

Prevalence of Latent Tuberculosis Infection among Health Care Workers in South Korea: A Multicenter Study

Kyung-Wook Jo, M.D.¹, Yoonki Hong, M.D.¹, Jae Seuk Park, M.D.², In-Gyu Bae, M.D.³, Joong Sik Eom, M.D.⁴, Sang-Rok Lee, M.D.⁵, Oh-Hyun Cho, M.D.³, Eun Ju Choo, M.D.⁶, Jung Yeon Heo, M.D.⁷, Jun Hee Woo, M.D.⁸ and Tae Sun Shim, M.D.¹

¹Division of Pulmonary and Critical Care Medicine, Asan Medical Center, University of Ulsan College of Medicine, Seoul, ²Department of Internal Medicine, Dankook University College of Medicine, Seoul, ³Department of Internal Medicine, Gyeongsang National University School of Medicine, Jinju, ⁴Division of Infectious Diseases, Department of Internal Medicine, Kandong Sacred Heart Hospital College of Medicine, Hallym University College of Medicine, Seoul, ⁵Department of Internal Medicine, Division of Allergy and Infectious Diseases, Cheongju St. Mary's Hospital, Cheongju, ⁶Division of Infectious Diseases, Department of Internal Medicine, Soon Chun Hyang University Bucheon Hospital, Soon Chun Hyang University College of Medicine, Bucheon, ⁷Department of Internal Medicine, Armed Forces Capital Hospital, Seoul, ⁸Division of Infectious Diseases, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea

Background: We investigated the prevalence of latent tuberculosis infection (LTBI) among the health care workers (HCWs) and analyzed its risk factors in South Korea.

Methods: A standard questionnaire regarding the baseline demographics and risk factors for LTBI was given to each participant and tuberculin skin test (TST), QuantiFERON-TB GOLD In-Tube (QFT-GIT) assay, and chest radiography were performed.

Results: A total of 493 participants, 152 (30.8%) doctors and 341 (69.2%) nurses were enrolled in eight tertiary referral hospitals. The mean age of the subjects was 30.6 years old, and 383 (77.7%) were female. Of the 152 doctors, 63 (41.4%) and 36 (23.7%) were positive by TST and by QFT-GIT, respectively, and among the 341 nurses, 119 (34.9%) and 49 (14.4%) had positive TST and QFT-GIT results, respectively. Overall, the agreement between the two tests was 0.22 by the chance corrected proportional agreement rate (kappa coefficient) in 493 subjects. Experience of working in tuberculosis (TB)-related departments was significantly associated with positive LTBI test results by QFT-GIT assay, not by TST. In multivariate analysis, only age was independently associated with increased risk of a positive TST result, while age and experience of working in TB-related departments (odds ratio, 2.29; 95% confidence interval, 1.01–5.12) were independently associated with increased risk of a positive QFT-GIT result.

Conclusion: A high prevalence of LTBI was found among South Korean HCWs. Considering the association between the experience of working in TB-related departments and high risk of LTBI, QFT-GIT may be a better diagnostic test for LTBI than TST in HCWs.

Keywords: Latent Tuberculosis; Health Personnel; Tuberculin Test; Interferon-gamma Release Tests; Republic of Korea

Address for correspondence: Tae Sun Shim, M.D.

Division of Pulmonary & Critical Care Medicine, University of Ulsan College of Medicine, Asan Medical Center, 88 Olympic-ro 43-gil, Songpa-gu, Seoul 138-736, Korea

Phone: 82-2-3010-3892, **Fax:** 82-2-3010-6968, **E-mail:** shimts@amc.seoul.kr

Address for Co-correspondence: Jun Hee Woo, M.D.

Division of Infectious Diseases, University of Ulsan College of Medicine, Asan Medical Center, 88 Olympic-ro 43-gil, Songpa-gu, Seoul 138-736, Korea

Phone: 82-2-3010-3302, **Fax:** 82-2-3010-6970, **E-mail:** junheewoo@amc.seoul.kr

Received: Nov. 25, 2012

Revised: Jan. 24, 2013

Accepted: Apr. 1, 2013

©It is identical to the Creative Commons Attribution Non-Commercial License (<http://creativecommons.org/licenses/by-nc/3.0/>).

Copyright © 2013 The Korean Academy of Tuberculosis and Respiratory Diseases. All rights reserved.

