Characterizing and Preventing Occupationally-Acquired Infectious Diseases

Rachael M. Jones, PhD, CIH
Associate Professor
Industrial Hygiene Program Director
School of Public Health
University of Illinois at Chicago

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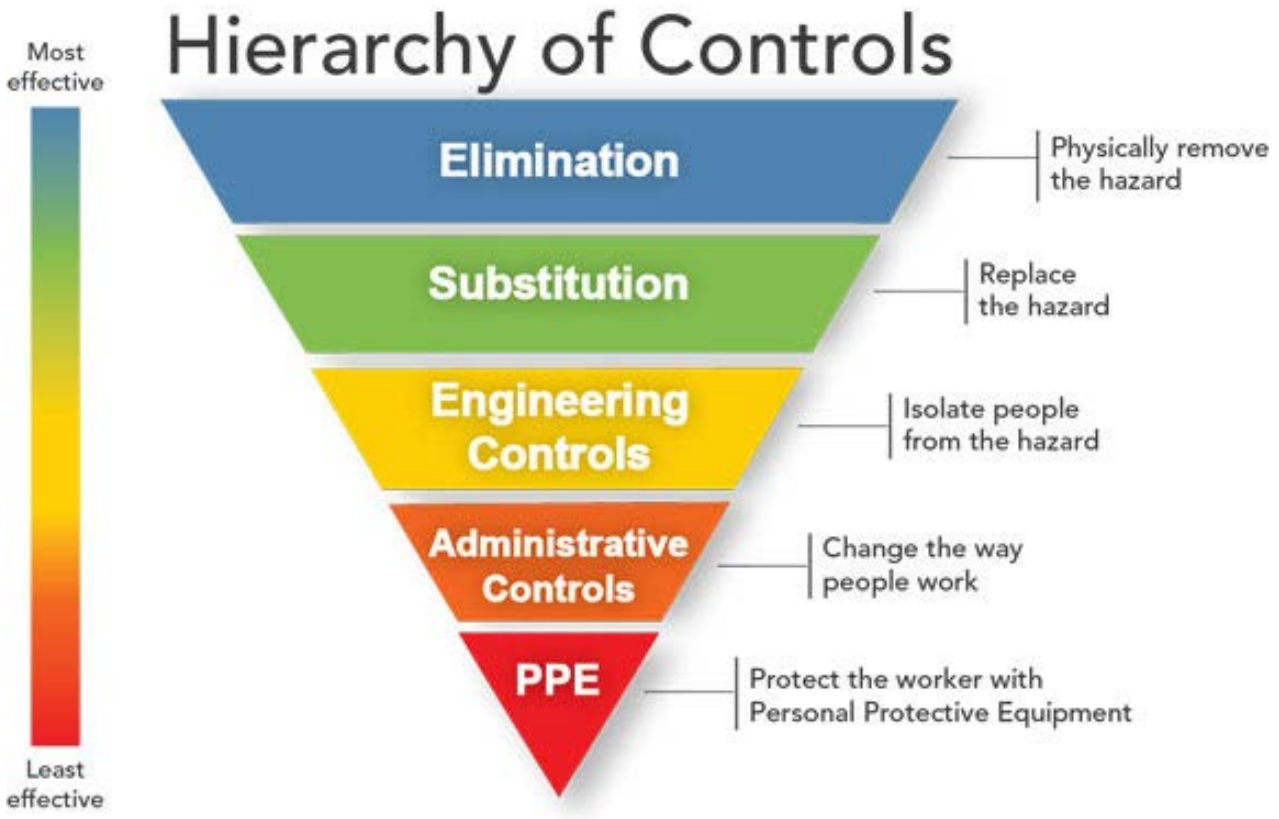
Evidence of the Burden in Healthcare

- Pulmonary tuberculosis
  - Surveillance
- Emerging infectious diseases
  - Novelty
  - Significant morbidity and mortality
- Crazy infections among laboratory workers

Endemic diseases? Not so much information.

