World Health Organization

WHO policy on TB infection control in health-care facilities, congregate settings and households

Annexes (CD-ROM)

Stop TB Department

Epidemic and Pandemic Alert and Response Department

HIV/AIDS Department

Patient Safety Programme

World Health Organization, Geneva, Switzerland

Contents

Introduction

The evidence given in these annexes was derived from systematic reviews and literature searches related to TB infection control measures. The main questions that were considered were:

1) How much TB transmission is there in different settings?

2) What is the effectiveness of triage, separation, cough etiquette and reduction of stay in health-care facilities?

3) What is the effectiveness of ventilation?

4) What is the effectiveness of ultraviolet germicidal irradiation (UVGI)?

5) What is the effectiveness of particulate respirators?

Each evidence profile contains the question in an adapted "PICOT" (population, intervention; comparison, outcome and time) format, the study selection process and a summary of the main results. The outcome that was considered for each question was the decrease in TB incidence (both drug-susceptible and drug-resistant TB), where:

- *TB incidence* was specified as the incidence of TB cases (new and recurrent) or TB infection, measured with cutaneous test or gamma interferon assays, or TB prevalence derived measures
- *decrease in TB incidence* was measured in patients (differentiating between HIV and non-HIV infected) and health workers (differentiating between HIV and non-HIV infected).

The GRADE system[a] was used to determine the quality of the collected evidence. This system considers factors such as study design, quality, consistency, directness and precision.

a. http://www.gradeworkinggroup.org/

ANNEX 1

Quantification of TB transmission in selected settings

A1.1 Question

Table A1.1

Question or intervention	Outcome	Setting	Population
Quantification of TB transmission in selected settings	TB incidence	Any ward TB ward MDR ward Outpatient Household Congregate[a]	Patients (HIV positive and all patients) HWs (HIV positive and all HWs)

HW, health worker; HIV, human immunodeficiency virus; MDR, multidrug resistant; TB, tuberculosis

[a] Congregate settings include prisons, homeless shelters, army barracks and nursing homes.

A1.2 Study selection process

- Health workers
  - TB infection incidence in low- and middle-income countries (LMICs – using the World Bank ranking) (10 studies, 7 from 1 systematic review (*1*) [see Section 1.5.1] and 3 independent reviews)
  - TB infection incidence in high-income countries (HICs –World Bank ranking) (35 studies, 33 from 2 systematic reviews (*2*,*3*) [see Section 1.5.1] and 2 independent reviews)
  - TB incidence in LMICs (22 studies, 20 from 1 systematic review (*1*) [see Section 1.5.1] and 2 independent reviews)
  - TB incidence in HICs (14 studies, 12 from 1 systematic review (*3*) [see Section 1.5.1] and 2 independent reviews)
- Inpatients in health-care facilities
  - TB infection and TB incidence (10 studies independent review, data only from HICs)
- Congregate settings contacts
  - TB infection incidence (9 studies independent review, data only from HICs)
  - TB incidence (17 studies independent review, data only from HICs)
- Household contacts
  - TB infection or TB incidence in HICs (14 studies independent review)

A1.3 Summary of evidence

Table A1.2 shows that the incidence of latent TB infection (LTBI) and TB disease among health workers in health-care facilities exceeds the incidence among the general population or among health workers not exposed to health-care facilities. Likewise, the incidence of LTBI and TB among individuals in congregate settings, such as prisons (for which evidence was readily available), and incidence of LTBI and TB among contacts in household settings, exceed the incidence among the general population.

Table A1.2 Pooled estimates (reference general population)

Population	Outcome	Settings	Risk ratio[a]
Health workers	LTBI	High income	10.06
	LTBI	Low income	5.77
	TB	Low income	5.71
	TB	High income	1.99
Congregate (mostly prisons)	LTBI	High income	2.74
	TB	High income	21.41
Household	LTBI and TB	High income	3.19

LTBI, latent TB infection; TB, tuberculosis

[a] Estimates were computed from studies reported in the GRADE profiles tables

A1.4 GRADE profiles

Table A1.3 Health-care facilities – quality assessment

No. studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Other considerations	Quality
LTBI incidence among HWs in high-income countries							
32	Observational study	No serious limitations	No serious inconsistency	No serious indirectness	No serious imprecision	Very strong association[a]	HIGH
LTBI incidence among HWs in low to middle-income countries							
10	Observational study	No serious limitations	No serious inconsistency	No serious indirectness	No serious imprecision	Very strong association	HIGH
TB incidence among HWs in high-income countries							
14	Observational study	No serious limitations	No serious inconsistency	No serious indirectness	No serious imprecision	Very strong association[b]	HIGH
TB incidence among HWs in low to middle-income countries							
22	Observational study	No serious limitations	No serious inconsistency	No serious indirectness	No serious imprecision	Very strong association[c]	HIGH

HW, health worker; LTBI, latent TB infection; IRR, incidence rate ratio.

[a] Thirteen studies, IRR >5; thirty three studies, IRR >2

[b] Two studies, IRR >5; six studies, IRR >2

[c] Seventeen studies, IRR >5; twenty one studies, IRR >2

Table A1.4 Health-care facilities (patients) – quality assessment

No. studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Other considerations	Quality
Nosocomial transmission of TB or LTBI incidence (patient population)							
10	Observational study	No serious limitations	No serious inconsistency	No serious indirectness	No serious imprecision	Very strong association[a]	HIGH

LTBI, latent TB infection; IRR, incidence rate ratio.
[a] One study, IRR>5;three studies, IRR>2

Table A1.5 Congregate settings – quality assessment

No. studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Other considerations	Quality
LTBI incidence among individual in congregate settings							
9	Observational study	No serious limitations	No serious inconsistency	No serious indirectness	No serious imprecision	Very strong association[a]	HIGH
TB incidence among individuals in congregate settings							
17	Observational study	No serious limitations	No serious inconsistency	No serious indirectness	No serious imprecision	Very strong association[b]	HIGH