Introduction

It has long been thought that health care workers (HCWs) are at an increased risk for *Mycobacterium tuberculosis* infection as a result of occupational exposure to patients infected with *M. tuberculosis*¹. Although some studies failed to show a higher estimated risk for tuberculosis (TB) among HCWs than among the corresponding local community, recent systematic analysis showed that the risk for TB among HCWs is consistently higher than the risk among the general population worldwide, irrespective of TB incidence in each country, and confirmed that TB is an occupational disease². HCWs working in TB-related departments (pulmonary department, medical intensive care unit, emergency room [ER], etc.), particularly nurses, have been reported to be at a higher risk of developing TB than other occupational subgroups of HCWs due to increased possibility of nosocomial transmission³⁻⁶.

In South Korea, an intermediate TB-burden country (92/100,000 general population), several studies have shown that the prevalence of latent TB infection (LTBI) among nurses was higher than in the general population^{6,7}. In addition, one study reported that nurses working in TB-related departments had approximately five-fold higher risk for TB development than the general population⁸, which indicates that LTBI remains a serious health problem among specific subgroups of HCWs in South Korea.

These findings indicate that various preventive strategies against LTBI in hospitals are still insufficient in South Korea. In order to implement stricter preventive measures, the exact prevalence of LTBI among HCWs, particularly nurses and doctors, and its risk factors should be obtained. To date, however, all studies on LTBI among HCWs have been performed at single center only⁶⁻⁹. In addition, no study has been conducted to address risk factors influencing LTBI prevalence in South Korea. Therefore, we evaluated LTBI prevalence among doctors and nurses at several tertiary care hospitals and analyzed its risk factors in South Korea.

Materials and Methods

1. Study subjects

A cross sectional study to assess LTBI prevalence among doctors and nurses and its risk factors was conducted from February 2012 to May 2012 among those working at eight tertiary referral hospitals in South Korea. Doctors and nurses participated in this study voluntarily. The Institutional Review Board at each participating institution approved the clinical protocol. According to our study protocol, those HCWs who were being treated for active TB at the time of enrollment were excluded. All participants gave informed consent. They were interviewed using a standardized questionnaire. Infor-

mation was obtained regarding age, gender, past history of any underlying disease, including TB, history of Bacillus Calmette-Guérin (BCG) vaccination, and history of tuberculin skin test (TST). Additional information regarding risk factors of in-hospital TB infection was also gathered: duration of employment as a HCW, history of working in TB-related departments (pulmonary department, medical intensive care unit, and ER), current working department (TB-related vs. not TB-related), and degree of contact with TB-infected patients during work. The degree of contact with patients with TB infection was arbitrarily further divided into four categories and was self-selected by participants; none, mild (rare contact with TB patients), moderate (sometimes), severe (frequently).

After the completed questionnaire had been obtained, TST and QuantiFERON-TB Gold In-Tube (QFT-GIT; Cellestis Ltd., Carnegie, VIC, Australia) assay were performed at the same time and simple chest postero-anterior and left lateral radiograph (chest X-ray) were taken. Additionally, information regarding infection control measures at each hospital was obtained, specifically; 1) whether each institution had medical personnel dedicated to in-hospital TB infection control; 2) the presence or absence of its own guidelines for preventing in-hospital TB transmission; and 3) whether they conducted close contact investigation of HCWs.

2. Tuberculin skin test

Each TST was performed by intradermal injection of 2 tuberculin units of purified protein derivative RT23 (Statens Serum Institute, Copenhagen, Denmark) into the forearm using the Mantoux technique¹⁰. Reactions were evaluated 48 to 72 hours after injection, with a positive result defined as an induration of ≥ 10 mm in the transverse diameter.

3. QuantiFERON-TB Gold In-Tube (QFT-GIT)

The QFT-GIT assay was performed in 2 stages, according to the manufacturer's instructions. One-milliliter aliquots of blood were drawn directly into three evacuated blood collection tubes, one containing heparin alone (negative control), one containing T cell mitogen (positive control), and one containing *M. tuberculosis*-specific antigens, including early secreted antigenic target 6, culture filtrate protein 10, and TB7.7 (TB-antigen tube). Following overnight incubation, 200 μ L of plasma was removed from each well and the concentration of interferon-gamma (IFN- γ) was determined by enzyme-linked immunosorbent assay, with a positive response defined as an antigen-nil IFN- γ concentration ≥ 0.35 IU/mL¹¹.

