INFECTIOUS DOSE CAN IT INFORM COVID-19 DECISIONS?

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Aerosol transmission of SARS-CoV-2
Person-to-person

- The virus is thought to spread mainly from person-to-person.
- Between people who are in close contact with one another (within about 6 feet).
- Through respiratory droplets produced when an infected person coughs, sneezes, or talks.
- These droplets can land in the mouths or noses of people who are nearby or possibly be inhaled into the lungs.
- COVID-19 may be spread by people who are not showing symptoms.

All Disease Transmission Routes are Possible for COVID-19

<table>
<thead>
<tr>
<th>Transmission Route</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Contact</strong></td>
<td>Transfer from infectious source or object to mucous membranes</td>
</tr>
<tr>
<td><strong>Droplet</strong></td>
<td>Large droplets “propelled” onto face and mucous membranes (no inhalation)</td>
</tr>
<tr>
<td><strong>Airborne</strong></td>
<td>Droplet nuclei inhaled ONLY when susceptible person is far from infectious source</td>
</tr>
<tr>
<td><strong>Aerosol</strong></td>
<td>Aerosols inhaled near the source</td>
</tr>
</tbody>
</table>
### Some Transmission Routes are More Likely Than Others

<table>
<thead>
<tr>
<th>Mode</th>
<th>CDC Statement</th>
<th>Additional Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact</td>
<td>CDC says that contact is NOT very important – I agree.</td>
<td></td>
</tr>
<tr>
<td>Droplet</td>
<td>CDC says that droplet transmission is important, but data suggest this may not be as important as everyone thinks</td>
<td></td>
</tr>
<tr>
<td>Airborne</td>
<td>CDC says that airborne transmission is not very important, but there are not enough data to rule this out.</td>
<td></td>
</tr>
<tr>
<td>Aerosol</td>
<td>This is probably an important mode of transmission not being given enough consideration.</td>
<td></td>
</tr>
</tbody>
</table>
Human-generated aerosols
Speaking & coughing generate wide range of particle sizes

- Wide range of particle sizes from < 1 µm to > 500 µm
- Similar size distributions with modes at 1-2 µm and 100-200 µm
- Coughing produces higher concentrations than speaking

People are highly variable in # particles they generate

- Most subjects generated more particles/cough during illness

Speech Generates Small Particles

Close-Range Aerosol Inhalation Route Dominates Near the Source

- Small droplet inhalation (aerosol transmission) dominates at most distances during talking and coughing
- Large droplet transmission (propulsion) is important only when > 100 µm within 0.5 ft (talking) or 1.5 ft (coughing)
  - Contributes < 10% exposure when droplets are < 50 µm and more than 1 ft apart

“Coughs and sneezes...consist of a turbulent cloud of buoyant gas with suspended droplets. The largest droplets follow a ballistic trajectory relatively unaffected by the flow in the gas phase, while the smaller droplets are suspended to varying degrees within the turbulent gas cloud, thereby having their range extended.”

• Droplets greater than 100 µm travel up to 4 m from coughs and less than 2 m from speech and settle within 10 sec
• Droplets less than 20 µm travel beyond 8 m from coughs and speech

What’s the exposure?

• Many mobile point sources (people)
• Lots of pre- and asymptomatic transmission
  • Minimal coughing and sneezing
• People exhale many large and small particles during breathing and talking
  • Larger particles rapidly evaporate to become smaller particles
• Concentrations are highest in the immediate vicinity of the source
• Hazardous aerosol with no occupational exposure limit
How do we make decisions for a novel aerosol?
Similar hazardous aerosol problems?