LTBI, latent TB infection; IRR, incidence rate ratio.
[a] One study, IRR>5; three studies, IRR>2
[b] Thirteen studies, IRR>5; fourteen studies, IRR>2

Table A1.6 Household settings – quality assessment

No. studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Other considerations	Quality
Household transmission of TB or LTBI incidence in high income countries							
14	Observational study	No serious limitations	No serious inconsistency	No serious indirectness	No serious imprecision	Very strong association [a]	HIGH

LTBI, latent TB infection; IRR, incidence rate ratio
[a] Four studies, IRR>5; nine studies, IRR>2

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A1.5.1 Systematic reviews

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ANNEX 2

Triage of people with TB symptoms and separation of infectious cases (Recommendations 8a and 8b)

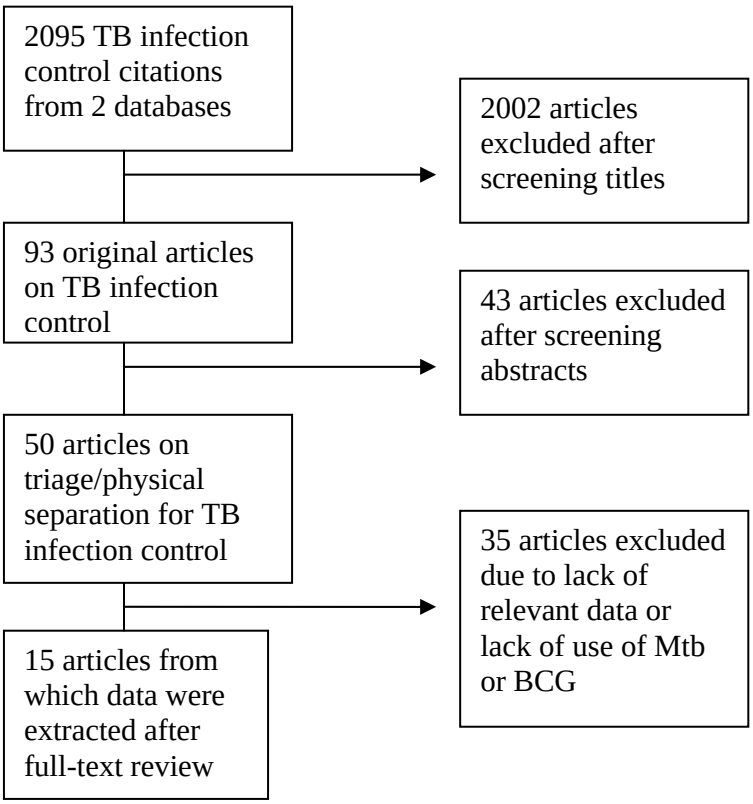
A2.1 Question

Question or intervention	Outcome	Settings	Population
Triage with and without separation versus no intervention	Reduction in TB incidence	Outpatient settings Any ward TB ward MDR ward Congregate settings[a]	Patients (HIV-positive and all patients) HWs (HIV-positive and all HWs)

HW, health worker; HIV, human immunodeficiency virus; MDR, multidrug resistant; TB, tuberculosis

[a] Congregate settings include prisons, homeless shelters, army barracks and nursing homes.

A2.2 Study selection process



BCG, Bacille Calmette Guerin; Mtb, *Mycobacterium tuberculosis*; TB, tuberculosis

A2.3 Summary of evidence

In total, 15 studies, including 3 (*1–3*) from LMICs, have been reviewed. The reviewed studies, including three that contained qualitative data only (*4–6*), support the implementation of triage and physical separation within a set of TB infection control measures. All the studies (*1–3*) from LMICs reported reduction of TB infection among health workers within a year of introduction of multiple infection control measures. In particular, in two studies (*2*, *3*), the decrease in LTBI incidence was statistically significant; the third study (*1*) showed a decrease of TB disease among health workers, but this decrease was not statistically significant.

In all studies conducted in HICs (*7–15*), indicators of nosocomial transmission rapidly declined following the implementation of recommended infection control measures.

Two studies (*11*, *14*) showed that the implementation of the full set of administrative measures reduces transmission of TB to health workers in nosocomial settings. One study showed that reduction of incidence of TB infection among health workers happened after introducing an expanded isolation policy (*7*). Four studies (*11*, *13–15*) addressed the issue of nosocomial transmission of multidrug-resistant TB (MDR-TB) following introduction of outbreak and administrative control measures. In one study within the HIV ward setting, the exclusive implementation of administrative controls resulted in the complete elimination of MDR-TB transmission among patients (*14*). However, identification of the key interventions responsible for the decrease in transmission is difficult, because many measures were introduced simultaneously in most facilities.

Overall, the limited evidence available suggests that risk of TB infection can be reduced with simple administrative controls, but this needs to be evaluated in larger, better controlled studies.

A2.4 GRADE profiles

Table A2. 1 Triage of people with TB symptoms and separation of infectious cases – quality assessment

No. studies	Design	Limitations	Inconsistency	Indirectness[a]	Imprecision	Quality
Triage						
12 (*1–3, 7–15*)	Observational studies	No serious limitations	No serious inconsistency	Serious indirectness	No serious imprecision	LOW
Physical separation						
12 (*1–3, 7–15*)	Observational studies	No serious limitation	No serious inconsistency	Serious indirectness	No serious imprecision	LOW

[a] Indirect intervention – the studies available assess the outcome for several administrative measures implemented concurrently.

