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# ICU Design and Infection Prevention

*Annual Board Review and Update in Pulmonary and Critical Care Medicine*

November 2022

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Hospital Epidemiologist, Brigham and Women's Hospital

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# Disclosures

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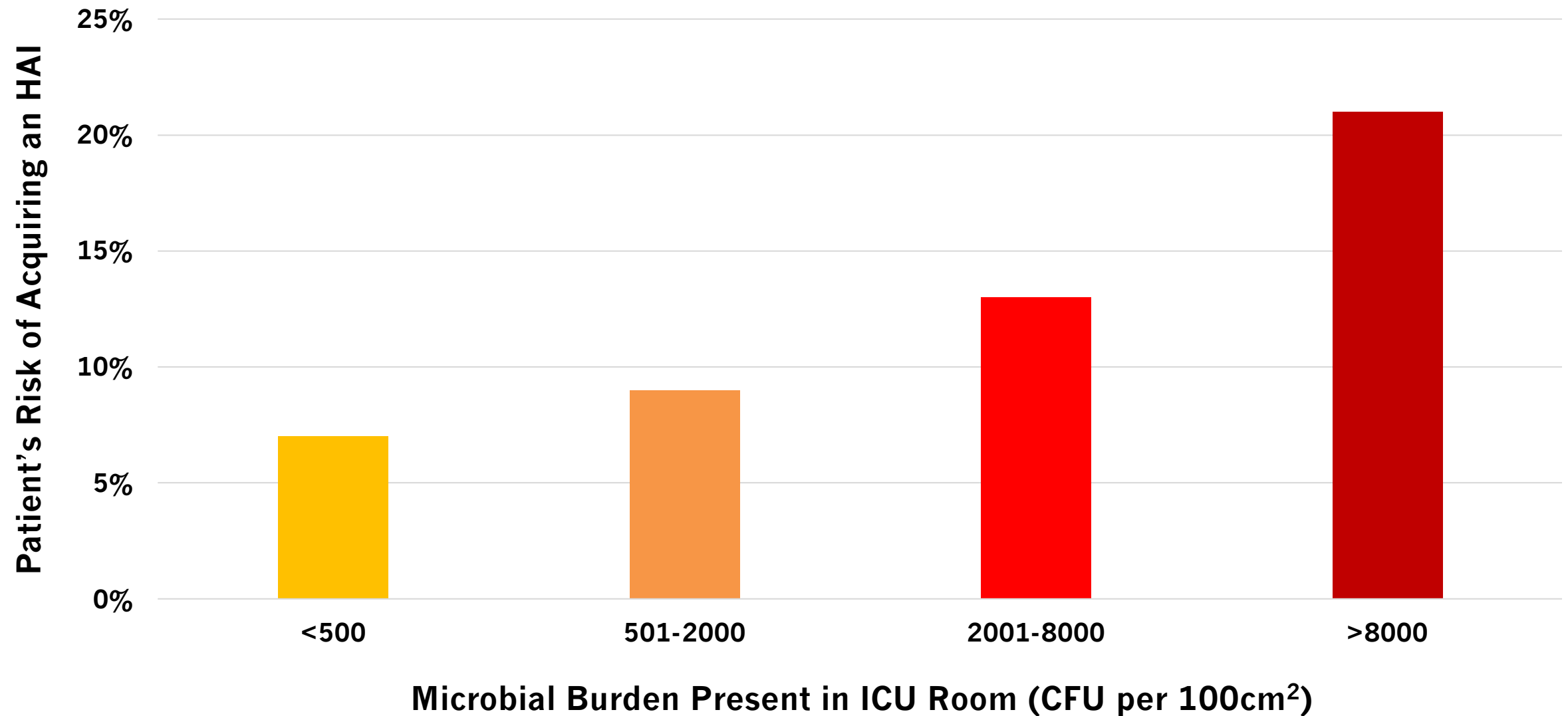
- **Grant funding**
  - US Centers for Disease Control and Prevention (CDC)
  - Agency for Healthcare Research and Quality (AHRQ)
  - Massachusetts Department of Public Health
- **Royalties**
  - UpToDate, Inc.



# Surfaces

<https://i.pinimg.com/originals/11/7f/0a/117f0a36c2cafcfa337cbd8b82979a73.jpg>

# Environmental Contamination and HAI Risk



# Odds of Pathogen Acquisition Based on Prior Room Occupant's Colonization Status

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**MRSA**

**Risk**

**1.4 to 2.9**

**Times  
Higher**

**VRE**

**Risk**

**1.6 to 2.4**

**Times  
Higher**

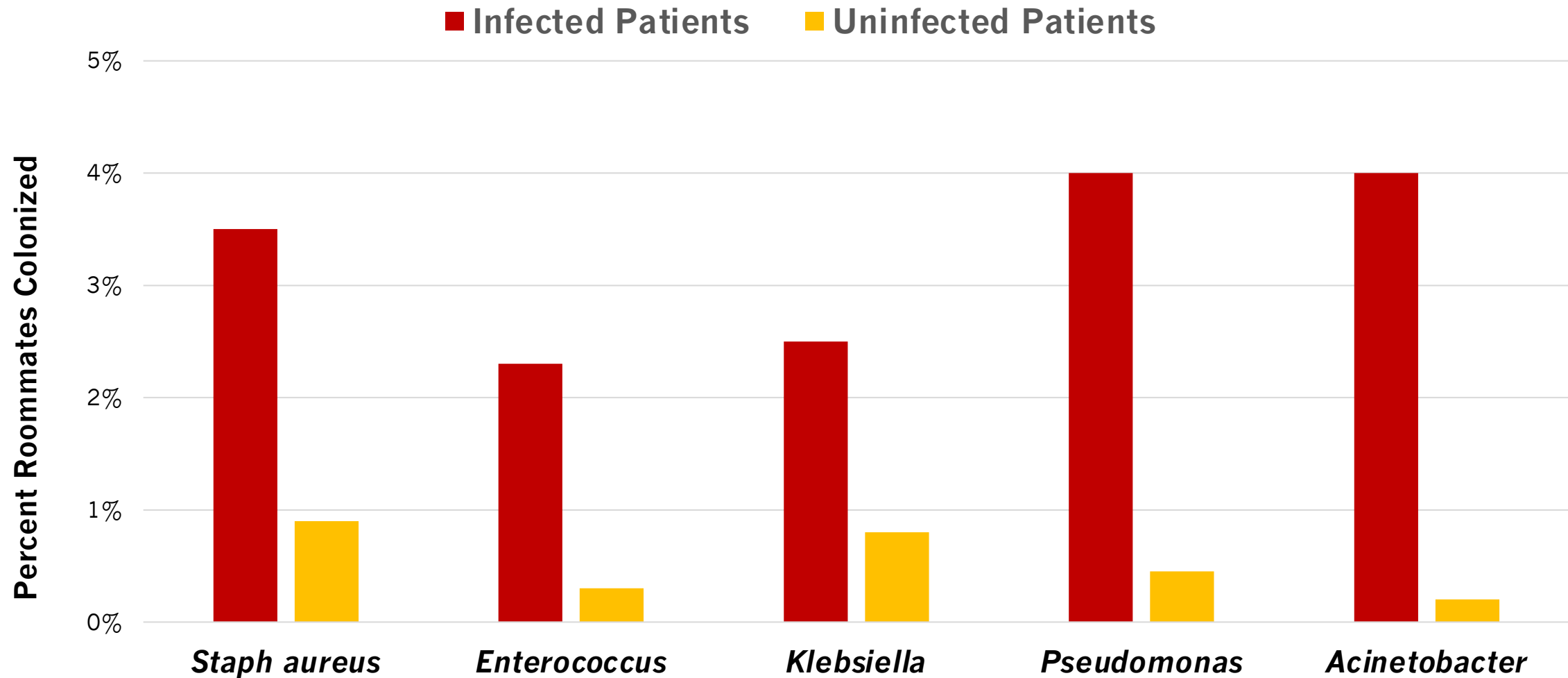
***C.difficile***

**Risk**

**2.6**

**Times  
Higher**

# Risk of Pathogen Acquisition if Roommate Colonized







THE MONTREAL GENERAL HOSPITAL



# Benefits of Moving to a New ICU with Single Rooms

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*Comparison of pathogen acquisition rates in Montreal General Hospital after moving from an old ICU with 2 rooms with 12 beds each to a new ICU with 24 private rooms, 2000-2005*