4. Statistical analysis

Comparisons between groups were made using the χ^2 tests for categorical variables. Concordance between results of the

TST and QFT-GIT were assessed by chance corrected proportional agreement rate; kappa (κ) coefficients, with $\kappa > 0.75$ defined as excellent agreement, $\kappa < 0.4$ as poor agreement, and κ between 0.4 and 0.75 as fair to good agreement¹². Odds ratio and multiple logistic regression analysis were used to calculate adjusted risk. Independent variables were selected on the basis of their statistical significance in univariate analysis and on the basis of being clinically applicable. All tests of significance were two sided; $p < 0.05$ was considered statistically significant. All statistical analyses were performed using SPSS version 12.0 (SPSS Inc., Chicago, IL, USA).

Results

1. Characteristics of study subjects

A total of 493 individuals including 152 (30.8%) doctors and 341 (69.2%) nurses participated in our study. The mean age of

Table 1. Clinical characteristics of 493 health care workers according to experience of working in TB-related department

Characteristic	Group A (n=379)	Group B (n=114)	p-value
Age, yr	30.7±5.8	30.6±6.7	0.852
Age range, yr			0.890
20–29	205 (54.1)	59 (51.8)	
30–39	137 (36.1)	44 (38.6)	
>40	37 (9.8)	11 (9.6)	
Gender			0.099
Male	91 (24.0)	19 (16.7)	
Female	288 (76.0)	95 (83.3)	
Previous TB history	6 (1.6)	3 (2.6)	0.466
BCG vaccine			0.899
Vaccinated	314 (82.8)	85 (74.6)	
Unvaccinated	11 (2.9)	4 (3.5)	
Uncertain	54 (14.2)	25 (21.9)	
Co-morbidity			0.489
HTN	3 (0.8)	0 (0)	
Thyroid disease	3 (0.8)	1 (0.9)	
Others	7 (1.8)	2 (1.8)	

Values are presented as means±standard deviations or number (%) of subjects.

Group A: health care workers with experience of working in TB-related department; group B: health care workers without experience of working in TB-related department.

TB: tuberculosis; BCG: Bacillus Calmette-Guérin; HTN: hypertension.

the 493 subjects was 30.6±6.0 years, 383 (77.7%) were female and 399 (80.9%) had been vaccinated with BCG. Baseline characteristics did not differ between 379 subjects who had experience of working in TB-related departments and 114 subjects who had not (Table 1). Abnormal chest X-ray findings suggestive of inactive, benign conditions, such as calcified granuloma, were found in four (0.8%) subjects. Although human immunodeficiency virus (HIV) tests were not conducted on our subjects, they did not have any clinical indications of HIV infection at baseline or during follow-up.

2. TST and QFT-GIT results of study subjects

Overall, of the 493 subjects, 181 (36.7%) were positive and 312 (63.3%) were negative on TST. In addition, 85 (17.2%)

Table 2. TST and QFT-GIT results among 493 health care workers

	QFT-GIT	
	Positive (%) (n=85)	Negative (%) (n=408)
TST		
Positive (n=181)	54 (11.0)	127 (25.8)
Negative (n=312)	31 (6.3)	281 (57.0)

TST: tuberculin skin test; QFT-GIT: QuantiFERON-TB Gold In-Tube.

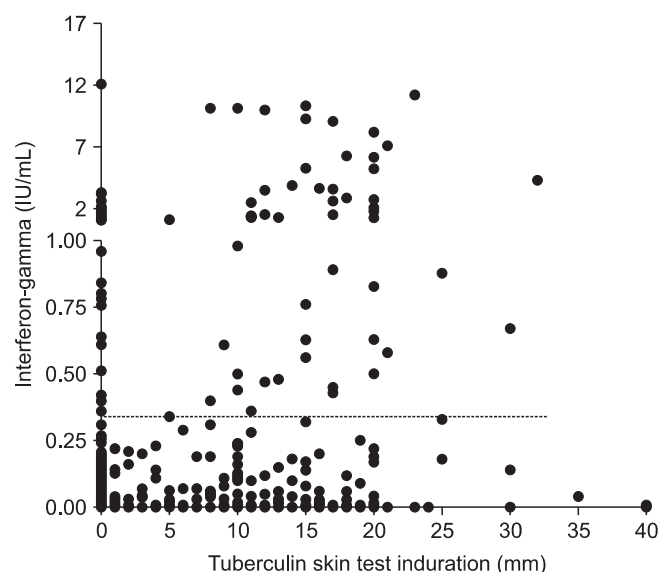


Figure 1. Dot plot of individual results of the tuberculin skin test and QuantiFERON-TB Gold In-Tube (QFT-GIT) of subjects. The dashed line represents the cutoff of 0.35 IU/mL for interferon-gamma. All points below zero among the QFT-GIT results in this figure have been assigned a value of zero.

