Aerobiology of TB and Covid-19
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139 years since Koch discovered M. tuberculosis as the causative agent of TB, its airborne route of TB transmission is not controversial

Unanswered questions – how does effective treatment stop transmission almost immediately?

Controversies exist – transmission dominates the S. African TB epidemic – where is it occurring?

103 years since the great H1N1 Flu pandemic, the mode of transmission has been controversial: airborne vs droplet spread, more recently thought to be predominantly airborne

18 years since the SARS epidemic, clear evidence of airborne spread, but was believed to be primarily droplet spread – has been controversial

18 months into the Covid-19 pandemic, the mode of transmission has been highly controversial, but now mostly conceded to be primarily aerosol spread.

Transmission terminology has been used differently by different disciplines

• Previous definitions of spread
  • Contact spread
    • Direct – droplets directly impact vulnerable mucosa
    • Respiratory droplets contaminating surfaces – spread to vulnerable mucosa
  • Airborne spread
    • Droplet nuclei – dried residua of larger respiratory droplets – evaporate to 1 – 5 µm
  • Aerosol behavior definition
    • Large respiratory droplets settle within a meter or so, droplet nuclei do not settle in occupied rooms
    • Airborne particle size is not the size of the naked organism – but of the respiratory droplet containing dried respiratory debris as well as virions
Aerosols:
- Respiratory aerosol < 2.5-5 µm
- Thoracic aerosols < 10-15 µm
- Inhalable aerosols < 100 µm

TB vs Covid-19 spread:

**TB**
- Spread predominantly indoors
- MTB must reach alveolar macrophage – 1-5 µm particles
- Environmentally adapted, stable in air
  - Can traverse ventilation systems
- Infectious dose can be low (1 – few)
- Chronically infectious
- Mostly symptomatic spread

**Covid-19**
- Also spreads mostly indoors
- SARS-CoV-2 virus target is ACE receptors in respiratory tract, and elsewhere in the body
  - Mucosa of mouth, eyes, nose, airways – 1 to > 100 µm particles
- Environmentally more fragile
  - No evidence of ventilation duct transmission yet reported
- Infectious dose very high (300-1000 viruses)
- Asymptomatic spread – 48 hrs infectious period

Relative contributions of transmission routes for COVID-19 among healthcare personnel providing patient care


The key finding was that droplet and inhalation transmission routes predominate over the contact route, contributing 35%, 57%, and 8.2% of the probability of infection, on average, without use of personal protective equipment.
Summary:
March 10, 2020, 2.5 hour choir rehearsal in a church:
No one had symptoms
53 of 61 persons present had proven or clinically diagnosed Covid-19
2 people died
Strict social distancing and hand sanitizing
Large droplet and surface spread highly unlikely to account for the extent of transmission
Estimated production of infectious aerosol:
1000 doses per hour (possibly more than one asymptomatic source)

Where is most Covid-19 transmission occurring?
• In the room?
• Throughout the ventilation circuit?
  Dilution and viral damage in return air

Air Disinfection
1. Natural Ventilation - variable
2. Mechanical ventilation – flow limited
3. Room air cleaners – flow limited
4. Upper room germicidal ultraviolet (GUV) air disinfection
   • Not flow limited – treats large volume of air at once
   • Most economical
   • Safe for room occupants
   • Highly effective against TB and SARS-CoV-2 virus
   • Influenza, measles, etc.
Comparison: Room air cleaner vs upper room GUV

(Pretoria meeting, July, 2016)

**Room Air cleaner (RSA)** = 60 cfm CADR
= 28.3 l/s
= 2.1 ACH (assuming no re-capture and good air mixing)

Upper room GUV – avg 30 uW/cm²
For TB, Z = 41
With good air mixing,
= approx 20 ACH!

Upper Room GUV Disinfects a Large Volume of Air at Once

Low velocity ceiling fans assure good air mixing

Upper Room UVC effectively prevented measles transmission in schools

Wells and Wells Am J Hyg 1942;35:97-121.
The Airborne Infections Research (AIR) Facility
Witbank, Mpumalanga Province, SA

Ventilation ducts in patient rooms
Paddle fans assure good air mixing

AIR, Experimental Plan

Guinea Pig Air Sampling
UVGI or other intervention

Pt. TB
RFLP

Odd days
Even days

3 patient rooms
Plus common areas

Intervention on/off on alternative days

Guinea Pig
UVGI or other intervention
Results:

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<td>TOTAL*</td>
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* p<0.0005

Combined hazard ratio 4.0 (CI 95: 2.8, 8.6) or about 80% effective – corrected for multiple hits.

Note: 6 ACH (mechanical) but UVGI added the equivalent of 24 EqACH

Cost effectiveness: ventilation vs 3 different room air cleaners vs GUV

Grigory V. Volchenkov, MD, Oblast TB Dispensary, Vladimir, Russia
in collaboration with Paul Jensen, PE, IH, PhD (CDC)

Test chamber studies: aerosolized 2 test bacteria, mechanical air sampling

Operating cost per year per Eq ACH

Relative maximum efficiency (ventilation = 1.0)

Global Warming: Ductless AC requires closed windows

AC produces little if any air exchanges with outdoor air

Ventilation reduced by 80% or more

AC sales in India, 2010 – 2015
Red bars are ductless models
Risk of airborne infection increases promptly when windows are closed?

CO$_2$ measurements over time CO$_2$ is a good surrogate for Rebreathed Air Fraction and risk of infection.

In one hour after window was closed in an occupied room, the risk of airborne infection doubled!

CO$_2$ measures over time CO$_2$ is a good surrogate for Rebreathed Air Fraction and risk of infection.

Summary:

• Like TB, Covid-19 is predominantly airborne (inhaled aerosol)
  • Large droplet spread and surface spread is relatively less important.
• RNA found on surfaces and in air is not replication competent
• Unlike TB, Covid-19 is briefly infectious – 48 hrs
• Unlike TB, infectious covid patients are often pre-symptomatic
• TB and Covid-19 spread predominantly indoors
  • TB, measles, etc can spread through ventilation ducts – no reports so far of Covid-19 spreading floor to floor or room to room without close contact
  • If Covid-19 is not being recirculated, duct filters may not help
  • Room air cleaners are flow-limited
• Upper room UV is the most cost-effective means of room air disinfection