**MRSA**

 **47%**

**C.difficile**

 **43%**

**Acinetobacter**

 **53%**



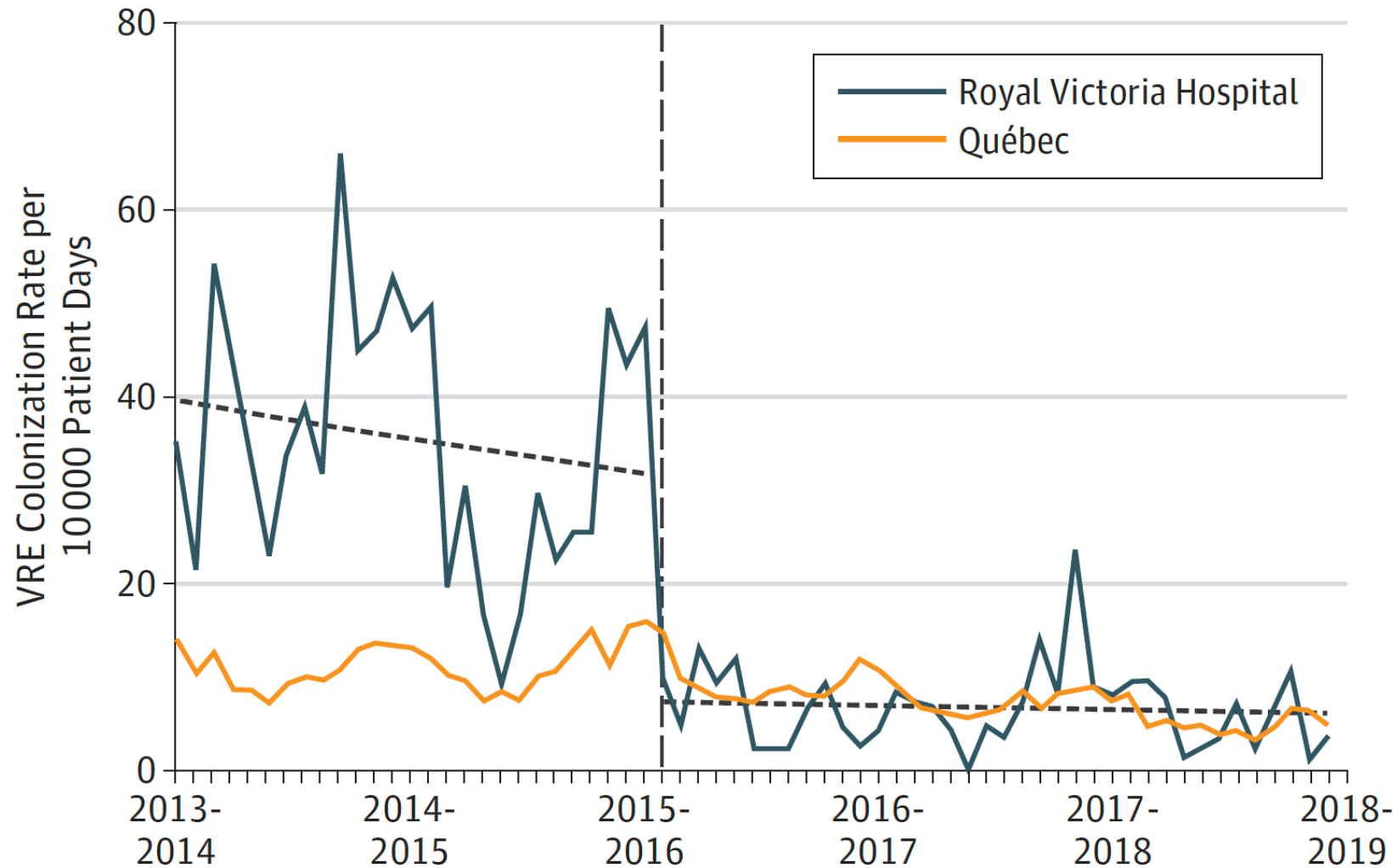
[www.mtlblog.com/news/montreals-old-royal-victoria-hospital-will-be-transformed-into-public-space](http://www.mtlblog.com/news/montreals-old-royal-victoria-hospital-will-be-transformed-into-public-space)



[groupeagf.com/en/steel/projects/mcgill-university-health-centre-glen-site-much](https://groupeagf.com/en/steel/projects/mcgill-university-health-centre-glen-site-much)

# Nosocomial **VRE** After Move to New Hospital with 100% Private Rooms

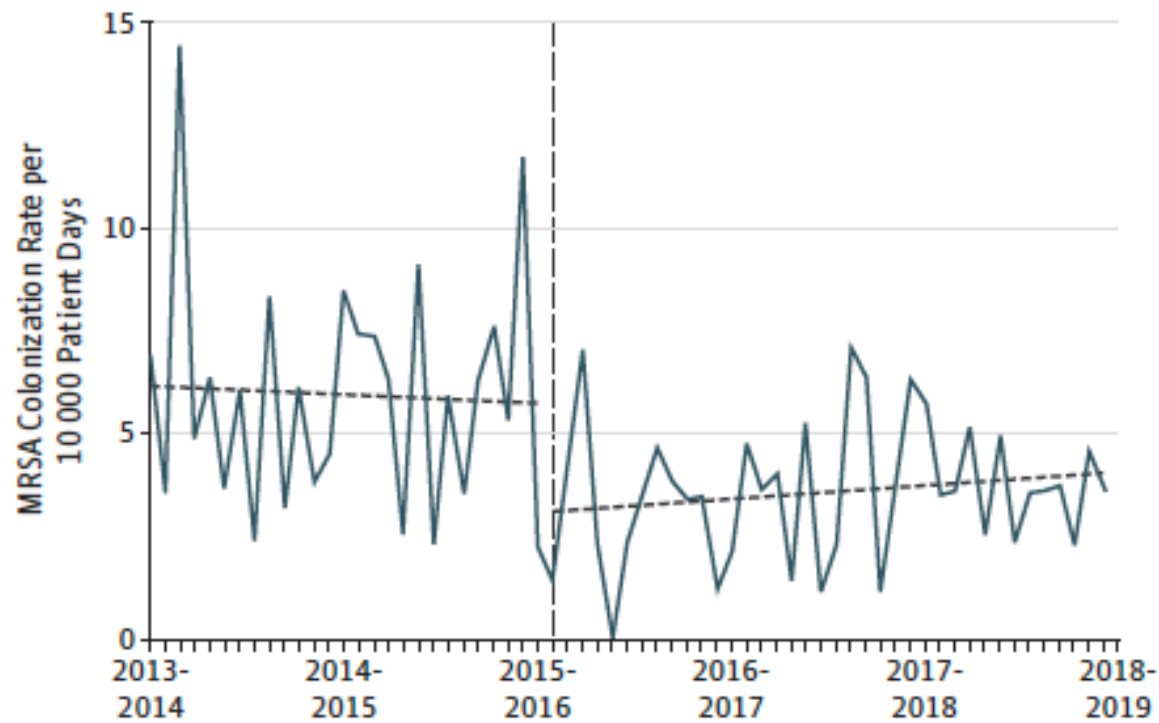
*Royal Victoria Hospital, Montreal*



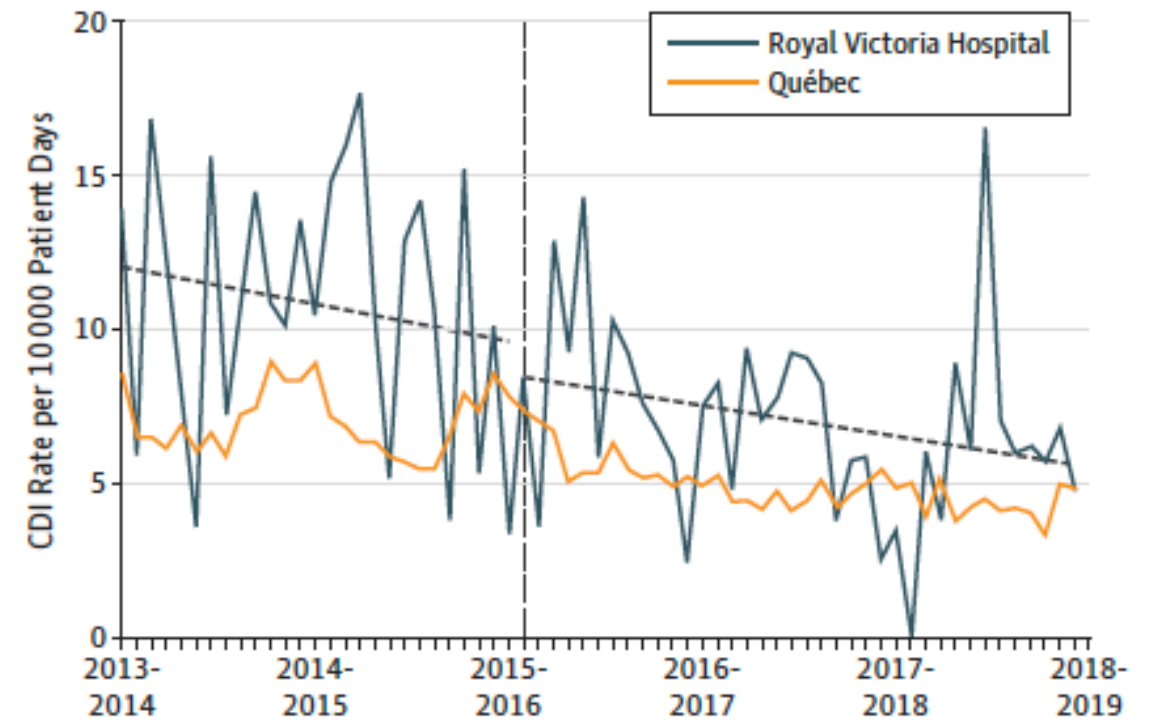
# Nosocomial MRSA & C.diff After Move to New Hospital with 100% Private Rooms

