

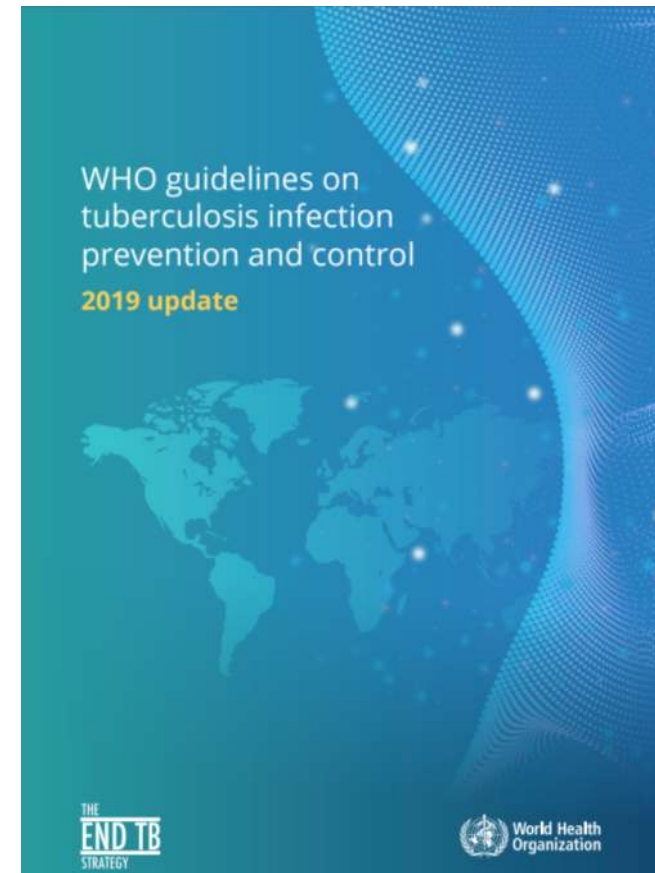
Administrative Measures to Control Airborne Infections Transmission

Grigory Volchenkov

Vladimir, Russia

WHO guidelines on tuberculosis infection prevention and control. 2019 update

- Integrated package of IPC interventions to prevent *M. tuberculosis* transmission.
- updated, evidence-informed recommendations outlining a public health approach within the clinical and programmatic management of TB
- hierarchy of infection control as a systematic and complex approach for strengthening IPC and reducing the risk of *M. tuberculosis* transmission.



COVID-19 and Bioaerosols



Nurses getting ready to go to work with COVID19 patients
Daughter of Yuhong Liu (ETI), February 2020

Science

PERSPECTIVES

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Reducing transmission of SARS-CoV-2

Kimberly A. Prather¹, Chia C. Wang^{2,3}, Robert T. Schooley⁴

¹Surgeon Institute of Oceanography, University of California San Diego, La Jolla, CA 92037, USA; ²Department of Chemistry, National Sun Yat-sen University, Kaohsiung, Taiwan 804, Republic of China; ³Research Science Research Center, National Sun Yat-sen University, Kaohsiung, Taiwan 804, Republic of China; ⁴Department of Medicine, Division of Infectious Diseases and Global Public Health, School of Medicine, University of California San Diego, La Jolla, CA 92035, USA. Email: prather@ucsd.edu

Masks and testing are necessary to combat asymptomatic spread in aerosols and droplets

Respiratory infections occur through the transmission of virus-containing droplets (>5 to $10\ \mu\text{m}$) and aerosols ($<5\ \mu\text{m}$) exhaled from infected individuals during breathing, speaking, coughing, and sneezing. Traditional respiratory disease control measures are designed to reduce transmission by droplets produced in the sneezes and coughs of infected individuals. However, a large proportion of the spread of coronavirus disease 2019 (COVID-19) appears to be occurring through airborne transmission of aerosols produced by asymptomatic individuals during breathing and speaking (1–3). Aerosols can accumulate, remain infectious in indoor air for hours, and be easily inhaled deep into the lungs. For society to resume, measures designed to reduce aerosol transmission must be implemented, including universal masking and regular, widespread testing to identify and isolate infected asymptomatic individuals.