A2.5 References

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ANNEX 3

Cough etiquette and respiratory hygiene (Recommendation 8c)

A3.1 Question

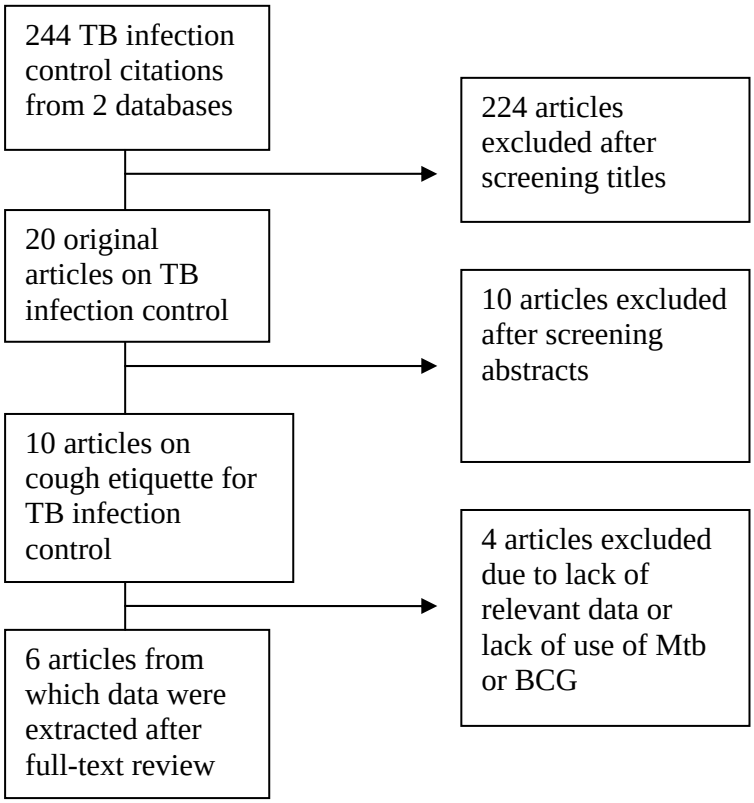
Table A3.1

Question or intervention	Outcome	Settings	Population
Source control interventions (masks, tissues, cough etiquette and respiratory hygiene) versus no intervention	Reduction in TB incidence	Any ward TB ward MDR ward Outpatient Congregate[a]	Patients (HIV positive and all patients) HWs (HIV positive and all HWs)

HW, health worker, HIV, human immunodeficiency virus; MDR, multidrug resistant; TB, tuberculosis

[a] Congregate settings include prisons, homeless shelters, army barracks and nursing homes.

A3.2 Study selection process



BCG, Bacille Calmette Guerin; Mtb, *Mycobacterium tuberculosis*; TB, tuberculosis

A3.3 Summary of evidence

Two observational studies (*1*, *2*) clearly mention respiratory hygiene among the administrative measures contained in the packages implemented. However, some articles addressed the impact of respiratory hygiene on the reduction of transmission of influenza and pertussis, diseases with transmission dynamics that differ from those of TB (*3–6*). The few data available from these studies support the implementation of cough etiquette to reduce the transmission of influenza and pertussis. These findings, although not TB related, are used to inform the public health recommendation for the role of cough etiquette for TB infection control.

A3.4 GRADE profile

Table A3.2 Cough etiquette and respiratory hygiene – quality assessment

No. studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Quality
2 [a]	Observational studies	Serious limitations	No serious inconsistency	No serious indirectness	No serious imprecision	LOW

[a] Table generated based on the TB-related papers only (*1,2*)

A3.5 References

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ANNEX 4

Minimizing time spent in health-care facilities (Recommendation 8d)

A4.1 Question

Table A4.1

Question or intervention	Outcome	Setting	Population
Minimise time spent in health-care facilities versus no intervention	Reduction in TB incidence	Any ward TB ward MDR ward	Patients (HIV positive and all patients) HWs (HIV positive and all HWs)

HW, health worker; HIV, human immunodeficiency virus; MDR, multidrug resistant; TB, tuberculosis

A4.2 Summary of evidence

No studies were found that directly assess the contribution of hospital stay to nosocomial TB transmission. Therefore, a GRADE table cannot be generated. There are several studies on cost-effectiveness of ambulatory management versus hospitalization.

A4.3 References

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ANNEX 5

Ventilation system: Natural, mixed-mode and mechanical ventilation (Recommendations 10, 10a and 10b)

A5.1 Question

Table A5.1

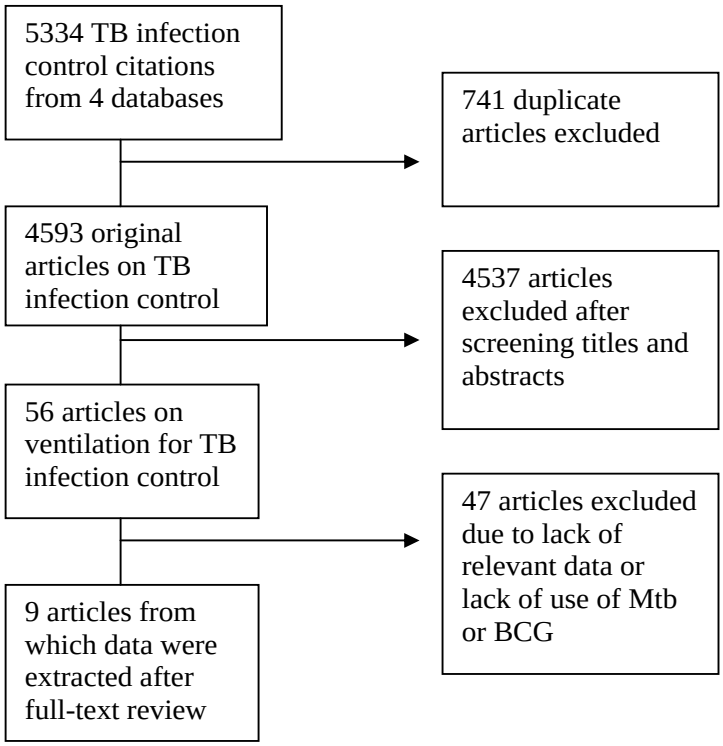
Question or intervention	Outcome	Setting	Population
Ventilation versus no interventions Mechanical ventilation versus no intervention Natural or mixed-mode ventilation versus mechanical Single occupancy versus ventilation or mechanical	Reduction in TB incidence Change in ACH Cost or cost–effectiveness	Any ward TB ward MDR ward Outpatient Congregate[a]	Patients (HIV-positive and all patients) HWs (HIV-positive and all HWs

ACH, air change per hour; HW, health worker; HIV, human immunodeficiency virus; MDR, multidrug resistant; TB, tuberculosis

[a] Congregate settings include prisons, homeless shelters, army barracks and nursing homes.