- Pharmaceuticals
  - No exposure limits
  - Bioactive and highly hazardous
  - Some animal toxicity

- Nanoparticles
  - No exposure limits
  - Highly hazardous materials
  - Limited animal toxicity at the beginning

Control Banding!
Exposure = Likelihood * Duration

<table>
<thead>
<tr>
<th>Likelihood</th>
<th>Daily Duration</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>D1 (0-3 hours)</td>
<td>D2 (3-6 hours)</td>
<td>D3 (&gt;6 hours)</td>
</tr>
<tr>
<td>L1 (Unlikely Exposure)</td>
<td>E1</td>
<td>E1</td>
<td>E1</td>
</tr>
<tr>
<td>L2 (Possible Exposure)</td>
<td>E2</td>
<td>E2</td>
<td>E3</td>
</tr>
<tr>
<td>L3 (Likely Exposure)</td>
<td>E2</td>
<td>E3</td>
<td>E3</td>
</tr>
</tbody>
</table>

Risk Group 3 = Agents associated with serious or lethal human disease for which preventive or therapeutic interventions may be available

Accounts for both the degree of harm and the availability of prophylaxis: [https://my.absa.org/Riskgroups](https://my.absa.org/Riskgroups)
Control Methods Should Follow a Hierarchy

- **FIRST - Source Controls**: isolation, social distancing
- **NEXT - Pathway Controls**: local exhaust ventilation, barriers
- **LAST-Receptor Controls**: personal protective equipment
### Aim to Lower Exposure Level

**GOAL**
Reduce exposure to E1 levels by selecting additional control strategies from the source and pathway categories and reducing reliance on PPE

<table>
<thead>
<tr>
<th>Band</th>
<th>Control Options</th>
</tr>
</thead>
</table>
| **A** | Source – Do these first!  
Pathway – May be prudent  
Receptor – Not necessary |
| **B** | Source – Do these first!  May require multiple options  
Pathway – Do these next & may require multiple options  
Receptor – Only if source and pathway controls are not effective |
| **C** | Source – Do these first!  May require multiple options  
Pathway – Do these next & may require multiple options  
Receptor - May be prudent |
City Bus Drivers Checkout During COVID-19 Pandemic

- Interacts with many people each workday
- Many may be infectious (even without fever or symptoms)
- Work 8 hr per day

Possible Likelihood of Exposure and Moderate Duration = Level of Exposure of E3
• Source Controls
  • Impossible to limit who boards the bus
• Effect of Source Controls
  • Does not reduce exposure
• Path Controls
  • The bus driver needs to be protected by a sealed enclosure to
• Effect of Path Controls
  • Reduces exposure to the bus driver
• Receptor Controls
  • If the bus driver needs to enter the main section of the bus, they may be required to wear a respirator

Use Receptor Controls (e.g. PPE) only if all other controls have been implemented and are not effective
Infectious Dose
What About Dose?

• For SARS, highest risk of infection occurred during aerosol-generating medical procedures
• COVID-19 shows higher attack rates in indoor clusters
• Suggests that SARS and COVID-19 infections may be related to dose
  • Concentration x Time
Aerosol Transmission = Inhalation of Infectious Particles

• The probability of getting infected depends on inhaling an “infectious dose” = the number of virions needed to make infection likely
  • Function of where particles land in the lung
  • Likelihood of deposition
• Infectious dose does not necessarily imply illness (symptoms and disease)
• Don’t know infectious dose for COVID-19, but might estimate 1000 virions by analogy to influenza and other coronaviruses

https://www.medrxiv.org/content/10.1101/2020.05.21.20108894v2
Infectious Dose

- Viral load (RNA copies per mL) in sputum = viral load in particles emitted during breathing, talking, coughing, sneezing, etc.
- Viral emission rate is a function of:
  - Viral load in sputum
  - Volume of air exhaled per breath
  - Breathing rate
  - Number of particles emitted per breath
  - Volume of a particle (function of particle diameter)

Steady-State Room

- Steady-state concentration of infectious particles in a room will be a function of:
  - Viral load in saliva (1000/nL)
  - Aerosol generation rate (nL/min) = varies for breathing, talking, etc.
  - Room ventilation rate (m$^3$/min)
  - Loss of particles due to settling and decrease in viability
- In a well-ventilated space settling will be minimal
- SARS-CoV-2 aerosol half-life may be 2-3 hr
- Exposure is a function of breathing rate, concentration and time spent in a space

• In a typical office with a ventilation rate of 10 m³/min and one infectious person mostly breathing but occasionally talking, the steady state concentration reaches the infectious dose at approx. 100 min.

