

# Review of Epidemiological Studies on the Occupational Risk of Tuberculosis in Low-Incidence Areas

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## Key Words

Tuberculosis · Occupational risk · Epidemiologic studies

## Abstract

This review summarizes the epidemiological evidence for occupationally acquired tuberculosis and considers the implications for the prevention of tuberculosis. The relevant epidemiological studies were identified on the basis of the Medline data bank, starting with the year 1966. The evaluation of occupational groups with an elevated tuberculosis risk is exclusively based on epidemiologic studies of good or acceptable quality, applying clearly defined criteria of methodological quality. In summary, the available epidemiological evidence suggests that the risk of tuberculosis is elevated in the following occupational groups: hospital employees in wards with tuberculosis patients; nurses in hospitals; nurses attending HIV-positive or drug-addicted patients; pathology and laboratory workers; respiratory therapists and physiotherapists; physicians in internal medicine, anaesthesia, surgery and psychiatry; non-medical hospital personnel in housekeeping and transport work; fu-

neral home employees, and prison employees. However, the epidemiological evidence is limited for all these occupations, with the exception of the nurses, because of the lack of methodologically adequate studies that have got the statistical power to differentiate between specific work tasks. There is a need for large population-based studies with precise definition of exposure, which should include molecular epidemiologic methods in the investigation of occupational risk factors of tuberculosis.

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## Introduction

At the beginning of the 20th century, medical occupations were accompanied by a high risk of tuberculosis. The incidence of active tuberculosis was 35- to 50-fold higher in the medical occupations than in the general population [1]. Parallel to the general decrease in the frequency of tuberculosis in industrial countries, there was a tendency to ignore the question of the risk of health care workers. However, in the 1980s and early 1990s several nosocomial outbreaks of tuberculosis were observed, par-

ticularly in the eastern United States. These outbreaks often involved HIV-infected individuals, and the high proportion of multidrug-resistant tuberculosis strains was particularly worrying. These outbreaks drew attention to the danger of infection in the medical occupations. Many publications pointed out that employees of affected hospitals were at greatly increased risk of infection. Conversion of the tuberculin test could be documented in 20–50% of the susceptible hospital employees in the context of one of these tuberculosis outbreaks [2–4].

Outbreak reports can nevertheless not contribute much to the assessment of the probability of occupationally acquired tuberculosis in medical personnel. Of course, the infectious pathway is quite clear if an employee is involved in a tuberculosis outbreak. However, it is more difficult to clarify the causal relationship between occupation and tuberculosis when the employee in the medical occupation has no obvious contact with tuberculosis patients.

The present analysis of the epidemiological literature was intended to further clarify the occupational risk of tuberculosis in specific medical occupations and to identify tasks that entail a particularly high risk. The analysis includes cross-sectional studies, case-control studies, cohort studies and interventional studies related to tuberculosis morbidity and mortality or to the conversion of the tuberculin test. The identification of high-risk occupational groups has consequences for the prevention of tuberculosis and compensation of tuberculosis as an occupational disease.

## Methods

The relevant epidemiological studies were identified on the basis of the Medline data bank, starting with the year 1966. The key words entered were: 'tuberculosis' and ('nosocomial' or 'occupational' or 'employees' or 'nurses' or 'physicians' or 'technicians'). These key words had already been selected by Menzies et al. [5] in their review article on tuberculosis in health care workers. Additionally, we entered the key words 'tuberculosis' and ('health care workers' or 'HCW').

The methodological quality of the identified epidemiological studies was rated according to standardized criteria. These criteria were a priori derived from the critical methodical points formulated by Markowitz [6] in his review article on epidemiological studies. The following items were considered (table 1): size of the study, participation rate, selection of the comparison group, regularity and completeness of the tuberculin testing of the study participants, differentiation of occupations, quality of the statistical evaluation, adjustment of the study results for potential confounders (namely age, sex, country of origin, BCG vaccination, household contact with tuberculosis, socioeconomic status and – for hospital-

based studies – the established protective measures in the hospitals involved). Each item was scored (table 1) and the quality of the study was assessed by the sum of the scores, the maximum being 10 points for studies on the risk of tuberculosis infection. The studies were subdivided into 'poor' studies (0–3.5 points), studies with 'acceptable' methodological quality (4–6.5 points), and 'good' studies (7–10 points).

Two-step tuberculin testing has been recommended because a single tuberculin test may elicit little response yet stimulate an anamnestic immune response so that a second test may elicit a much larger, or boosted, response. The performance of a two-step test procedure can raise the methodical quality of an epidemiological study [7–9]; however, there remains some doubt as to the necessity of a two-phase test procedure [10]. In our study evaluation, the performance of a two-phase test was not included in the overall evaluation, nor did the evaluation specify whether the standard tuberculin test [11] – the Mantoux intracutaneous test – was used or the 'stamp test', which is less sensitive and less specific [12]. Most studies used the intracutaneous test, although some [13, 14] also used the stamp test. It should be pointed out that these evaluation criteria should only be used for information. For example, a study with some minor methodical deficiencies might attain the same formal methodical quality as a study which cannot be reasonably interpreted because of a serious methodical error. It is important, in the final analysis, to consider the overall significance of the methodical advantages and disadvantages of each study. The classification of the methodical quality into 'inadequate', 'acceptable' and 'good' nevertheless makes it possible in most cases to arrive at a tenable assessment. However, one study, although formally classified as methodologically 'acceptable' [15], was excluded from the following review because of the inadequately operationalized comparison group and because of the low numbers of tuberculin test conversions ( $n = 30$ ). All methodologically 'inadequate' studies [13, 16–52] were excluded from the following review. In this review, no statistical meta-analyses were performed, as there were large differences among the studies of adequate methodologic quality.

The aim was to arrive at a statement on the risk of occupational tuberculosis in regions of low tuberculosis incidence. For this reason, studies from regions with a tuberculosis incidence of above 50/100,000 and studies in hospitals with more than 50 tuberculosis patients per 10,000 admissions or in hospitals with 200 or more tuberculosis patients per year were excluded. We nonetheless believe that there is also a need for further analytical and interventional studies dealing with the problem of occupationally acquired tuberculosis in high-incidence areas, e.g. in Eastern Europe. Moreover, as the incidence of tuberculosis in immigrants in industrial countries is increased 10- to 20-fold [53–55], immigration of workers from high-incidence areas might raise both the occupational and the non-occupational risk of tuberculosis in Western industrialized countries. However, the methodologically adequate Canadian study conducted by Menzies et al. [56] reported no association between the proportion of immigrants at school or at the workplace and a positive tuberculin test.