A5.2 Study selection process

4537 articles excluded after screening titles and abstracts



BCG, Bacille Calmette Guerin; Mtb, *Mycobacterium tuberculosis*; TB, tuberculosis

A5.3 Summary of evidence

Of the nine included articles (*1, 9*), three were epidemiologic studies (cohort or cross-sectional designs) (*3–5*) that looked at tuberculin skin test (TST) conversion rates in health workers; four were modelling studies (*1, 6–8*) and two described the costs of ventilation interventions (*2, 9*). No randomized controlled trials studying the effectiveness of ventilation measures were found. One study focused on natural ventilation only (*7*), the other studies assessed mechanical ventilation. The three epidemiological studies showed a link between ventilation and TST conversion rates: the lower the ventilation, the higher the TST conversion rate in health workers. The factors studied in the nine included articles vary widely.

In general, even if the evidence for ventilation is of low quality, studies suggest that these interventions are useful for TB infection control.

A5.4 GRADE profiles

Table A5.2 Natural, mixed-mode and mechanical ventilation for TB infection control – quality assessment

No. studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Quality
9	Observational, modelling, environmental, animal, and cost studies	Serious limitations	Serious	Serious	Serious	LOW

Table A5.3 Key findings from the systematic review on natural and mechanical ventilation

Country, type of study, years and reference	Setting and subjects	Type of ventilation	Comparison type	Data without ventilation	Data with ventilation	Notes
South Africa Modelling study (*1*)	Hospital HWs and patients	Mechanical and natural	Cases of XDR-TB prevented	Mechanical ventilation prevents 12% of XDR-TB cases (range 10–20%)	Improvements to natural ventilation could prevent average of 33% of XDR-TB cases (range 8–35% due to wind patterns)	Mechanical ventilation and HEPA filters can reduce extra 10% of XDR-TB cases (range 20–35%)
USA 1989–1994 Cost study (*2*)	5 hospitals, 4 with MDR-TB outbreaks			Nonrecirculated air: $30,000–132,900	Room exhaust fans: $3,500–9,800	

Country, type of study, years and reference	Setting and subjects	Type of ventilation	Comparison type	Data without ventilation	Data with ventilation	Notes
USA Prospective cohort study part of screening program 1993–1996 (*3*)	ED Hospital staff	Intervention included: 4 isolation rooms (as per CDC standards), 100% nonrecirculated air in trauma area, improved ventilation with at least 25% fresh air in ED, laminar flow of air, Plexiglas droplet shields	TST conversion rates over 6-month intervals (10 mm cutoff, 5 TU)	(Baseline) Cycle 1: 451/4547 (8.1%) in other departments, 8/88 (9.1%) in Emergency dept. Cycle 2: 6/50 (12%) for ED, 51/2514 (2%) for OD	Cycle 3 after implementation of all measures: 0/64 (0%) for ED and 36/3000 (1.2%) for OD	Annual incidence of TB disease was 22.1/100,000
Canada Cross-sectional survey 1992–1995 (*4*)	17 acute-care hospitals in 4 cities Nurses, physiotherapists, respiratory therapist, aides, orderlies, housekeepers, clerks nonclincial personnel		TST conversion groups (Mantoux, 10 mm cutoff, 5TU)	Inadequate ventilation of nonisolation rooms significantly associated with TST conversion among nursing, housekeeping and respiratory therapy personnel ($p<0.001$). inadequate ventilation of bronchoscopy rooms also significantly associated with conversion among respiratory therapists	In multi proportional hazards regression, earlier time to conversion significantly associated with ventilation <2ACH in nonisolation rooms (hazards ratio 3.4 (2.1–5.8)) but not with ventilation in respiratory isolation rooms (<6ACH vs >6ACH) 1.02 (0.8–1.3)	Ventilation measured by Smoke tubes and CO_2 release measured by infrared direct reading monitor

Country, type of study, years and reference	Setting and subjects	Type of ventilation	Comparison type	Data without ventilation	Data with ventilation	Notes
Canada Cross-sectional study (5)	17 acute care hospitals in 4 cities Nurses, pathology and microbiology technicians physiotherapists, respiratory therapist, nonclinical personnel as reference		TST conversion groups (Mantoux, 10 mm cut-off, 5TU)	In converted group, ACH averaged 16.7 In nonconverted group, ACH averaged 32.5 TST conversion significantly associated with lower ventilation (<0.001)	In multivariate analysis, ratio of actual ventilation to minimum recommended (comparing half vs equal) gave OR 1.3 though not significant (CI: 0.9, 1.9)	
USA Modelling study using Wells-Riley model (6)	Holding facility Deputy sheriffs		TST conversion rates (Mantoux, 5TU)	At measured ventilation (1763 CFM), 4/37 sheriffs infected; at designed ventilation (4954 CFM), only 1.5/37	62.5% reduction in infection by increasing ventilation by 64%	Annual incidence of TB disease ranged 3–7.3/100,000
Peru Mathematical modelling using Wells-Riley model (7)	8 hospitals including TB wards and clinics (5 built before 1950 and 3 built 1970–1990) ; susceptible individuals who are exposed	Natural and mechanical ventilation	Median risk of TB transmission (% of individuals infected)	Median risk was 97% for natural-ventilation facilities with windows/doors closed, 33% for natural-ventilation facilities in modern hospitals and 11% in pre-1950 hospitals with windows/doors opened	39% for mechanical-ventilated negative-pressure isolation rooms at 12 ACH	ACH measured using tracer gas concentration decay technique, CO_2 concentrations measured using infrared gas analyzer