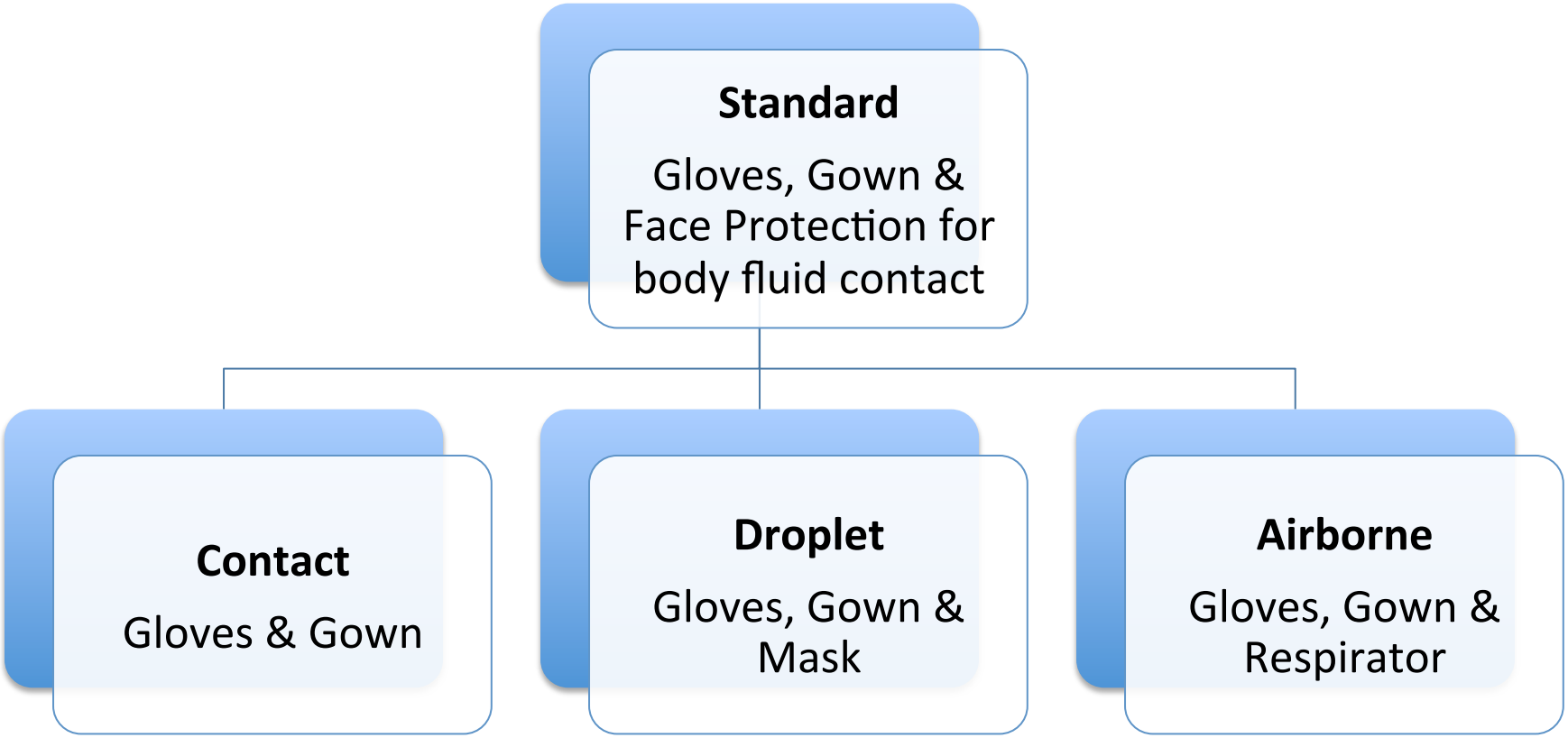
What Protects Healthcare Workers?



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

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

Personal Protective Equipment



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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

Setting	Tuberculosis	Influenza
Ambulatory Care	108,000	31,500,000
Emergency Department	4,500	1,140,000
Hospitals	930,800	7,690,000
TOTAL	**1,043,000**	**81,800,000**