**Table 1.** Summary of evaluation criteria

Criteria	Assessment		
	0 points	0.5 points	1.0 point
<i>Design and material</i>			
Size of the study group			
Cohort study of skin test conversions	<50 skin tests	≥ 50, ≤200 skin test conversions	>200 skin test conversions
Cross-sectional studies of skin test positivity	<250 positive skin tests	≥ 250, ≤ 1,000 positive skin tests	>1,000 positive skin tests
Studies of clinically manifest tuberculosis	<20 TB cases	≥ 20, ≤ 100 TB cases	>100 TB cases
Participation rate	<50% or inadequate or insufficiently described inclusion criteria	≥ 50, <80%	≥ 80%
Comparison group	Inappropriate	Partially appropriate	Appropriate
<i>Measurement of outcome</i>			
Reliability of diagnosis			
Studies of skin test conversions/positivity	Irregularly conducted and incomplete skin tests <sup>1</sup>	Irregularly conducted or incomplete skin tests	Regularly conducted and complete skin tests
Studies of clinically manifest tuberculosis	Poor sensitivity and specificity of TB diagnosis	Acceptable sensitivity and specificity of TB diagnosis	High sensitivity and specificity of TB diagnosis
<i>Measurement of exposure</i>			
Classification of tasks	Very crude job categories	Crude job categories	Differentiating job tasks
<i>Potential confounding</i>			
Statistical analysis	Inadequate; tests of significance missing		Adequate; significance level/confidence intervals reported
Demographic factors (age, sex, country of origin)	Not considered		Considered
BCG vaccination	Not considered		Considered
Household contacts with TB patients	Not considered		Considered
Hospital characteristics/socioeconomic status			
Studies of skin test conversions/positivity	Hospital characteristics (air exchange; proportion of TB patients) not considered	Hospital characteristics (air exchange; proportion of TB patients) partly considered	Hospital characteristics (air exchange; proportion of TB patients) considered
Studies of clinically manifest tuberculosis	Socioeconomic status not considered		Socioeconomic status considered

<sup>1</sup> Cross-sectional studies generally get 0 points for the item 'measurement of outcome'.

### Results of the Evaluation of the Tuberculosis or Tuberculosis Infection Risk in Specific Occupations

The results of all methodologically acceptable and good studies are given in detail in table 2 (Studies on the risk of a positive tuberculin test) and table 3 (Studies on tuberculosis morbidity and mortality). The interpretation of tuberculosis infection studies must take into consideration limitations in the accuracy of the tuberculin

test procedure itself [57–59]. Moreover, false-positive test results in BCG-vaccinated persons might influence the study results [60] even if adjusted for BCG vaccination. However, our analysis does not point to systematic differences between the results of infection studies and those of studies referring to clinically manifest tuberculosis. Therefore studies on infection rates and those on clinically manifest tuberculosis were combined in the following summary of the occupation-specific risks.

**Table 2.** Epidemiological studies on the frequency of a positive tuberculin test or tuberculin test conversion

Study <sup>1</sup>	Time	Site	Study group	Exposure group	Infection rate if unknown, positive test	Relative risk	Confounders	
<i>A. Cohort studies (and combined cohort and cross-sectional studies)</i>								
Behrman and Shofer 1998 [79]	1993–96	Philadelphia	5,697 employees of a 1,000-bed hospital in Philadelphia, 88 of these working in emergencies (with 43,000 patients/year)	Employees (excluding physicians) in emergency department vs. other hospital departments before introduction of protective measures 1994/95	12 vs. 2%	5.9 (2.7–13.1)	none	
				Employees (excluding physicians) in emergency department vs. other hospital departments after introduction of protective measures 1996	0 vs. 1.2%			–
Berman et al. 1981 [82]	1971–76	Baltimore	1,900 employees of a 516-bed hospital in Baltimore (Sinai Hospital)	nurses vs. radiologists	5.05 vs. 1.32%/5 years	2.1 (NS) (RR) 8.3 (p < 0.01) 6.7 (p < 0.01) 15.0 (p < 0.001) 1.3 (NS) 1.7%/6 mo. 1.4%/6 mo. 0.6%/6 mo. 0.4%/6 mo. p < 0.001 1.94 vs. 12.9/100 PY 1.09 vs. 5.98/100 PY 3.18/100 PY 2.67/100 PY 1.79/100 PY 1.73/100 PY 1.33/100 PY 1.24/100 PY 0.79/100 PY 0/100 PY	RR univariate; conversions rates adjusted for age, ethnicity, sex, social status and duration of employment	
				maintenance and engineering personnel vs. radiologists	19.0 vs. 1.32%/5 years			
				housekeeping employees vs. radiologists	15.6 vs. 1.32%/5 years			
				laundry employees vs. radiologists	34.4 vs. 1.32%/5 years			
				pathologists vs. radiologists	2.08 vs. 1.32%/5 years			
				HCW 1992, second half year	1.7%/6 mo.			
				HCW 1993, first half year	1.4%/6 mo.			
				HCW 1993, second half year	0.6%/6 mo.			
				HCW 1994, first half year	0.4%/6 mo.			
				physicians, department of internal medicine 1993–97 (after introduction of extensive safety measures) vs. 1992	1.94 vs. 12.9/100 PY			
				physicians, all departments 1993–97 (after introduction of extensive safety measures) vs. 1992	1.09 vs. 5.98/100 PY			
				physicians, department of internal medicine	3.18/100 PY			
				gynaecology/obstetrics	2.67/100 PY			
				rehabilitation, family and preventive medicine, public health, emergency medicine	1.79/100 PY			
surgery	1.73/100 PY							
pathology	1.33/100 PY							
radiology	1.24/100 PY							
anaesthesiology	0.79/100 PY							
dermatology; neurology; ophthalmology; paediatrics; psychiatry	0/100 PY							
Boudreau et al. 1997 [67]	1989–92	Miami	249 ‘exposed’ and 355 ‘not exposed’ employees of the Jackson Memorial Hospital without pos. tuberculin test or BCG vaccination in the history	all employees on ‘TB-exposed’ vs. non-exposed wards	14.5 vs. 1.4%/4 years	10.3 (4.1–25.8)	sex	
				all employees on ‘TB-exposed’ (without ward of the MDR-TB outbreak) vs. non-exposed wards	13.4 vs. 1.4%/4 years			9.6 (3.8–24.4)
				exposed vs. non-exposed nurses	18.2 vs. 1.5%/4 years			12.3 (4.4–34.4)
				exposed vs. non-exposed ward assistants	15.6 vs. 0%/4 years			p < 0.02
				physicians in second year of advanced training	8.62%			
physicians in third year of advanced training	11.11%							
physicians in fourth year of advanced training	14.29%							
Christie et al. 1998 [81]	1986–94	Cincinnati	between 2,886 (1986) and 4,390 (1994) employees of a paediatric university hospital (361 beds) tested annually	employees in the paediatric hospital with (e.g., physicians, nurses) vs. without patient contact (e.g. basic scientists, administrators)	0.19 vs. 0.22%/year	NS	none	
Cooper-Arnold et al. 1999 [20]	1993–95	Connecticut	n = 377 tuberculin-negative sheriffs were retested 1–2 years later	time of office of the sheriff tuberculosis incidence at the place of residence of the sheriff		p < 0.036 0.89 (OR), p < 0.059	? age, time of office	
Lainez et al. 1999 [74]	1992–97	Barcelona	320 trainee nurses registered at Barcelona University	nurses during 3 years of training nurses with vs. without work which risks infection	3.8/100 PY	0.89 (0.3–2.6) (OR)	age, sex?	