*Royal Victoria Hospital, Montreal*

MRSA

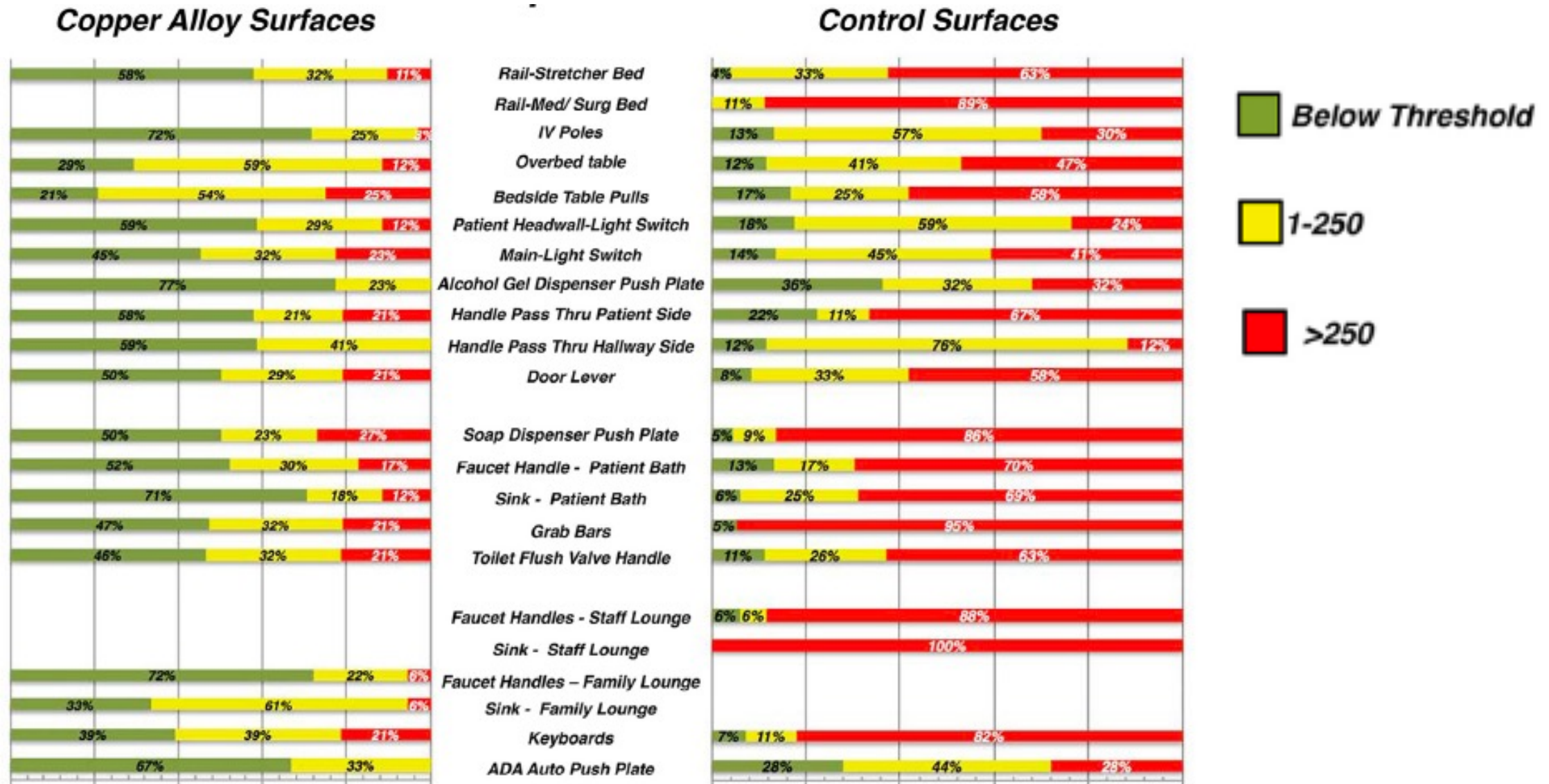


*C. difficile*

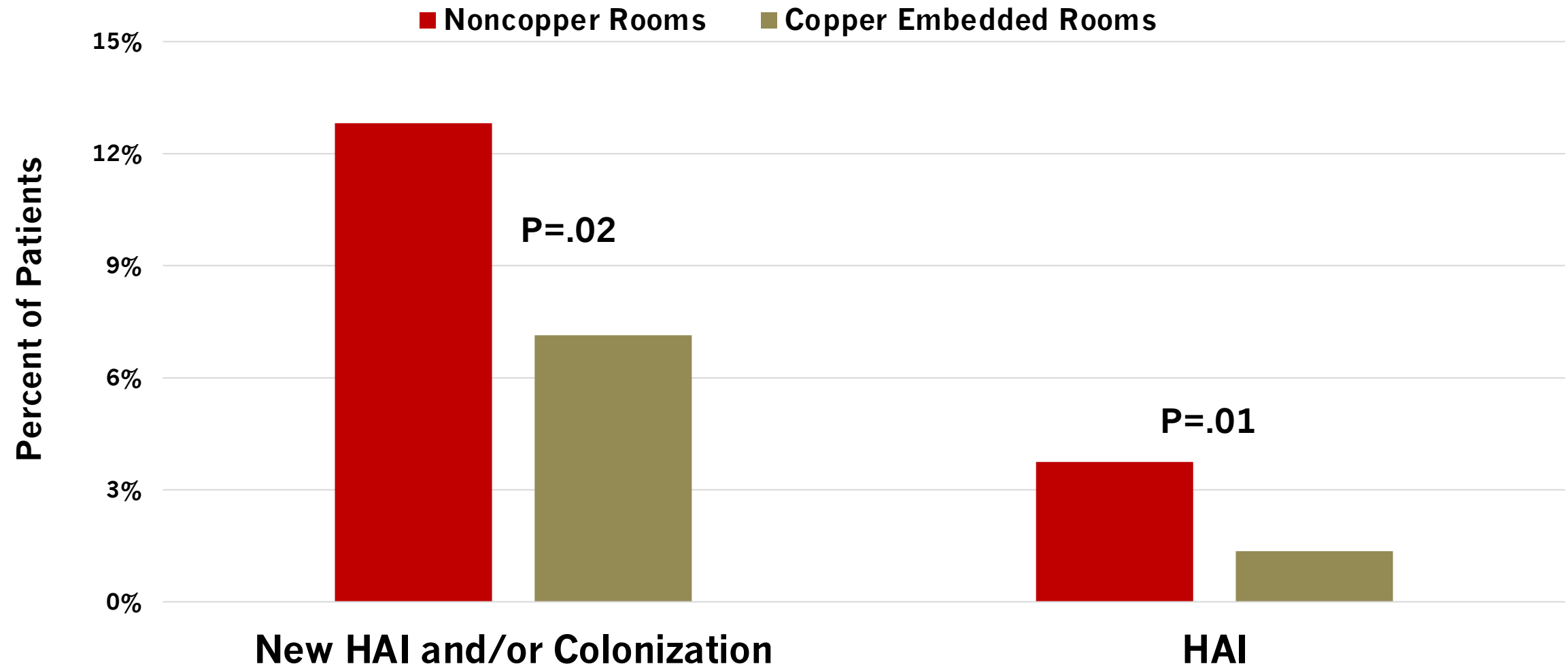




# Copper Impregnated Surfaces and Bacterial Contamination Rates



# Impact of Copper Surfaces on HAIs



Air



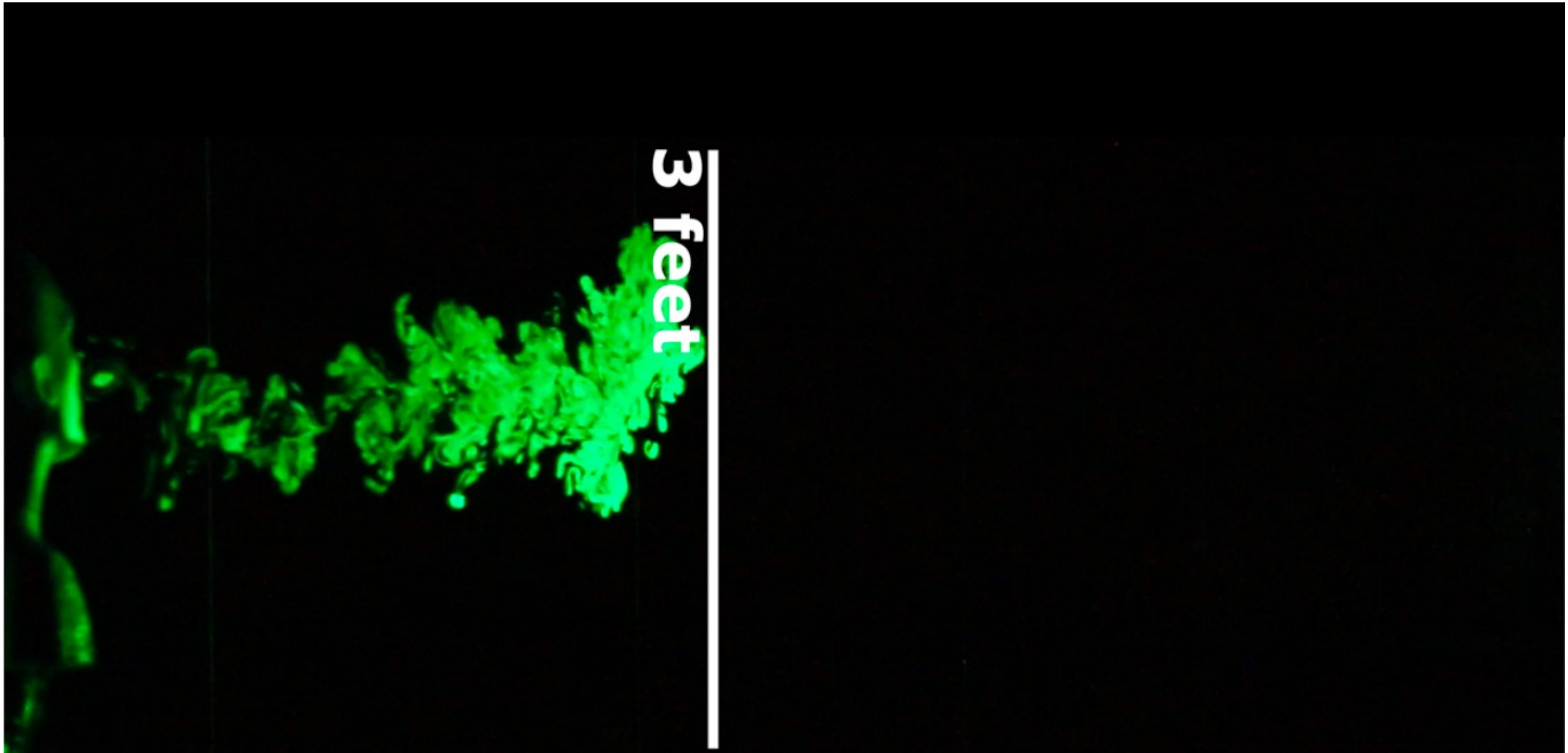


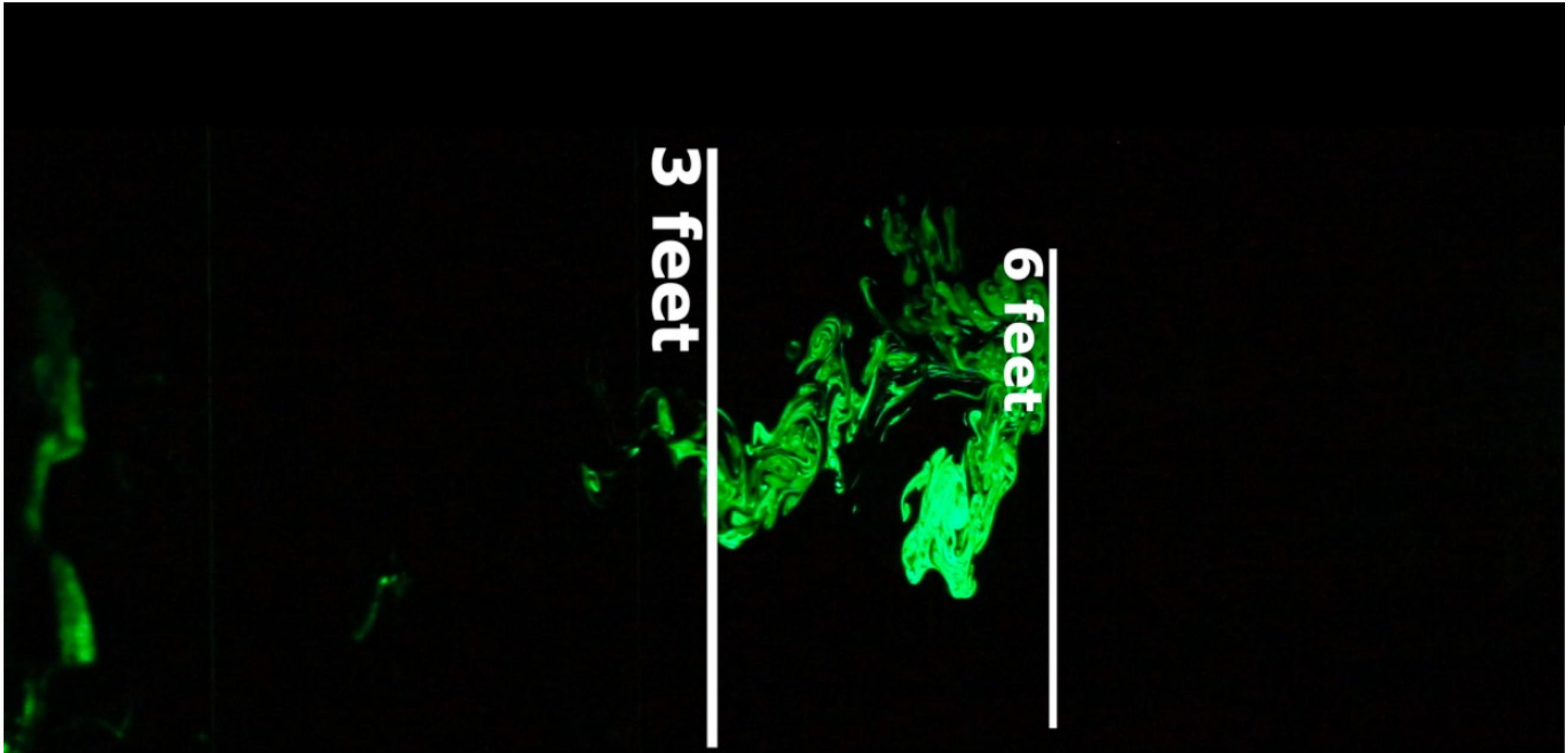
# Respiratory Viruses Recovered from Air Samples in Clinics and Hospitals

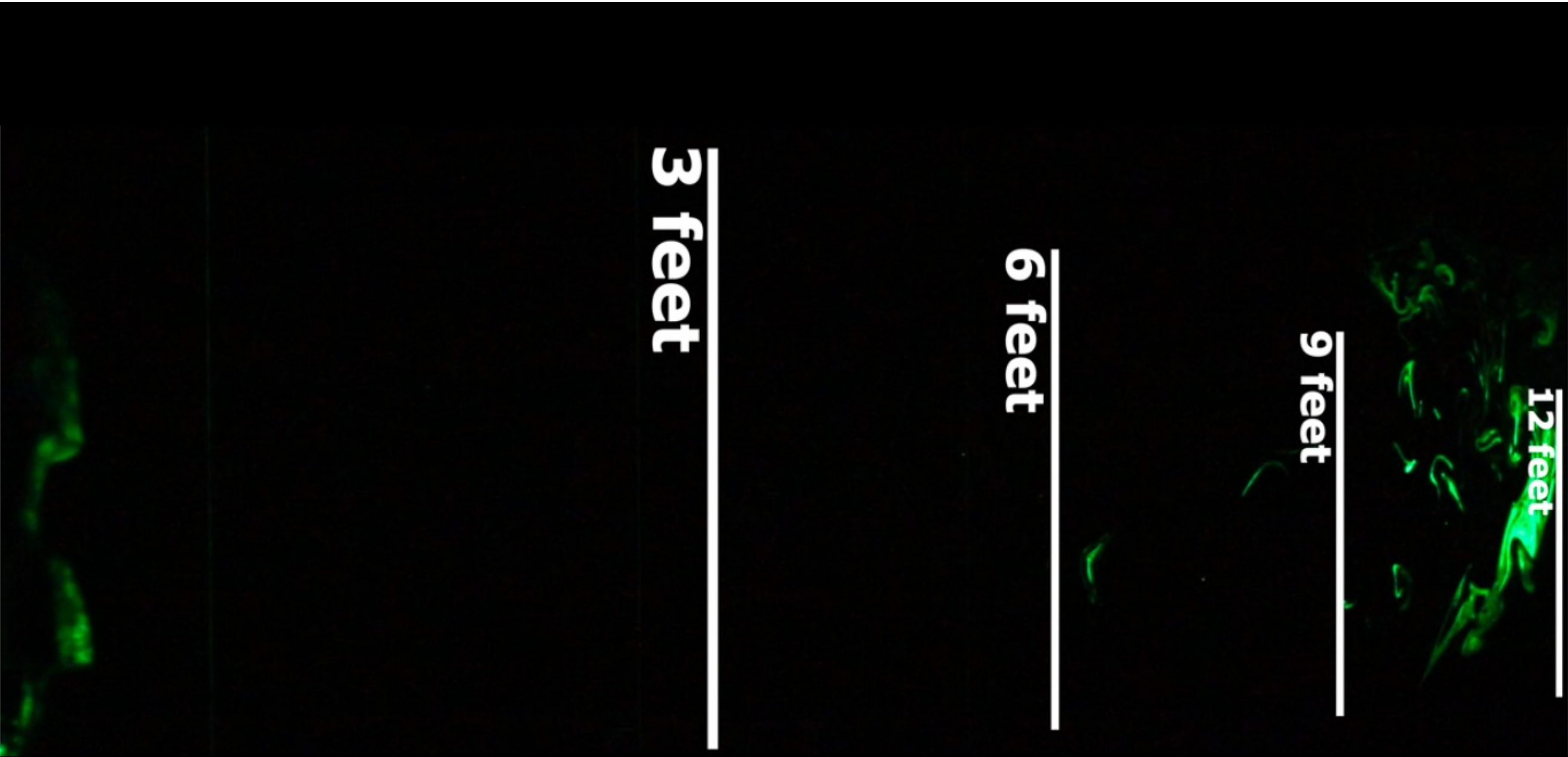
**SARS-CoV-2**  
**Influenza**  
**RSV**  
**Rhinovirus**  
**MERS...**

Wong, *Infection Control Hospital Epidemiol* 2022; PMID 35811422  
