Respiratory Protection Solutions for Healthcare Workers: Planning for Routine and Pandemic Use

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Disclosures

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Learning Objectives

• Recognize the need for alternative respiratory protection solutions to N95 shortages.
• Describe features of user acceptance of elastomeric respirators in healthcare.
• Define logistical barriers to optimal implementation of elastomeric respirator-based hospital RPPs
What is an N95?

• **N95 Filtering Facepiece Respirator (N95-FFR)?**
  - **N95** Defined by US Code of Fed Reg (42 CFR 84)
    - **N:** No oil aerosols  **95:** ≥ 95% particles filtered > 0.3 µm
  - **Filtering Facepiece Respirator (FFR)**
    - The filter medium is the **body** of the respirator
    - Filters **particles**

• Efficacy depends on **seal** btwn mask and user’s face
  - Requires a fit-test

*Slide courtesy Dr. William Lindsley, NIOSH*
Yesterday was national N95 Day!

9/5

N95 Day, A NIOSH-Approved Observance

This year we're getting particular about protection against particulates

https://www.cdc.gov/niosh/npptl/n95day.html
Familiar Respirator Use Scenarios in Healthcare:

- **Tuberculosis**
- **Avian Influenza**
- **Varicella**
- **Measles**
- **Novel pathogens**

  - High Hazard Procedures
    - Bronchoscopy
    - Intubation
    - Sputum induction
    - Aerosolized administration of certain meds (Ribavirin, Pentamidine)

Do healthcare workers (HCWs) need respirators during a respiratory viral pandemic – ex. Influenza?

• The question of whether influenza is spread significantly by *airborne transmission* has been debated.
  – We know it is present in aerosols & not just droplets (Jones & Brosseau, 2015)

• If influenza is spread by *small airborne particles*, a surgical mask will not protect workers, and a respirator is needed.

*Slide courtesy Dr. William Lindsley, NIOSH*
NIOSH Influenza Studies

• Airborne sampling during flu season (ED, Urgent Care)
  – 40-50% of the influenza virus in particles $\leq 4 \mu m$
    (Blachere et al. 2009; Lindsley et al. 2010)

• Cough aerosols from student health clinic, 2009
  – 65% of airborne influenza carried by particles $\leq 4 \mu m$
    (Lindsley et al. 2010)

• Viability of cough aerosols
  – Almost all of the virus was detected in small particles
    ($0.3$ to $8 \mu m$) (Lindsley et al. 2010)
Amount of Influenza virus inhaled depends on protection worn

• Unsealed surgical mask allowed almost **half** of the virus to be inhaled.

• Sealing the mask blocked most of the virus

• N95 with **face seal leaks** admitted ~ **16%** of the virus.

• N95 respirator with a **good face seal** blocked virtually **all** of the virus.

Lindsley et al. JOEH 2012; Clin Infect Dis 2012;

% of influenza virus that passed through or around the mask or respirator.

*Slide courtesy Dr. William Lindsley, NIOSH*
We know that **respiratory protection** will be important for the next airborne infectious disease pandemic

As part of Multi- 
Pronged approach

**Hierarchy of Exposure Control**

Apply the highest level of control commensurate with the risk level—lower value controls may be used in the interim until long-term controls are implemented.

- ELIMINATION
- SUBSTITUTION
- ENGINEERING
- ADMINISTRATIVE
- BEHAVIOR
- PPE

Increasing effectiveness 
and sustainability

N95

Increasing participation 
and supervision 
needed
Issues related to Pandemic Preparedness

- US DHHS Recommends that healthcare facilities stockpile a 6-8 week supply of disposable N95s.
- CDC estimates BILLIONS of N95s would be needed to protect HCWs during a 42 day pandemic.
- Most commonly, N95 FFRs discarded after each patient contact.

CDC RFA-OH-14-009 2014

Photos: http://www.cdc.gov/phpr/stockpile/stockpile.htm
Examples: Have we been ready?
Barriers to Stockpiling Disposable N95s

• Lack of storage space
• Possible expiration issues
  – NIOSH certification does not govern shelf-life
  – Shelf-life is conservatively set by major manufacturers
    • Determined by testing
    • Temperature and humidity limits
• Limited # of “on-hand” supplies due to “just-in-time” supply chain and group purchasing procurement operations
One Alternative – Reusable Elastomeric Respirators

- Commonly used outside of healthcare
- Each worker assigned own respirator, done in advance
- Could reduce the need for stockpiling
- Can be disinfected multiple times
- Financially advantageous?
Elastomeric Respirators and N95s share most features

- Both are **tight-fitting, air-purifying, particulate respirators**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>N95 FFR</th>
<th>Elastomeric half-face</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assigned Protection Factor (APF)</td>
<td>10</td>
<td>10*</td>
</tr>
<tr>
<td>Filtration Efficiency</td>
<td>95%</td>
<td>≥95%</td>
</tr>
<tr>
<td>Fit-test required?</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Unknowns regarding use of Elastomeric Respirators in Healthcare?