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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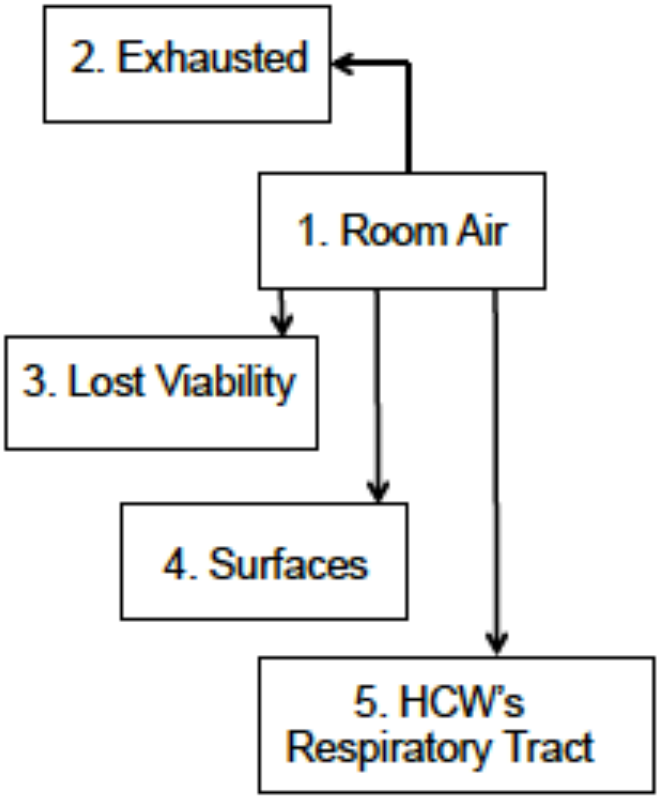
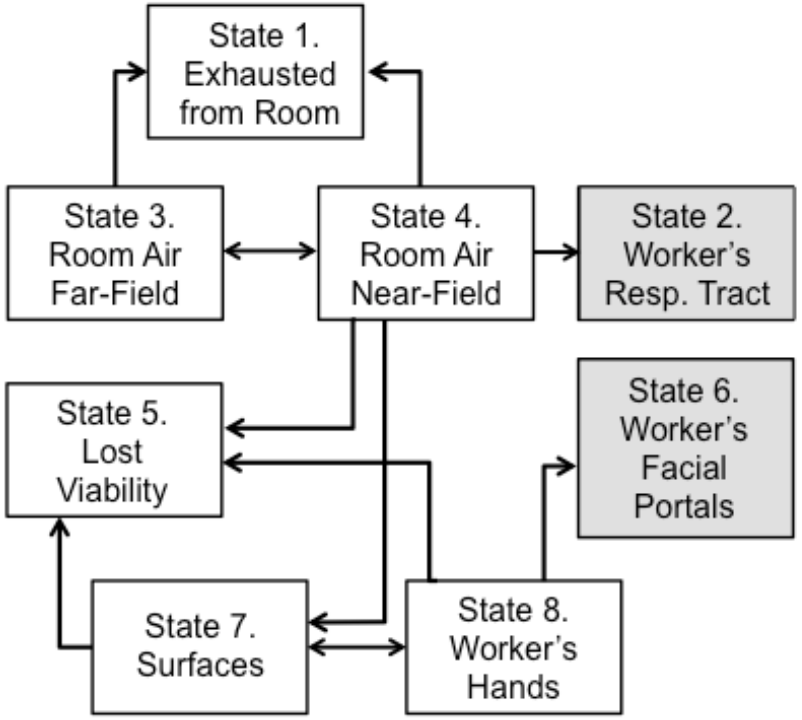
Jones and Xia (2016) Occupational exposures to influenza among healthcare workers in the United States. *JOEH 13: 213*
Jones (2017) Burden of occupationally-acquired pulmonary tuberculosis among healthcare workers in the United States*:* A Risk Analysis *Ann Work Exp Health.* 61: 141-151

Exposure Models

Tuberculosis: Airborne



Influenza: Droplet and Contact



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

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

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- Estimate 2.5% of occupational TB infections progress to disease
- About 40% of influenza infections are symptomatic

Droplet vs. Airborne Transmission

Characteristic	Droplet	Airborne
Distance form source	< 3 feet	A 'long' distance
Particle sizes	Large droplets ≥ 50 µm	Droplet nuclei < 5µm
Exposure route	Projection onto facial mucous membranes	Inhalation

Does this distinction reflect the physical processes?