**Table 2** (continued)

Study <sup>1</sup>	Time	Site	Study group	Exposure group	Infection rate if unknown, positive test	Relative risk	Confounders
Liss et al. 1996 [63]	1991–94	Ontario Canada	809 tuberculin-negative employees of a general hospital	patient contact, ≥ 2 vs. ≤ 1 h/day patient contact, 2–3 vs. ≤ 1 h/day patient contact, ≥ 4 vs. ≤ 1 h/day hospital areas with TB patients vs. non-exposed departments	2.5 vs. 0.5% 3.4 vs. 0.5% 2.2 vs. 0.5% 2.4 vs. 0.38%	5.7 (0.7–44.4) no information 5.5 (0.7–45.3) 6.3 (0.9–52.8)	age, sex  age
<u>Menzies et al. 2000 [66]</u>	1994–97	Montreal Toronto Alberta Vancouver	1,289 clinical and non-clinical hospital employees (PDD-neg.), no physicians (82% women, 37.2 years) in 17 hospitals (n = 15 hospitals with ≥ 6 TB pat./year, 2 hospitals with max. 1 TB pat./year)	hosp. (n = 15) with ≥ 6 TB pat./year vs. hosp. (n = 2) with max. 1 TB pat./year nurses vs. non-clinical work respiratory therapists vs. non-clinical work physiotherapists vs. non-clinical work housekeeping vs. non-clinical work non-isolation rooms: <2 vs. ≥ 2 exchanges of air/h isolation rooms: <6 vs. ≥ 6 exchanges of air/h hospitals with ≥ 6 TB pat./year vs. hospitals with max. 1 TB pat./year contact with patients with unknown smear-pos. TB (per 10 days) age on employment (per 5 year) sex: male vs. female origin: birth outside vs. within Canada BCG vaccination as child vs. none BCG vaccination as adult vs. none TB in domestic environment vs. no TB regional TB incidence (per 20/100,000)	19 vs. 12% 20 vs. 7% 20 vs. 7% 9 vs. 7% 54 vs. 7%   19 vs. 12%    18 vs. 18% 20 vs. 18% 20 vs. 9% 38 vs. 9% 38 vs. 18%	hazard ratio = 2.2 (1.3–3.5) 4.3 (2.7–6.9) 6.1 (3.1–12.1) 3.3 (1.5–7.2) 4.2 (2.3–7.6) 3.4 (2.1–5.8)  1.02 (0.8–1.3)  2.2 (1.3–3.5)  1.0 (0.96–1.03)  1.2 (1.02–1.3) 0.9 (0.6–1.4) 2.6 (1.5–4.7) 2.2 (1.4–3.3) 1.8 (1.3–2.5) 1.5 (0.8–2.8) 0.8 (0.6–1.1)	age, sex, birth in Canada, BCG vaccination, TB in domestic environment, regional TB incidence, TB cases in hospital, work, ventilation, patient contact
Menzies et al. 2003 [87]	no information	Montreal Toronto Alberta Vancouver	111 initially TST-negative laboratory and pathology employees; 74 non-clinical hospital employees	pathology technicians vs. non-clinical work lab technician vs. non-clinical work	24% (n = 9) 7% (n = 5)	5.4 (1.3–22) 1.6 (0.3–9.1)	age at start of employment, sex, BCG vaccination, duration of employment, TB mortality of the hospital
Raad et al. 1989 [65]	1984–87	Florida	3,080 employees of a university hospital and 3126 employees of a psychiatric hospital	employees of a university hospital with 4 TB patients/year vs. employees of a psychiatric hospital with 1 TB pat./year (average)	0.13 vs. 0.42%/year	p < 0.001	none
<u>Schwartzman et al. 1996 [61]</u>	1992–93?	Montreal	522 employees in hospital A, specialising in respiratory diseases (100 beds) and in medical centre B (700 beds; selected areas)	clin. personnel (hospitals A+B) vs. non-clinical personnel (hospital A) inhalation therapists (hospitals A+B) vs. non-clinical personnel (hospital A) nurses, physiotherapists, occupational therapists (hospital A) vs. non-clinical personnel (hospital A) nurses in internal medicine or intensive care, physiotherapists, occupational therapists (hospital B) vs. non-clinical personnel (hospital A) surgical nurses (hospital B) vs. non-clinical personnel (hospital A)	14 vs. 5% 15 vs. 5% 27 vs. 5% 7 vs. 5% 20 vs. 5%	13.6 (1.4–132.4) (OR) 14.9 (0.9–247.3) 32.7 (1.9–557.8) 5.6 (0.5–66.6) 23.4 (2.1–264.3)	age, origin, sex, BCG status
Ussery et al. 1995 [86]	1992	New York	21 employees of a pathology institute; of 881 autopsies (1991), n = 8 exhibit TB, of these n = 6 with MDR-TB + HIV+	participation vs. no participation in MDR-TB autopsy		4.3 (1.61–11.69)	none (according to authors, comparable age, ethnicity, sex, years of employment); all volunteers born in the USA
Zahnow et al. 1998 [78]	1992–95	USA	766 tuberculin-negative HCW (of 1,014 examined) from 16 institutions for treating HIV (hospitals, medical practices)	physicians, nurses social workers, office workers prop. HIV+ patients 0–49% prop. HIV+ patients 50–100% prop. patients with active TB <25% prop. patients with active TB ≥ 25% drug program vs. other professional settings (in-patients, out-patients, private practice)	1.7/100 PY (0.8–3.0) 1.8/100 PY (0.9–3.3) 1.7/100 PY (0.6–3.7) 1.8/100 PY (1.0–3.0) 1.7/100 PY (1.0–2.8) 4.6/100 PY (1.2–11.7) 9.5/100 PY (3.1–22.1)	4.4 (1.5–12.3) (OR)	age, place of work, origin, BCG status, HIV patients, patients with TB, direct patient contact, procedures to induce cough

