was done on the ward, and still others thought the patients went outside the building to produce the samples. It is essential to have a standard operating procedure (SOP) for sputum production at home and at the Hospital. The goal of the home or hospital SOP is the same, i.e., to limit HCW or patient *M. tuberculosis* exposure and prevent *M. tuberculosis* transmission to family members, HCWs, patients, and/or visitors. The hospital SOP may consist of using either a ventilated enclosure (booth or tent) in the laboratory or having the patient collect the sample outside, away from any people. The enclosure air would be exhausted to the roof and dispersed.

3.4. X-ray and HIV/TB counseling rooms

The X-ray room (#2) and room used for HIV counseling (near OPD waiting area) are small, enclosed spaces with no ventilation. Workers in these areas would benefit greatly by adding engineering controls to remove airborne contaminants. Since general ventilation is not feasible, an auxiliary air-cleaning unit may be appropriate. Air-cleaning units may contain a 95% ASHRAE efficiency filter to remove the airborne microorganisms or UVGI lamps to inactivate the airborne microorganisms, or both. The key to an effective control system is for good directional air flow. Ceiling- or wall-mounted units are preferential to portable units. Portable units tend to be in the way of the worker and are often placed in locations which limit their effectiveness in cleaning airflow patterns beneficial to the removal of airborne microorganisms.

The rooms used for HIV counseling are small, enclosed spaces with air conditioner but no open windows. Since HIV/AIDS patients are at high risk of TB, forced-air ventilation should be added to this room, similar to Figure 1e. The air conditioner unit could be designed to duct in and condition outside air. Then, an exhaust could be installed near the opposite corner and room air

exhausted onto the roof through an upper window.

The area used for private TB counseling is located at the end of a larger office, separate from the treatment areas of the hospital. Some workers within this larger office handle OPD paperwork. The Department of Preventive and Social Medicine, a break room, and an additional counseling room are located off this room. The counseling portion of the room could easily be isolated with a floor-to-ceiling wall to separate the counseling area from the other areas and workers. The simplest ventilation solution for the counseling portion of the room would be to keep all windows in this newly isolated area open. This will permit natural wind currents to flow to/from the adjacent area (containing the refrigerator) from/to the outside (window/doors in the counseling area). After implementation, if sufficient directional airflow is not obtained, additional engineering controls to remove airborne contaminants could be considered (e.g., an auxiliary air-cleaning unit may be appropriate).

3.5. Bronchoscopy room

Bronchoscopy is performed on an infrequent basis (approximately 10 per year). When performed, it is conducted in a small operating room (OR). As discussed during our visit, ORs are normally at positive pressure in relation to other areas (hallways, other rooms) for purposes of infection control. When conducting a procedure on an infectious TB patient, however, it is important for the HCWs involved to wear respiratory protection. Furthermore, the washroom area adjacent to the OR should be at positive pressure relative to both the OR and the outside. This will aid in preventing the spread of airborne contaminants from the OR to the hallway. The OR configuration is similar to Figure 1c, with an air conditioner. The bronchoscopy room should be retro-fitted with a clean air supply and an exhaust air system. Air should flow from the surgical nurse/equipment area, across the physician, across the patient, and out of the room. By exhausting more air than supplied, the OR will remain negative relative to the remainder of the OR wing, thus reducing the potential of transmission of airborne microorganisms into the hospital.

3.6 New building

The new building looks like it is a long-needed, great addition to the hospital. Two floors of this new building will be female wards (to be moved from building 9). Two isolation rooms are located on each floor of this building. In addition to the 30-bed open ward, a three-bed room capable of being used as an isolation is located on each floor. The floor plan is a combination of the

current female and male medical's ward. As currently designed, the isolation rooms (four single-patient and two three-patient) are not ventilated. Since these six rooms are located vertically above/below each other, now is the opportune time to add and install ventilation (Figures 1d and 1e). Because of the vertical construction and the isolation rooms located on the upper floors, the modification cost will be minimized. In these isolation rooms, air should be pulled into the rooms and then exhausted out of the far side of the room through ductwork to the roof. The rooms would then be negative pressure relative to nearby rooms or hallways. Solid-pane, immobile windows in the open ward, nursing station, treatment room, and toilet/shower room should be replaced with louvered windows to permit maximum air exchange.