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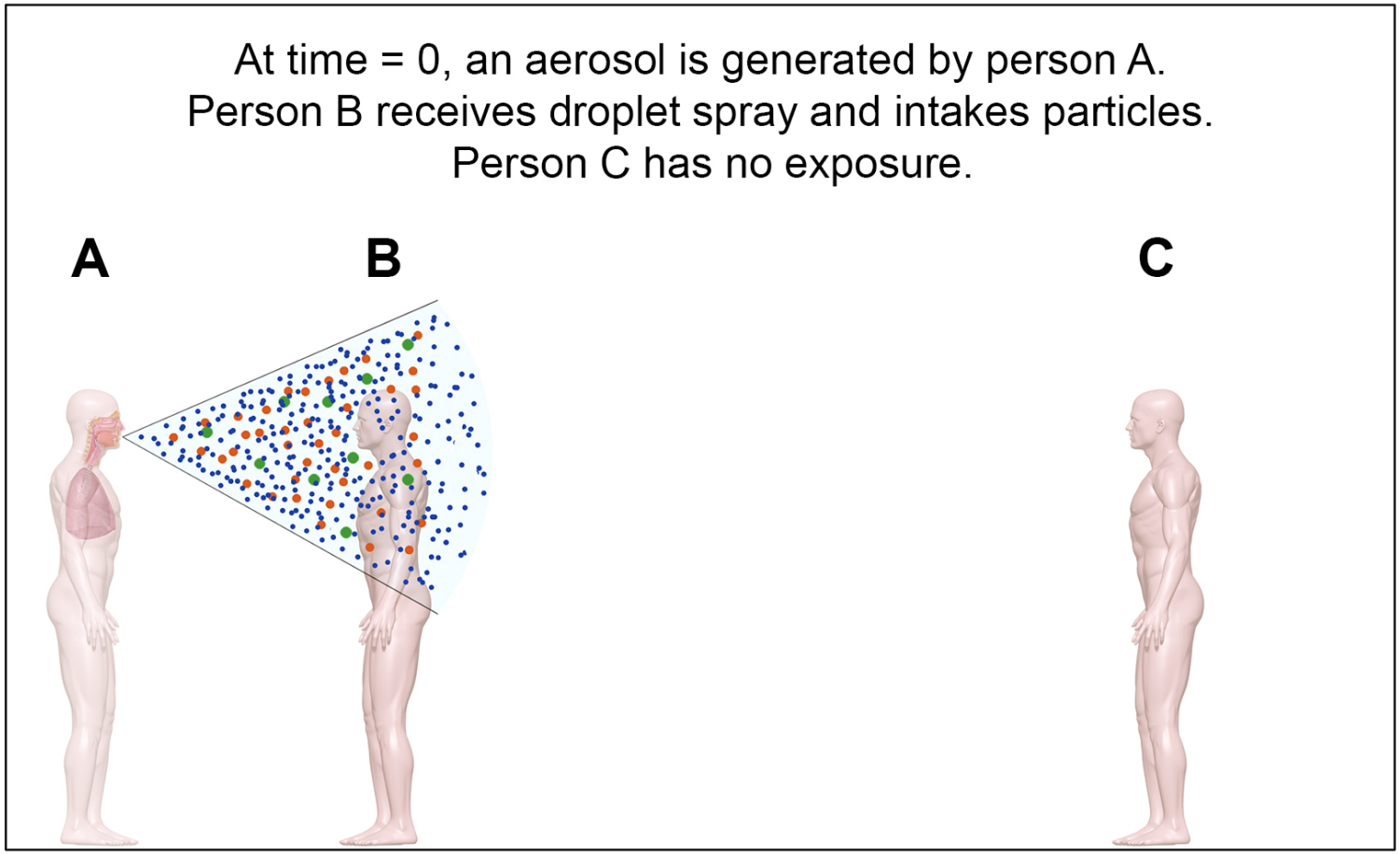
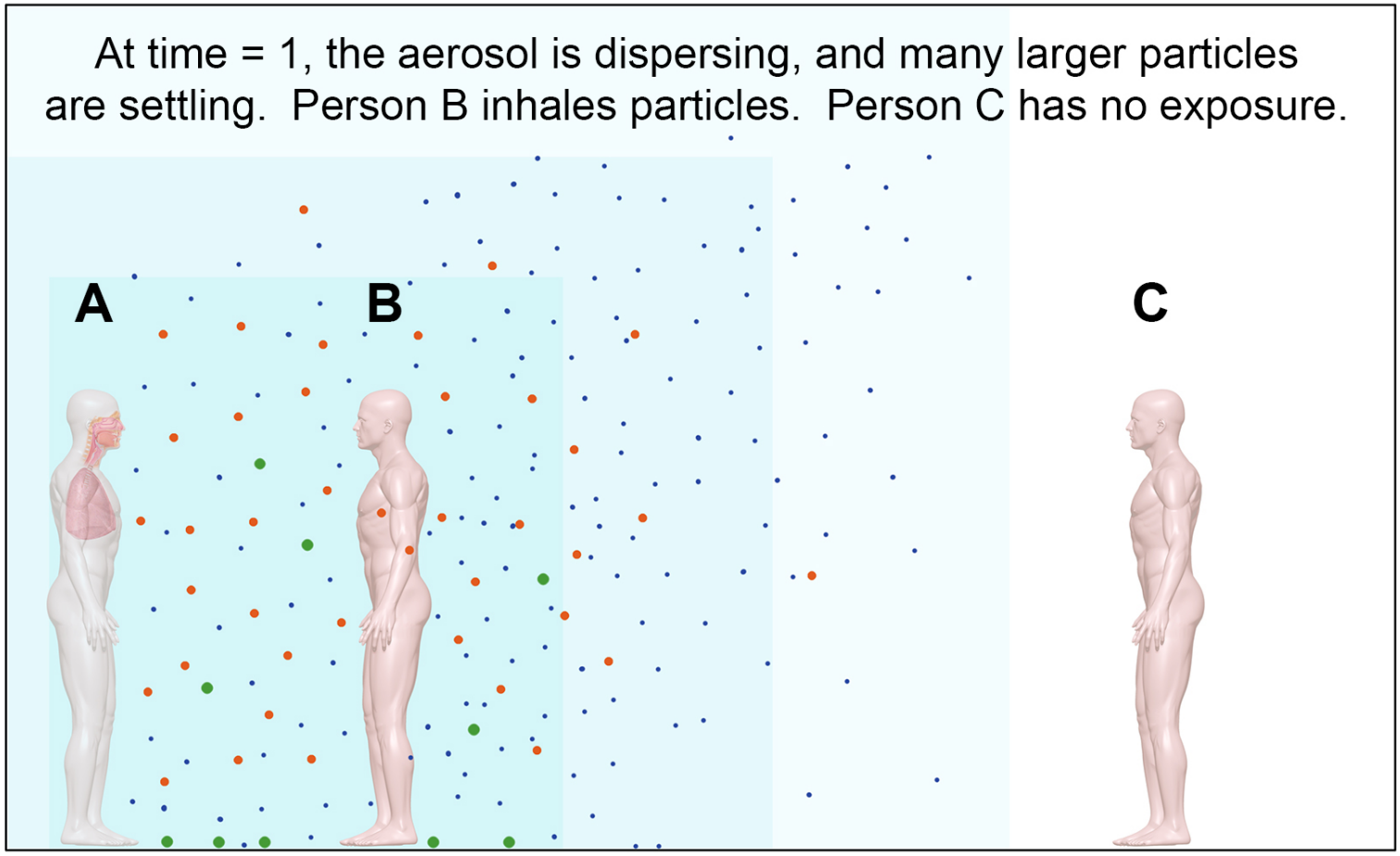
Aerosol Exposures