Table 3. TB infection control measures and results of TST and QFT-GIT in each of the 8 participating hospitals

Hospitals	A	B	C	D	E	F	G	H
No. of hospital beds	2,680	736	640	836	902	900	500	498
No. of enrolled subjects	110	60	49	68	76	51	30	49
Medical personnel dedicated to TB infection control	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes
TB infection control guidelines	Yes	No	Yes	No	Yes	Yes	Yes	No
Contact investigation	Yes	No	Yes	No	Yes	No	No	Yes
Positive TST results, n (%)	49 (44.5)	20 (33.3)	17 (34.7)	32 (47.1)	21 (27.6)	17 (33.3)	9 (30.0)	17 (34.7)
Positive QFT-GIT results, n (%)	12 (9.1)	9 (15.0)	14 (28.6)	11 (16.2)	6 (7.9)	17 (33.3)	7 (23.3)	9 (18.4)

Values are presented as number (%) of subjects.

TB: tuberculosis; TST: tuberculin skin test; QFT-GIT: QuantiFERON-TB Gold In-Tube.

Table 4. Predictive factors for positive TST and QFT-GIT among 493 HCWs

	No.	Positive TST		Positive QFT-GIT	
		No. (%)	p-value	No. (%)	p-value
Age range, yr			<0.001		<0.001
20–29	264	72 (27.3)		26 (9.8)	
30–39	181	87 (48.1)		40 (22.1)	
>40	48	23 (47.9)		19 (39.6)	
Gender			0.020		0.010
Female	383	131 (34.2)		57 (14.9)	
Male	110	51 (46.4)		28 (25.5)	
Profession			0.189		0.011
Doctors	152	63 (41.4)		36 (23.7)	
Nurses	341	119 (34.9)		49 (14.4)	
Years working in hospital			<0.001		0.005
<1	41	8 (19.5)		5 (12.2)	
1–5	245	75 (30.6)		32 (13.1)	
6–10	114	56 (49.1)		22 (19.3)	
11–15	68	29 (42.6)		16 (23.5)	
>15	25	14 (56.0)		10 (40.0)	
Experience of working in TB-related department			0.985		0.006
Yes	379	140 (36.9)		75 (19.8)	
No	114	42 (36.8)		10 (8.8)	
Degree of contact with TB patients			0.656		0.135
None	63	19 (30.2)		5 (7.9)	
Mild	282	105 (37.2)		54 (19.1)	
Moderate	70	28 (40.0)		10 (14.3)	
Severe	78	30 (38.5)		16 (20.5)	
Current department			0.930		0.140
TB-related	180	66 (36.6)		37 (20.1)	
Not TB-related	313	116 (37.1)		48 (15.3)	

TST: tuberculin skin test; QFT-GIT: QuantiFERON-TB Gold In-Tube; HCWs: healthcare workers; TB: tuberculosis.

were positive and 408 (82.6%) were negative on QFT-GIT. A total of 54 (11.0%) subjects were positive on both tests (Table 2). The agreement between TST and QFT-GIT assay was chance corrected proportional agreement rate (0.22). The median value of the QFT-GIT of subjects who had positive QFT-GIT responses was 1.39 IU/mL (range, 0.35–12.09) (Figure 1).

3. TB infection control programs and results of TST and QFT-GIT assay in each 8 hospital

The magnitude, the number of enrolled subjects, the difference of TB infection control programs and the results of TST and QFT-GIT at each hospital are summarized in Table 3. No variables related to TB infection control program affected the positive rate of TST or QFT-GIT assay.

4. Risk factors for positive results on TST and QFT-GIT assay

Generally, the TST and QFT-GIT assay tended to have higher positive results with increasing age (Table 4). When the positive results of both tests were analyzed using three age classes, no significant differences were observed according to the profession, gender, duration of employment as a HCW, current working department, and degree of contact to patient with TB during work.