Birghand, *JAMA Network Open* 2020;3:e2033232  
Phan, *Infect Control Hospital Epidemiol* 2020;41:259-266  
Kim, *Clin Infect Dis* 2016;63:363-9

photo: [phil.cdc.gov/phil/details.asp?pid=11162](http://phil.cdc.gov/phil/details.asp?pid=11162)







# Transmission Risk in Shared Hospital Rooms



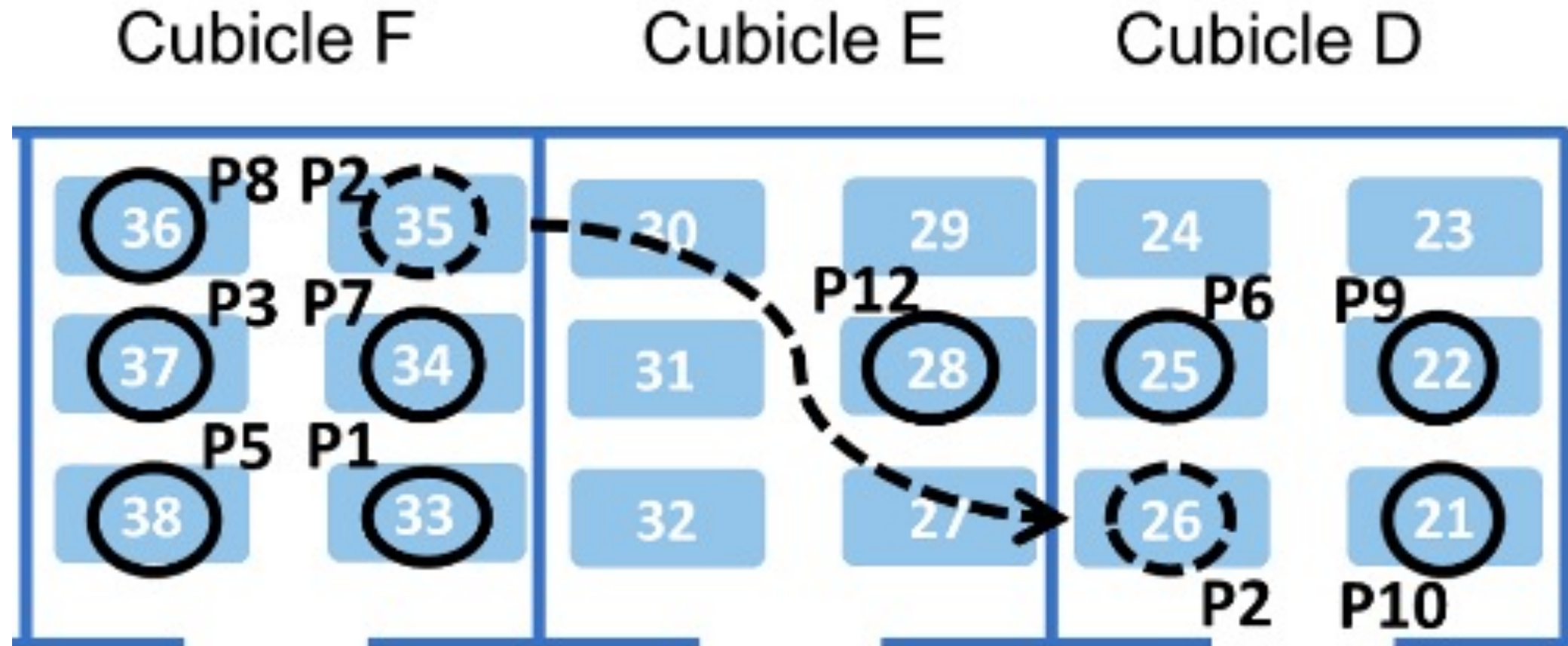
[irishtimes.com/life-and-style/health-family/a-private-room-in-a-hospital-may-not-always-be-the-best-choice-1.4099197](https://www.irishtimes.com/life-and-style/health-family/a-private-room-in-a-hospital-may-not-always-be-the-best-choice-1.4099197)