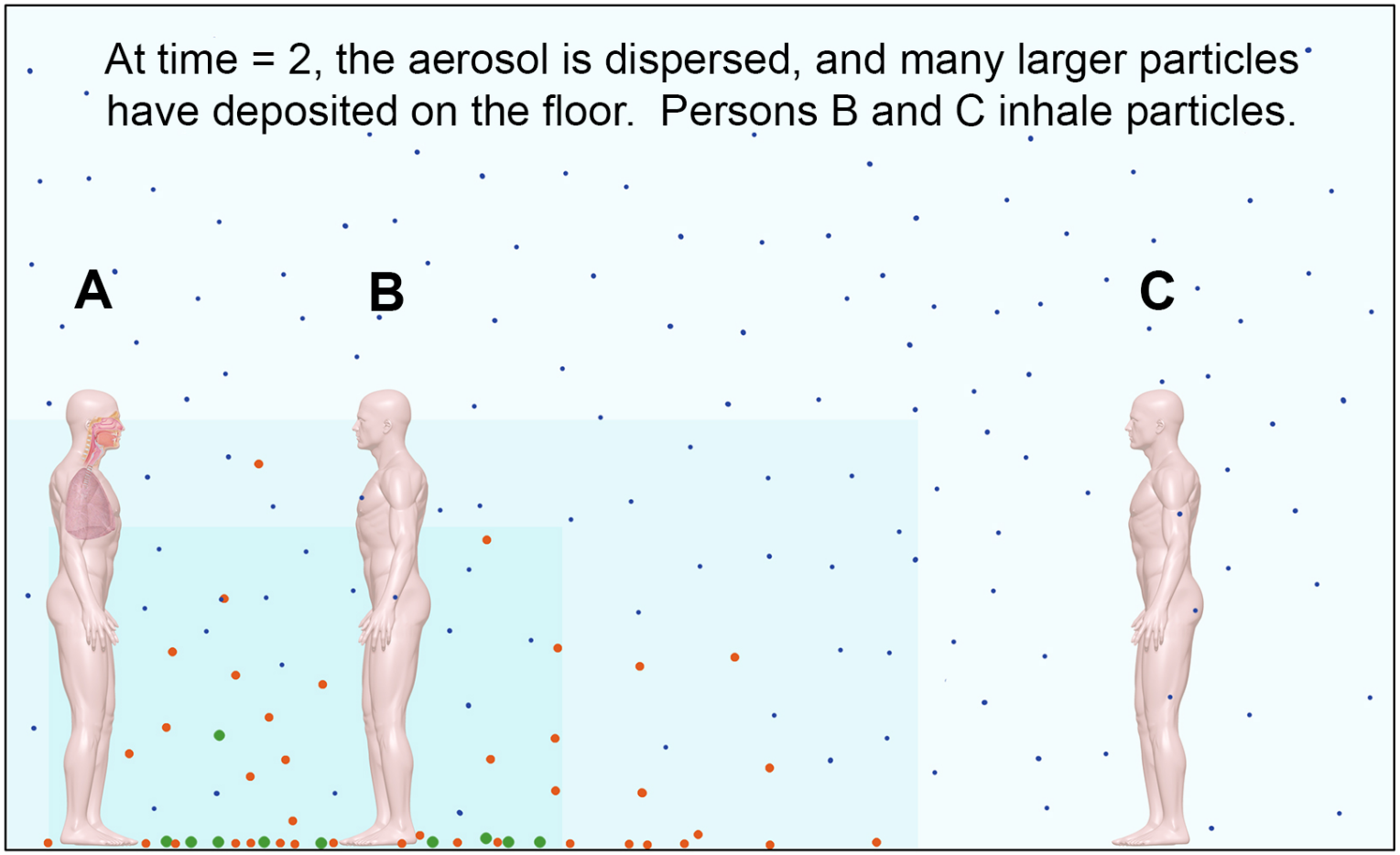


Jones and Brosseau (2015) Aerosol transmission of infectious disease *J Occup Environ Med* 57: 501-508
Figures by Carlyn Iverson

Aerosol Exposures



Aerosol Exposures



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
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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

