Protection Against Airborne Respiratory Viruses

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Background

• Millions have lost their lives to respiratory viruses such as influenza
• Epidemics of varying severity occur worldwide each year.
• Novel Influenza strains are the latest threats
• Current Recommendations for Influenza (CDC, WHO):
  • Droplet/Contact Precautions since Influenza transmission has been thought to primarily occur by large-particle respiratory droplets.
  • Only during aerosol-generating procedures such as bronchoscopies are fit-tested respirators required.
  • New Influenza Strains – airborne plus contact plus eye-protection
Transmission routes: droplet, airborne, direct contact, and indirect contact.¹

Evidence of Influenza Aerosols - Burden:

- Blachere et al.: up to 16,278 viral RNA copies/m³ air (Infl. A)¹
- Lindsley et al.: 0.7 – 75.4 pg RNA/m³ air (Infl. A)²
- Tseng et al.: 167.6 – 5,020 viral RNA copies/m³ air (Infl. A)³
- Leung et al.: 94 – 383 viral RNA copies/m³ air (Infl. A)⁴
- Yang et al.: 1.6 + 0.9 x 10⁴ viral RNA copies/m³ air⁵
- Bischoff et al.: 0.9 - >200 viral RNA copies/m³ air⁶

Alford et al.: HID₅₀ 0.6-3 TCID₅₀ = RNA load of 90-1,950 viral copies⁷

Exposure Risk

• Evidence of Influenza Aerosols – Particle Size:
  • Blachere et al.: 53% in particles < 4.1 μm (Infl. A)\(^1\)
  • Lindsley et al.: 53% in particles < 4.1 μm (Infl. A)\(^2\)
  • Yang et al.: 64% < 2.5 μm (Infl. A)\(^3\)
  • Bischoff et al.: up to 89% < 4.7 μm (Infl. A and B)\(^4\)

Viral recovery higher in larger particle sizes
(93% > 4 μm vs. 7% in 1-4 μm particles)\(^5\)

Exposure Risk

- Infectious Heterogeneity (super-emitters)

Exposure Risk

• Entry Routes:
  • Mouth, Nose:
    • Surgical/Medical Masks:
      • Oberg et al. – nine masks tested, none with adequate protection
      • Aiello et al., MacIntyre et al. – no clear protection in community or health care settings
      • Bischoff et al. – no protection against LAIV
    • Patients:
      • Johnson et al. – no difference in mask type in preventing aerosol particles emission in patients
      • Diaz et al. – bench model demonstrating successful deflection of exhaled particles

Exposure Risk

• Entry Routes – Mouth, Nose

Results of meta-analysis to determine effectiveness of N95 respirators versus surgical masks in protecting health care workers against acute respiratory infection.

Smith JD et al. CMAJ 2016;188:567-574
Exposure Risk

• Entry Route:
  • Eyes:
    • Replication of influenza, adenovirus, RSV within ocular tissue²
    • Influenza – successful ocular-only aerosol inoculation in ferrets²,
    • Influenza – trans-ocular entry of seasonal influenza virus in volunteers detected³
  
• Should ocular protection be considered besides respiratory protection?

Efficacy of N95 Respirators Against Aerosolized Influenza Virus
Objective

• To assess the efficacy of a commercially available N95 Respirator mask against a novel half-mask Powered Air Purifying Respirator (PAPR) in a human exposure model.
Methods

• Healthy volunteers randomized to:
  • N95 (Kimberly-Clark N95 particulate filter respirator and surgical mask, Irving, TX)
  • PAPR (Pioneer 300, Celios, Tampa, FL) exposure group
• Qualitative fit-testing (3M, FT-10)
• Negative control by nasal swabs before exposure
• Exposure Agent: Seasonal, cold-adapted, live attenuated Influenza vaccine as exposure agent (LAIV; 2015/16 FluMistTM Quadrivalent, Gaithersburg, MD)
• Participants fitted with disposable gowns, gloves, cap, shoe covers, and air-tight goggles
Methods

• Placement in HEPA air filtration exposure chamber
• LAIV aerosolized with nebulizer MQ5800 Airial, Medquip, Bluffon, SC)
• During exposure participants performed a standardized set of movements and reading exercises to mimic normal daily usage
• 20 minute exposure run followed by five minute evacuation run
• Nasal swabs post evacuation run
• qRT-PCR targeting Influenza A strains in LAIV
Results

N-95

10%
NOT PROTECTED

PAPR

100%
PROTECTED
Results

• For PAPR users no Influenza virus was detected (0%; exact 95% CI, 0-0.12)
• For N95 respirators Influenza virus was detected in 3 out 29 participants (10%; exact 95% CI, 0.02-0.27)
• The three subjects with virus detection included two Caucasian males (ages 31 and 40) and one African American female (age: 23)
• Total RNA copies recovered from the three subjects were 4,745, 5,471, and 65,206 copies (mean: 25,141 copies)
• No adverse events were noted during the trial.
Conclusion

• Participants wearing the N95 respirator encountered breakthrough events to LAIV in 3 out of 29 cases (10% failure)

• RNA copies recovered all above known HID$_{50}$ for Influenza

• The PAPR completely blocked the transmission of LAIV (100% protection)

• NIOSH assigned protection factor (APF):
  • N95 respirators: APF 10 – match
  • PAPR: APF 50

• Is a 10% failure rate for N95 respirators acceptable?