**39% of exposed roommates  
were infected**

- Brigham & Women's Hospital, Sept 2020 - April 2021
- 25 patients diagnosed with SARS-CoV-2 after admission to a shared room
- 31 potentially exposed roommates
- Roommates ~7 feet apart and separated by a curtain
- $\geq 6$  air changes per hour
- Median duration of exposure: 18 hours (IQR 12-47 hours)
- 12/31 (39%) roommates infected

# SARS-CoV-2 Clusters in Multibed Wards

*United Christian Hospital, Hong Kong, Dec 2020, 6 Air Changes per Hour*

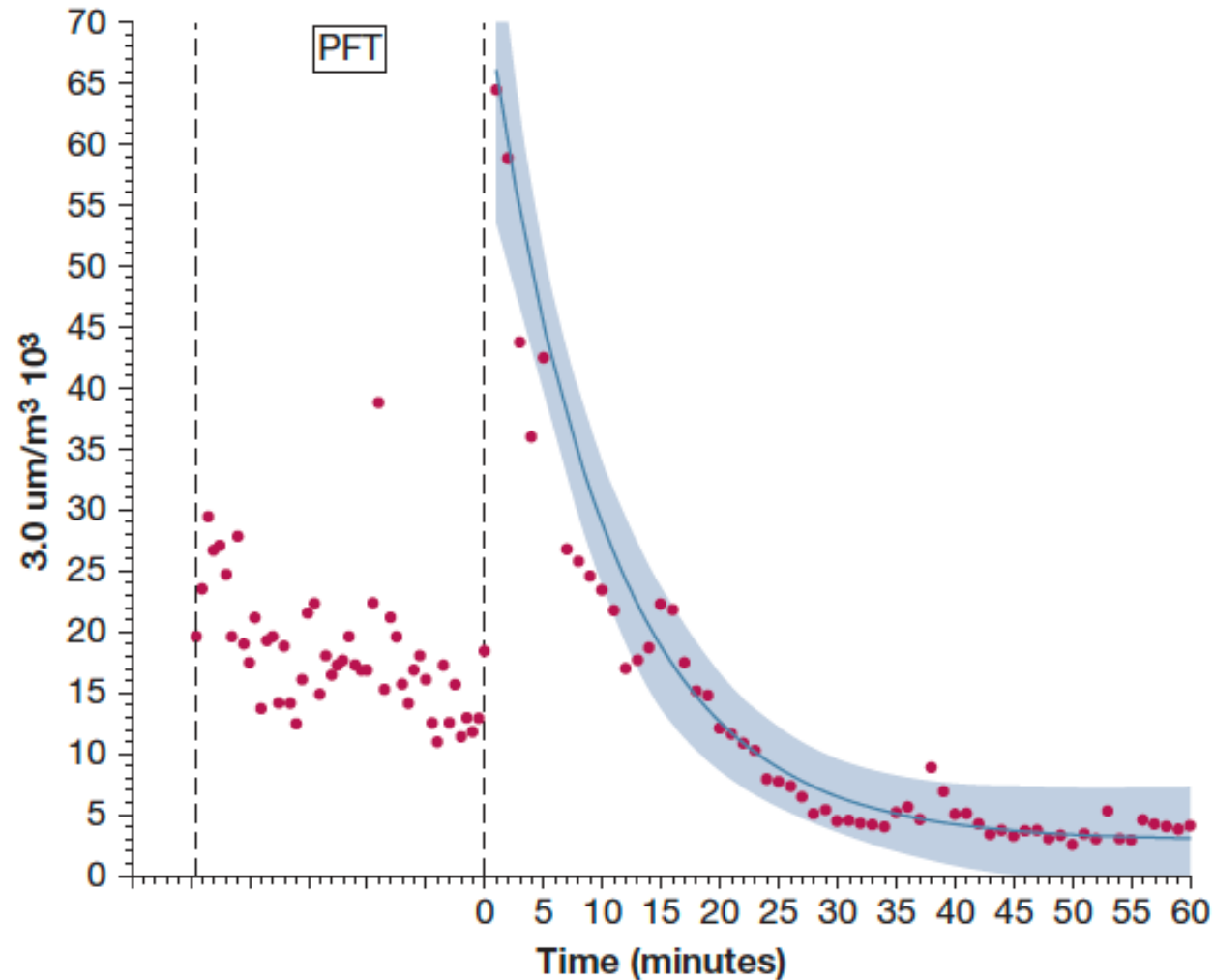


**AIIIR**

Airborne Infection Isolation Rooms

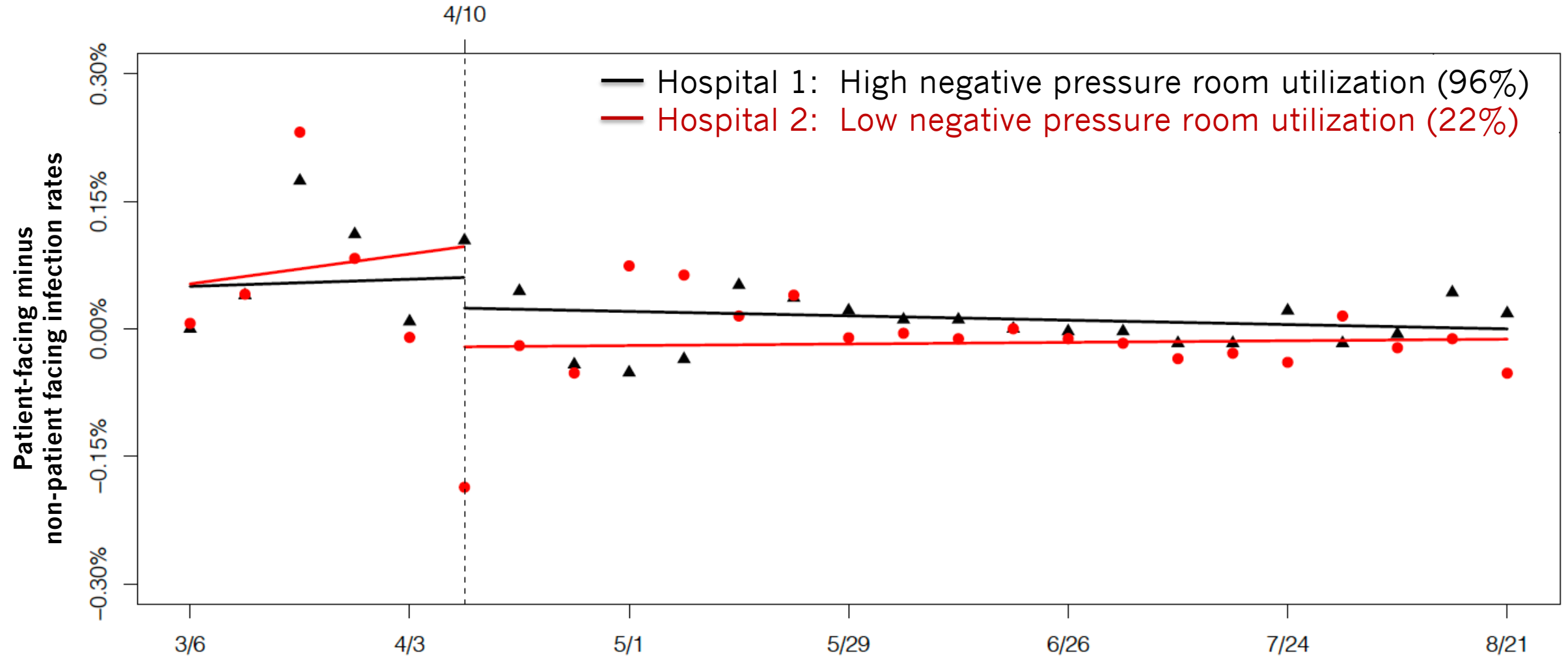
# Aerosols Rapidly Dissipate in Well Ventilated Spaces

*Aerosol quantification before, during, and after forced expiration, clinic with 5 air changes per hour*