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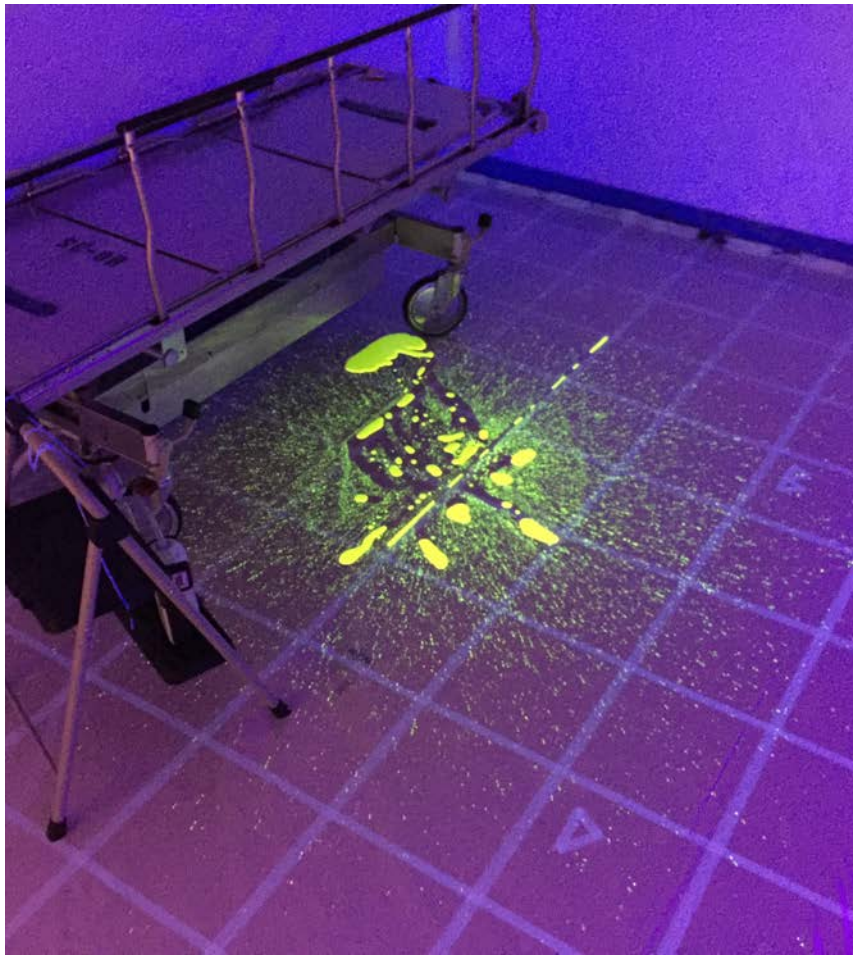
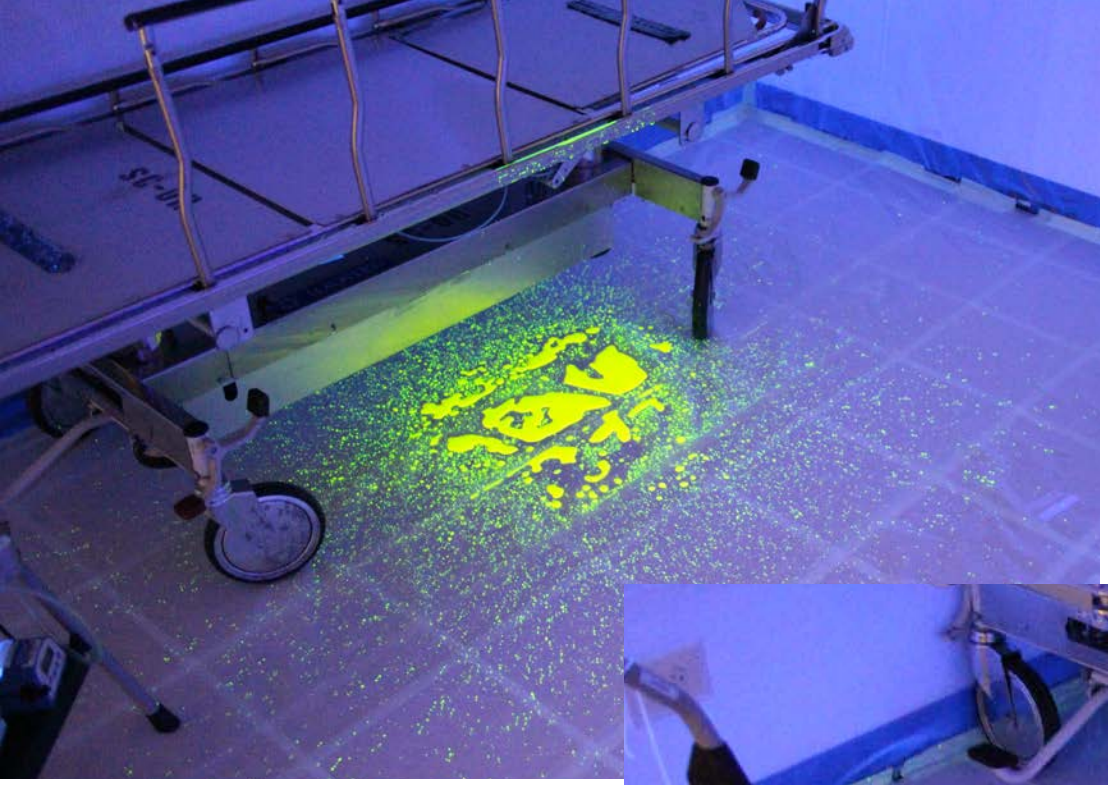
Su et al. (2017) *Am J Infect Control* doi: 10.1016/j.ajic.2017.07.005;
Phan et al (2017) *Am J Infect Control*. In press.