The "ideal" TB isolation room should be a single-patient room with mechanical ventilation of at least 12 air changes per hour (ACH). To prevent the escape of infectious droplet nuclei, the TB isolation rooms should be maintained under negative pressure relative to the surrounding areas (i.e., air will flow from surrounding areas into the isolation room). The door(s) should be kept closed, except when patients or personnel must enter or exit the room, so that negative pressure can be maintained. Air from TB isolation rooms should be exhausted to the outside; the exhaust should be located away from air intakes and in a location that would not allow reintrusion of contaminated air back into the facility. In any case, the air should not be recirculated directly into the general ventilation system. Grouping TB isolation rooms together (horizontally) may reduce the possibility of transmitting *M. tuberculosis* to other people and facilitate care of TB patients and installation and maintenance of optimal engineering controls. Grouping TB isolation rooms together (vertically) permit the separation of patients by ward, sex, or other parameters and allows for economical installation and maintenance of engineering controls.

An alternative option to the "ideal" single-patient isolation room is multiple rooms or wards. This ward should be sized for the appropriate population of confirmed TB patients. The construction should be "open"; windows open on all sides of the ward (minimum opposite sides) to allow natural dilution of potentially contaminated air. To prevent dissemination of *M. tuberculosis* to other persons, "open" should be such that natural air currents (i.e., wind) would carry potentially contaminated air away from other portions of the hospital (e.g., near first floor waiting room). Ideally, the isolation ward(s) should be located above the first floor, away from high traffic areas, and preferably away from other patients, visitors, HCWs, etc. Access to the ward(s) should be restricted.

One potential solution to the problem of varying numbers of confirmed and suspected TB

patients would be a large (i.e., 40 patients) ward which could be subdivided into four 10-patient units. Thus, the confirmed and suspected TB patients would be isolated from other patients and from each other. Other than floor-to-ceiling walls between the four 10-patient units (with windows on either end), obstruction of natural air flow should be minimized. To assure proper directional air flow, doors should be kept closed and windows open. If resources permit, and/or natural ventilation is not sufficient, exhaust fans (larger than the "kitchen" exhaust fans seen in various parts of the hospital) could be installed in the smaller, 10-patient units. The fans should be installed to assure directional airflow from the nursing station, across the patient area, and outside (away from other patients, HCWs, visitors, etc.). The minimum flow rate would be 12 air changes per hour with 6 being the absolute minimum. Assuming a 10-person room is 6 m by 6 m by 3 m, a flow rate of 22 m³/min (750 ft³/min) would be required. A bank of four rooms could be effectively and economically exhausted using a total flow rate of approximately 85 m³/min (3000 ft³/min).

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Table 1 Proposed interventions for TB infection control at Chiang Rai Hospital

Intervention	Degree of priority
--------------	--------------------

Continuous management

- | | |
|---|----|
| - Implementing surveillance of MTB infection among HCWs | A* |
| - Standardized surveillance of active TB among HCWs | A* |
| - Standardized surveillance of TB patients | B |

HCWs

- | | |
|---|----|
| - Training and education | |
| - Fundamentals of TB transmission | A |
| - CRH policy for controlling MTB infection | A |
| - TST screening and TB prevention (including voluntary HIV testing) | A |
| - Limitations of personal respiratory protection | B |
| - TST screening program | A |
| - Prevention of active TB | |
| - Evaluation of TST converters with physical and chest x-ray | A |
| - Follow-up of TST converters | A |
| - Preventive therapy for recent TST converters | A |
| - Preventive therapy for persons with positive TST at entry | B |
| - Voluntary HIV counseling and testing | A |
| - Personal respiratory protection of HCW exposed to TB patients | B† |

Patients

- | | |
|---|---|
| - Identification and isolation | |
| - Develop a suspicion index and guidelines for managing TB suspects | A |
| - Surgical masks on suspects until final determination is made | A |
| - Rapid AFB smears and chest x-rays | A |
| - TB isolation rooms | B |
| - Wards for treating proven TB cases | A |
| - Surgical masks on proven TB patients when circulating out of TB wards | A |
| - Limit length of hospitalization of TB patients | A |
| - Education of TB patients on TB transmission | A |

Environment (See prioritized table on the following page)

A*: absolute priority; A: high priority; B important

† Higher priority (A*) should be given to personal respiratory protection as an interim measure until the recommended infection control measures can be fully implemented. If TB isolation rooms or wards are not implemented, personal respirators should be used by HCWs carrying for infectious TB patients or those involved with high risk (autopsy, bronchoscopy, sputum induction) procedures.