Humans produce respiratory droplets ranging from 0.1 to $1000\ \mu\text{m}$. A competition between droplet size, inertia, gravity, and evaporation determines how far emitted droplets and aerosols will travel in air (4, 5). Respiratory droplets will undergo gravitational settling faster than they evaporate, contaminating surfaces and leading to contact transmission. Smaller aerosols ($<5\ \mu\text{m}$) will evaporate faster than they can settle, and thus can be affected by air currents, which can transport them over longer distances. Thus, there are two major respiratory virus transmission pathways: contact (direct or indirect between people and with contaminated surfaces) and airborne inhalation.

In addition to contributing to the extent of dispersal and mode of transmission, respiratory droplet size has been shown to affect the severity of disease. For example, influenza virus is more commonly contained in aerosols with sizes below $1\ \mu\text{m}$ (submicron), which lead to more severe infection (4). In the case of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), it is possible that submicron virus-containing aerosols are being transferred deep into the alveolar region of the lungs, where immune responses seem to be temporarily bypassed. SARS-CoV-2 has been shown to replicate three times faster than SARS-CoV-1 and thus can rapidly spread to the pharynx from which it can be shed before the innate immune response becomes activated and produces symptoms (6). By the time symptoms occur,

the patient has transmitted the virus without knowing.

Identifying infected individuals to curb SARS-CoV-2 transmission is more challenging compared to SARS and other respiratory viruses because infected individuals can be highly contagious for several days, peaking on or before symptoms occur (2, 7). These “silent shedders” could be critical drivers of the enhanced spread of SARS-CoV-2. In Wuhan, China, it has been estimated that undiagnosed cases of COVID-19 infection, who were presumably asymptomatic, were responsible for up to 79% of viral infections (2). Therefore, regular, widespread testing is essential to identify and isolate infected asymptomatic individuals.

Airborne transmission was determined to play a role during the SARS outbreak in 2003 (1, 4). However, many countries have not yet acknowledged airborne transmission as a possible pathway for SARS-CoV-2 (7). Recent studies have shown that in addition to droplets, SARS-CoV-2 may also be transmitted through aerosols. A study in hospitals in Wuhan, China, found SARS-CoV-2 in aerosols farther than 6 ft from patients with higher concentrations detected in more crowded areas (8). Estimates using an average sputum viral load for SARS-CoV-2 indicate that 1 min of loud speaking could generate >1000 virus-containing aerosols (9). Assuming viral titers for infected super-emitters (with 100-fold higher viral load than average) yields an increase to more than 100,000 virions in emitted droplets per minute of speaking.

The World Health Organization (WHO) recommendations for social distancing of 6 ft and hand washing to reduce the spread of SARS-CoV-2 are based on studies of respiratory droplets carried out in the 1930s. These studies showed that large, $>100\ \mu\text{m}$ droplets produced in coughs and sneezes quickly underwent gravitational settling (7). However, when these studies were conducted, the technology did not exist for detecting submicron aerosols. As a comparison, calculations predict that in still air, a $100\text{-}\mu\text{m}$ droplet will settle to the ground from 8 ft in 4.6 s whereas a $1\text{-}\mu\text{m}$ aerosol particle will take 12.4 hours (4). Measurements now show that intense coughs and sneezes that propel large droplets more than 20 ft can also create thousands of aerosols that can travel even further (7). Increasing evidence for SARS-CoV-2 suggests the 6 ft WHO recommendation is

VIEWPOINT

Airborne Spread of SARS-CoV-2 and a Potential Role for Air Disinfection

Edward A. Nardelli, MD, MPH
Ingram and Veterans Hospital, Division of Global Health Equity, Harvard Medical School, Boston, Massachusetts

