Characterizing and Preventing Occupationally-Acquired Infectious Diseases

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Evidence of the Burden in Healthcare

• Pulmonary tuberculosis
  – Surveillance

• Emerging infectious diseases
  – Novelty
  – Significant morbidity and mortality

• Crazy infections among laboratory workers

Endemic diseases? Not so much information.
What Protects Healthcare Workers?

Hierarchy of Controls

- Elimination: Physically remove the hazard
- Substitution: Replace the hazard
- Engineering Controls: Isolate people from the hazard
- Administrative Controls: Change the way people work
- PPE: Protect the worker with Personal Protective Equipment

What regulations apply to infectious diseases among workers in healthcare settings?

Image from: https://www.cdc.gov/niosh/topics/hierarchy/
Personal Protective Equipment

- **Standard**
  - Gloves, Gown & Face Protection for body fluid contact

- **Contact**
  - Gloves & Gown

- **Droplet**
  - Gloves, Gown & Mask

- **Airborne**
  - Gloves, Gown & Respirator

**Enhanced**
- Gloves (2 pairs), impermeable body and face coverings, respirator
The Infectious Diseases Standard

A proposed programmatic standard from the Occupational Safety and Health Administration that would require healthcare facilities to:

• Develop and implement a program
• Assess infection risks for work tasks
• Select and implement control strategies

In rulemaking, OSHA must estimate the costs and benefits of standard
Risk Analysis

• Hazard Identification
  – The agent/exposure route
• Exposure Assessment
  – The dose received
• Dose-Response Assessment
  – The probability of infection
• Risk Characterization & Management
  – Is this a ’high’ risk, and how can it be reduced
Methodological Approach

1. Determine the number of occupational exposures
   – Number of people with the disease annually,
   – Healthcare utilization for the disease, and
   – Worker time-activity patterns

2. Determine the probability of infection during an exposure
   – Model pathogen transport to susceptible sites
   – Consider infection control interventions
   – Apply dose-response function

3. Determine the annual burden
   – Number of exposures for each worker
   – Calculate cumulative probability of infection
   – Calculate mean number of infections
   – Consider vaccination
# Annual Number of Exposures

<table>
<thead>
<tr>
<th>Setting</th>
<th>Tuberculosis</th>
<th>Influenza</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambulatory Care</td>
<td>108,000</td>
<td>31,500,000</td>
</tr>
<tr>
<td>Emergency Department</td>
<td>4,500</td>
<td>1,140,000</td>
</tr>
<tr>
<td>Hospitals</td>
<td>930,800</td>
<td>7,690,000</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>1,043,000</strong></td>
<td><strong>81,800,000</strong></td>
</tr>
</tbody>
</table>

Number of exposures and workers exposed varies among and by disease

~ 1 TB exposure on average, per year
~ 7 influenza exposure on average, per year

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Exposure Models

**Tuberculosis: Airborne**

1. Room Air
2. Exhausted
3. Lost Viability
4. Surfaces
5. HCW's Respiratory Tract

**Influenza: Droplet and Contact**

- State 1. Exhausted from Room
- State 3. Room Air Far-Field
- State 4. Room Air Near-Field
- State 5. Lost Viability
- State 6. Worker's Facial Portals
- State 7. Surfaces
- State 8. Worker's Hands
- State 2. Worker's Resp. Tract
Dose-Response Models

**Tuberculosis**

Two exponential models:
1. Wells-Riley ($\kappa = 1$)
2. Saini et al. ($\kappa = 0.38$)

**Influenza**

An exponential model:

- Alford ($\kappa = 0.18$)

A 3-parameter Beta-Poisson model:

- Watanabe et al. ($\alpha = 0.295$, $N_{50} = 4.42 \times 10^5$, and $\gamma = 1.07 \times 10^3$)
### Estimated Burden Hospitals/EDs

<table>
<thead>
<tr>
<th></th>
<th>Current Compliance</th>
<th>Full Compliance</th>
<th>Infections Avoided</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tuberculosis</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wells DR</td>
<td>5,013 (3,557, 6,285)</td>
<td>3,214 (2,273, 4,038)</td>
<td>~1800</td>
</tr>
<tr>
<td>Saini DR</td>
<td>2,146 (1,738-3,055)</td>
<td>1,480 (1,038, 1881)</td>
<td>~650</td>
</tr>
<tr>
<td><strong>Influenza</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alford DR</td>
<td>151,300 (115,300, 181,500)</td>
<td>101,700 (77,810, 121,900)</td>
<td>~50,000</td>
</tr>
<tr>
<td>Watanabe DR</td>
<td>34,150 (26,950, 40,900)</td>
<td>24,680 (19,650, 29,460)</td>
<td>~9,000</td>
</tr>
</tbody>
</table>

- Estimate 2.5% of occupational TB infections progress to disease
- About 40% of influenza infections are symptomatic
# Droplet vs. Airborne Transmission

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Droplet</th>
<th>Airborne</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance form source</td>
<td>&lt; 3 feet</td>
<td>A ‘long’ distance</td>
</tr>
<tr>
<td>Particle sizes</td>
<td>Large droplets ≥ 50 μm</td>
<td>Droplet nuclei &lt; 5μm</td>
</tr>
<tr>
<td>Exposure route</td>
<td>Projection onto facial mucous membranes</td>
<td>Inhalation</td>
</tr>
</tbody>
</table>

Does this distinction reflect the physical processes?
At time = 0, an aerosol is generated by person A. Person B receives droplet spray and intakes particles. Person C has no exposure.
At time = 1, the aerosol is dispersing, and many larger particles are settling. Person B inhales particles. Person C has no exposure.
Aerosol Exposures

At time = 2, the aerosol is dispersed, and many larger particles have deposited on the floor. Persons B and C inhale particles.