Country, type of study, years and reference	Setting and subjects	Type of ventilation	Comparison type	Data without ventilation	Data with ventilation	Notes
USA Mathematical modelling based on contact investigation (*8*)	Office building Workers		TST conversion (Mantoux, 10 mm cut-off, 5TU) 4 month intervals	Baseline conversion:27/67 (40%) Decrease in ventilation by 10 CFM would double infection rate (52/67 or 78%)	Increase of 10cfm would reduce rate by 26.9% (18/67) Increase 20 CFM would reduce to13/67 (19%)	Further increases in outdoor air ventilation predicted to result in progressively smaller reductions in infection
USA Life cycle cost analysis for 25 years in 3 cities (*9*)				Waiting room recirculation: Los Angeles (LA)– $1,707,409 New York (NY)– $1,387,717 Atlanta– $1,718,853	100% exhaust in waiting room: LA–$1,753,471 NY–$1,437,056 Atl–$1,770,116	100% exhaust for entire building: LA– $1,783,945 NY– $1,492,515 Atl– $1,847,992

ACH, air changes per hour; CDC, Centers for Disease Control and Prevention, Atlanta, Georgia, United States of America; CFM, cubic feet per minute; ED, emergency department; HEPA, high-efficiency particulate air, HW, health worker, LA, Los Angeles; MDR, multidrug resistant; NY, New York; OD, outpatient department; TST, tuberculin skin test; TU, tuberculin unit; XDR extensively drug resistant

A5.5 References

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ANNEX 6

Use of ultraviolet germicidal irradiation fixtures (Recommendation 11)

A6.1 Question

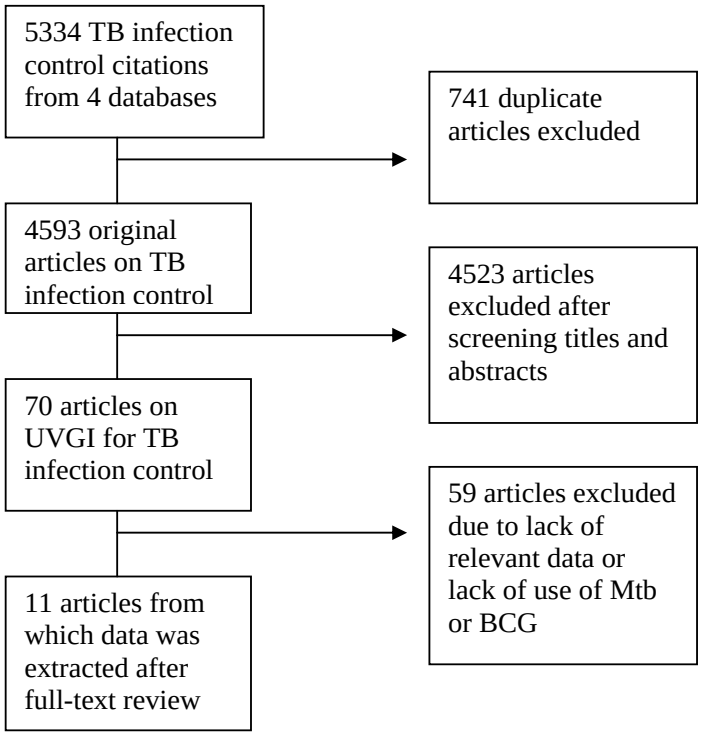
Table A6.1

Questions/interventions	Outcome	Setting	Population
• UVGI lights versus no intervention • UVGI lights versus UV lights plus other interventions	• Reduction in TB incidence • Cost or cost–effectiveness • Adverse outcomes	• Any ward • TB ward • MDR ward • Outpatient • Congregate[a]	• Patients (HIV-positive and all patients) • HWs (HIV-positive and all HWs)

HW, health worker, HIV, human immunodeficiency virus; MDR, multidrug resistant; TB, tuberculosis; UVGI, ultraviolet germicidal irradiation

[a] Congregate settings include prisons, homeless shelters, army barracks and nursing homes.

A6.2 Study selection process



BCG, Bacille Calmette Guerin; Mtb, *Mycobacterium tuberculosis*; TB, tuberculosis; UVGI, ultraviolet germicidal irradiation

A6.3 Summary of evidence

There is wide variation in the factors studied in the 11 included articles (*1–11*). Only one is an epidemiologic study that looked at TST conversion rates in health workers showing no major additional benefit (*2*). However, one well designed animal model study demonstrated that UVGI could reduce TB transmission and disease in guinea pigs (*1*). All the three laboratory experiments studies showed reduction in bacteria concentration, and absence of tubercles in animals exposed to UVGI (*8*, *9*, *11*).

Two are modelling studies (*3*, *5*), another looks at adverse effects (*7*), and one article describes the costs of the UVGI intervention (*4*). There are no randomized controlled trials studying the effectiveness of UVGI. However, given the ethical consideration for the conduction of a randomized controlled trial in humans to determine the efficacy of UVGI, results from the animal model study represent the closest proxy to a randomized controlled trial.

There is little evidence on the effectiveness of UVGI as an intervention. However, the available evidence, though weak and indirect, is generally favourable on its use for TB infection control.