• Are they as acceptably comfortable compared to disposable respirators?
• Do they interfere more with patient care than disposable respirators?
  – Communication
  – Physical obstruction
  – Patient fear?
• Available at point of use?
• Do wearers maintain/clean them?

Case study: Large, urban US academic medical center – 6/2014

Figure: Employees enrolled in Respiratory Protection Program (RPP) TFR=Tight-fitting respirator; PAPR=Powered Air Purifying Respirator

- 9300 Employees
  - 5630 in RPP
    - 2113 in TFR
    - 3517 in PAPR
    - 1972 in Elastomeric
  - 141 in Disposable N95
Research Questions

Are elastomeric respirators an alternative to N95-FFRs in healthcare?

- Acceptable (i.e. user acceptability)
- Feasible (logistics – storage, cleaning, supply)
Methods – Study setting

- Survey of Healthcare Workers in RPP in 5 sites within a health system
  - Urban academic medical center
    • (elastomeric, N95, PAPR)
  - Associated ambulatory practices
    • (1° elastomeric)
  - Urban community hospital
    • (1°N95)
  - Suburban community hospital
    • (1°N95)
  - Suburban/rural community hospital
    • (1°PAPR)
Questionnaire Development

- Based on key issues identified from focus groups/interviews
- Modified questions from other surveys
  - AHRQ Patient Safety Survey
  - WorkSafeBC
  - REACH II study
- Domains
  - Respiratory Protection Attitudes
  - Respirator Preferences
  - Risk Perception
  - Compliance Factors
  - Safety Culture
- Pilot Testing

Below are three types of respirators that protect against airborne diseases. The first two are tight fitting respirators that fit over the face - the disposable N95 respirator, and the reusable elastomeric respirator. The third device is a loose-fitting powered air-purifying respirator (PAPR).

Questions below pertain to the types of respirators depicted in the pictures.

The particular respirator that you use may look slightly different, but should fall into one of the three classes of respirators found below.

**Disposable N95 Respirator:**

**Reusable Elastomeric Respirator:**

**Powered Air-Purifying Respirator (PAPR):**

(Click on any of the images on the page to expand them)

^ THESE ARE NOT RESPIRATORS, THEY ARE SURGICAL MASKS ^
Questionnaire Deployment

• 20 Minute Survey
• Web-based
• Self-administered
  – Disseminated via email
  – On-site completion via laptops provided by study team
• $20 e-gift card for participation
Data Analysis

- SAS and R studio
- Group differences
  - Significant demographic differences between groups included in multivariable analyses

3 groups: N95 vs. EHFR vs. PAPR

- Group-level comparison of Likert-scale outcomes (3 groups)
  - Diverging stacked bar charts (neutral at zero)
  - Converted Likert-scale to continuous variable (1 to 5)
    - $\chi^2$

- Preference analysis
  - Odds Ratios
    - Multinominal logistic regression
    - GEE
Results

Major Article

User acceptance of reusable respirators in health care

Stella E. Hines MD, MSPH *, Clayton Brown PhD, Marc Oliver RN, MPH, MBA, Patricia Gucer PhD, Melissa Frisch MD, MPH, Regina Hogan RN, MS, Tracy Roth RN, MSN, James Chang CIH, Melissa McDiarmid MD, MPH, DABT

Department of Medicine, Division of Occupational and Environmental Medicine, The University of Maryland-Baltimore, School of Medicine, Baltimore, MD
Demographics of Survey Respondents, n=1152

<table>
<thead>
<tr>
<th>Demographics</th>
<th>EHFR Users, n=280</th>
<th>N95-FFR Users, n=606</th>
<th>PAPR Users, n=266</th>
<th>Overall</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female Gender</td>
<td>85%</td>
<td>80%</td>
<td>77%</td>
<td>80%</td>
<td>0.033</td>
</tr>
<tr>
<td>Job Type</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nurse</td>
<td>47%</td>
<td>42%</td>
<td>62%</td>
<td>48%</td>
<td></td>
</tr>
<tr>
<td>Provider</td>
<td>9%</td>
<td>27%</td>
<td>11%</td>
<td>19%</td>
<td></td>
</tr>
<tr>
<td>RT</td>
<td>7%</td>
<td>6%</td>
<td>3%</td>
<td>6%</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>38%</td>
<td>25%</td>
<td>23%</td>
<td>28%</td>
<td></td>
</tr>
<tr>
<td>Employer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban, academic</td>
<td>81%</td>
<td>68%</td>
<td>73%</td>
<td>72%</td>
<td></td>
</tr>
</tbody>
</table>
With regard to comfort, how much do you like your respirator?