What the Participant Can't See



Participants clean using normal practices

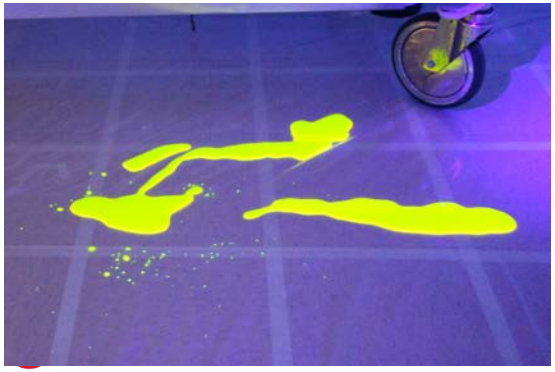
Contacts recorded from videos



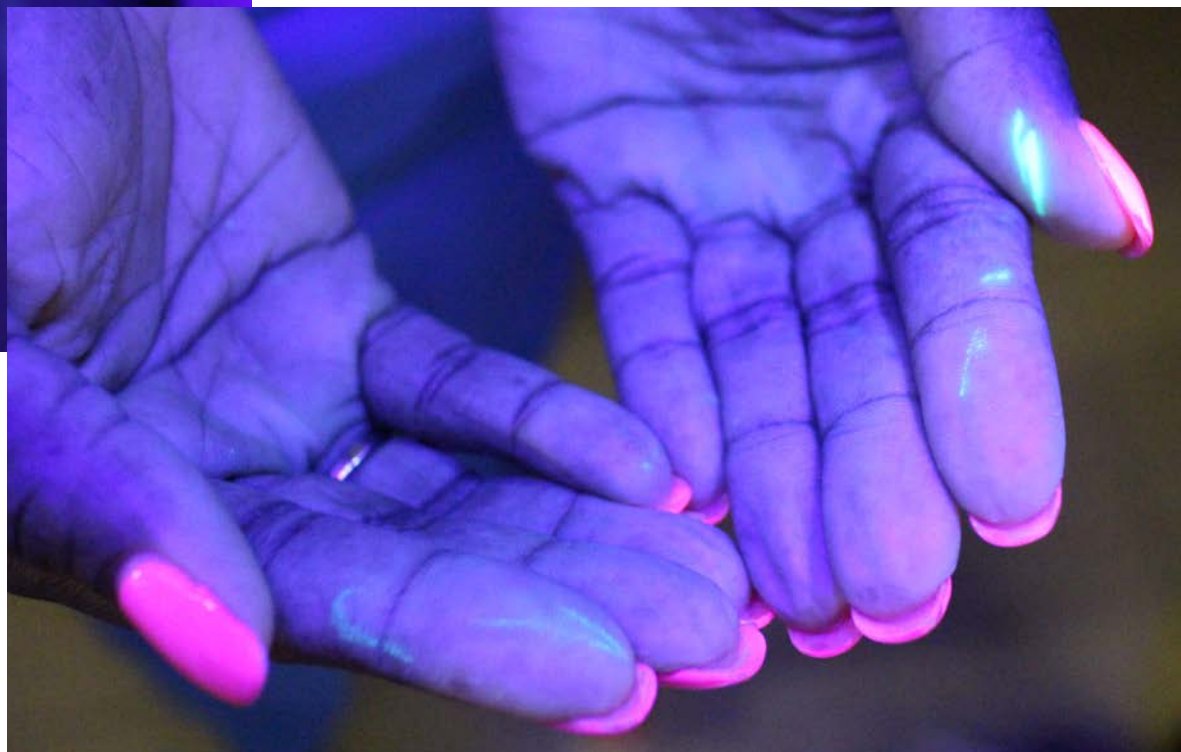
Experimental Trial 173A:
Low Viscosity Vomitus on Gurney
Before and After Cleaning

Cleaning is not always perfect!