Table 2: List of engineering recommendations and suggested priorities

Item #	Location (Building #)	Priority *	Recommendation
1	Male/AIDS Ward (12) Male Ward (12)	0 1	Okay -- Open more windows and open/replace solid-pane immobile windows Need windows on toilet side of ward opened and open/replace other solid-pane immobile windows
2	Male Ward Isolation Rooms (12)	1 1 1	Re-duct exhaust and duct supply for better directional air flow within the room and negative relative to the surrounding areas Renovate upper level for additional isolation rooms Keep windows and doors open and open/replace solid-pane immobile windows
3	Female Ward (9)	0	The open portion is fine for non-infectious patients (moving April 1997)
4	Female Ward TB/HIV Isolation (9)	2	The hallway and TB/HIV rooms may house infectious patients and should be isolated from the rest. Install exhaust in isolation rooms and don't house patients in the hallway (moving April 1997).
5	TB Clinic (3)	1 1 1 1 2	Isolate TB clinic from remainder of hospital Dispense meds for TB patients in TB clinic Keep doors and windows open and open/replace solid-pane immobile windows Supplemental air cleaning in exam room Make Medical Dept. Staff office positive pressure relative to TB clinic
6	OPD Clinic (3)	2 1	Keep windows and doors open and open/replace solid-pane immobile windows Supplemental air-cleaning in exam rooms w/o outside windows
7	Mycobacteria Lab (9)	2 2 2	Small hood - fix exhaust system & ID where it's exhausted Large hood - modify exhaust system (flow rate too high!) Both hoods - wear glasses and cover skin whenever the UV lamps are on
8	General Lab (5)	0	Okay
9	Sputum Production (5? And 9)	1	Develop Standard Operating Procedure for collection @ hospital and @ home
10	X-Ray Room #2 (2)	2	Supplemental air-cleaning
11	HIV Counseling Room (3)	1	Supplemental air-cleaning
12	TB Counseling Area (1)	1 1 2	Isolate counseling area (wall) Open windows/door If necessary, supplemental air-cleaning
13	Bronchoscopy (9)	1 1	Negative pressure relative to rest of OR ward Directional air flow from attendant to physician to patient to exhaust
14	New Building (NEW)	2 1	Keep open wards and open/replace solid-pane immobile windows Install exhaust system in isolation rooms
15	Personal Respiratory Protection	1 2	Education on limitations of PRP Training (including fit-testing) on how to use PRP

*0 = no action recommended 1 = High priority 2 = Medium priority

Table 3. Permissible Ultraviolet exposures*

Duration of exposure per day	Effective irradiance E_{eff} ($\mu\text{W}/\text{cm}^2$)
8 hrs	0.1
4 hrs	0.2
2 hrs	0.4
1 hr	0.8
30 min	1.7
15 min	3.3
10 min	5
5 min	10
1 min	50
30 sec	100
10 sec	300
1 sec	3000
0.5 sec	6000
0.1 sec	30000

*Extracted from the 1996 TLVs[®] (Threshold Limit Values) and BEIs[®] (Biological Exposure indices) published by the American Conference of Governmental Industrial Hygienists (ACGIH)