**Respirator user groups**

- **All**
- **N95-FFR**
- **EHFR**
- **PAPR**

**All Responses**

- Very much dislike
- Dislike
- Neither like nor dislike
- Like
- Very much like

**Current Respirator**

- Very much dislike
- Dislike
- Neither like nor dislike
- Like
- Very much like

**User group totals**

- 1152
- 606
- 280
- 266

**Likert Scale**
Likert scale responses about respirator attributes among respirator user groups, n=1152

<table>
<thead>
<tr>
<th></th>
<th>EHFR users (n=280)</th>
<th>N95-FFR users (n=606)</th>
<th>PAPR users (n=266)</th>
<th>Overall comparison*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COMFORT</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How much do you like your respirator? (1=Very much dislike; 3= neither like/dislike; 5= very much like)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean (SD)</td>
<td>3.28 (1.08)</td>
<td>3.42 (0.93)</td>
<td>3.06 (1.12)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

*Significance level unchanged after adjustment for covariates
With regard to **communication**, how much do you like your respirator?
Likert scale responses about respirator attributes among respirator user groups, n=1152

<table>
<thead>
<tr>
<th></th>
<th>EHFR users (n=280)</th>
<th>N95-FFR users (n=606)</th>
<th>PAPR users (n=266)</th>
<th>Overall comparison*</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMMUNICATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How much do you like your respirator? (1=Very much dislike, 3= neither like/dislike, 5=very much like)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean (SD)</td>
<td>2.76 (1.1)</td>
<td>3.29 (0.94)</td>
<td>2.70 (1.18)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

*Significance level unchanged after adjustment for covariates
With regard to your own protection from airborne disease, how well do you think your respirator protects you?

Respirator user groups

All

Current Respirator

N95-FFR

EHFR

PAPR

User group totals

All Responses

All

1152

Current Respirator

N95-FFR

606

EHFR

280

PAPR

266

Percent

Not well at all

Somewhat

Not Sure

Well

Very well

Likert Scale
**Results – User Acceptance**

### Likert scale responses about respirator attributes among respirator user groups, n=1152

<table>
<thead>
<tr>
<th></th>
<th>EHFR users (n=280)</th>
<th>N95-FFR users (n=606)</th>
<th>PAPR users (n=266)</th>
<th>Overall comparison*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SENSE OF PROTECTION</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>How well do you think your respirator protects you? (1=not well at all, 3=neutral, 5= very well)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean (SD)</td>
<td>4.12 (0.97)</td>
<td>3.55 (1.15)</td>
<td>3.84 (1.08)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

*Significance level unchanged after adjustment for covariates*
I am **confident** that my respirator will protect me based on the **fit-testing or training** I have received.
Likert scale responses about respirator attributes among respirator user groups, n=1152

<table>
<thead>
<tr>
<th></th>
<th>EHFR users (n=280)</th>
<th>N95-FFR users (n=606)</th>
<th>PAPR users (n=266)</th>
<th>Overall comparison*</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONFIDENCE FROM TRAINING or FIT-TESTING</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I am confident that my respirator will protect me (1=strongly disagree, 3=neither agree nor disagree, 5=strongly agree)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean (SD)</td>
<td>3.94 (1.05)</td>
<td>3.62 (0.98)</td>
<td>3.60 (0.98)</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

*Significance level unchanged after adjustment for covariates
Preferences under different hypothetical risk scenarios

<table>
<thead>
<tr>
<th>Preferred Respirator</th>
<th>Current EHFR Users (n=280)</th>
<th>Current N95-FFR Users (n=606)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EHFR (%</td>
<td>N95-FFR (%)</td>
</tr>
<tr>
<td>Rule out TB</td>
<td>56%</td>
<td>37%</td>
</tr>
<tr>
<td>Active TB</td>
<td>69%</td>
<td>15%</td>
</tr>
<tr>
<td>Pandemic H1N1 or SARS</td>
<td>61%</td>
<td>18%</td>
</tr>
</tbody>
</table>
### Adjusted odds of preferring EHFR or PAPR (versus N95-FFR) under hypothetical threat scenarios

**Current EHFR Users (n=280)**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Preference for:</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>EHFR</td>
<td>PAPR</td>
<td>N95-FFR</td>
<td></td>
</tr>
<tr>
<td><strong>Active TB</strong></td>
<td>3.2</td>
<td></td>
<td></td>
<td>(ref)</td>
</tr>
<tr>
<td></td>
<td>[2.3-4.6]</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pandemic H1N1 or SARS</strong></td>
<td>2.4</td>
<td></td>
<td></td>
<td>(ref)</td>
</tr>
<tr>
<td></td>
<td>[1.8-3.4]</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Perceptions about risk

Results – User Acceptance

Perceived Risk of Contracting Disease if not wearing a respirator
All Respondents (N=1152)

– No significant differences by respirator group
Summary – User Acceptance

• **N95s** score highest in both **comfort & communication**

• **Elastomerics** score highest in **sense of protection** from disease & **confidence** that the respirator will protect.