# High vs Low Negative Pressure Room Utilization & HCW Infections

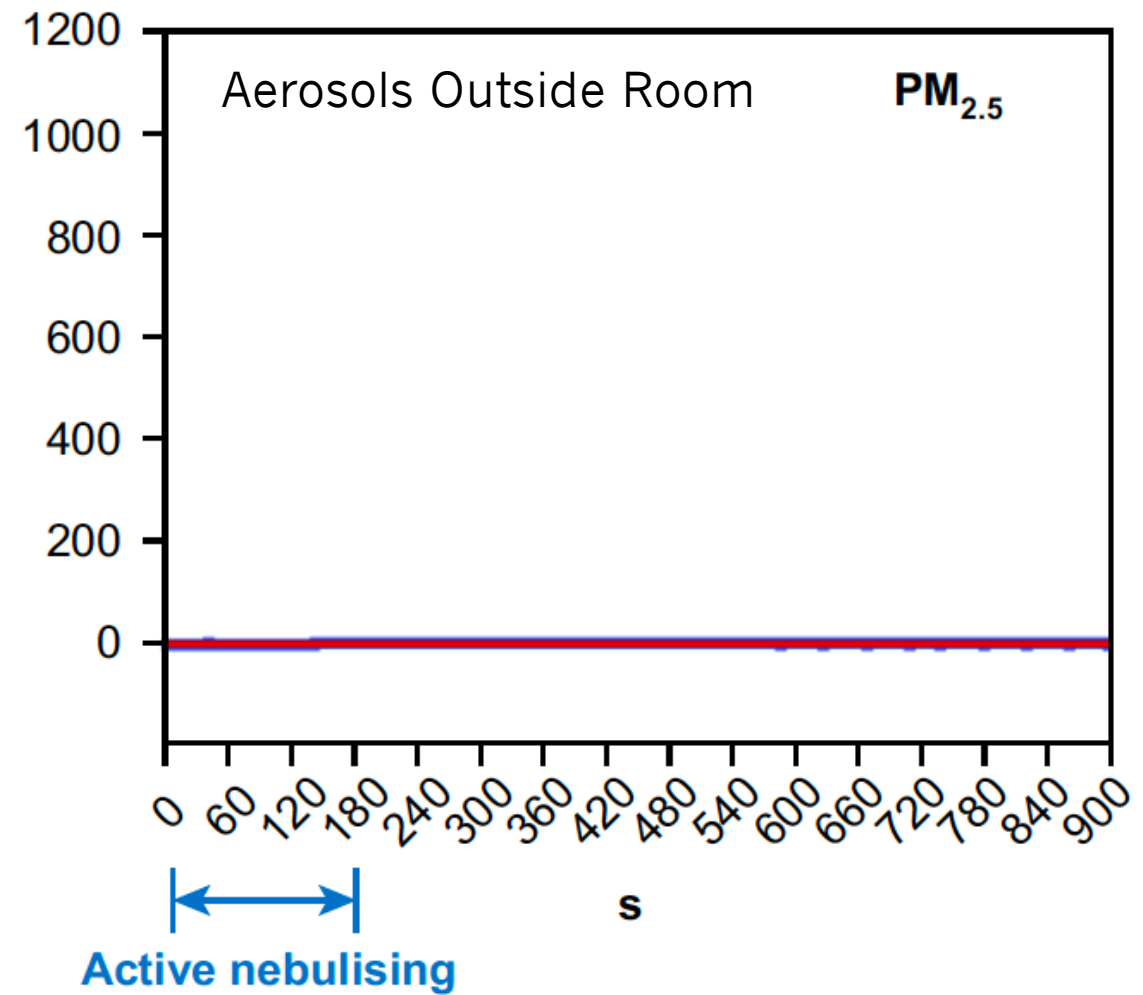
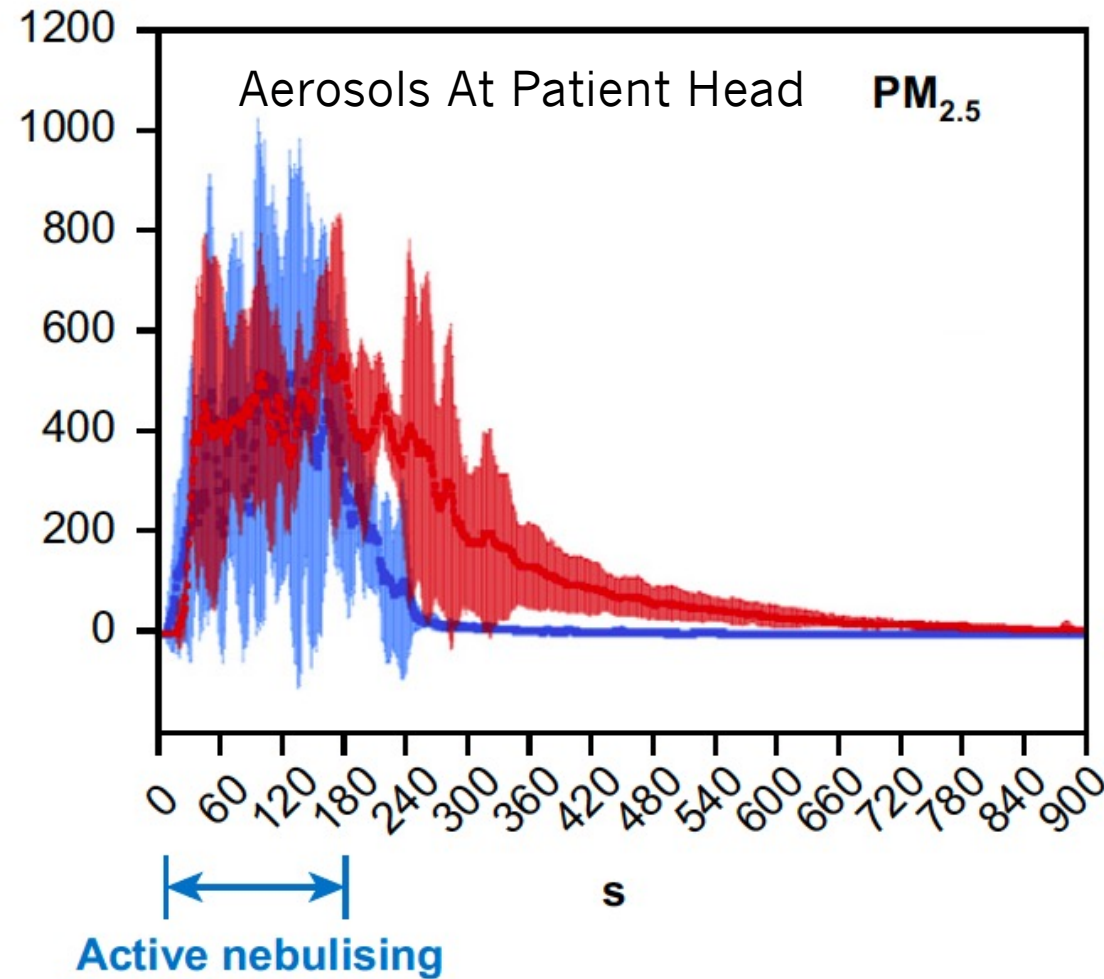
Excess infections in patient-facing vs non-patient-facing employees in a hospital with high negative pressure room utilization (96% of Covid patient-days) vs a hospital with low negative pressure room utilization (22% of Covid patient-days)



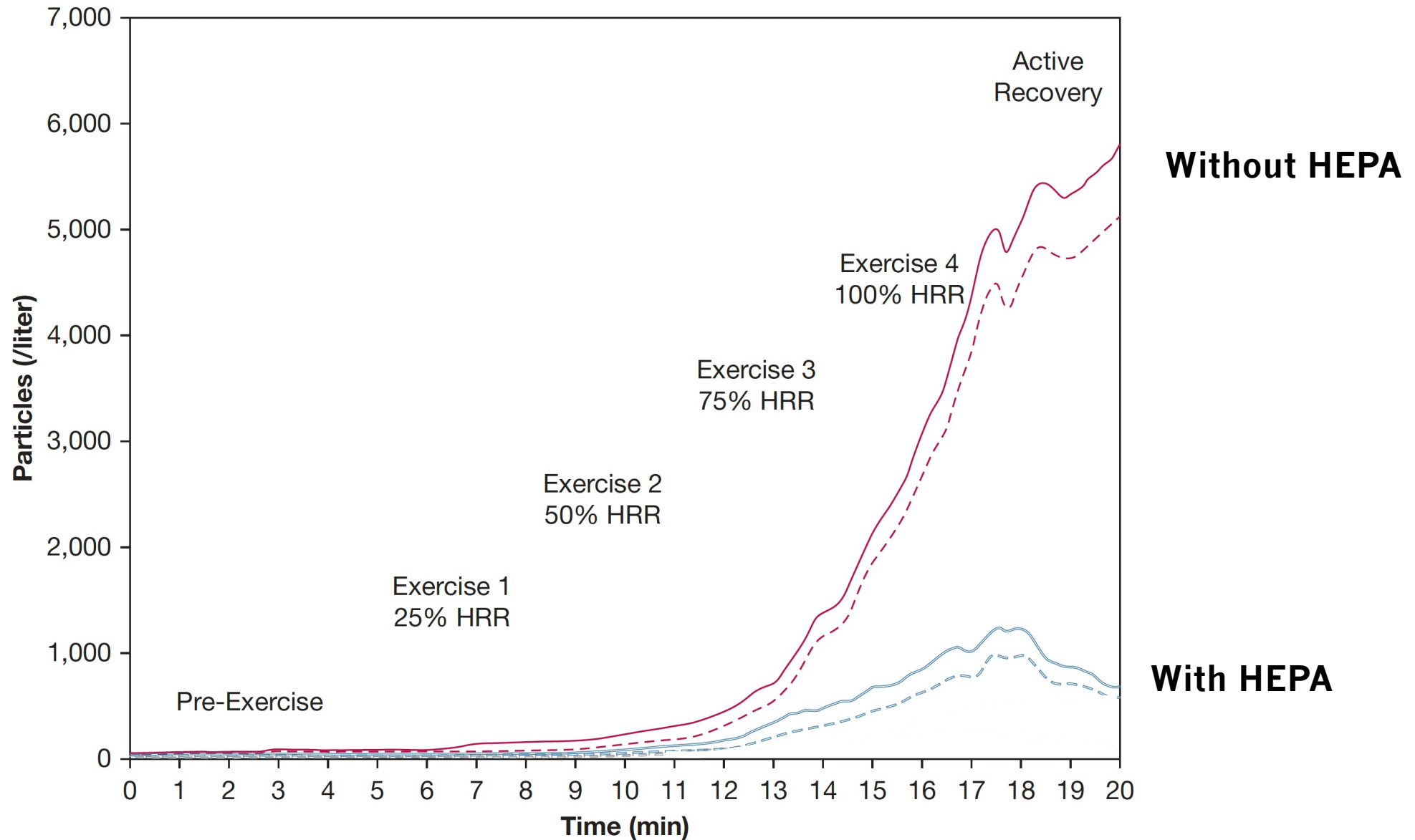
# Aerosol Clearance in Well Ventilated Hospital Rooms

