THE ASSOCIATION BETWEEN ENVIRONMENTAL FACTORS AND TUBERCULOSIS INFECTION AMONG HOUSEHOLD CONTACTS

Songpol Tornee[1], Jaranit Kaewkungwal[1], Wijitr Fungladda[1], Udomsak Silachamroon[2], Pasakorn Akarasewi[3] and Pramuan Sunakorn[3]

[1]Department of Social and Environmental Medicine, [2]Department of Clinical Tropical Medicine, Faculty of Tropical Medicine, Mahidol University, Bangkok; [3]Department of Disease Control, Ministry of Public Health, Nonthaburi, Thailand

Abstract. A cross-sectional study was conducted to determine the association between environmental factors and tuberculosis infection among household contacts aged less than 15 years in Bangkok, Thailand, between May and December 2003. During the study period, 480 household contacts aged under 15 years were identified. The prevalence of tuberculosis infection among household contacts was 47.08% (95% CI = 42.60-51.56). A generalized estimating equation (GEE) indicated that the risk of positive tuberculin skin testing in household contacst was found to increase with household crowding. Children living in a crowded household were five times more likely to have tuberculosis infection (OR = 5.19, 95% CI = 2.65-8.69). The association between environmental factors and tuberculosis infection assists community tuberculosis staff in understanding the risks for tuberculosis infection in the community and planning appropriate preventive actions based on this risk.

INTRODUCTION

Tuberculosis is one of the most neglected health crises and is out of control in many parts of the world (WHO, 1998). The World Health Organization estimated that at least 180 million children aged less than 15 years were infected with *Mycobacterium tuberculosis* worldwide (Dolin *et al*, 1994). Approximately one-third of the population of Thailand is infected with tuberculosis and nearly 100,000 Thai people suffer from active tuberculosis every year (WHO, 1999). Nearly 20% of people with tuberculosis live in Bangkok, where one-sixth of Thailand's total population lives (WHO, 1998).

The risk for infection is particularly high among close contacts of infectious patients (CDC, 1995). These close contacts are usually family members. The assumption exists that transmission of TB to children is typically from parents to children through household contact (Wells and Nelson, 2004). One tuberculosis patient can spread *M. tuberculosis* to the other 10 persons who may be living in the house. Tuberculosis transmission occurs by airborne spread of infectious droplets. Transmission generally occurs indoors, where droplet nuclei can stay in the air for a long time (WHO, 1997). Droplet nuclei can remain suspended in the air for several hours, depending on the environment.

Correspondence: Songpol Tornee, Department of Health Education, Faculty of Physical Education, Srinakharinwirot University, Sukhumvit Road, Bangkok 10110, Thailand.
E-mail: songpoltor@yahoo.com

The association between environmental factors and tuberculosis infection has long been recognized (Clark *et al*, 2002), and tuberculosis transmission has long been known to be associated with poor ventilation (Sepkowitz, 1996). Overcrowded housing conditions can increase exposure of susceptible people to those with infectious respiratory disease, and may increase the probability of transmission. This study was thus conducted to determine the association between environmental factors and tuberculosis infection among household contacts aged less than 15 years in Bangkok, Thailand. This study was reviewed and approved by the Ethics Committee of the Ministry of Public Health and the Ethics Committee of the Bangkok Metropolitan Administration (BMA).

MATERIALS AND METHODS

Study population and data collection techniques

The index cases included sputum smear-positive pulmonary tuberculosis patients aged over 15 years old who registered for tuberculosis treatment at Bangkok Chest Clinic under the Ministry of Public Health and Health Care Centers under the Bangkok Metropolitan Administration, between May and December 2003. All of the identified household contacts <15 years old of the index cases were subsequently investigated.

All sputum smear-positive pulmonary tuberculosis patients during the specified period were asked to enroll in the study. Three hundred and twenty-five tuberculosis patients and their 480 household contacts were eligible for the study.

Tuberculin skin test

Tuberculin skin test was performed by the Mantoux method. The Mantoux skin test was administered by injecting 0.1 ml of 5 tuberculin units (TU) of purified protein derivative (PPD) intra-dermally into the volar surface of the forearm. The result was read 48-72 hours afterwards (American Thoracic Society, 2000). The diameter of induration was measured across the forearm.

Questionnaire

A structured questionnaire was used in this study. Environmental information included type of house, number of rooms, and house size. An index case was defined as the smear-positive pulmonary tuberculosis patient aged >15 years who had at least one household contact aged <15 years. The contact could be a family member or any other person living and sleeping in the same house as the tuberculosis patient for at least three months before the commencement of tuberculosis treatment of the index case.

House size was defined as the number of rooms in the house. Household size was determined by the number of family members in the household. Crowding was expressed as the average number of persons per room. It was estimated by dividing the number of people living in the house by the number of rooms. The definition of a slum area was an urban residential area characterized by deteriorated, unsanitary buildings, poor ventilation, poverty, and social disorganization. In this study, a slum area was defined using the criteria set by the Bangkok Metropolitan Administration.

Statistical analysis

Data abstraction and interview forms were checked for completeness and then double-entered and validated in Stata Program version 7 (Stata Corp, College Station, TX). Univariate analysis was performed using χ^2 to assess associations between environmental factors and tuberculin skin test positivity. Odds ratios and their 95% confidence intervals were also calculated. In multivariate analysis, generalized estimating equation (GEE) was used to determine adjusted odds ratio. For all statistical tests, associations were considered significantly at p-value ≤ 0.05.