Of the 152 doctors, 63 (41.4%) were positive by TST and 36 (23.7%) were positive by QFT-GIT. The agreement between the two tests was chance corrected proportional agreement rate (kappa coefficient, 0.18). In addition, 119 (34.9%) had positive TST and 49 (14.4%) showed positive QFT-GIT result among 341 nurses. The agreement between the two tests was

chance corrected proportional agreement rate (0.24).

In contrast, subjects with experience of working in TB-related departments had higher positive rate of QFT-GIT than subjects without the same experience. Among 379 subjects who had experience of working in TB-related departments, 140 (36.9%) were positive by TST and 74 (19.5%) were positive by QFT-GIT whereas in 114 subjects without experience of working in TB-related departments, 42 (36.8%) were positive by TST and 10 (8.8%) were positive by QFT-GIT ($p=1.00$ and $p=0.007$, respectively).

Age, gender, and duration of employment as a HCW were significantly associated with having a positive TST result in univariate analyses. Moreover, age, gender, profession, duration of employment as a HCW, and experience of working a TB-related department were significantly related to positive QFT-GIT result (Table 4). In multivariate analyses, only age was independently associated with increased risk of a positive TST result, while age and experience of working in TB-related departments (odds ratio [OR], 2.42, 95% confidence interval [CI], 1.10–5.34) were independently associated with increased risk of having a positive QFT-GIT result (Table 5).

Discussion

This is the first multicenter study to investigate LTBI prevalence of doctors and nurses and its risk factors in South Korea using both the TST and the QFT-GIT test. In the present multicenter study, we documented that among 152 doctors, 63 (41.4%) were positive by TST and 36 (23.7%) were positive by QFT-GIT. In addition, 119 (34.9%) had positive TST and 49 (14.4%) showed positive QFT-GIT result among 341 nurses.

Table 5. Multivariate logistic regression analyses of predictive factors for positive TST and QFT-GIT among 493 HCWs

	Positive TST		Positive QFT-GIT	
	OR (95% CI)	p-value	OR (95% CI)	p-value
Age range, yr				
30-39*	2.44 (1.61–3.69)	<0.001	2.50 (1.43–4.37)	0.001
>40*	2.44 (1.29–4.60)	0.006	5.76 (2.79–11.90)	<0.001
Gender, female [†]	1.79 (0.92–3.62)	0.062	1.47 (0.69–3.11)	0.321
Profession, nurse [‡]	1.39 (0.75–2.57)	0.294	0.90 (0.44–2.03)	0.895
Experience of working in TB-related department	0.87 (0.51–1.48)	0.604	2.42 (1.10–5.34)	0.029
Degree of contact with TB patients				
Mild [§]	1.50 (0.77–2.91)	0.229	1.80 (0.63–5.14)	0.273
Moderate [§]	1.88 (0.81–4.29)	0.141	1.24 (0.35–4.32)	0.739
Severe [§]	1.51 (0.66–3.39)	0.344	1.73 (0.53–5.74)	0.367

TST: tuberculin skin test; QFT-GIT: QuantiFERON-TB Gold In-Tube; HCWs: healthcare workers; OR: odds ratio; CI: confidence interval; TB: tuberculosis.

*OR was calculated as compared to age '20-29'. [†]OR was calculated as compared to male. [‡]OR was calculated as compared to doctors. [§]OR was calculated as compared to degree of contact 'None.'

Two tests generally showed poor agreement. We also revealed that experience of working in TB-related departments was significantly associated with positive LTBI test results by QFT-GIT assay not by TST. This suggests that a positive QFT-GIT result may be a better indicator of LTBI than a positive TST result.

Our study showed poor agreement between the TST and the QFT-GIT, which is consistent with previous reports^{6,12}. In South Korea, where BCG vaccination is mandatory, children are vaccinated with BCG at birth; until 1997, TST non-responders were revaccinated again at age 12 or 13 years¹³. This BCG vaccination strategy may result in a substantial number of false-positive TST results, especially in young people. Because our participants mainly consisted of young people with a mean age of 30.6 years (82.6% of participants were younger than 35 years old), the QFT-GIT may estimate the LTBI prevalence of our population more accurately rather than the TST. The statistically significant association between the experience of working in TB-related departments and a positive LTBI result on QFT-GIT and not on TST in our study supports the above hypothesis. This assumption was also made in previous studies which were conducted in South Korea^{6,9,12} as well as in other countries^{4,14,15}. Moreover, while the positive rate of the TST in the present study was not different from that in the general population, the positive QFT-GIT rate was significantly higher than that in general population in South Korea (unpublished data). All of these findings suggest that the QFT-GIT would be more helpful than the TST for the detection of LTBI in South Korean HCWs, especially doctors and nurses.