• To safely share an office with this person (no more than 10% infectious dose) over 8 hr, would need a ventilation rate of more than 50 m³/min (2000 CFM).

• Obviously, more than 1 infectious person in the room increases the concentration and decreases the amount of time to an infectious dose for any non-infected occupants.

https://www.medrxiv.org/content/10.1101/2020.05.21.20108894v2
Transient Events

Well-Mixed Environment

• 70 ft$^2$ bathroom with 70 CFM fan
• An infectious person enters the room, spends 5 min, coughs 1-2 times
• Need to wait approx. 15 min to allow the room to clear before the next person enters
• Increasing the ventilation to 350 CFM would eliminate the need for a wait time between people

Poorly-Ventilated Environment

• Sneeze in an elevator would require waiting for approx. 5 air changes (if ACH = 2, this means a wait time of 2.5 hr between elevator riders!)
Advantages of Infectious Dose

<table>
<thead>
<tr>
<th>Illustrate</th>
<th>Calculate</th>
<th>Compare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact of ventilation, distance, contact time, number of people in a space</td>
<td>Safe contact and necessary wait times</td>
<td>Effect of interventions</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Face covering (protection factor &lt; 2), surgical mask (PF ≈ 4), respirator (fit factor = 100 if fit tested FFR)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Portable air cleaners (ACH and filtration)</td>
</tr>
</tbody>
</table>
Extra Slides
Evidence for Aerosol Transmission

Inhalation of Particles Near the Source
SARS-CoV-2 in Body Fluids

- Viable SARs-CoV-2 and SARS-CoV-2 RNA have been found in sputum (figure)
- Shedding peaks early, with mild symptoms
- Virus found in
  - Saliva
  - Oropharynx
  - Nasopharynx
  - Sputum

Wolfel et al. (2020) Nature. DOI: 10.1038/s41586-020-2196-x
To et al. (2020) Lancet Infect Dis. DOI: 10.1016/S1473-3099(20)30196-1
Aerosol Viability

ACE-2 Receptor for SARS-CoV-2

This receptor is widely expressed or can be activated in:

• Oral mucosa (tongue, floor of mouth)
• Respiratory tract (airway epithelium)
• Lung (type II alveolar cells)
• Intestine

Xu et al. (2020) Int J Oral Sci
Leung et al. (2020) Eur Resp J. 55: 2000688
Zou et al. (2020) Front Med. DOI: 10.1007/s11684-020-0754-0
Transmission in Animal Models

- SARS-CoV-2 infected ferret
- Direct contacts
- Indirect contacts
- SARS-CoV-2 shed in nasal washes, saliva, urine, feces

Transmission in the absence of direct contact in:
- Ferrets
- Golden hamsters
- Transgenic mice

Bao et al. (2020) J Infect Dis. DOI: 10.1093/infdis/jiaa281/5842264
Sia et al. (2020) Nature. DOI: 10/1-38/s41586-020-2342-5
Weight of Evidence for Aerosol Transmission (Inhalation at Close Range)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aerosol Generation</td>
<td>2</td>
</tr>
<tr>
<td>Viability in Environment</td>
<td>3</td>
</tr>
<tr>
<td>Access to Target Tissue</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>7</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Risk Group</th>
<th>Weight of Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Influenza</td>
<td>9</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>8</td>
</tr>
<tr>
<td>Norovirus</td>
<td>7</td>
</tr>
<tr>
<td>SARS</td>
<td>6</td>
</tr>
<tr>
<td>Ebola</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>4</td>
</tr>
<tr>
<td>COVID-19</td>
<td>3</td>
</tr>
</tbody>
</table>

CONCLUSION: Aerosol transmission is of **high concern**

RESEARCH PRIORITY: To characterize emission of viable virus

What about personal protective equipment?
Performance of Masks & Respirators Depends On

- Efficiency of the filter - How well does the filter collect airborne particles?
- Fit - How well does the facepiece prevent inward leakage of particles?
- Proper use - Proper donning and checking the seal may influence performance
Filter Testing

Use

Worst case test conditions
- High flow rate (80-90 L/min)
- Particles in most penetrating particle size