Rebecca E. Rothwell-Harmon, MD, MPH
Beth Israel Deaconess Medical Center, Division of Infectious Diseases, Harvard Medical School, Boston, Massachusetts

Supplemental content

An April 2, 2020, expert consultation from the National Academies of Sciences, Engineering, and Medicine to the White House Office of Science and Technology Policy concluded that available studies are consistent with the potential aerosol spread of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), not only through coughing and sneezing, but by normal breathing. This response to a white house request for a rapid review of the literature likely contributed to the recommendation from the US Centers for Disease Control and Prevention (CDC) that healthy persons wear nonmedical face coverings, when in public, to reduce virus spread from undiagnosed infectious cases.

Although clear evidence of person-to-person airborne transmission of SARS-CoV-2 has not been published, an airborne component of transmission is likely based on other respiratory viruses such as SARS, Middle East respiratory syndrome, and influenza. While air sampling for SARS-CoV-2 in a clinical setting has demonstrated detectable viral RNA, the extent of transmission resulting from airborne particles relative to large respiratory droplets, directly and on surfaces, is not yet known. But if fitted HEPA respirators can be justified as a

ing costs when intake air must be heated or cooled and dehumidified. Portable room air cleaners may be a potential solution, but depending on room volume, their specified clean air delivery rates generally add too few equivalent air changes per hour to provide adequate protection against airborne infection. In contrast, commercially available upper-room GUV air disinfection (with an effective rate of air mixing) has been shown, in clinical settings, to reduce airborne tuberculosis transmission by 80%, equivalent to adding 24 room air changes per hour (1).

In resource-limited settings, where air disinfection depends on natural ventilation, upper-room GUV may be increasingly important as windows are closed due to use of ductless air conditioners in response to global warming and severe outdoor air pollution. In resource-rich settings, upper-room GUV can be retrofitted into most areas with sufficient ceiling height. GUV technology is effective against viruses that have been tested, including influenza and SARS-CoV-1 (2).

Direct whole-room GUV is also used for room surface disinfection in unoccupied rooms (e.g., between infectious patients), and GUV devices are being used to decontaminate respirators used for COVID-19 patient care. Although not its primary purpose, and as yet unproven experimentally, upper-room GUV in occupied rooms could possibly also reduce infectious virus settling on surfaces, and through 34-ft low-level reflected GUV exposure from the upper room, possibly accelerate virus inactivation on surfaces in the lower room.

Conventional thinking has been that person-to-person airborne spread of viral respiratory pathogens is the exception, although the term airborne has not been used uniformly. As defined by Wells and Riley in 1932, true airborne transmission is by infectious droplet nuclei, that is, the $1\text{- to }5\text{-}\mu\text{m}$ dried residues of larger respiratory droplets that stop settling, buoyed by ordinary room air currents, and able to spread far beyond the trajectory of larger respiratory droplets that land to settle within a meter or so of the infectious source. But other experts clearly as airborne the direct spread of larger respiratory droplets from an infectious source to the eyes, nose, or mouth of another person, without the intermediary of transfer by hands or fomites. Recent modeling of cough- and sneeze-generated aerosol suggest the potential for projecting large respiratory droplets well beyond 2 m, but that is not direct nuclear transmission (3). Although many respiratory

Management of the current crisis and preparation for future respiratory viral pathogens should include consideration of the use of upper-room GUV to help mitigate airborne transmission.

prudent precaution against airborne infection for health care workers with regular exposure to patients with novel coronavirus 2019 (COVID-19) and nonmedical face coverings justified to be worn in public to reduce aerosol spread, should not air disinfection be deployed in intensive care units, emergency departments, waiting rooms, and ambulatory clinics? This approach may be especially important to prevent spread from asymptomatic persons with infection, who may be sources of transmission in selected public settings.