A       B       C
Aerosol Transmission of Ebola?

- Aerosol source: AGPs, vomiting, toilet flushing
- Susceptible sites: Epithelial tissue
UIC Epicenter for Prevention of Healthcare Associated Infections

School of Public Health
• Lisa Brosseau, ScD
• Adam Cox, BX
• Yuwa Edomwandae
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• Monica Sikka, MD
• Rachel Yudkowsky, MD

Alums:
Yu-min Su, MS
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Agnes Kalat, MPH
Kyle Cambell, BA
Exposures during Body Fluid Cleaning

Aim 1: Measure the magnitude and determinants of pathogen emission and fate in healthcare settings

• Recruited 7 Environmental Service Worker participants

• Four experimental conditions:
  – High or low viscosity fluorescent simulated vomitus
  – Spilled on side of gurney or floor
  – Total of 21 experimental trials and 9 blank trials

• Participants instructed to clean the vomitus using normal procedures:
  – Tools: Microfiber mops and towels (moist and dry), squirt bottle of disinfectant, disposable wipes, cleaning cart
  – PPE: gloves, shoe covers, facemasks, N95 FFR, safety glasses

What the Participant Can’t See
Participants clean using normal practices

Contacts recorded from videos
Experimental Trial 173A:
Low Viscosity Vomitus on Gurney
Before and After Cleaning

Cleaning is not always perfect!

High Viscosity Vomitus
Observed and quantified contamination on participants' bodies after cleaning.
Sioutas impactor samples particles from air and separates them into five size bins.

3M Sponge sick samples material from surfaces.
Environmental Surface Contacts

Variation is driven by the **individual**, not the trial condition or day
Total contacts per trial: 6-65, median 20
Self Contacts during Cleaning

Contacts to Body
• In 8 of 21 (38%) trials
  – Range 1-15 per trial
  – Range 3-122 per hour
• By 4 of 7 (57%) participants
• Driven by adjustments of clothing

Contacts to Face
• In 4 or 21 (19%) trials
  – Range 1-3 per trial
  – Range 4-20 per hour
• By 3 of 7 (42%) participants

Contacts with PPE Doffing: Pending
Body Contamination

• Gloves were always contaminated, most on the palm of the right hand
  – Not associated with contact patterns
• Bottom of shoe covers were always contaminated, sometimes the top
• Contamination on rest of the body was rare and associated with specific actions,
  – Kneeling
Residual Floor Contamination

<table>
<thead>
<tr>
<th>Extent of Floor Contamination After Cleaning</th>
<th>Percent (#)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worse</td>
<td>26% (5)</td>
</tr>
<tr>
<td>Partially Clean</td>
<td>32% (6)</td>
</tr>
<tr>
<td>Fully Clean</td>
<td>42% (8)</td>
</tr>
</tbody>
</table>

All participants removed material from the floor, but some increased the area contaminated.

**Why?**
- Underestimated area contaminated
- Didn’t clean under gurney
- Didn’t follow procedure

Good cleaning was associated with using towels to pick up bulk fluid.

Low viscosity trials had more fluorescein remaining on the floor.

Workers also contaminated the cleaning cart!
## Aerosol Formation

<table>
<thead>
<tr>
<th>Sampler Stage (Particle Size)</th>
<th>% Non-Detected</th>
<th>Mean Fluorescein Concentration Detected (μg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (&gt; 2.5 μm)</td>
<td>56%</td>
<td>0.04</td>
</tr>
<tr>
<td>B (1-2.5 μm)</td>
<td>63%</td>
<td>0.55</td>
</tr>
<tr>
<td>C (0.5-1 μm)</td>
<td>75%</td>
<td>0.71</td>
</tr>
<tr>
<td>D (0.25-0.5 μm)</td>
<td>81%</td>
<td>0.26</td>
</tr>
<tr>
<td>E (&lt; 0.25 μm)</td>
<td>69%</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Initial analysis of real-time particle concentration data similarly **do not indicate high levels of aerosol formation during cleaning**
Ongoing Research

Simulation Studies
- Bathing Patients
- Central Line Catheterization
- Intubation
- Endotracheal Suctioning
- Physical Exam/Vitals

Observation Studies
- Care delivery for patients with respiratory infections
- Bronchoscopy procedures
- Clinical microbiology laboratory work activities
- Measurements:
  - Pathogens in air/surfaces
  - Contact patterns
  - Workers/activities
  - Patient characteristics
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