A6.4 GRADE profiles

Table A6.2 UVGI for TB infection control – quality assessment

No. studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Quality
11	Observational, modelling, environmental, animal and cost studies	Serious limitations	Serious	Serious	Serious	LOW

Table A6.3 Key findings from the systematic reviews of ultraviolet germicidal irradiation (UVGI) fixtures

Country, type of study, years and reference	Setting and subjects	Type of UVGI	Comparison type	Data without UVGI	Data with UVGI	Notes
Peru Animal study (*1*)	Three wards Guinea pigs	Upper room	TST conversion and detection of TB disease	106 tuberculin-positives in the control group, 43 in the group protected by ionizers, and 29 in the group only exposed to ward air when UV lights were switched on (P <0.0001). Tuberculosis transmission was reduced by 58% by ionizers (log-rank 27; P <0.0001) and by 72% by UV lights (log-rank 46; P <0.0001).	There was autopsy or organ culture evidence of tuberculosis disease in 26 control group animals, compared with 11 in those protected by ionizers (log-rank 3.7; P = 0.055) and 11 in those protected by UV lights (log-rank 5.4; P = 0.02).	
USA Cross-sectional survey 1991–93 (*2*)	Hospital HWs, hospital employees	Upper room	TST conversion rates	30/145 (20.7%) baseline conversion rate with several IC measures	Starting from 7/219 (3.2%); changed to 14/227 (6.2%) for first 6 months, then to 4% for next 6 months	TST with 10 mm cut off at 6-month intervals

Country, type of study, years and reference	Setting and subjects	Type of UVGI	Comparison type	Data without UVGI	Data with UVGI	Notes
Italy Prediction modelling (*3*)	Hospital, HIV wards HWs, hospital employees	N/A	TST conversion rates for 4 types of high-risk procedure	GV: 34.3–99.9% GV+SM: 22.3–98.1% GV+DMR: 5.9–61.5% GV+HM: 1.3–17.9%	GV+UV: 5.8–90% GV+SM+UV: 3.5–42.8% GV+DMR+UV: 0.9–12.6% GV+HM+UV: 0.2–2.8%	
USA Cost study 1989–94 (*4*)	5 hospitals, 4 with MDR-TB outbreaks	Upper room, in ventilation duct	Cost	Wall mounted: $84,000 for 12 fixtures, $93,000 for 8 fixtures at another hospital	In ventilation system: $61,400 for 12 fixtures	
USA Risk analysis Hypothetical modelling (*5*)	Hospital	Upper room	TB risk, mean annual new infection rate, cost effectiveness	UVGI reduced TB risk by 1.6-fold in low-risk setting UVGI reduced mean infection rate from 2.2 to 1.3 per year at low irradiance	UVGI reduced TB risk by 4.1-fold in high-risk setting; UVGI reduced mean infection rate from 2.2 to 0.6 per year at high irradiance	Mean cost effectiveness ranged from $133 per TST conversion saved in high-risk setting to $1017 per TST conversion saved in low-risk setting
Canada cross-sectional survey 1997–98 (*6*)	Hospital	Upper room, portable device	ACH measured by proxy, not directly	2.0 w/o UV 3.1 for upper-room UV 2.2 for UV + unmixed air	4.0 with UV 7.7 for portable UV 4.5 for UV + mixed air	All $P<.05$ Measured other bacteria in air, did not include Mtb
USA Double-blind, placebo-controlled field trial, not randomized 1997–2004 (*7*)	Homeless shelter Shelter staff	Upper room	Adverse effects	223/3611(6%) interviews reported skin or eye symptoms	95 cases entirely during active UV period, 36 during placebo, 36 uncertain (Chi-square $P = 0.4$)	

Country, type of study, years and reference	Setting and subjects	Type of UVGI	Comparison type	Data without UVGI	Data with UVGI	Notes
USA Laboratory study (*8*)	Dental clinic in TB hospital	Upper room	Reduction of TB bacteria on culture plates after UV exposure for 24 hours	Count range 150–350	Count range 15–30	9-fold reduction in TB bacteria on plates
USA Laboratory study 1974–75 (*9*)	Laboratory room	Upper room	ACH	ACH when UV off: 2–4	ACH for 1 UV fixture: 12 ACH for 2 UV fixtures: 21–37 difference in ACH: range 10–33	Ratio of disappearance of BCG for UV versus no UV was 9:1
USA Animal study 1995 (*10*)	Six-room pilot ward	Upper room	Presence of tubercles in 12 rabbits exposed to BCG	Tubercles ranged from 2 to 10	No rabbits had tubercles	Used BCG
USA Laboratory study (*11*)	Laboratory room	Upper room	Culturable bacteria count concentration (CFU/m^3)	First time: 7.67×10^4 Repeat: 3.71×10^4	First time: 5.51×10^3 Repeat: 1.01×10^3	UV lamps reduced average room BCG concentration between 96–97% at 50% relative humidity

ACH, air changes per hour; BCG, Bacille Calmette Guerin; CFU, colony forming unit; DMR, dust-mite respirator; GV, general ventilation; HEPA, high-efficiency particulate air; HIV, human immunodeficiency virus; HM, HEPA mask; HW, health worker; MDR, multidrug resistant; Mtb, *Mycobacterium tuberculosis*; N/A, not applicable; SM, surgical masks; TB, tuberculosis; TST, tuberculin skin test; UV, ultraviolet; UVGI, ultraviolet germicidal irradiation

A6.5 References

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ANNEX 7

Use of particulate respirators for health workers (Recommendation 12)