Other than natural or mechanical ventilation, only 2 practical methods of air disinfection exist: room air cleaners (e.g., using filters, UV, or other means of disinfection) and upper-room germicidal UV (GUV) fixtures (see efigure in the Supplement). For effective air disinfection, ventilation with 4 to 12 room air changes per hour is recommended by the CDC (4). This can be achieved with natural ventilation under favorable outdoor conditions and by mechanical ventilation systems designed for such high-flow rates—but at high operat-

However, these additional beneficial effects require evidence from rigorously conducted studies.

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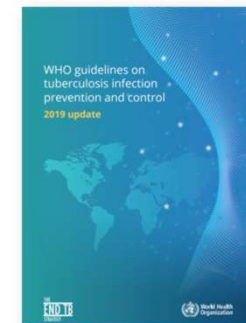
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PREPAREDNESS MATTERS



Administrative Controls



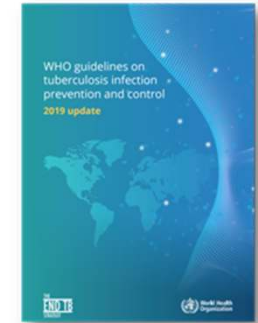
Recommendation 1: Triage of people with TB signs and symptoms, or with TB disease, is recommended to reduce *M. tuberculosis* transmission to health workers (including community health workers), persons attending health care facilities or other persons in settings with a high risk of transmission.

Recommendation 2: Respiratory separation / isolation of people with presumed or demonstrated infectious TB is recommended to reduce *M. tuberculosis* transmission to health workers or other persons attending health care facilities.

Recommendation 3: Prompt initiation of effective TB treatment of people with TB disease is recommended to reduce *M. tuberculosis* transmission to health workers, persons attending health care facilities or other persons in settings with a high risk of transmission.

Recommendation 4: Respiratory hygiene (including cough etiquette) in people with presumed or confirmed TB is recommended to reduce *M. tuberculosis* transmission to health workers, persons attending health care facilities or other persons in settings with a high risk of transmission.

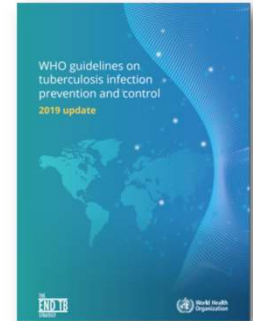
Environmental Controls



Recommendation 5: Upper-room germicidal ultraviolet (GUV) systems are recommended to reduce *M. tuberculosis* transmission to health workers, persons attending health care facilities or other persons in settings with a high risk of transmission.

Recommendation 6: Ventilation systems (including natural, mixed-mode, mechanical ventilation and recirculated air through high-efficiency particulate air [HEPA] filters) are recommended to reduce *M. tuberculosis* transmission to health workers, persons attending health care facilities or other persons in settings with a high risk of transmission.