**Table 2** (continued)

Study <sup>1</sup>	Time	Site	Study group	Exposure group	Infection rate if unknown, positive test	Relative risk	Confounders
Zarzuela Ramirez et al. 2000 [68]	1989–96	Cadiz	475 or 400 tuberculin-negative (according to Span. or CDC criteria) employees of a 850 bed university hospital in Cadiz	nurses nurses (nursing) assistants transport workers physicians residents kitchen personnel technical personnel others transport workers and engineers vs. all others 'high risk group' vs. 'low risk group'	3.7/100 PY 3.7/100 PY 2.0/100 PY 6.9/100 PY 2.2/100 PY 3.1/100 PY 2.5/100 PY 5.4/100 PY 3.7/100 PY  4.9 vs. 1.9/100 PY	2.15 (1.00–4.60)  2.1 (1.11–3.99)	age, risk group  age, occupational group
<i>B. Case control studies</i>							
Calder et al. 1991 [77]	1987–88	Palm Beach County, Fla.	16 tuberculin-converted out-patient workers; 34 repeatedly negative control persons	time spent in a room with pentamidine aerosol treatment  work in the first floor (nursing area)	31.2 vs. 2.9%  93.7 vs. 61.8%	19.5 (stat. significant in the univariate analysis)  11.7 (stat. significant in the univariate analysis)	stepwise LR: adj. for work in the first story or presence during pentamidine treatment
<i>C. Cross-sectional studies</i>							
Bailey et al. 1995 [64]	1989–91	St. Louis Mo.	n = 6,070 employees of a hospital, 5,475 of these with complete data	limited vs. no patient contact frequent vs. no patient contact Nurses Physicians supporting personnel <sup>2</sup> clinical personnel <sup>2</sup> other <sup>2</sup>	10 vs. 14% 11 vs. 14% 10% 7% 13% 12% 7%	1.03 (0.78–1.38) 1.18 (0.96–1.45) no information no information no information no information	
Dooley et al. 1992 [76]	1989	San Juan P.R.	908 employees of a training hospital in San Juan	nurses on a HIV ward vs. office workers  nurses in internal medicine vs. office workers other nurses (without HIV ward) vs. office workers ancillary staff (watchmen, maintenance, domestic employees) extra-professional TB contact vs. no extra-professional TB contact	56 vs. 17%  55 vs. 17% 19 vs. 17% 39 vs. 17% 43 vs. 23%	6.4 (2.2–18) (OR) 6.0 (3.3–11) 1.2 (0.7–2.0) 3.1 (1.8–5.4) 2.5 (1.5–4.1)	age, extra-professional TB exposure   ?
Gershon et al. 1998 [88]	?	USA	During a congress of the 'National Funeral Directors Association' (14,000 members) 1,200 of 2,400 participants attended a meeting to provide information on the study; n = 864 fulfilled the criteria for inclusion	embalming vs. non-embalming employees of the funeral home embalmers with ≥20 years work vs. embalmers with <20 years work	14.9 vs. 7.2% 20.2 vs. 6.3%	1.92 (1.09–3.4) (OR) 6.9 (2.9–16.4)	age, sex age, other (unnamed) factors
Jochem et al. 1997 [89]	1995	Montreal	102 employees of a women's prison, born in Quebec	BCG vaccination at age of ≥2 years vs. no BCG vaccination travel in endemic TB areas duration of work in study prison (per 5 years) duration of work in other prisons (per 5 years)	46 vs. 23% 63 vs. 30%	4.53 (1.5–13.5) (OR) 7.68 (1.4–43.3) 1.12 (0.8–1.6) 2.53 (1.2–5.2)	sex, BCG vaccination, travels in endemic TB areas, age at start of work in prison time in study prison, time in other prisons (always without examined factor)
Kralj et al. 1997b [14]	1995	Freiburg University Hospital	4,216 hospital employees called in for health examinations	forensic medicine/pathology  kitchen  nursing school	60%  no information (between 50 and 60%)  no information (between 25 and 30%)	no information effect estimate (p < 0.05) no information effect estimate (p < 0.05) no information effect estimate (p < 0.05)	age, years in occupation, area of hospital (ward), area of work, origin, hepatitis C status, cigarette consumption