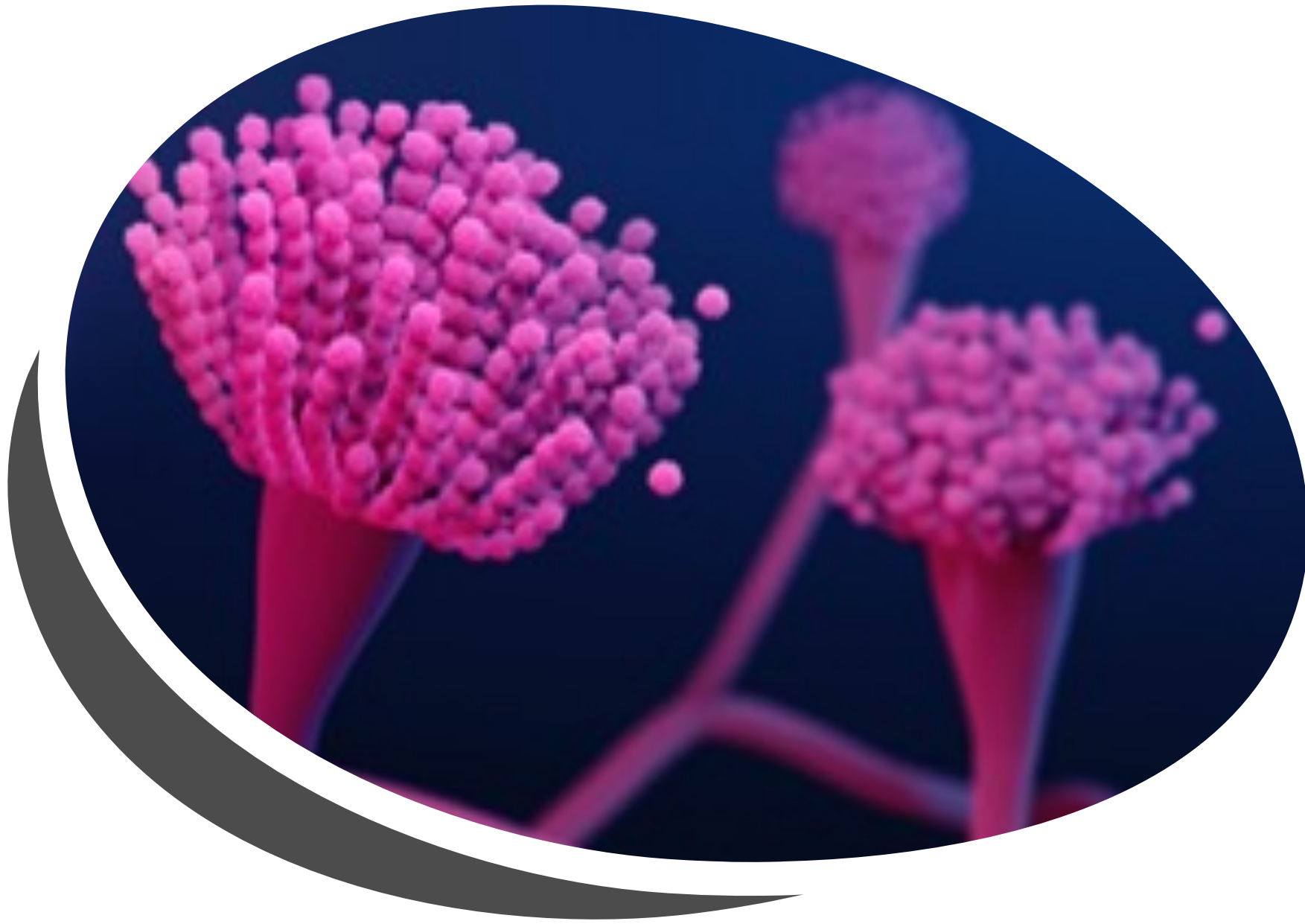
● Negative Pressure Room, 12 air changes/hour

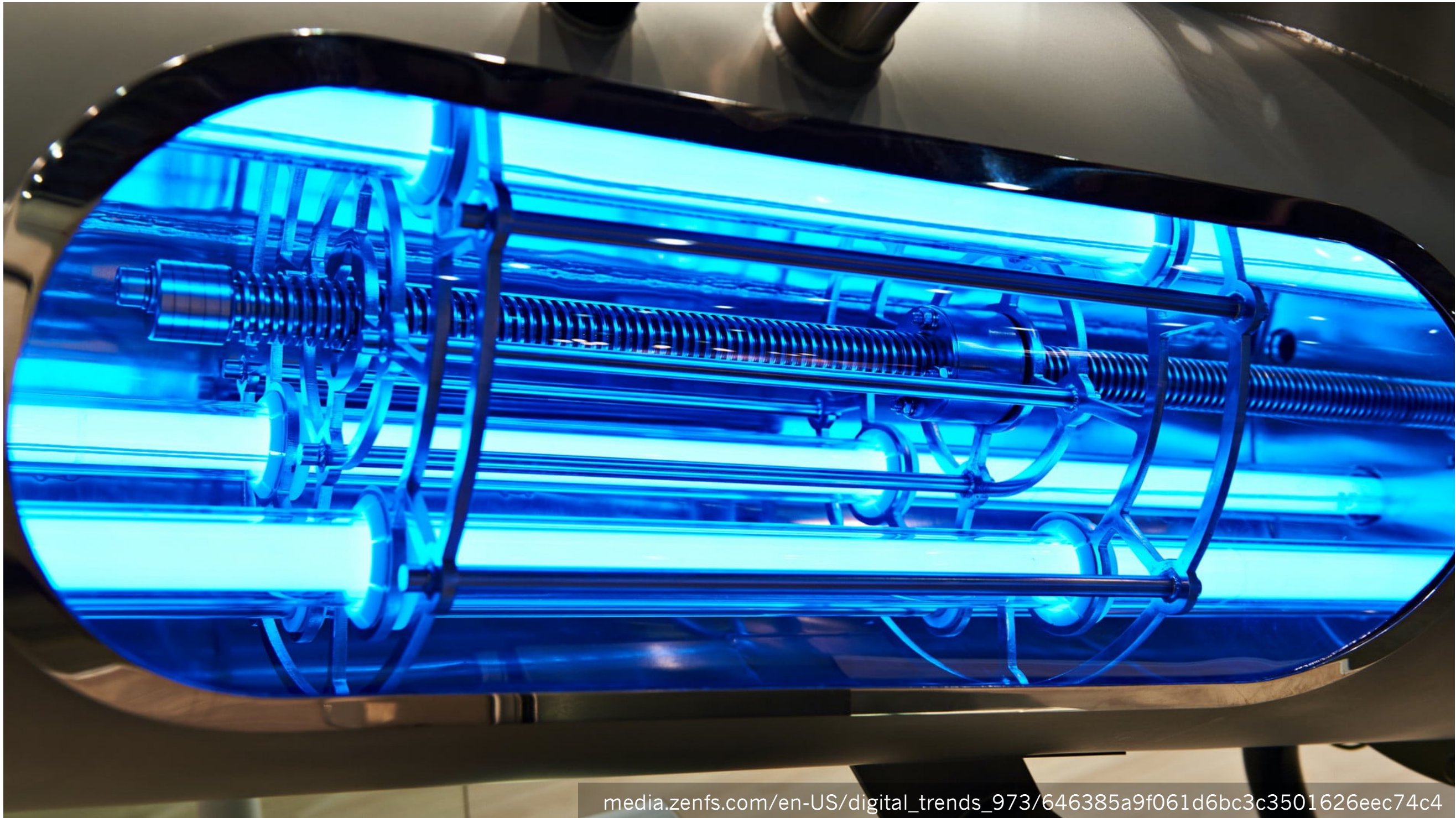
■ Operating Room, Pos Pressure, 27 air changes/hour