Personal Respiratory Protection

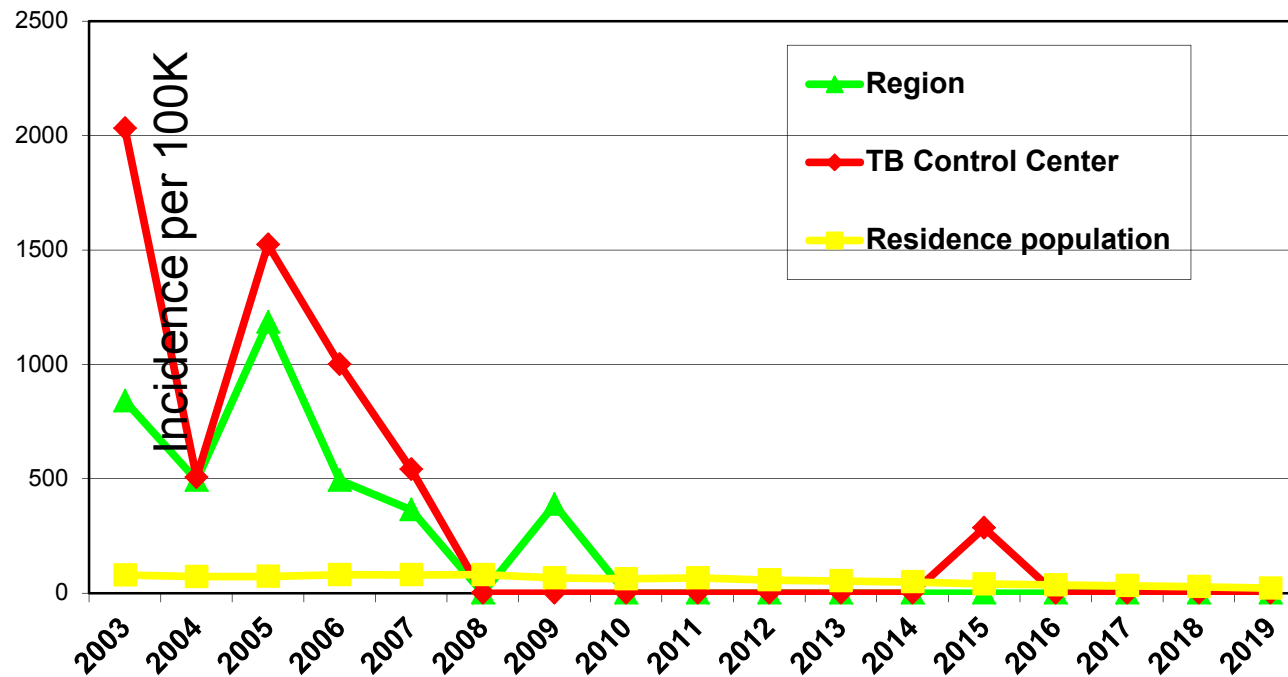
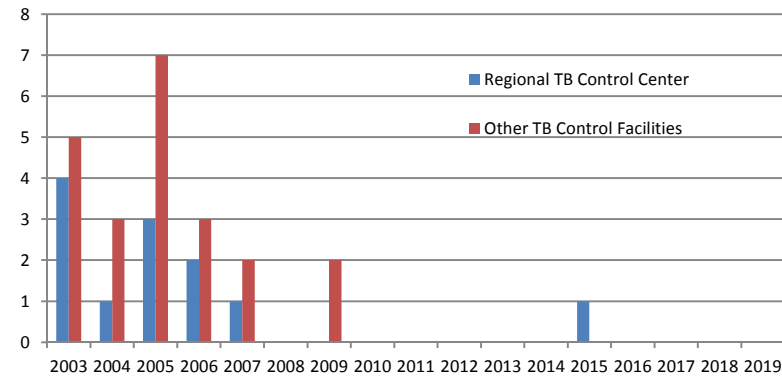


Recommendation 7: Particulate respirators, within the framework of a respiratory protection programme, are recommended to reduce *M. tuberculosis* transmission to health workers, persons attending health care facilities or other persons in settings with a high risk of transmission.

TB (Airborne) Infection Control Hierarchy



Occupational TB incidence among HCWs of TB control facilities Vladimir region, Russia



Occupational TB risk for Emergency Hospital Staff

	Total staff amount	Active TB cases notified*	Annual TB notification rate per 100K**	Relative risk of occupational TB
Doctors	106	2	157,2	6,3
Nurses	236	8	282,5	11,4
Auxiliary HCWs	114	0	0,0	0,0
Others	94	0	0,0	0,0
Total	550	10	151,5	6,1

* - in 2002 – 2013 (12 years)

** - TB notification rate for Vladimir city residents in 2013 – 27,3 per 100K.

Potential HIGH risk Airborne Transmitters

- Undetected, undiagnosed coughing patients
- Respiratory patients which do not receive EFFECTIVE treatment
 - Treatment delay, interruption, default
 - Ineffective treatment regimen
- For TB: most sensitive and available contagiousness indicator – sputum smear microscopy - before effective treatment initiation!