**Table 2** (continued)

Study <sup>1</sup>	Time	Site	Study group	Exposure group	Infection rate if unknown, positive test	Relative risk	Confounders	
Menzies et al. 1997 [56]	1987–91	Montreal	n = 3,710 non BCG-inoculated, persons born in Canada: pupils, preclinical students in health occupations, office workers, heavy workers, employees of the clothing industry	occupational groups (work/school):		(OR)		
				class 6 vs. all other groups	1.3 vs. 3.0%	0.8 (0.3–1.8]		
				class 10 vs. all other groups	2.9 vs. 2.3%	1.7 (0.97–3.0)		
				students in health occupations vs. all other groups	1.8 vs. 2.5%	0.6 (0.3–1.0)		
				workers (office, heavy industry, clothing industry)	4.3 vs. 1.8%	1.5 (0.7–2.7)		
				former domestic contact with TB patients vs. no domestic TB contact	10 vs. 2%	4.2 (1.4–12.7)	age, domestic contacts with TB patients	
Schwartzman et al. 1996 [61]	1992–93?	Montreal	522 employees in hospital A, specialising in respiratory disease (100 beds) and in medical centre B (700 beds; selected areas)	clinical personnel (hospitals A+B) vs. non-clinical personnel (hospital A)	38 vs. 36%	2.6 (1.3–5.2)	age, origin, sex, BCG status	
				respiratory therapy (hospitals A+B) vs. non-clinical personnel (hospital A)	31 vs. 36%	3.2 (1.0–10.0)		
				nurses, occupational and physiotherapists (hospital A) vs. non-clinical personnel (hospital A)	46 vs. 36%	3.2 (1.3–8.2)		
				nurses in internal and intensive medicine, occupational and physiotherapists (hospital B) vs. non-clinical personnel (hospital A)	33 vs. 36%	1.8 (0.8–4.0)		
				surgery nurses (hospital B) vs. non-clinical personnel (hospital A)	43 vs. 36%	3.3 (1.5–7.5)		
Snider and Cauthen 1984 [48]	?	USA: Pennsylvania, Colorado, Maryland, Texas, New Mexico, Ohio, Montana, New Hampshire, Georgia	2,753 tuberculin-tested employees in 10 hospitals with available information on risk factors	physicians and nurses (non-adjusted prevalence of positive tests)	12.3%	adjusted 14.1%	age, sex, ethnicity, hospital, occupational exposure to TB	
				'paramedical' and pharmaceutical work	10.0%	adjusted 15.2%		
				laboratory work	7.8%	adjusted 9.2%		
				administrative work	8.1%	adjusted 9.6%		
				service area	22.0%	adjusted 14.1%		
				other	6.8%	adjusted 6.9%		
				TB-patient contact 50–100% vs. 0–10%	12.5 vs. 13.9%			age, sex, ethnicity, hospital, occupation
				TB-patient contact 11–49% vs. 0–10%	9.9 vs. 13.9%			
				contact with TB cultures vs. 0–10% TB-patient contact	8.6 vs. 13.9%			
				respiratory therapy vs. 0–10% TB-patient contact	4.7 vs. 13.9%			
Stuart et al. 2001 [73]	1996–99	Melbourne, Australia	employees of 14 hospitals (4,070 clinical and 4,298 non-clinical employees)	HCW vs. non-HCW <sup>1</sup>	19.3 vs. 13.7%	1.6 (1.4–1.9)	age, sex, years at work, BCG inoculation, years since BCG inoculation, land of birth; for non-occupational factors: occupation	
				physicians vs. non-HCW <sup>1</sup>	9.3 vs. 13.7%	0.9 (0.7–1.4)		
				nurses vs. non-HCW <sup>1</sup>	20.5 vs. 13.7%	1.7 (1.5–2.0)		
				other HCW vs. non-HCW <sup>1</sup>	13.5 vs. 13.7%	1.5 (1.0–2.4)		
				3–7 vs. <3 years of work in the hospital	11.0 vs. 7.6%	1.1 (0.9–1.4)		
				8–12 vs. <3 years of work in the hospital	17.4 vs. 7.6%	1.3 (1.0–1.7)		
				13–20 vs. <3 years of work in the hospital	22.3 vs. 7.6%	1.5 (1.1–1.8)		
				>20 vs. <3 years of work in the hospital	23.5 vs. 7.6%	1.4 (1.1–1.9)		
				BCG inoculation vs. no BCG inoculation	18.2 vs. 7.5%	1.5 (1.1–1.9)		
				land of birth with >15/100,000 vs. ≤15/100,000 TB cases/year	25.1 vs. 14.8%	1.8 (1.6–2.2)		
Warren et al. 2001 [80]	1992–98	St. Louis, Washington	n = 1,574 physicians in training in the Barnes-Jewish Hospital in St. Louis (tw. Rotanden)	specialists in internal medicine vs. radiologists	46 vs. 6%	2.53 (1.28–5.02)	age, ethnicity, BCG status, speciality, origin (apart from variable analysed)	
				surgeons vs. radiologists	20 vs. 6%	2.04 (0.98–4.26)		
				anaesthetists vs. radiologists	10 vs. 6%	3.61 (1.55–8.39)		
				pathologists vs. radiologists	8 vs. 6%	1.80 (0.76–4.29)		
				psychiatrists vs. radiologists	10 vs. 6%	3.69 (1.53–8.88)		
				birth outside vs. within USA	71 vs. 29%	2.69 (1.59–4.56)		
				BCG inoculation vs. no BCG inoculation	63 vs. 37%	8.30 (5.08–13.6)		

**Table 2** (continued)

Study <sup>1</sup>	Time	Site	Study group	Exposure group	Infection rate if unknown, positive test	Relative risk	Confounders
Zahnow et al. 1998 [78]	1992–93	USA	1014 HCW in 16 HIV treatment units (hospitals, medical practices)	New York City vs. other region	31.1 vs. 16.7%	1.82 (1.21–2.74) <sup>3</sup> (OR)	age, place of work, origin, BCG status, HIV patients, patients with TB, direct patient contact, procedures to induce cough
				birth outside USA or >1 year in TB-endemic area vs. birth in USA	51.4 vs. 17.3%		
				BCG inoculation vs. no BCG inoculation	75.2 vs. 16.3%	significant	
				physicians	34.1%		
				nurses	27.3%		
				social workers	21.6%		
				office workers	17.4%		
				other occupations	20.5%		
				5–9 vs. <5 years in nursing	24.0 vs. 13.7%		
				10–14 vs. <5 years in nursing	23.2 vs. 13.7%		
≥ 15 vs. <5 years in nursing	31.8 vs. 13.7%						
			in all: per 5 years work as nurse			1.37 (1.23–1.52) <sup>3</sup>	

Abbreviations: CO = Cohort study; CS = cross-sectional study.

<sup>1</sup> Only studies of acceptable or high methodological quality are considered; studies of high methodological quality are underlined.

<sup>2</sup> Support personnel includes: housekeeping, cafeteria workers, transport workers; ‘clinical personnel’ includes: respiratory therapists, physiotherapists, nutritionists, clinical social workers; no information given on the occupation of the ‘others’.

<sup>3</sup> Only employees without previous BCG inoculation included (because of effect modification by BCG status).

### Health Care Workers (General)

Epidemiological studies often do not apply to specific medical occupational groups, but calculate the risk of infection or disease for the *overall group of health care workers*. The methodologically good prospective conversion study and methodologically acceptable prevalence study of Schwartzman et al. [61] reported a significantly and markedly increased infection risk for health care workers. The relative risk estimate for medical personnel is 13.6 in the cohort study and 2.6 in the cross-sectional study. On the other hand, the study of McKenna et al. [62] found no evidence for an association between health care work in general and clinically manifest tuberculosis. A possible explanation for the lack of epidemiological evidence for an association between health care work in general and tuberculosis infection or disease may be attributed to the highly heterogeneous definition of ‘health care work’, which includes both occupational groups with a potentially increased risk and groups without any contact with tuberculosis patients.