Well-characterized inert particles (not biological, anthropogenic, or naturogenic)

Instruments that quantify collection efficiency in narrow size categories

Include

- N95 FFR or similar as positive control
Some Basics About Fit

- **Need a good filter for fit to matter**
  - Particles follow the path of least resistance
- **Fit depends on a good seal at every contact point with the face**
  - Half-facepiece respirators hardest to fit – nose & chin
  - Full-facepiece respirators easier to fit – forehead vs. nose
- **Straps and facepiece edge design impact fit**
  - Adjustable straps
  - Head harness
  - Multiple flanges
- **Best designs use human panels with range of representative facial dimensions**
- **Quantitative measures of fit better than qualitative**
## Face Coverings, Surgical Masks & Respirators

<table>
<thead>
<tr>
<th>Face Coverings</th>
<th>Surgical Masks</th>
<th>Respirators</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Filters are very inefficient</td>
<td>• Filters may be a little more efficient than face coverings, but impossible to predict</td>
<td>• Filters are very efficient</td>
</tr>
<tr>
<td>• Fit is almost impossible to achieve</td>
<td>• Fit is very poor</td>
<td>• Fit must be evaluated for each person &amp; respirator</td>
</tr>
<tr>
<td>• May be possible to get a fit factor of 2</td>
<td>• May be possible to get a fit factor of 4-6 for masks with “good” filters</td>
<td>• Must be able to achieve a fit factor of 100 for use in the workplace</td>
</tr>
</tbody>
</table>
• Particles < 5 µm contain higher quantities of influenza than larger particles

• Ear loop surgical mask prevented emission of large particles only

Personal Protective Equipment

• Face coverings and surgical masks are not personal protective equipment!
• We wouldn’t recommend these for any other exposure to a highly hazardous aerosol
• Respirators are scarce and difficult to wear
• No reason to wear gloves – contact is a very unimportant mode of transmission
• Face shields? Droplet transmission is an unlikely and unimportant mode of infection.
  • But ocular transmission might be important
More on controls
### Source Controls for Hazardous Aerosols

<table>
<thead>
<tr>
<th>Elimination</th>
<th>Substitution</th>
<th>Isolation (remove sources &amp; lower concentration)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Screening for symptoms &amp; other risk factors</td>
<td>• Job re-design</td>
<td>• Increase distance (but 6 feet is not a magic number)</td>
</tr>
<tr>
<td>• Testing for infection</td>
<td></td>
<td>• Decrease density (fewer people – fewer sources)</td>
</tr>
<tr>
<td>• Exclude and quarantine</td>
<td></td>
<td>• Shorter shifts</td>
</tr>
<tr>
<td>• Work from home</td>
<td></td>
<td>• Job re-design</td>
</tr>
</tbody>
</table>
Pathway Controls for Hazardous Aerosols

- **Dilution ventilation**
  - Won’t eliminate exposure near a source

- **Local exhaust ventilation**
  - Portable air cleaners

- **Barriers**
  - Could change air flow patterns and dilution
  - Could result in high particle concentrations
  - Could introduce new or exacerbate current hazards – ergonomics, communication, isolation, stress
  - Might have unexpected and unwanted effects on particle movement
General Ventilation Recommendations

- Increase ventilation rate
- Decrease recirculation
- Maybe use better filters
- Consider use of local ventilation (portable air cleaners) or upper room UV-C irradiation
- Don’t turn off the ventilation system!
- Don’t use ionizers (generate ozone)
- Remember that general ventilation does not lower exposures close to the source
- More natural ventilation (windows) may be necessary in older buildings
Basic Principles

- Conduct a thorough workplace hazard assessment, adding COVID-19 aerosols to the mix
- Don’t neglect any current hazards
- Don’t introduce new hazards
- Rely on source and pathway controls
- Eliminate need for respiratory protection (no cloth or surgical masks)
- Use modeling and measurement whenever possible, to evaluate the effectiveness of controls
- Slower production might be the best you can do
More on filters and fit
Fibrous Filters

• Filters are NOT sieves
• Mat of fibers
• Air moves through mat, taking a tortuous path, bringing particles into contact with fibers
Mechanical Collection of Particles