Effect of Chemotherapy on Transmission



- Rouillon A, Perdrizet S, Parrot R. Transmission of tubercle bacilli: The effects of chemotherapy. *Tubercle* 1976; 57:279-299.

- Sputum smear and culture positivity correlate with transmission before but not on therapy
- Discordance between effect of treatment on culture and smear
- Evidence that smear and culture positive TB patients on therapy do not infect close contacts.

“There is an ever-increasing amount of evidence in support of the idea that **abolition of the patient’s infectiousness** – a different matter from ‘cure,’ which takes months and from negative results of bacteriological examinations, direct and culture, which may take weeks – is very probably obtained **after less than 2 weeks of treatment**”.

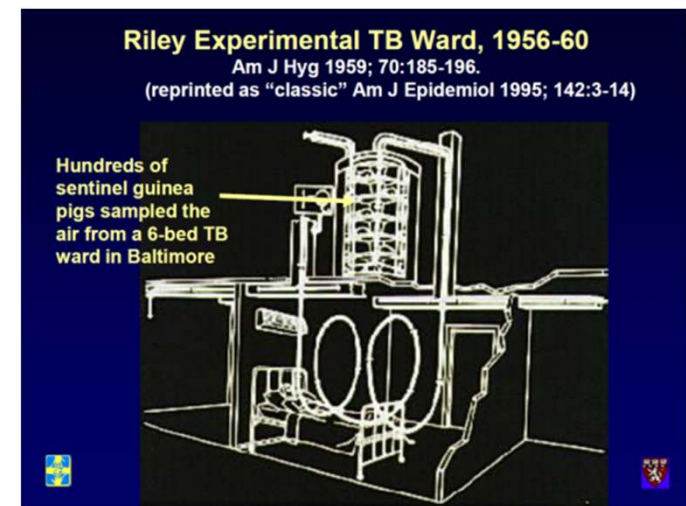
“These facts seem to indicate **very rapid and powerful action** by the drugs on infectivity...”

“The future reduction of transmission will essentially depend on the maintenance of an adequate system ensuring the **early diagnosis and correct treatment** of cases, which will inevitably continue to appear among the already infected portion of the population. “

Richard L. Riley и William F. Wells

(1959 – 1962 – 1974)

“The treated patients were admitted to the ward at the time treatment was initiated and were generally removed before the sputum became completely negative. Hence the decrease in infectiousness preceded the elimination of the organisms from the sputum, indicating that the effect was prompt as well as striking.”



Courtesy of Edward Nardell

Dramatic reduction of transmission risk after EFFECTIVE treatment initiation

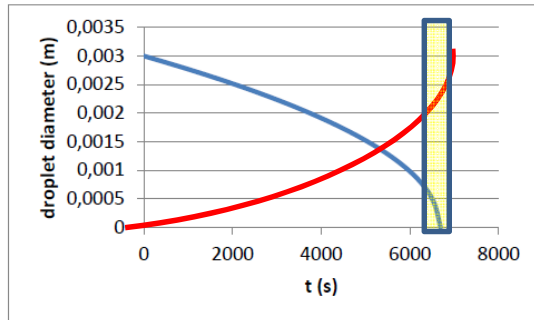


Figure 6: Variation of droplet diameter over time.

TB drugs
concentration

$R_3 = 5 \mu\text{m}$

$R_2 = 10 \mu\text{m}$

$R_1 = 100 \mu\text{m}$

$$C = m / V$$
$$V = 4/3 \pi R^3$$

where: C - drug concentration in a droplet (particle);

m - drug mass;

V - particle volume;

R - particle radius.