However, the criterion ‘frequency of patient contacts’ is of only limited use for the identification of employees at increased risk of disease. Unfortunately, no epidemiological studies of high methodological quality deal with this question. In the very small study of Liss et al. [63] (n = 18 tuberculin conversions), the relationship between the frequency of patient contacts and tuberculosis infec-

tion or disease approached statistical significance. In the cross-sectional study conducted by Bailey et al. [64], the tuberculin conversion rate of employees with frequent patient contacts was slightly increased. On the other hand, Raad et al. [65] even found a negative association between the frequency of patient contacts and tuberculosis infection or disease. However, the latter result is likely to be explained by the choice of an inappropriate comparison group and by confounding. *All* reviewed epidemiological studies detected an association between *work on wards with tuberculosis patients* and tuberculosis infection and disease [63, 66–68]. Relative risk estimates range from 2.1 [68] to 10.3 [67]. The study of Menzies et al. [66] detected *no* increased risk for contact with patients with *initially missed diagnosis*. This result was qualified by a later evaluation of the same study by Greenaway et al. [69], including the participation of Menzies. According to this publication, the risk of infection for hospital employees is associated with delayed diagnosis and treatment. In the hospitals studied, as the rate of tuberculosis admissions decreased, the likelihood of delayed diagnosis and risk of transmission of tuberculosis infection *per hospitalized patient with tuberculosis* increased. Despite the apparent (and only partially comprehensible) discrepancies between the published results of this research group, this study indicates that professional experience in the management of tuberculosis might, to a certain extent,

protect from occupationally acquired tuberculosis infections.

### Nurses

The methodologically good or acceptable studies on the occupational risk of tuberculosis of nurses give a largely *consistent picture*. All epidemiologically good [61, 66, 70, 71] and acceptable studies [14, 70, 72–75] on this question reveal an *increased risk of tuberculosis for nurses*. Relative risk estimates for nurses range from 1.7 [73] to 32.7 [61]. In the study conducted by Hill et al. [70] in England and Wales, the risk of tuberculosis is elevated only for white nurses. According to this study, reactivation of an earlier acquired infection might play a more important role in foreign-born health care workers than occupation; however, this is rather speculative. In the mortality study conducted by the American Centers for Disease Control and Prevention, the proportional mortality rates are significantly increased solely for white male nurses, the corresponding risk estimates for black men, white women and black women are non-significantly decreased [72]. Another study reported no statistically elevated risk of tuberculosis disease for nurses, in contrast to nursing aids, orderlies, and attendants [62]. As the number of relevant studies is low, it is difficult to assess the risk for specific nursing tasks. Only one study deals with the infection risk of *nurses in internal medicine*; this study reveals a clearly and significantly elevated risk [76]. However, the ward for internal medicine in that study was near the HIV ward, so the increased risk is not unambiguously due to the patients treated in the ward for internal medicine. In the study conducted by Schwartzman et al. [61], the elevated infection risk among *surgical nurses* was ascribed to inadequate ventilation of the surgical units as well as delayed diagnosis. Two studies [76–77] found an association between the tuberculosis infection risk and the care of *HIV-positive patients*. The increased risk in the latter study was found to be related to the pentamidine aerosol treatment of HIV patients. In their combined cross-sectional and cohort study on employees attending HIV-positive patients, Zahnnow et al. [78] found a statistically significant association between infection rate and work in a drug program. Only a single study relating to work in an *emergency ward* reported a significant and clearly increased risk of infection before the introduction of adequate protective measures [79].

### Physicians

The methodologically good study of Meredith et al. [71] reported a significantly 2.7-fold increased tuberculo-

sis risk for *physicians*. However, the picture is not as consistent as with nurses, as one methodologically good study [70] and a methodologically acceptable study [73] found no association between work as a physician and the risk of tuberculosis infection or disease; one methodologically acceptable study even found a negative association [62]. However, in the latter study, socioeconomic status was not included in the analysis as a confounder. Because of the inadequate data, it is difficult to evaluate the tuberculosis risk in different medical specialties. One study found an increased infection risk for *specialists in internal medicine, anaesthetists, surgeons and psychiatrists* [80]. The study of Christie et al. [81] found no increased risk of infection for *paediatricians*. The study of Berman et al. [82] conducted in a general hospital in Baltimore reported a significantly lower infection risk for *radiologists* than for maintenance and engineering, housekeeping, or laundry employees. In their cross-sectional study, Plitt et al. [83] found a significant association between a positive tuberculin test and work in respiratory medicine, general surgery, or internal medicine.

### Laboratory Employees

The risk of tuberculosis in the dissecting room has been an issue for centuries [84]. In a review on occupationally acquired infections of health care workers, Sepkowitz [85] throws light on tuberculosis infections in pathologists and laboratory workers. An overall examination of the epidemiological studies involving pathologists and laboratory employees gives the following picture: Most of the studies that have been carried out on this subject, none of which are methodologically good, found an elevated risk of tuberculosis for *pathological work*. Three studies of acceptable quality reveal a statistically significant association between work in pathology and tuberculosis infection: Ussery et al. [86] reported an elevated conversion risk for employees who had participated in autopsies of persons with multidrug-resistant tuberculosis. In the small hospital-based study conducted by Menzies et al. [87], the tuberculin conversion risk was significantly elevated for pathology employees in comparison with non-clinical employees. Kralj et al. [14] found a significantly increased prevalence of infection in the department of pathology, but they did not give any risk estimates. One cross-sectional study found a non-significant relative risk of having a positive tuberculin test [78]. No association between *laboratory work* and tuberculosis infection was found in the small study of Menzies et al. [87].