RESULTS

During the study period, 325 eligible index cases and their 480 household contacts were identified. All contacts enrolled in the study had received BCG vaccination at birth. Of the 480 exposed children, the median age was 6 years (range 1 year - 14 years). The prevalence of tuberculosis infection among household contacts was found to be 47.1% (95% CI = 42.60-51.56). Of the 480 contacts, 280 (58.3%) lived in slum areas, and 186 (38.8%) lived in a house with more than three persons per room.

The univariate analysis of the association between environmental factors and tuberculosis infection among household contacts was summarized in Table 1. The prevalence of a positive tuberculin skin test was inversely associated with the house size (p = 0.000). The risk was greatest in household contacts living in the house with 1 room (OR = 6.17, 95% CI = 3.89-9.77). Household contacts living in slum areas were three times more likely to have tuberculosis infection (OR = 3.45, 95% CI = 2.17-5.49). The prevalence of positive tuberculin skin tests was significantly associated with household size (p = 0.039). The risk of a positive tuberculin skin test in household contacts was found to increase with household crowding. Children living in a crowded household were four times more likely to have tuberculosis infection (OR = 4.59, 95% CI = 3.09-6.82).

The results of multivariate analysis were summarized in Table 2. In the generalized estimating equation (GEE), the risk of tuberculosis infection was still significantly associated with living in a crowded household (Adjusted OR = 5.19, 95% CI = 2.65-8.69).

DISCUSSION

The prevalence of tuberculosis infection among household contacts was found to be 47.08% (95% CI = 42.60-51.56). The results of our study confirmed the existing knowledge that tuberculosis transmission is associated with environmental factors. It could be explained that tuberculosis transmission occurs by airborne spread of infectious droplets. Transmission generally occurs indoors, where droplet nuclei can stay in the air for a long time (WHO, 1997). Droplet nuclei can remain suspended in the air for several hours, depending on the environment. The association between environmental factors and tuberculosis infection has long been recognized (Clark *et al*, 2002). Tuberculosis transmission has long been known to be associated with poor ventilation (Sepkowitz, 1996). Poorly ventilated living conditions and crowding are important factors for tuberculosis transmission. The study of Lienhardt *et al* (2003) indicated that the risk of tuberculin skin test positivity was associated with the total number of people living in the household of the individual with TB. Bener *et al* (1996) reported

Table 1
Univariate analysis of the association between environmental factors and tuberculosis infection.

Environmental factors	TST Positive/total	(%)	OR	95%CI	p-value
House size (no. of room)					0.000
1	169/244	69.3	6.17	3.89-9.77	
2	19/94	20.2	0.69	0.37-1.29	
> 2	38/142	26.8	1		
Type of house					0.000
Slum	158/280	56.4	3.45	2.17-5.49	
Flat/apartment	35/79	44.3	2.12	1.17-3.86	
House	33/121	27.3	1		
Household size (no. of family member)					0.039
1-3	50/100	50.0	1.87	1.04-3.36	
4-6	145/291	49.8	1.86	1.13-3.04	
> 6	31/89	34.8	1		
Crowding (person/room)					0.000
Not crowded	97/294	33.0	1		
Crowded	129/186	69.3	4.59	3.09-6.82	

Table 2
Multivariate analysis of the association between environmental factors and tuberculosis infection.

Environmental factors	Adjusted OR	95%CI	p-value
House size (no. of room)			
1	3.24	0.93-11.26	0.062
2	0.53	0.20-1.42	0.208
> 2	1		
Type of house			
Slum	1.69	0.89-3.20	0.105
Flat/apartment	1.26	0.60-2.65	0.538
House	1		
Household size (no. of family member)			
1-3	1		
4-6	1.09	0.43-2.74	0.848
> 6	1.47	0.43-5.07	0.535
Crowding (person/room)			
Not crowded	1		
Crowded	5.19	2.65-8.69	0.000

the association between house size (number of room) and tuberculosis infection.

The results of our study revealed that slum areas were risky for tuberculosis transmission because of poor living conditions, poor ventilation, poor hygiene and crowding. These conditions facilitate transmission of many diseases, including tuberculosis (Tupasi *et al*, 2000). Tuberculosis is associated with poverty. Poorer living areas have been associated with tuberculosis transmission in both industrialized countries and

developing countries (Gustafson *et al*, 2004). Crowding and poor ventilation increase the likelihood of tuberculosis infection. Persons who live in crowded or poorly ventilated areas are at higher risk for exposure to tuberculosis.

Overcrowded housing conditions have the potential to increase exposure of susceptible people to those with infectious respiratory diseases, and may increase the probability of transmission. This is because close proximity makes it more likely for these individuals to come in contact with air contaminated with the bacteria that causes the infection. The association between housing density and tuberculosis incidence has long been recognized (Hawker *et al*, 1999). The study of Clark *et al* (2002) suggested that tuberculosis incidence was higher in communities with a higher average housing density. It was possible that communities with overcrowded housing also experienced a higher prevalence of latent tuberculosis infection. The association between environmental factors and tuberculosis infection assists community tuberculosis staff in understanding the risk for tuberculosis infection in the community and planning appropriate preventive actions based on this risk.

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