Water evaporation effect on drug concentration in a droplet:

- in particle #2 - **1000** times higher, than in #1
- in particle #3 - **8000** times higher, than in #1

**INITIATION OF EFFECTIVE THERAPY RAPIDLY
STOPS TB TRANSMISSION**

F-A-S-T



A refocused, intensified, administrative tuberculosis transmission control strategy

Find cases **A**ctively by cough surveillance and rapid molecular sputum testing, **S**eparate safely, and **T**reat effectively based on rapid drug susceptibility testing (DST).

Four underlying principles:

- 1) TB is spread in institutions predominantly by coughing patients with unsuspected TB or unsuspected drug resistance,
- 2) most potentially infectious patients can be identified by cough surveillance,
- 3) coughing TB patients most likely to be infectious can be diagnosed using rapid molecular sputum tests, including drug resistance (Xpert MTB/RIF)
- 4) by dramatically reducing the duration of institutional exposure through effective treatment, transmission among patients and to health care workers will be reduced proportionately

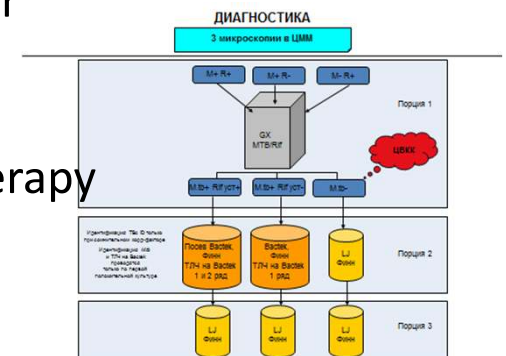
CONCLUSIONS

- Considerable portion of Airborne Infections Transmission takes place from undetected, undiagnosed patients
- Case finding with rapid testing to identify *M. tuberculosis* or other *Airborne pathogen* and its drug susceptibility, if available, should be the first priority, followed by:
 - Prompt and effective Airborne Isolation
 - Effective therapy rapidly ends TB transmission long before smear microscopy and culture conversion

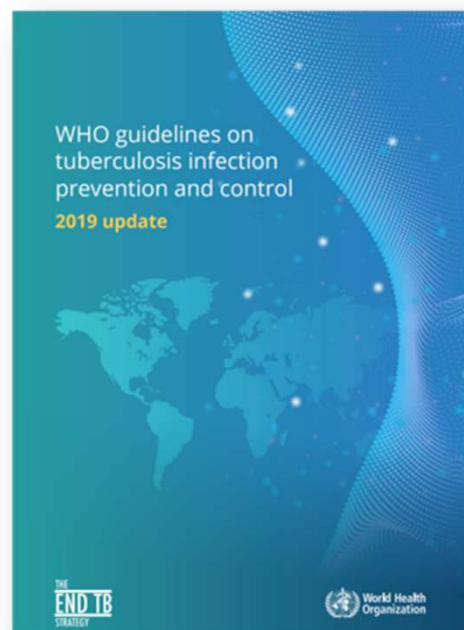


KEY ADMINISTRATIVE MEASURES

- Education and training
- Active screening for all patients, visitors and staff
- Airborne transmission risk assessment and facility zoning based on risk level
- Use of surgical masks or valveless respirators for all
- Separation of patients, visitors and staff flows
- Hospitalization criteria revision for TB and other Airborne Infections patients
- Reconstruction and restructuring of the facilities based on Airborne IPC principles to ensure staff and inmates safety and Airborne transmission risk reduction
- Introduction of diagnostic algorithms including rapid molecular testing to identify *M. tuberculosis*, SARS-CoV-2 and drug susceptibility
- Immediate initiation of AIRBORNE isolation and EFFECTIVE therapy based on rapid testing and DST results



TB (Airborne) Infection Control Hierarchy



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vlchnkv@yahoo.com

<http://www.stoptb.org/wg/ett/resources.asp>