Infectious Drops and Aerosols

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Transmission Modes of Respiratory Viruses

- **Contact (direct and indirect)**
  - Case to finger of contact
  - Fomite to finger of contact
  - Finger to eye, nose, or mouth

- **Sprayborne**
  - Ballistic drops (> 100 µm)
  - Direct hit on eye, nostril, or mouth

- **Aerosol inhalation**
  - Nasopharyngeal (Inhalable) ≤ 100 µm
  - Thoracic ≤ 10-15 µm
  - Respirable ≤ 5 µm
## Comparison with Known Aerosol Transmitted Respiratory Infections

### Tuberculosis
- Low rate of infectious dose generation (0.5 to 1.2 / hour) for months
- Target: alveolar macrophage
- Aerosol sampling: Negative (except cough box)
- Easily detected in surface samples
- \( R_0 \) 0.2 (Netherlands) to 4.3 (China)
- Prolonged close contact
- Long-range transmission only evident in low prevalence settings
- Face masks masks effective as source control

### Measles
- High rate of infections dose generation (2 to 10 / minute) for days
- Target: airway dendritic cells & alveolar macrophage
- Aerosol sampling: RNA detected in aerosol – No culture evidence of infectious aerosols
- Easily detected in surface samples
- \( R_0 > 15 \)
- Incidental contact
- Long-range transmission only evident in low prevalence settings
- Face mask?
Where SARS Viruses Bind and Infect

H. Xu et al., Int J Oral Sci. 12, 8 (2020).
Total & Regional Respiratory Tract Deposition of Aerosols

- Aerosols
  - Liquid and/or solid particles suspended in air

- When inhaled
  - Large particles get stuck in the nose, mouth, and throat
  - Smaller ones penetrate into the large air tubes in the lung
  - Very small ones get into the deepest parts of the lung

Two ways to define droplets and particles that can carry respiratory viruses

**Medical categories**

- **Respiratory droplets**
  - Droplets that do not travel very far
  - Mode of inoculation unclear but generally not thought to be ‘inhaled’
  - Not considered “airborne infection transmission”

- **Aerosols**
  - Sometimes called droplet-nuclei
  - Less than 5 µm in diameter
  - Small enough to travel long distances and cause infection far from the source.
  - Considered the only cause of “airborne infection”

**Exposure science based categories**

Droplets smaller than 10 µm can remain suspended for many minutes to hours.
Indoor Air is not Still: Droplets Can Travel >>2 m Indoors

Travel distance of droplets released from a height of 1 m with directional airflow

10 µm >15 to >60 m, 20 µm > 4 to > 15 m, and 30 µm > 2 to > 5 m, depending on air velocity. Aerosol science does not support the idea that droplets > 5 µm fallout within 6 meters.

With turbulence distance traveled is less, but settling time is longer.
Randomized Controlled Transmission Study?

Optimize & Test Ventilation System
Collected blood & NP swab for DFA
Inoculation of Donors via intranasal instillation

Monitor Temperature, RH, CO₂ (days 1-4)
Collected exhaled breath & cough if on >1 day (days 1-4)
Collected NPS daily (days 1-6)
Measured temperature & recorded symptoms 3x daily (days 1-6)

DAYS
-2 ... 0 1 2 3 4 5 6 7 8 ... 28

Example exposure group in exposure room*

Area A (Donor Sleeping Quarters)
Area B (Recipient Sleeping Quarters)
Area C (Symptomatic Recipient Holding Area)

Survey Monitor

Discharge Donors with oseltamivir
Discharge Recipients with oseltamivir

Gesundheit-II Sampler

Collected blood (day 28 ± 3)

Note: Exposure groups shifted rooms each day

J. S. Nguyen-Van-Tam et al., PLOS Pathogens. 16, e1008704 (2020).
Aerosols in SARS and MERS

Amoy Gardens SARS Outbreak 187 Cases

Infectious MERS-CoV in Hospital Corridor Air


### SARS-CoV-2 Aerosols in Containment Unit, Singapore

**Diagram:** Illustration showing the setting with patient in a containment unit and air samplers placed around.

**Table:**

<table>
<thead>
<tr>
<th>Patient</th>
<th>Day of illness</th>
<th>Symptoms reported on day of air sampling</th>
<th>Clinical Ct value*</th>
<th>Airborne SARS-CoV-2 concentrations (RNA copies m⁻³ air)</th>
<th>Aerosol particle size</th>
<th>Samplers used</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>Cough, nausea, dyspnea</td>
<td>33.22</td>
<td>ND</td>
<td>ND</td>
<td>NIOSH</td>
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<tr>
<td>2</td>
<td>5</td>
<td>Cough, dyspnea</td>
<td>18.45</td>
<td>2,000</td>
<td>&gt;4 μm</td>
<td>NIOSH</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1,384</td>
<td>1-4 μm</td>
<td>SKC Filters</td>
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<tr>
<td>3</td>
<td>5</td>
<td>Asymptomatic†</td>
<td>20.11</td>
<td>927</td>
<td>&gt;4 μm</td>
<td>NIOSH</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>916</td>
<td>1-4 μm</td>
<td></td>
</tr>
</tbody>
</table>

*Clinical Ct value indicates the threshold cycle number.
†Asymptomatic patient.

Average breathing rate ~12-14 m³ per day

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Aerodynamic analysis of SARS-CoV-2 in two Wuhan hospitals

(a) Fangcang Hospital Zone B
Protective Apparel Removal Room

(b) Fangcang Hospital Zone C
Protective Apparel Removal Room

(c) Fangcang Hospital
Medical Staff's Office

Aerosol and Surface Transmission Potential

Range of Gene Copies Recovered per Sample Type

Sample Type

Bedside Table, Rail
Air Handling Gate
Floor Under Bed
Misc. Personal Items
Phones
Remote
Toilet
Bedroom Air Samples
Hallway Air Samples
Personal Air Sampler
Transmission Distance
Viable SARS-CoV-2 in the air of a hospital room 1 with COVID-19 patients

Human Cough and Sneeze Collectors 1960s

Gesundheit-II Human Bioaerosol Collector

- Coarse aerosol (> 5 and < 80 µm)
- Fine aerosol (> 0.05 µm and ≤ 5 µm)
- Influenza virus was cultured from fine aerosol (~1/min)
- Influenza virus is present in exhaled breath – even without coughing.

Influenza virus in exhaled breath

Masks as Source Control

Influenza Virus Copy Number In Aerosol Particles Exhaled By Patients With And Without Wearing Of An Ear-loop Surgical Mask

Masks as Source Control

Infectious aerosol generation and impact of face masks in SARS-CoV-2 infection