Large particles collected by:
  • **Inertial impaction** (large or heavy particles can’t follow air streamlines)
  • **Interception** (particles brought into contact with fibers)

Small particles collected by:
  • **Diffusion** (random movements around streamlines)

Images from: http://www.engr.psu.edu/ae/iec/abe/control/filtration.asp
Mechanical Filter Efficiency Curve

- Most Penetrating Particle Size

- Diffusion Regime
- Diffusion and Interception Regime
- Inertial Impaction and Interception Regime
Effect of Velocity on Mechanical Filter Efficiency

Higher velocity decreases MPPS and increases penetration at all sizes.
Electrostatic Filters

• Charged filter fibers collect particles (large and small)
• Advantages are:
  • Low pressure drop (less breathing resistance)
  • Highly effective collection mechanism
• Most penetrating particle size occurs in the range of 40 - 100 nm (0.04 – 0.1 μm)*
• At 85 L/min (heavy work rate) N95 filtering facepiece respirators generally have filter penetration less than 5% at 50 nm
## Filter Testing

### Worst Case Test Conditions
- High flow rate (80-90 L/min)
- Particles in most penetrating particle size

### Use

#### Well-characterized inert particles (not biological, anthropogenic, or naturogenic)

#### Instruments that quantify collection efficiency in narrow size categories

### Include
- N95 FFR or similar as positive control
Some Basics About Fit

- Need a good filter for fit to matter
  - Particles follow the path of least resistance
- Fit depends on a good seal at every contact point with the face
  - Half-facepiece respirators hardest to fit – nose & chin
  - Full-facepiece respirators easier to fit – forehead vs. nose
- Straps and facepiece edge design impact fit
  - Adjustable straps
  - Head harness
  - Multiple flanges
- Human panels with range of representative facial dimensions
- Quantitative measures of fit better than qualitative
At high flow rate (99 L/min) commercial cloth masks had approximately 10% collection efficiency at MPPS of 0.3 µm

At 99 L/min sweatshirts had 10% collection efficiency for 0.3 μm particles.

At 99 L/min t-shirts had 1% collection efficiency for 0.3 μm particles.

Fleece towels (cotton & polyester/nylon) had 20% collection efficiency.

Cotton scarves had 10% collection efficiency.

Polyester scarf had 20% collection efficiency (also highest breathing resistance of all tested cloth materials).
Cloth Masks - Fit

- Most studies of cloth mask fit didn’t measure or incorrectly measured filter efficiency
- Measures of fit were generally not done correctly
- One study used a TSI Model 8095 Portacount Plus & N95 Companion to measure fit of a homemade mask (100% cotton t-shirt) on 21 adults (20-44 yrs)*


TABLE 2

<table>
<thead>
<tr>
<th>Condition</th>
<th>Median and Interquartile Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Homemade Mask</td>
</tr>
<tr>
<td>Normal breathing</td>
<td>2.0 (2.0, 2.5)</td>
</tr>
<tr>
<td>Heavy breathing</td>
<td>2.0 (2.0, 3.0)</td>
</tr>
<tr>
<td>Head moving side to side</td>
<td>2.0 (1.0, 2.0)</td>
</tr>
<tr>
<td>Head moving up and down</td>
<td>2.0 (1.5, 2.0)</td>
</tr>
<tr>
<td>Bending over</td>
<td>1.0 (1.0, 2.0)</td>
</tr>
<tr>
<td>Talking</td>
<td>2.0 (1.0, 2.0)</td>
</tr>
<tr>
<td>Normal</td>
<td>2.0 (1.0, 2.0)</td>
</tr>
<tr>
<td>All data</td>
<td>2.0 (1.0, 2.0)</td>
</tr>
</tbody>
</table>

Median Fit Factor for Homemade Mask = 2 and Surgical Mask = 5
Cloth Masks as Source Control or PPE? Neither!

