Aerobiology of TB and Covid-19

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Aerobiology of TB and Covid-19

- **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.

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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 virons*

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Journal of the Pediatric Infectious Diseases Society
EDITORIAL COMMENTARY

A Rosetta Stone for Understanding Infectious Drops and Aerosols

Donald K. Milton
Institute for Applied Environmental Health, University of Maryland School of Public Health, College Park, Maryland, USA

Aerosols:

Respiratory aerosol < 2.5-5 µm

Thoracic aerosols < 10-15 µm

Inhalable aerosols < 100 µm

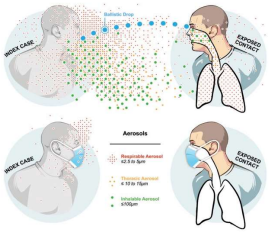

Figure 1. Short-range transmission potential of ballistic drops and droplet aerosols in the inhalable, thoracic, and respiratory aerosol size ranges and the impact of face masks as source control.

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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
  - Envelope RNA viruses fragile in environment
    - No evidence of ventilation duct transmission yet reported
- Infectious *dose* very high (300-1000 viruses)
- Asymptomatic spread – 48 hrs infectious period

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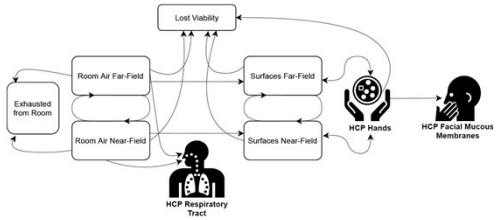
Relative contributions of transmission routes for COVID-19 among healthcare personnel providing patient care

Rachael M. Jones (2020):
Journal of Occupational and Environmental Hygiene,
DOI: 10.1080/15459624.2020.1784427https://doi.org/10.1080/15459624.2020.1784427



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.

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Submitted to *Indoor Air* 15 June 2020

Transmission of SARS-CoV-2 by inhalation of respiratory aerosol in the Skagit Valley Chorale superspreading event

Shelly L. Miller[1], William W Nazaroff[2], Jose L. Jimenez[3], Atze Boerstra[4], Giorgio Buonanno[5], Stephanie J. Dancer[6], Jarek Kurnitski[7], Linsey C. Marr[8], Lidia Morawska[9], Catherine Noakes[10]

[1] Mechanical Engineering, University of Colorado Boulder

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)

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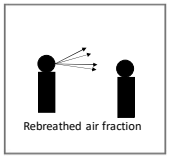
Where is most Covid-19 transmission occurring?

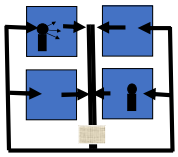
- In the room?



High volume ventilation, Room air cleaners
Upper room germicidal UV (GUV) air disinfection

- Throughout the ventilation circuit?

Dilution and viral damage in return air



Air filter or UV in return duct

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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.

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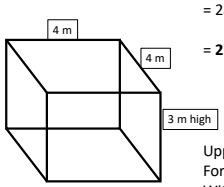
Comparison:

Room air cleaner vs upper room GUV

(Pretoria meeting, July, 2016)



48 m^3
1 ACH = 48 m^3/h
1 ACH = 13.3 l/s

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/cm^2
For TB, Z = 41
With good air mixing,
= **approx 20 ACH!**

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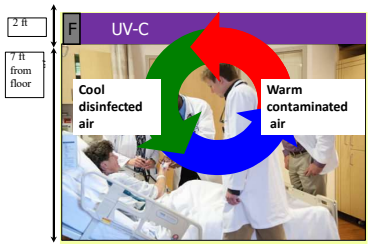
Upper Room GUV Disinfects a Large Volume of Air at Once



Low velocity ceiling fans assure good air mixing

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Upper Room UVC effectively prevented measles transmission in schools

Wells and Wells Am J Hyg 1942;35:97-121.

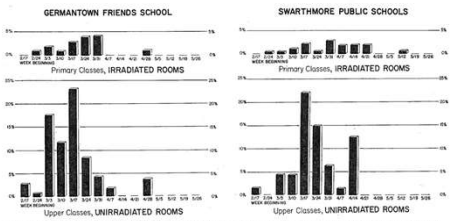

FIGURE 45. MEASLES EPIDEMIC IN PHILADELPHIA, 1941. Weekly attack rate among susceptibles (home secondaries excluded)

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The Airborne Infections Research (AIR) Facility
Witbank, Mpumalanga Province, SA

Department of Health and Human Services
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

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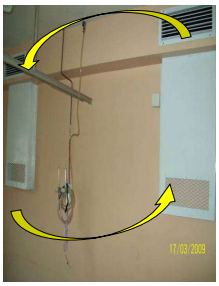
Ventilation ducts in patient rooms



Paddle Fans Assure Good Air Mixing

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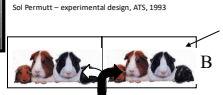
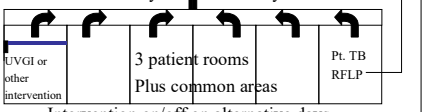
AIR, Experimental Plan

Guinea Pig Air Sampling

Sol Permutt – experimental design, ATS, 1993



Odd days Even days



Intervention on/off on alternative days

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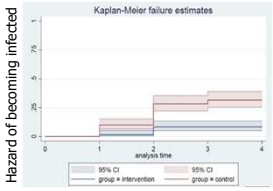
Results:

ORIGINAL ARTICLE

Institutional Tuberculosis Transmission
Controlled Trial of Upper Room Ultraviolet Air Disinfection: A Basis for New Dosing Guidelines

	Intervention	*Control*
UV1		
TST-1	0	1
TST-2	0	3
TST-3	0	5
TST-4	0	0
TOTAL	0	9
UV2		
TST-1	3	17
TST-2	12	30
TST3	0	1
TOTAL*	15	48

*p<0.0005



Combined hazard ratio 4.9 (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**

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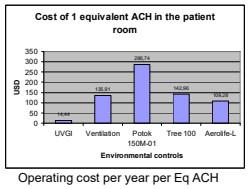
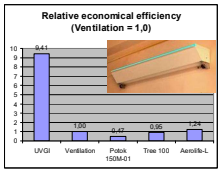
Cost effectiveness: ventilation vs 3 different room air cleaners vs GUV

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

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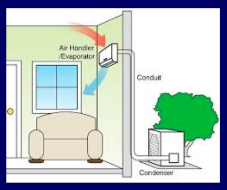
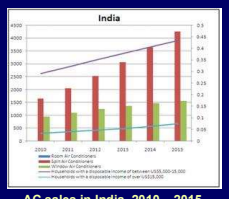
Global Warming: Ductless AC requires closed windows

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

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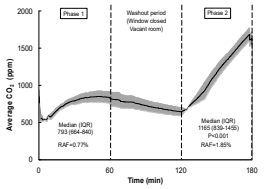
Risk of airborne infection increases promptly when windows are closed?



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!

Received: 10 September 2019 | Accepted: 29 September 2019
DOI: 10.1111/ina.12608

EDITORIAL

WILEY

Cool but dangerous: How climate change is increasing the risk of airborne infections

Indoor Air. 2020;30:195–197.

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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

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