High Viscosity Vomitus



Observed and quantified contamination on participants bodies after cleaning



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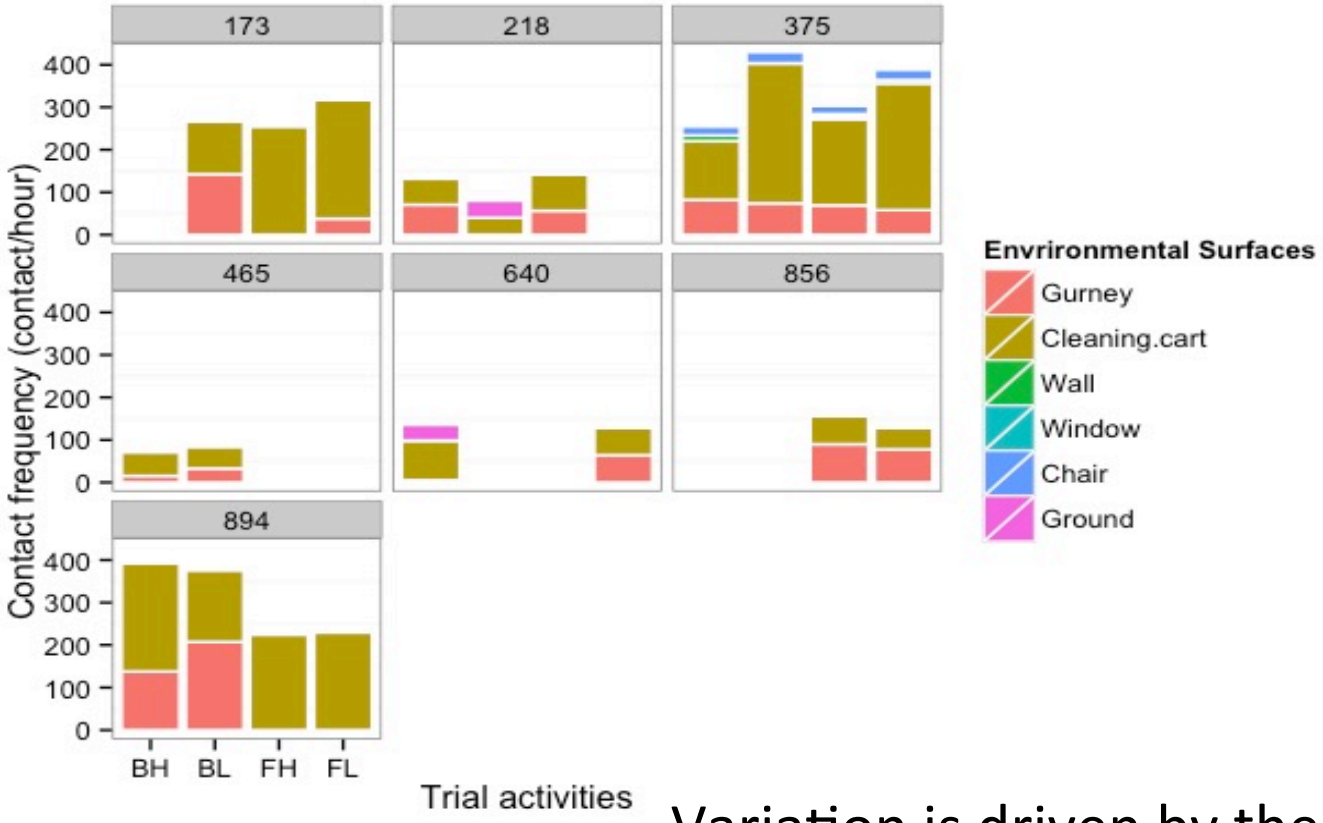
Measurement Devices

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

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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

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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

Extent of Floor Contamination After Cleaning	Percent (#)
Worse	26% (5)
Partially Clean	32% (6)
Fully Clean	42% (8)

Low viscosity trials had more fluorescein remaining on the floor

- 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

Workers also contaminated the cleaning cart!

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Aerosol Formation

Sampler Stage (Particle Size)	% Non-Detected	Mean Fluorescein Concentration Detected (µg/m³)
A (> 2.5µm)	56%	0.04
B (1-2.5 µm)	63%	0.55
C (0.5-1 µm)	75%	0.71
D (0.25-0.5 µm)	81%	0.26
E (< 0.25 µm)	69%	0.03

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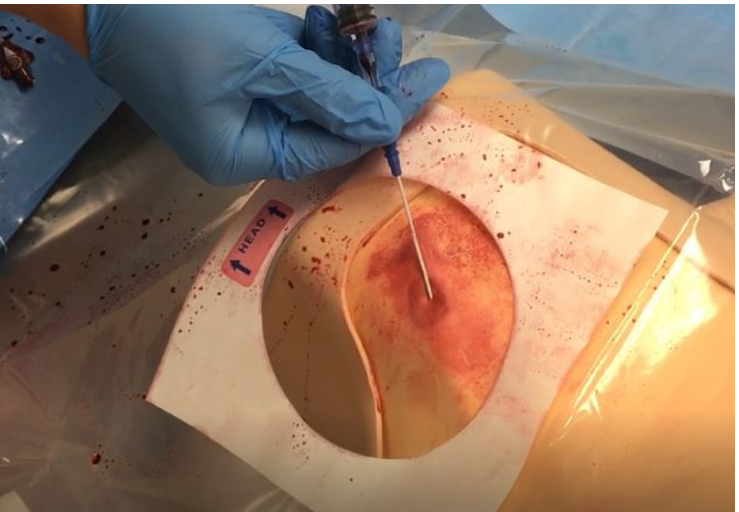
Initial analysis of real-time particle concentration data similarly do not indicate high levels of aerosol formation during cleaning

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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