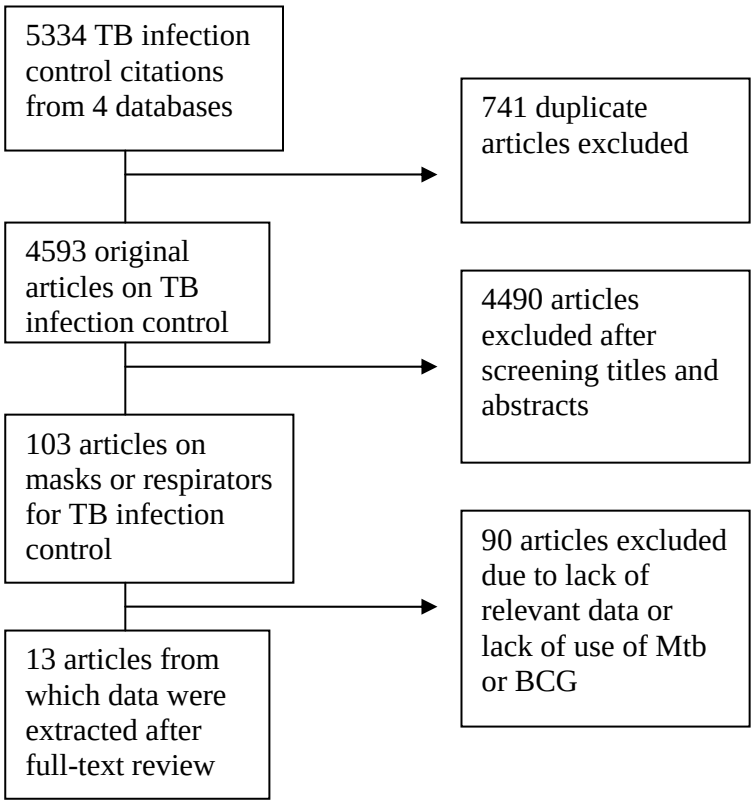
A7.1 Question

Table A7.1

Question/interventions	Outcome	Settings	Population	Special situations
Respirators (N95 or equivalent) versus no intervention	Reduction in TB incidence	Any ward TB ward MDR ward Outpatient	HWs (HIV-positive and all HWs)	Procedures involving aerosol versus other procedures
Fit test versus fit check and/or training	Proper use of the respirator	Any ward TB ward MDR ward Outpatient	HWs (HIV-positive and all HWs)	

HW, health worker; HIV, human immunodeficiency virus; MDR, multidrug resistant; TB, tuberculosis

A7.2 Study selection process



BCG, Bacille Calmette Guerin; Mtb, *Mycobacterium tuberculosis*

A7.3 Summary of evidence

Of the 13 relevant studies included in the review (*1–13*), 3 epidemiologic studies (cross-sectional surveys) evaluated TST conversion rates in health workers and showed a decrease in TST conversion in health workers following the introduction of respirators (*6*, *7*, *10*). Four articles were modelling studies (*2*, *3*, *7*, *12*), and four studies described the cost/cost-effectiveness of respirators (*2,9,11,13*). One study showed low compliance with use of respirators by HWs even if proper training is ensured (*4*). One study demonstrated that user seal check should not be used as a surrogate for respirator fit testing (*5*).

A majority of the cost studies determined respirators are expensive and not very cost-effective. There is little evidence on the effectiveness of respirators as an infection control intervention by themselves. However, the available evidence, though weak and indirect, is generally favourable on its use for TB infection control.

A7.4 GRADE profile

Table A7.2 Respirators for TB infection control – quality assessment

No. studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Quality
13	Observational, modelling, environmental, animal and cost studies	Serious limitations	Serious	Serious	Serious	LOW

Table A7.3 Key findings from systematic review on respirators

Country, type of study, years and reference	Setting and subjects	Type of mask or respirator	Comparison type	Data with or without mask or respirator	Data with mask or respirator	Notes
USA Cost study (*1*)	Tertiary case hospital HWs	Various	Cost	Simple isolation mask: $1,833 DMR: $1866–28,106 Disposable HEPA respirator: $15,396–114,715 Respirator with replaceable HEPA: $18,614–138,697	Estimated cost of preventing one case of occupational TB Disposable HEPA respirator $631,236 Respirator with replaceable HEPA filter: $5,686,577 Fit testing: $312,422 Fit training: $268,086	Fit testing for 350 new employees per year: $6,124 ($312,422 over 41-year period) Fit training for new employees in year: $5,256 ($268,086 for 41 years)
USA Modelling study (*2*)	Hospital HWs	Various	Risk reduction and person-hours to TST conversion	Protection rate versus no respiratory protect (reduce risk fold) • surgical mask 2.4 • disposable dust-mite or dust-fume respirator or disposable HEPA respirator 17.5 • negative pressure cartridge HEPA respirator 45.5 • powered air-purifying respirator 238	Under no UVGI and 6 ACH, 2560 person-hours required for skin-test conversion for no respirator protection, increases to 6100 hours for surgical mask, 44900 hours for DF/DM mask or disposable HEPA, 116000 hours for negative pressure cartridge HEPA respirator, and 610,000 for powered air-purifying respirator	
South Africa Modelling study (*3*)	Hospital HWs and patients	N95 respirators for staff and masks for patients	Cases of XDR-TB prevented	Respirator mask use would prevent 2% of XDR cases and 2/3 in staff. 5% of XDR infections averted if patients provided with surgical masks	Enforcement of adherence would increase number of XDR cases averted by average of 1% (range 0–2%)	Mask use more effective when combined with other strategies (reducing length of stay, improved natural ventilation, MODS, voluntary testing and counselling with antiretroviral therapy, isolation with 5 patients)
Brazil Cross-sectional 2000–01 (*4*)	Hospital HWs	N95 respirators	Compliance	During high-risk procedures: 20% of patient encounters had HW wear N95 versus 27.6% in non-high-risk procedures (OR = 1.53, *P* = 0.367)	In TB isolation room: 39.5% of patient encounters had HW wear N95 versus 8.7% when patient not isolated (OR = 6.85, p<0.001)	39% of HWs found to have facial-seal leakage (i.e. masks not worn properly); 25.5% of patient encounters had HW wear N95