Figure 1a

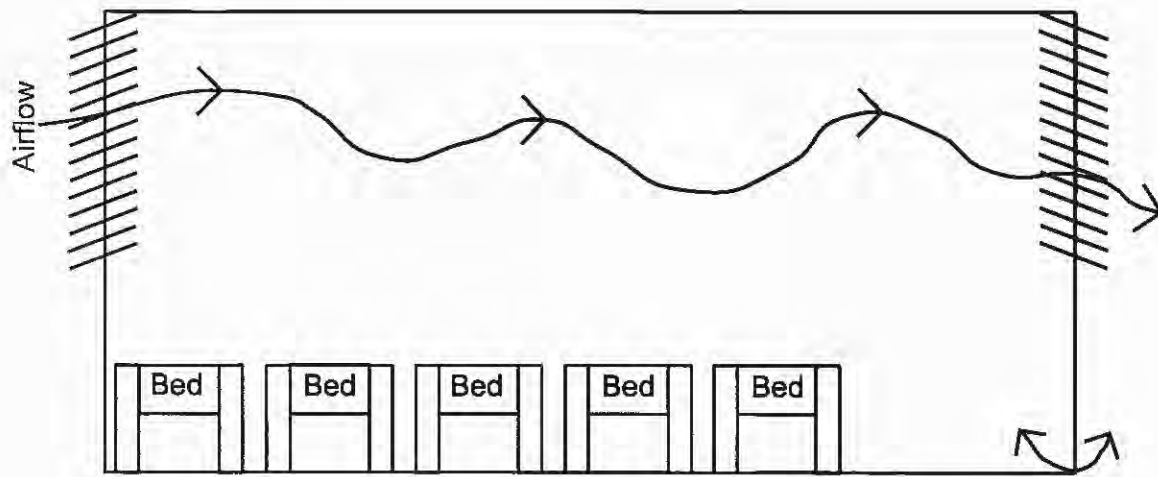


Figure 1b

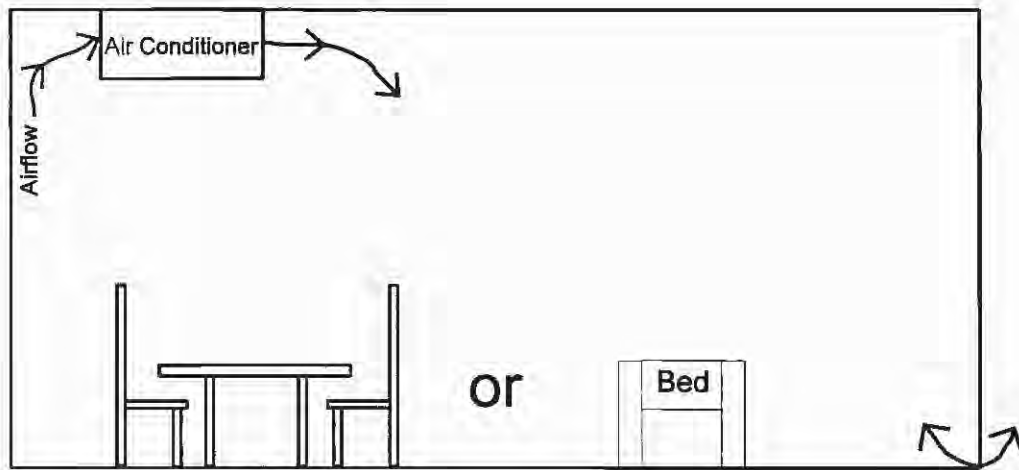


Figure 1c

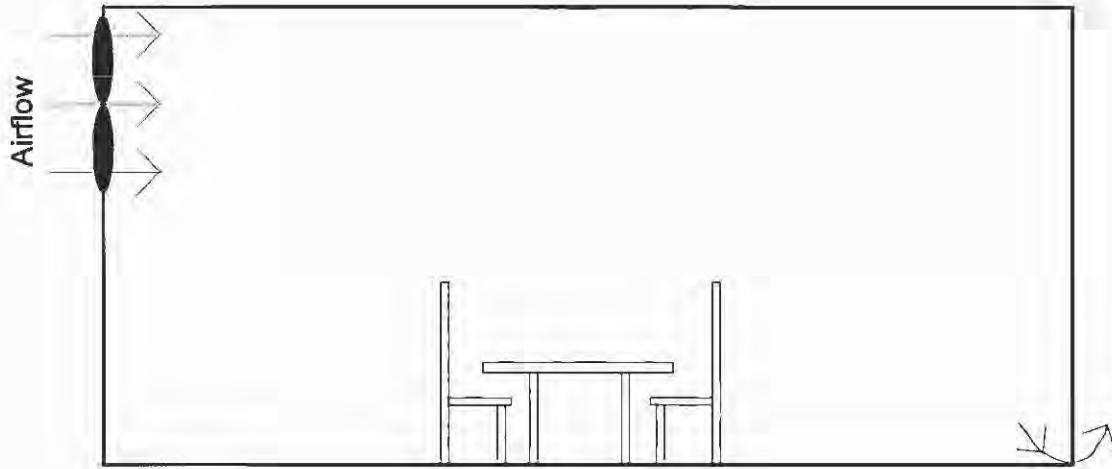


Figure 1d

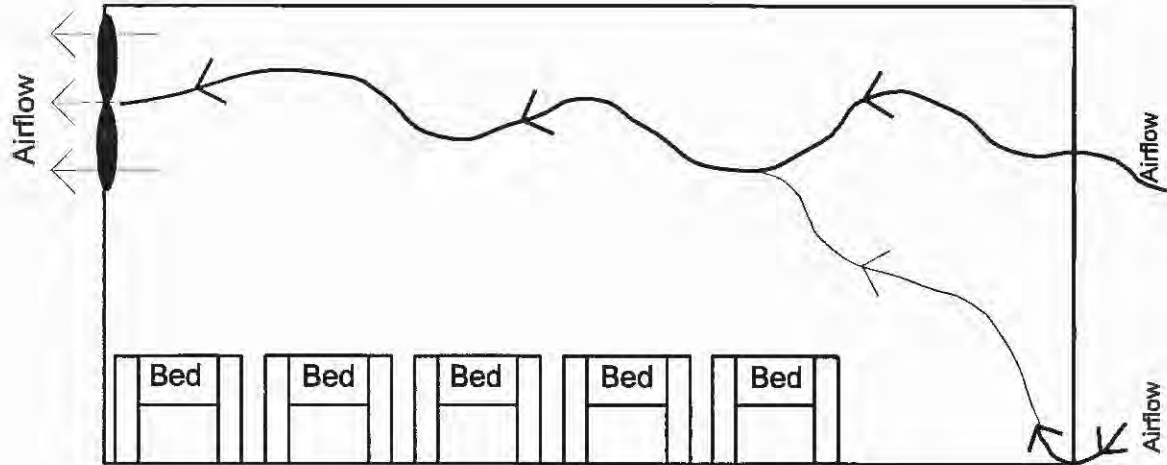


Figure 1e

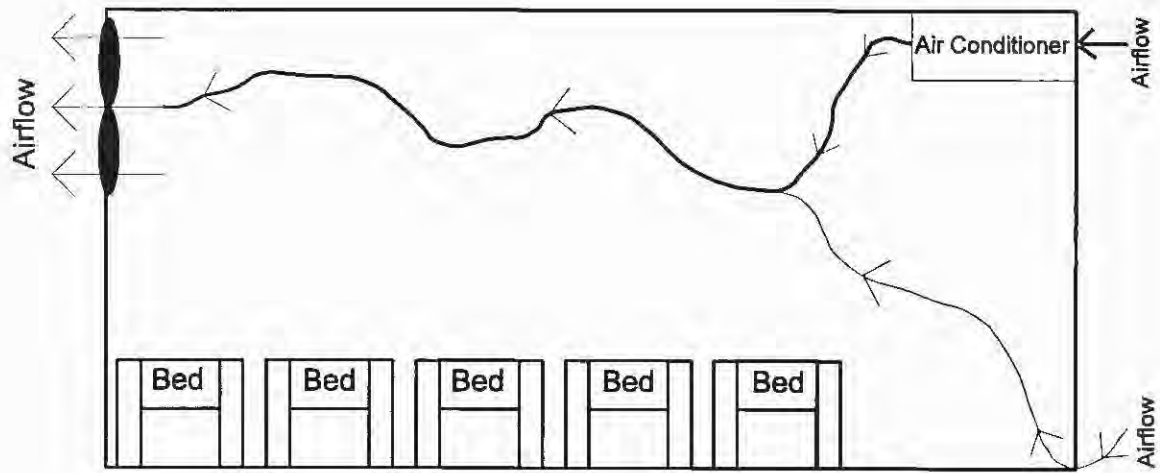
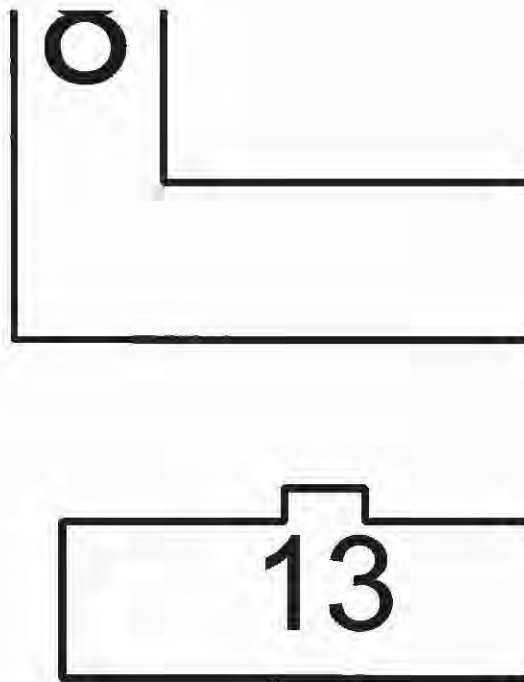


Figure 2



- 1 Dr. Wat's office (1a), OPD workers (1b), TB counseling area (1c)
- 2 X-ray rooms (Room #2 for CXR)
- 3 OPD clinic (3a, large area), Orthopedic clinic (3b), TB clinic (3c, northwest corner), HIV counseling area
- 4 OB-GYN
- 5 Clinical laboratories
- 6 Surgery ward
- 7 Labor rooms
- 8 Private ward (surgery)
- 9 Laboratories (1st floor), OR (2nd floor), Female ward and Female TB/HIV isolation (3rd floor)
- 10 Pediatric ward
- 11 Private ward (medicine)
- 12 Male wards
- 13 Monk ward