- Infectious dose by aerosol of influenza = 3 TCID$_{50}$
- Sampling during the H1N1 outbreak in healthcare, daycare and airplane settings found $35 \pm 21$ TCID$_{50}$ per m$^3$ air*
- Estimated inhalation doses ranged from:
  - $30 \pm 18$ TCID$_{50}$ for 1 hr exposure
  - $236 \pm 140$ TCID$_{50}$ for an 8 hr exposure
  - $708 \pm 419$ TCID$_{50}$ for a 24 hr exposure
- A fit factor of 2 means a cloth mask made from a cotton t-shirt will decrease the outside concentration by 50% (maybe)
- Need a mask with a fit factor of at least 10 for a 1 hr exposure; 80 for an 8-hr exposure & 236 for a 24-hr exposure

**Surgical Mask History**

**Developed in early 1900s**

- Proposed when research showed that bacteria from nose and mouth are present in droplet nuclei and a study suggested surgical masks would reduce surgical wound infections (Meleny 1940s & 50s).

**1935**

- New materials & designs; new testing methods (Spooner, 1967)
  - Gauze masks have ineffective filters
  - Wetting lowered efficiency
  - Improper fitting allowed leakage around the sides
  - Multiple layers uncomfortable

**1940s & 50s**

- Gauze masks have ineffective filters
- Wetting lowered efficiency
- Improper fitting allowed leakage around the sides
- Multiple layers uncomfortable

**1970s**

- Surgical masks deflect droplet nuclei around sides of mask but do not lower levels of airborne contamination (Ritter 1975)
Surgical Masks Show No Clinical Effectiveness

• First randomized controlled trial (6 mos) finds no difference in wound infection rates with and without surgical masks (Orr, 1981)

• Second randomized controlled trial in new OR also found no difference with and without masks (Mitchell and Hunt, 1991)
  • “…with the exception of high risk surgery, the wearing of surgical masks by the surgeon and scrubbed assistants is an unproven value.”

• Third randomized controlled trial (2 yr) with 3 different surgical masks in OR found similar rates of infection with and without masks (Tunevall, 1991)
How is Filter Performance Evaluated for Surgical Masks?

Considered medical devices, regulated by FDA
- “Cleared for marketing” by FDA
- At least as good as masks currently on the market
- Particle filtration, fluid resistance, flammability

- Filter tests involve challenges with biological or inert aerosols
  - *Staphylococcus aureus*, average diameter 0.8 µm, polydisperse, organisms in liquid, 28 L/min [mean particle size of aerosol = 3 µm]
  - Latex spheres, diameter 0.1 µm, monodisperse solid particles, challenge flow can vary [low flow can be selected]

- Healthcare settings are not required to purchase FDA-cleared surgical masks (many do not)
How Well Do Surgical Masks Filters Perform Using “Worst-Case” Tests?

• Collection efficiency of surgical mask filters is highly variable, ranging from 2 to 98%

• Most surgical mask filter efficiencies range from 30-50%

• Impossible to predict the collection efficiency of a surgical mask, however...

  • Bacterial efficiency tests are not predictive of performance in most penetrating particle size range

Surgical Mask as Source Control

- Particles < 5 µm contain higher quantities of influenza than larger particles
- Ear loop surgical mask prevented emission of large particles only

Surgical Mask Fit

- Study with Kimberly Clark Tecnol PCM 2000 masks (0.1 µm fluid shield) showed 80% penetration of 3 to 14 µm latex powder aerosols (generated by gloves) INTO the facepiece (Mitakakis, 2000) [FF = 1]

- Study of 5 surgical masks with < 0.6% filter penetration (0.9 µm latex spheres) and 20 subjects (10 male, 10 female) (Oberg and Brosseau, 2008), using quantitative fit testing (TSI Portacount)
  - Unassisted Donning
    - Average Fit Factor = 4.4 ± 0.9 (2.5 – 6.9)
  - Assisted Donning
    - Average Fit Factor = 5.7 ± 0.8 (2.8 – 9.6)
Surgical Masks as Source Control or PPE?

- May prevent emission of larger particles (> 5 µm) from an infectious source, but will not prevent emission of smaller particles (< 5 µm)
- Fit factors of 4-5 (for surgical masks with high-performing filters) indicate concentrations inside the mask are 20-25% those outside (particles > 1 µm)
- Recall calculations of typical TCID50 influenza exposures
  - A surgical mask with a high-performing filter might offer protection from larger particles for about 30 min (if it fits)
  - I can’t tell you which surgical mask has a high-performing filter, however!