There have been several studies assessing the prevalence of LTBI among HCWs in South Korea. Lee et al.⁷ reported that annual risk of TB infection among newly employed nurses was at least 3% on the basis of results of both the TST and QFT-GIT test. Similarly Park et al.⁹ showed that a minimum of 3.3% of HCWs experienced conversion on serial QFT-GIT tests. While these studies mainly focused on the conversion rate of the TST and/or the QFT-GIT in HCWs at a single center, this was a multicenter study tried to assess the LTBI prevalence among doctors and nurses by using both tests. Our results were similar with earlier studies, which reported that the LTBI prevalence of HCWs was 37.8% on TST and 23.2% on QFT-GIT in a university hospital⁶.

Since positive results on both tests are known to increase with age in usual settings, we analyzed the rates of positive results of both tests according to three age group categories in order to reduce confusing effect of age and better identify possible risk factors. As a result, we found no significant differences in the rates of positive of the two tests depending on the various risk factors. The exception to this was the experience of working in TB-related departments. A number of studies have reported various risk factors affecting the prevalence of LTBI in other nations, such as history of close contacts

with individuals with active TB⁴, work in a TB clinic¹⁴, total years spent as a HCWs¹⁵, and employment as a HCW for >5 years¹⁶. However, these various risk factors may not be directly comparable to our study because of several factors: marked heterogeneity of the TB burden, a national program to detect patients and contacts, and characteristics (such as socioeconomic status, baseline demographics or ethics) of enrolled HCWs. We did not include the variable of current working department in the multivariate analysis because of the confounding effect of this parameter owing to rotation of HCWs, especially doctors. Similarly, although age was revealed to be independently associated with positive results of both tests, it was considered as a general feature, not only in HCWs.

In the majority of tertiary hospitals, including the eight participating hospitals in our study, infectious patients with TB are admitted to isolation rooms equipped with negative-pressure ventilation with and without ultraviolet germicidal irradiation. HCWs or visitors entering such room are required to wear N95 respirators. However, our study suggests that these measures are still insufficient and more appropriate measures should be considered. For example, despite general guidelines, many young doctors do not wear N95 respirator when they enter an isolation room, because this type of respirator is hard to wear due to its tight facial seal. Moreover, many hospitals in South Korea do not have isolation rooms for confirmed or suspected TB patients in their emergency department. Such patients can transmit TB to HCWs during their stay in the ER, which can sometimes take as long as several days. Although Korean guidelines for TB exist, it simply recommends for HCWs of high-risk group to be tested for LTBI regularly, without presenting any specific recommendations. The practical guidelines including these amendable factors need be revised to reduce TB burden of high-risk group.

We investigated whether the prevalence of LTBI among doctors and nurses differed among hospitals according to the type of management program in place to prevent nosocomial transmission of TB. Since all eight hospitals have their own isolation room and rules concerning the wearing of N95 respirators, these variables were not included in analysis. Some patients were diagnosed as having TB during their stay in general hospital wards rather than at admission to isolation rooms. Such patients may infect both HCWs and neighboring patients. Therefore, close contact investigation of HCWs who have had contact with such patients would be important in reducing the TB infection rate among HCWs. This is supported by a trend suggesting that the result of the QFT-GIT was more likely to be positive in subjects working for hospitals where contact investigation was not done. However, this trend did not have statistical significance (OR, 1.28; 95% CI, 1.010–1.622; $p=0.055$).

Our study had several limitations. First, because we included only HCWs working in tertiary hospitals, the population of present study was not a representative sample of South

Korean HCWs in general. Small hospitals and private clinics were not involved in this study. TB infection control measures at such institutions would most likely be inferior to larger hospitals since facilities such as isolation rooms are not well equipped in these hospitals. In addition, we were not able to objectively quantify the degree of contact with TB patients in the questionnaire. This might have resulted in no statistical differences in the positive TST or QFT-GIT rates according to the degree of contact to TB patients. Finally, because there were mostly men in the doctor's group and the majority of nurses were women, there might have been gender bias among doctors and nurses.