Country, type of study, years and reference	Setting and subjects	Type of mask or respirator	Comparison type	Data with or without mask or respirator	Data with mask or respirator	Notes
Hong Kong Retro-spec-tive (5)	Hospital Nurses	N95 and N100	User fit check versus fit test-ing with Porta-Count reading of 100 as the criterion for a cor-rectly fit-ted mask	The user seal check wrongly indicated that the mask fitted on 18–31% of occa-sions	User seal check wrongly indicated that it did not fit on 21–40% of occasions	Results indicate that user seal check should not be used as a surrogate fit test
USA 1991–1993 cross-sec-tional (6)	Hospital HWs, hospital employ-ees	Vari-ous	TST conver-sion rates (several IC mea-sures to-gether, includ-ing neg-ative-pres-sure rooms and UV lights)	30/145 (20.7%) baseline conver-sion rate with Technol shield	Conversion rate at 3.2 then 6.2 (with UV) then 4.0 for particulate respi-rators 5.8 for dust-mist-fume respirators	TST with 10 mm cut-off at 6-month inter-vals
USA Mod-elling study with modi-fied Wells-Riley (7)		Vari-ous	Risk of infection	Risk under mod-erate exposure category with disposable respi-rator (leakage 0.2), ACH 6 = 0.042	Risk goes down to 0.021 with a elastomeric half-face respirator (w/leak-age of 0.1)	Risk of infection de-creases exponentially with increasing per-sonal respirator pro-tection; relative efficacy of such pro-tection decreases with increased venti-lation

Country, type of study, years and reference	Setting and subjects	Type of mask or respirator	Comparison type	Data with or without mask or respirator	Data with mask or respirator	Notes
USA Cross-sectional survey 1992–95 (8)	Hospital HWs	Various	TST conversion rates	For hospitals reporting > 6 patients in 1992: submicron respirator protection (submicron surgical masks, NIOSH-approved disposable particulate respirators: dust mist, DFM and HEPA-filter respirators): TST conversion rate 289/29376 (0.98%) Surgical masks: 497/52648 (0.94%) *P* = 0.98	For hospitals reporting > 6 patients in 1992 among high-risk HWs (including bronchoscopists and respiratory therapists): Submicron respirator protection: TST conversion rate was 15/750 (1.9%) Surgical masks: 19/1183 (1.6%) *P* = 0.50	Similar analysis for hospitals reporting <6 TB patients/year, no significant differences in HW TST conversion rate between hospital compliant or not compliant with TB infection control measures
USA Cost study 1994 (9)	Five hospitals HWs	Various	Cost	Total program cost of HW respirator fit-testing program: $8,736–$26,175	Estimate of N95 respirator program cost, assuming single use: $270–422,526	These findings, in contrast to other studies, suggest cost of respirator protection program at most hospitals not excessive
Brazil Cross-sectional study 1997–99 (*10*)	Hospital Nurses	Various	TST conversion rates	In relation to use of Technol PFR95 masks, 31/68(68.9%) who reported using them did not convert, as compared to only 2/8 (25%) who showed tuberculin conversion (RR = 0.3, *P* = 0.03 CI:0.09–1.01)	In relation to use of surgical masks, 28/68(62.2%) who reported using them did not convert, as compared to 6/8 (75%) who showed tuberculin conversion (p = 0.7)	TST testing Mantoux 2TU with 10 mm cut-off
USA Cost-effectiveness study (11)	159 veteran affairs hospitals HWs	HEPA respirators	Cost effectiveness	Using HEPA respirators in HWs: Would cost $7 million to prevent 1 case of TB in HW	Using HEPA respirators in HWs: Would cost $100 million to save one life	

Country, type of study, years and reference	Setting and subjects	Type of mask or respirator	Comparison type	Data with or without mask or respirator	Data with mask or respirator	Notes
USA Modelling study (*12*)		Various	Cumulative risk of infection	10-year cumulative risk for low-risk scenario: 0.15 (no respirator), 0.067 (surgical mask), 0.0094 (disposable DMF respirator), 0.0033 (elastomeric half-mask HEPA respirator), 0.00064 (HEPA PAPR) Of 1000 HWs, number of expected cases after 10 years: 150, 67, 9, 3, 1 (same order as above)	10-year cumulative risk for high-risk scenario: 0.48 (no respirator), 0.24 (surgical mask), 0.037 (disposable DMF respirator), 0.013 (elastomeric half-mask HEPA respirator), 0.0026 (HEPA PAPR); of 1000 HWs, number of expected cases after 10 years: 480, 240, 37, 13, 3 (same order as above)	
USA Cost study 1992–95 (*13*)	Hospital HWs	Various	Cost of personal protective equipment program	Tecnol fluidshield: $80,600 in 1992 to $41,067 in 1995 Moldex 2200 particulate respirator $25,239 in 1992 to $5,550 in 1995	3M dust-mist-fume 9220: $990 in 1992 to $21,450 in 1993 American threshold fluid-resistant: $19,443 in 1995	3M HEPA 9920: $66,960 in 1994 to $16,000 in 1995

ACH, air changes per hour; CDC, Centers for Disease Control and Prevention; CI, confidence interval; DF, dust/fume; DM, dust/mist; DMF, dus/mist/fume; DMR, dust/mist respirator; HEPA, high-efficiency particulate air; HW, health worker; IC, infection control; MODS, microscopic-observation drug-susceptibility; NIOSH, National Institute for Occupational Safety and Health; OR, odds ratio; PAPR, powered air purifying respirator; RR, relative risk; TB, tuberculosis; TST, tuberculin skin test; UV, ultraviolet; UVGI, ultraviolet germicidal irradiation; XDR, extremely drug resistant

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