- OK as source control on infectious patients &
  - to limit viral load from larger particles in healthcare settings
- Not OK as personal protective equipment
Respirator Filter Performance

- Respirators are certified by the National Institute for Occupational Safety and Health (NIOSH).
- NIOSH certification tests evaluate the performance of filters by measuring collection efficiency using NaCl (solid) and DOP (liquid oil) aerosols (0.3 µm) charge neutralized at 85 L/min.
- 3 categories of oil resistance:
  - N = not resistant to oil, R = resistant to oil, P = oil proof.
- 3 levels of filter efficiency:
  - 95 = 95% efficient, 99 = 99%, 100 = 99.97%.
- 9 possible classes of respirators (3 oil resistance x 3 efficiencies).
Guidance for Industry and FDA Staff

Class II Special Controls Guidance Document: Filtering Facepiece Respirator for Use by the General Public in Public Health Medical Emergencies

Document issued on: July 3, 2007

For questions regarding this document, contact Sheila A. Murphy, MD at 240-278-3700 or by email at sheila.murphy@fda.hhs.gov.

U.S. Department of Health and Human Services
Food and Drug Administration
Center for Devices and Radiological Health

Infection Control Devices Branch
Division of Anesthesiology, General Hospital, Infection Control, and Dental Devices
Office of Device Evaluation

Supports the classification of filtering facepiece respirators for use by the general public in public health medical emergencies as class II (special controls) devices.
Fit Assessment with a Test Panel

- Enough subjects for valid statistical analysis of test results
- No prior experience with occupational respirators
- No prior respirator training or fit testing
- Provide intended labeling, including donning instructions, to subjects prior to fit testing
- Use a quantitative fit test described in published scientific articles (e.g. Portacount Plus with N95 Companion)
- Follow procedures in 29 CFR 1910.134 (exercises)
- FDA recommends triplicate or more testing of each test subject
Data Analysis

• Test subjects must obtain a minimum FF of 2 (50% leakage)
• Calculate percent of subjects who obtain specific fit factors for at least 95% of donnings for FF = 2, 5, 10, 50 and 100
• Should consider both within- and between-subject variability
Fit Testing

• TSI Portacount Plus and N95 Companion
• Subject donned a respirator following written instructions and photos
• No effort was made to correct donning
  • Observed and noted improper techniques
• Two tests on each mask; new mask donned for each test; random order
• Eight exercises
Subjects & Donning

• 35 subjects in final dataset (20 females, 15 males)
  • Most between 18 and 35 years
  • 17 students
  • 6 Asian; 29 Caucasian
• Most correctly placed respirator on face and formed the nose clip to nose
• 25% did not properly place straps
  • Reversed straps or looped lower strap over ears
## Percent of Users Who Will Achieve Given Fit Factor for 95% of Donnings

<table>
<thead>
<tr>
<th>Fit Factor</th>
<th>Respirator A % Users (95% CI)</th>
<th>Respirator B % Users (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>99 (77-100)</td>
<td>100 (77-100)</td>
</tr>
<tr>
<td>5</td>
<td>94 (38-100)</td>
<td>96 (42-100)</td>
</tr>
<tr>
<td>10</td>
<td>76 (14-99)</td>
<td>86 (19-100)</td>
</tr>
<tr>
<td>50</td>
<td>13 (0-76)</td>
<td>29 (1-92)</td>
</tr>
<tr>
<td>100</td>
<td>3 (0-46)</td>
<td>10 (0-76)</td>
</tr>
</tbody>
</table>
Respirators as Source Control or PPE?

- Respirators could be either source control or PPE.
- Better source control than cloth or surgical masks.
- The only option for PPE, especially in workplace settings where there is the probability for high concentrations of small infectious aerosols.
- Should consider higher levels of protection for higher exposures
  - More infectious patients being cared for
  - Longer time exposed to infectious patients
  - Aerosol generating procedures
  - Patients with significant symptoms (cough)