• **Despite** comfort & communication, elastomeric users still **PREFER** to use them in certain risk scenarios
Feasibility

• Questions specific to elastomeric respirator use
• Responses from “Current” users (n=280)
<table>
<thead>
<tr>
<th>Availability</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>2</td>
</tr>
<tr>
<td>Sometimes</td>
<td>0</td>
</tr>
<tr>
<td>About half the time</td>
<td>2</td>
</tr>
<tr>
<td>Usually</td>
<td>19</td>
</tr>
<tr>
<td>Always</td>
<td>75</td>
</tr>
</tbody>
</table>

### Storage location

When my reusable elastomeric respirator is not in use, I store it:

<table>
<thead>
<tr>
<th>Option</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>In a drawer near the patient’s room</td>
<td>5</td>
</tr>
<tr>
<td>Somewhere in the patient care area nearby (like a locker)</td>
<td>60</td>
</tr>
<tr>
<td>Somewhere on campus</td>
<td>9</td>
</tr>
<tr>
<td>In my car/at home/don’t know</td>
<td>6</td>
</tr>
<tr>
<td>Other</td>
<td>19</td>
</tr>
</tbody>
</table>

### Storage Technique

<table>
<thead>
<tr>
<th>Storage Method</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>In a sealed plastic bag so that it retains its shape</td>
<td>58%</td>
</tr>
<tr>
<td>In a sealed plastic bag but not protected from being compressed or deformed</td>
<td>16%</td>
</tr>
<tr>
<td>Not in a sealed plastic bag, but protected so it retains its shape</td>
<td>19%</td>
</tr>
<tr>
<td>Not in a sealed plastic bag and not protected from being compressed or deformed/other</td>
<td>6%</td>
</tr>
</tbody>
</table>

### Cleaning & Disinfection - 1

#### How clean is the respirator when you use it?

<table>
<thead>
<tr>
<th>Cleanliness</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very clean</td>
<td>45%</td>
</tr>
<tr>
<td>Clean</td>
<td>44%</td>
</tr>
<tr>
<td>Somewhat clean</td>
<td>9%</td>
</tr>
<tr>
<td>Not clean</td>
<td>0%</td>
</tr>
</tbody>
</table>
### Cleaning & Disinfection - 2

I wipe my respirator with an alcohol pad or disinfectant wipe after each use.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>4</td>
</tr>
<tr>
<td>Sometimes</td>
<td>11</td>
</tr>
<tr>
<td>Half the time</td>
<td>6</td>
</tr>
<tr>
<td>Usually</td>
<td>21</td>
</tr>
<tr>
<td>Always</td>
<td>58</td>
</tr>
</tbody>
</table>
Cleaning & Disinfection - 3

I remove the filters and wash inside of my respirator with soap and water

<table>
<thead>
<tr>
<th>Frequency</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rarely/never</td>
<td>69</td>
</tr>
<tr>
<td>Yearly</td>
<td>11</td>
</tr>
<tr>
<td>Monthly</td>
<td>9</td>
</tr>
<tr>
<td>Weekly</td>
<td>3</td>
</tr>
<tr>
<td>After each shift</td>
<td>8</td>
</tr>
</tbody>
</table>
Predictors of Compliance with Expected Respirator Use

• Concordant vs. Discordant Users

Summary - Feasibility

• Most current elastomeric users report the respirator is *usually* or *always* available when needed
• Up to **40%** do **not** store in a **convenient** location & do so sub-optimally
• Up to **30%** do not **regularly wipe-down** and most never have cleaned by submersion*
  – *recommended by manufacturer
Next Steps

• Storage solutions
  – Unit-based supply vs individual carrying-case

• Cleaning & disinfection
  – What is the best disinfection method?
    • Subhash et al 2014; Lawrence et al 2017
  – Centralized Cleaning vs. Individual responsibility
Conclusions

• Elastomeric respirators have been used successfully in healthcare

• We have quantified the barriers
  – *Now we can craft informed solutions*

• Reusable respirators can be a feasible and user-acceptable alternative to use of N95s in healthcare
Acknowledgments

• Study Team
  – Marc Oliver, RN, MPH, MBA
  – Clayton Brown, PhD
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  – Jim Chang, CIH
  – Bethany Weiler, MD
  – Melissa McDiarmid MD, MPH, DABT

  • Chair, Division of Occupational & Environmental Medicine

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Sept 5 – Respirator Day (9/5)