**Table 3.** Epidemiological studies on the risk of clinical tuberculosis disease

Study <sup>1</sup>	Time	Site	Study group	Exposure group	TB incidence exposed group	TB incidence comparison group	Relative risk	Confounders
Burrill et al. 1985 [75]	1969–79	British Columbia	57 nurses with active TB	all nurses vs. all women	26/100,000	11/100,000	0.91 (SIR)	age, origin age
				nurses born in Asia vs. all women born in Asia	248/100,000	595/100,000	0.41	
				nurses born in Europe vs. all women born in Europe	21/100,000	19/100,000	1.11	
				nurses born in Canada vs. all women born in Canada	20/100,000	12/100,000	1.90	
				tuberculin-positive nurses (only born in Canada)	55.5/100,000			
				tuberculin-negative nurses without earlier BCG inoculation (only born in Canada)	26.2/100,000			
				tuberculin-positive nurses with earlier BCG inoculation (only born in Canada)	11.0/100,000			
CDC 1995 [94]	1979–90	28 US States	1,024 of 2,206 deaths from tuberculosis with either $\geq 4$ deaths from TB or PMR $>200$ or sig. PMR in at least 1 ethnic and sex-spec. category; n = 20 HCW	white male employees in the health service (mostly nurses and nursing assistants)	n = 7 deaths	unknown	3.5 (1.41–7.21)	age
				black male employees in the health service (mostly nurses and nursing assistants)	n = 1 deaths	unknown	0.24 (0.01–1.35)	
				white female employees in the health service (mostly nurses and nursing assistants)	n = 7 deaths	unknown	0.88 (0.35–1.82)	
				black female employees in the health service (mostly nurses and nursing assistants)	n = 5 deaths	unknown	0.73 (0.24–1.69)	
				male white undertakers	n = 4 deaths	unknown	2.99 (0.82–7.66)	
				male black undertakers	unknown	unknown	1.35 (0.03–7.54)	
Hill et al. 1997 [70]	1992–95	West Midlands region, England	5,840 physicians, 3,9848 nurses, 9,683 other medical/scientific/technical-hospital employees	nurses (white and other, none of Indian origin); n = 8	6/100,000 (2–10)	5/100,000 (4–6)	1.3 (0.6–2.7)	Stratified analysis with respect to age, ethnicity and sex (by restriction of the comparison group)
				white nurses; n = 7	6/100,000 (2–10)	2/100,000 (1–3)	2.4 (1.1–5.5)	
				physicians of Indian and other origin (none white); n = 13	170/100,000 (78–262)	118/100,000 (85–151)	1.4 (0.8–2.7)	
				white physician (n = 1)	10/100,000 (0.2–20)	6/100,000 (5–7)	1.6 (0.6–4.4)	
				other (mortuary assistant, X-ray assistant, physiotherapist, OP technician); n = 4				
McKenna et al. 1996 [62]	1984–85	29 USA States	9,534 TB cases	all health occupations vs. all persons of working age	6.7/100,000	8.4/100,000 (16–64 year)	1.0 (0.9–1.1)	age, sex, ethnicity, origin
				physicians	6.6/100,000		0.4 (0.2–0.6)	
				registered nurses	5.8/100,000		1.2 (0.9–1.5)	
				respiratorion therapists	15.6/100,000		2.9 (1.2–6.0)	
				clinical laboratory technicians	6.7/100,000		0.9 (0.5–1.5)	
				licensed nurses	6.1/100,000		1.1 (0.7–1.6)	
				technical health occupations	4.9/100,000		0.7 (0.3–1.4)	
				other health care workers (not nurses)	4.1/100,000		0.6 (0.3–1.2)	
				nursing assistants, ambulance workers supervisors,	10.5/100,000		1.3 (1.1–1.5)	
				contact with children in schools or in day care	2.1/100,000		0.4 (0.3–0.4)	
				service occupations with much public contact	6.7/100,000		0.7 (0.6–0.9)	
				funeral home workers			3.9 (2.2–6.3)	
				unemployed (excluding housewives, etc.)	337.2/100,000		61.8 (57.8–66.7)	

**Table 3** (continued)

Study <sup>1</sup>	Time	Site	Study group	Exposure group	TB incidence exposed group	TB incidence comparison group	Relative risk	Confounders
<u>Meredith et al. 1996 [71]</u>	1988 and 1993	England and Wales	cases from 2 clin. surveys 1988 and 1993; denominator (occupational distribution in GB population) 1991; n = 119 HCW and n = 364 comparable occupations with TB	professional medical occupations (physicians, dentists, pharmacists, ophthalmological opticians, vets) vs. other professional occupations (including firm managers)	23.9/100,000	2.5/100,000	2.7 (1.9–3.8)	age, sex, ethnic group
				associate professional medical occupations (nurses, midwives, radiology technicians, physiotherapists, chiropodists, opticians medical technicians, occupational and speech therapists, environmental advisors) vs. other associate professional occupations (including clerks)	8.9/100,000	4.0/100,000	2.0 (1.5–2.6)	
Sepkowitz et al. [106]	1992–94 1995	New York City	20 HCW in 142 TB-cases, diagnosed in 6 hospitals in NYC	employees in medical occupations vs. other occupations HIV-positive vs. HIV-negative persons			2.77 (1.19–6.41) (OR); p = 0.018 p = 0.029	age, sex, ethnicity, HIV status age, sex, ethnicity, occupation

<sup>1</sup> Only studies of acceptable or high methodological quality are considered; studies of high methodological quality are underlined.

Taken together, the epidemiological evidence suggests that the tuberculosis risk is increased for pathologists. There is also some epidemiologic evidence for a relationship between laboratory work and tuberculosis infection. It should however be pointed out that, firstly, there is a lack of methodologically high-quality studies and, secondly, that an overall statement on laboratory work is problematical. It would be preferable to relate the risk of tuberculosis to discrete tasks, in particular to work with infectious material.

#### *Funeral Home Employees*

Two methodologically acceptable epidemiological studies deal with the specific infection risk for funeral home employees: The study of Gershon et al. [88] found a positive association between embalming bodies and the infection risk. The study of McKenna et al. [62] – which did not include socioeconomic status as a potential confounder – found an increased risk of tuberculosis for funeral directors in spite of their high social status.

#### *Respiratory Therapists and Physiotherapists*

All studies surveyed found that employees working in *respiratory or inhalation therapy* had an increased tuberculosis risk. This applies to two studies of high methodological quality [61 (conversion study), 66] and to two methodologically acceptable studies [61 (cross-sectional

study), 62]. The relative risk estimates for respiratory therapists range between 2.9 and 14.9. Only the methodologically good study of Menzies et al. [66] included physiotherapists; this study reported a significantly increased infection risk of 3.3.