In conclusion, we found high prevalence of LTBI among South Korean HCWs. There was poor level of agreement between the two tests and we suggest that the QFT-GIT is a more appropriate test for the detection of LTBI in South Korean HCWs. This suggestion may be extrapolated to any other intermediate TB-burden countries where BCG vaccination is common among HCWs. Finally, given that experience of working in TB-related departments were significantly associated with TB infection in our study, stricter preventive measure should be implemented for this occupational subgroup.

Acknowledgements

This study was supported by a grant from the Korean Institute of Tuberculosis (2011-KIT-03).

References

1. Menzies D, Fanning A, Yuan L, Fitzgerald M. Tuberculosis among health care workers. *N Engl J Med* 1995;332:92-8.
2. Baussano I, Nunn P, Williams B, Pivetta E, Bugiani M, Scano F. Tuberculosis among health care workers. *Emerg Infect Dis* 2011;17:488-94.
3. Kim SJ, Lee SH, Kim IS, Kim HJ, Kim SK, Rieder HL. Risk of occupational tuberculosis in National Tuberculosis Programme laboratories in Korea. *Int J Tuberc Lung Dis* 2007;11:138-42.
4. Rafiza S, Rampal KG, Tahir A. Prevalence and risk factors of latent tuberculosis infection among health care workers in Malaysia. *BMC Infect Dis* 2011;11:19.
5. Khanna P, Nikolayevskyy V, Warburton F, Dobson E, Drobniewski F. Rate of latent tuberculosis infection detected by occupational health screening of nurses new to a london teaching hospital. *Infect Control Hosp Epidemiol* 2009;30:581-4.
6. Lee KJ, Kang YA, Kim YM, Cho SN, Moon JW, Park MS, et al. Screening for latent tuberculosis infection in South Korean healthcare workers using a tuberculin skin test and whole blood interferon-gamma assay. *Scand J Infect Dis* 2010;42:672-8.
7. Lee K, Han MK, Choi HR, Choi CM, Oh YM, Lee SD, et al. Annual incidence of latent tuberculosis infection among newly employed nurses at a tertiary care university hospital. *Infect Control Hosp Epidemiol* 2009;30:1218-22.
8. Jo KW, Woo JH, Hong Y, Choi CM, Oh YM, Lee SD, et al. Incidence of tuberculosis among health care workers at a private university hospital in South Korea. *Int J Tuberc Lung Dis* 2008;12:436-40.
9. Park HY, Jeon K, Suh GY, Kwon OJ, Chung DR, Yoonchang SW, et al. Interferon-gamma release assay for tuberculosis screening of healthcare workers at a Korean tertiary hospital. *Scand J Infect Dis* 2010;42:943-5.
10. Sokal JE. Editorial: Measurement of delayed skin-test responses. *N Engl J Med* 1975;293:501-2.
11. Mori T, Sakatani M, Yamagishi F, Takashima T, Kawabe Y, Nagao K, et al. Specific detection of tuberculosis infection: an interferon-gamma-based assay using new antigens. *Am J Respir Crit Care Med* 2004;170:59-64.
12. Kang YA, Lee HW, Yoon HI, Cho B, Han SK, Shim YS, et al. Discrepancy between the tuberculin skin test and the whole-blood interferon gamma assay for the diagnosis of latent tuberculosis infection in an intermediate tuberculosis-burden country. *JAMA* 2005;293:2756-61.
13. Jo KW, Jeon K, Kang YA, Koh WJ, Kim KC, Kim YH, et al. Poor correlation between tuberculin skin tests and interferon-gamma assays in close contacts of patients with multidrug-resistant tuberculosis. *Respirology* 2012;17:1125-30.
14. Drobniewski F, Balabanova Y, Zakamova E, Nikolayevskyy V, Fedorin I. Rates of latent tuberculosis in health care staff in Russia. *PLoS Med* 2007;4:e55.
15. Torres Costa J, Sa R, Cardoso MJ, Silva R, Ferreira J, Ribeiro C, et al. Tuberculosis screening in Portuguese healthcare workers using the tuberculin skin test and the interferon-gamma release assay. *Eur Respir J* 2009;34:1423-8.
16. Mirtskhulava V, Kempker R, Shields KL, Leonard MK, Tsertsvadze T, del Rio C, et al. Prevalence and risk factors for latent tuberculosis infection among health care workers in Georgia. *Int J Tuberc Lung Dis* 2008;12:513-9.