#### *Non-Medical Hospital Employees*

When evaluating the risk of tuberculosis for non-medical hospital employees it is particularly important to bear in mind the methodological quality of the epidemiological studies, as especially methodologically inadequate studies are open to bias introduced by social and cultural confounding factors. The only methodologically adequate study indicated that the risk of infection for housekeeping personnel was significantly and clearly raised [66]. There was also a significant and clear increase in risk in the study of Dooley et al. [76], although the housekeepers are only considered together with the escorts and maintenance workers. One study found an association between transport personnel (in hospital) and tuberculosis infection [64]. Only a single study dealt specifically with the infection risk of *employees in the laundry* [82]; this study found a significantly and markedly increased conversion rate. *Kitchen personnel* has also been the subject of a single study [14]; this study found a significantly elevated infection risk.

### *Prison Employees*

The cross-sectional study conducted by Jochem et al. [89] found a positive association between work as a *prison employee* (however only in men's prisons) and tuberculosis infection.

## **Conclusion and Outlook**

The results of the present analysis agree to a large extent with the recommendations of the OSHA (US Occupational and Health Administration) dealing with work-related tuberculosis risks in the USA [90]. In summary, the available epidemiological evidence suggests that the risk of tuberculosis is elevated in the following occupational groups:

- hospital employees in wards with tuberculosis patients;
- nurses in hospitals;
- nurses of HIV-positive or drug-addicted patients;
- pathology and laboratory workers;
- respiratory therapists and physiotherapists;
- physicians in internal medicine, anaesthesia, surgery and psychiatry;
- non-medical hospital personnel in housekeeping and transport work;
- funeral home employees, and
- prison employees.

It should nevertheless be pointed out that the epidemiological evidence is limited for all these occupations, with the exception of the nurses, as only a small number of studies can be regarded as being of adequate methodological quality. Moreover, few studies have got the statistical power to differentiate between specific tasks. Therefore, further epidemiologic research should address specifically defined tasks rather than roughly defined occupational groups as, for example, 'nurses'.

Differences in task-specific risk estimators of health care workers might, on the one hand, reflect methodological shortcomings. However, we have tried to minimize this potential bias by excluding methodologically inadequate studies from our review. On the other hand, the differences in the reported task-specific risk estimators might be partially explained by regional, individual, and workplace-specific factors that are difficult to measure in epidemiologic studies, e.g. regional differences in health-seeking behaviour of tuberculosis patients, professional experience of health care workers, hospital-specific spacious conditions and protective equipment, and hospital-

specific case management procedures. Further epidemiologic studies should more specifically address these potentially risk-modifying factors to develop more purposeful and efficient prevention strategies for occupationally acquired tuberculosis.

Our finding of elevated risks in specific occupational groups rather raises the question of enforced protective efforts to prevent health care workers from contracting tuberculosis. Unfortunately only a few epidemiologic studies address the preventive potential of protective measures. In the methodologically high-quality study of Menzies et al. [66], inadequate ventilation in 'general' sick-rooms, defined as less than two exchanges of air per hour, was statistically significantly associated with tuberculin conversions. In the methodologically acceptable study of Behrman and Shofer [79], the conversion rates in the emergency department could be lowered from 12% per year to 0% by the introduction of specific protective measures. These measures include setting up isolation rooms in the emergency department, prevention of recirculation of air, improved ventilation in the whole emergency department, and improved personal protective measures.

In accordance with the recommendations of the OSHA [90], the authors recommend to perform periodical tuberculin testing for all employees in the mentioned occupational groups even in Western European areas with a low incidence of tuberculosis. This procedure would not only enhance the early detection of infected individuals, but would also improve the data basis for in-depth epidemiologic analyses of task-specific infection risks. However, we cannot conclude from the epidemiologic evidence that it is necessary to conduct this testing annually in low-incidence areas.

A decreased incidence of tuberculosis in the general population may lead to reduced professional experience in health care workers. As a consequence, the likelihood of delayed diagnosis and the risk of transmission of tuberculosis infection per hospitalized patient with tuberculosis might increase. Therefore, we would like to emphasize the importance of regular information and training measures concerning protective measures as well as the diagnosis and treatment of tuberculosis. Early recognition, efficient treatment and isolation of patients with tuberculosis are key issues regarding the prevention of work-related tuberculosis [91–96]. A patient with lung tuberculosis should be instructed about coughing hygiene and should wear a surgical mask. Particular emphasis should be laid on the ventilation of the isolation room. Re-circulation of contaminated air should be avoided, the air stream should

be redirected into the isolation room or outside. When a ventilation system is used, the air change rate should be at least 4–6 times per hour [94, 95, 97]. The hospital staff should wear masks during the treatment of infectious patients. A surgical mask is considered to be ineffective because of the leakage and the small particle filtration effect [98]. A mask with a filter capacity of 95% for particles with a diameter of 1 µm and a leakage rate of less than 10% is recommended in the US and Canada [94, 99]. These requirements are fulfilled by the FFP 2 (Filtering Face Pieces) mask, recommended in different European countries [95, 100]. The FFP 2 mask has a leakage rate of no more than 11% for particles with a diameter of 0.6 µm [101]. While dealing with multi-drug resistant tuberculosis or in special infectious situations (like bronchoscopy), FFP 3 masks (leakage rate 5%) or even the use of respirators might be considered [102].

Moreover, there is a need for improved strategies for contact tracing that avoids ineffective procedures and allows a better-targeted identification of cases. As several studies have shown that conventional contact tracing is an unreliable procedure [103–105], those traditional methods of contact tracing should be complemented by new molecular biology methods. The use of molecular biology ‘fingerprint’ analyses is expected to enlarge the epidemiologic knowledge concerning occupationally acquired tuberculosis. A promising perspective is offered

by the study of Sepkowitz et al. [106], which combines new molecular epidemiologic methods with conventional epidemiologic methods. Molecular biological ‘fingerprint’ analyses are used to separate tuberculosis patients who belong to a chain of recent transmission from patients with endogenously reactivated tuberculosis (for an overview of the molecular epidemiology of tuberculosis transmission, please see Seidler et al. [107]). The study of Sepkowitz et al. [106] indicates that the risk of recent tuberculosis transmission may possibly be clearly increased in health care workers. It would seem to be a promising approach to improve the precision of occupational risk assessment by performing large population-based studies with differentiated data collection on occupational exposure and combining the methods of conventional epidemiology and molecular epidemiology.

The identification of high-risk occupational groups even in low-incidence areas might have consequences not only for preventive matters, but also for compensation practice. In Germany, until a short while ago, tuberculosis was only recognized as an occupational disease if the source of infection could be definitely identified. Against the backdrop of the reported epidemiologic evidence, an expert group has recommended to drop this general claim of a concrete infection source in specific high-risk occupations [108].

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