# HEPA Filters Can Effectively Reduce Aerosol Counts



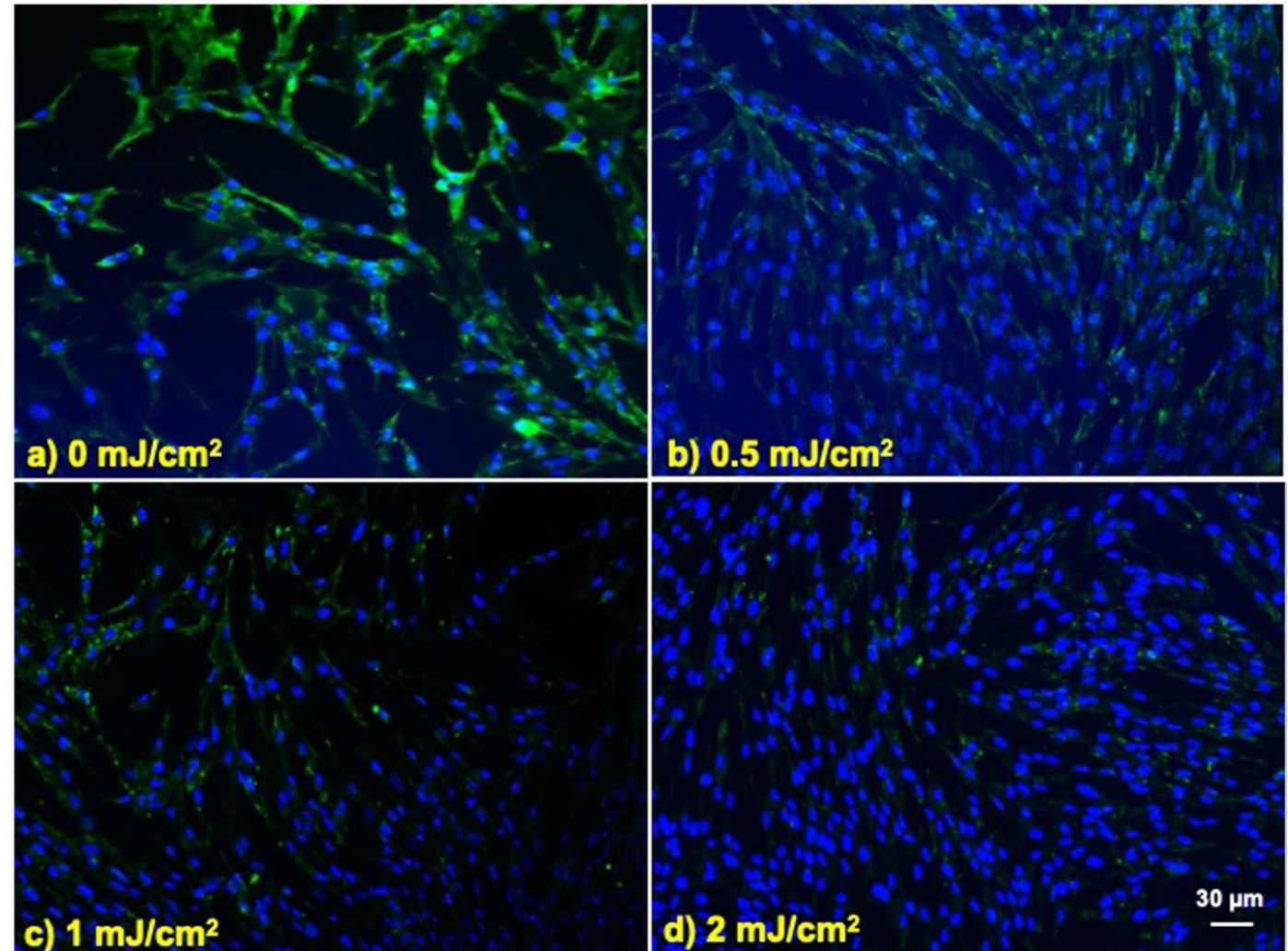




# Upper Room Germicidal UV using Far-UVC (222nm)

- Far UVC light may be a feasible option to decrease airborne virus
- Active against airborne respiratory viruses including coronavirus
- Cannot penetrate the stratum corneum or the ocular tear layer so may be safe for prolonged human exposure

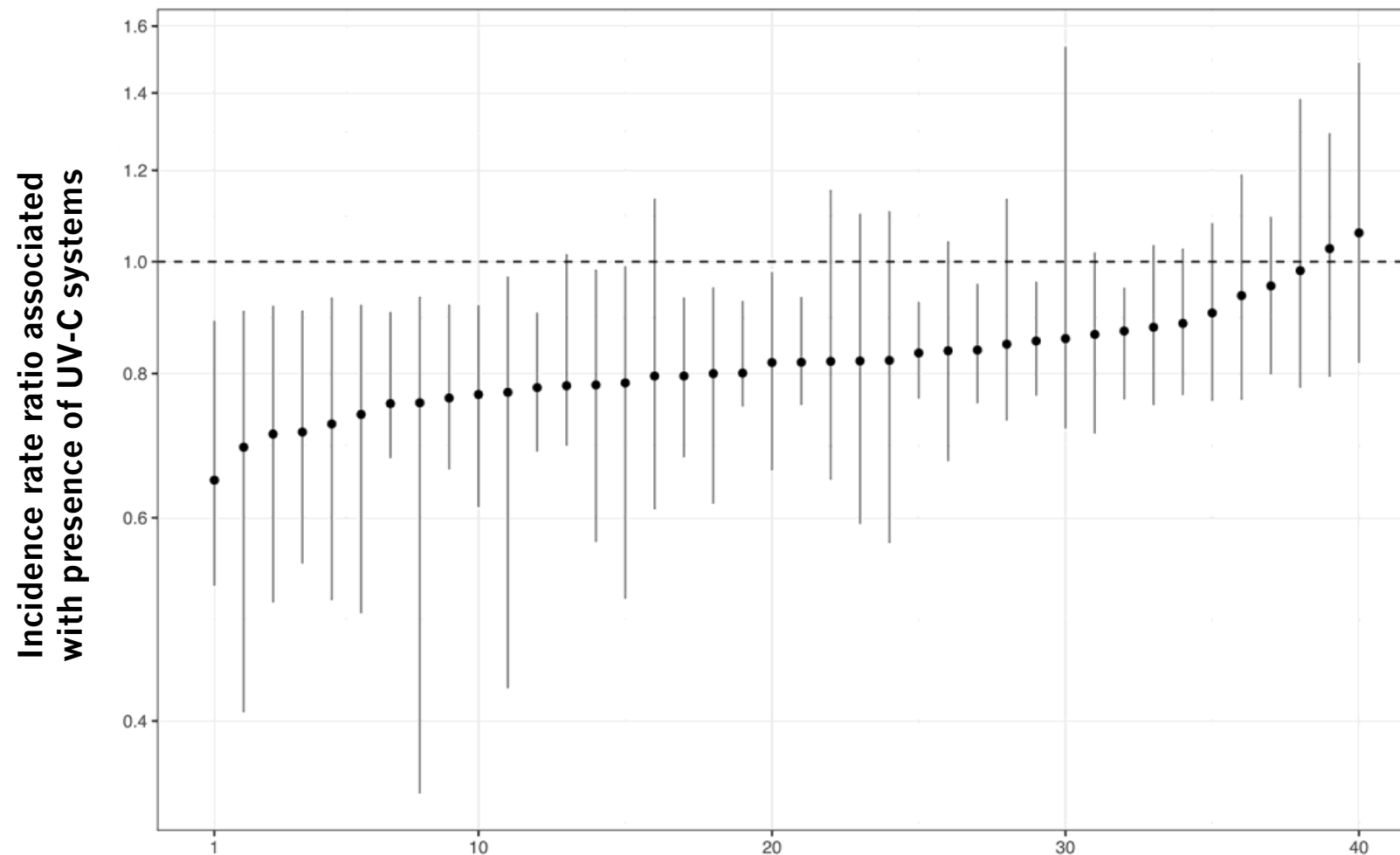
Beta HCoV-OC43 in normal human lung WI-38 fibroblasts  
Green = Anti-human coronavirus spike glycoprotein; Blue= DAPI





# UV Room Disinfection Post-Discharge and GNR Bacteremia

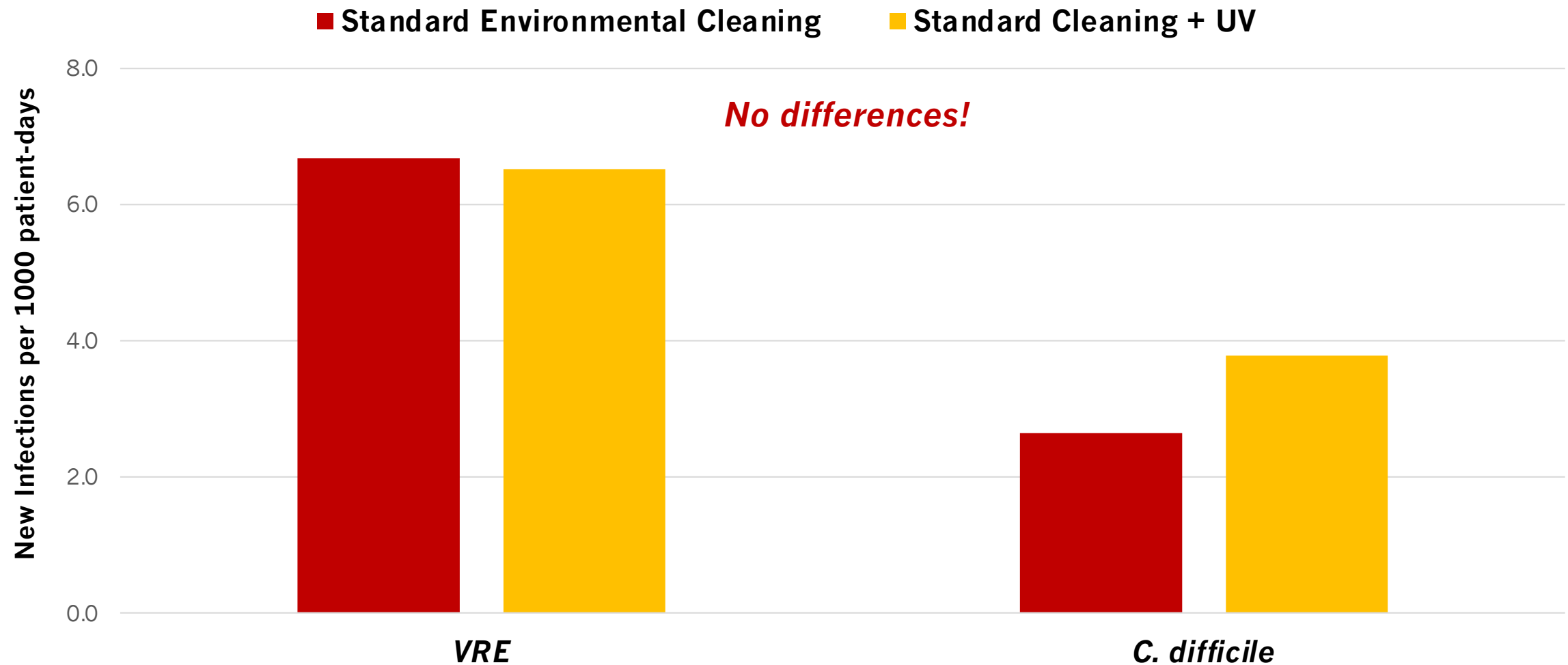
*Estimates of the impact of UV disinfection on hospital-onset GNR bacteremia in 40 Veterans Affairs hospitals*



Hospitals ranked by association between UV-C and HO-GNR incidence rates

# Cluster Randomized Trial

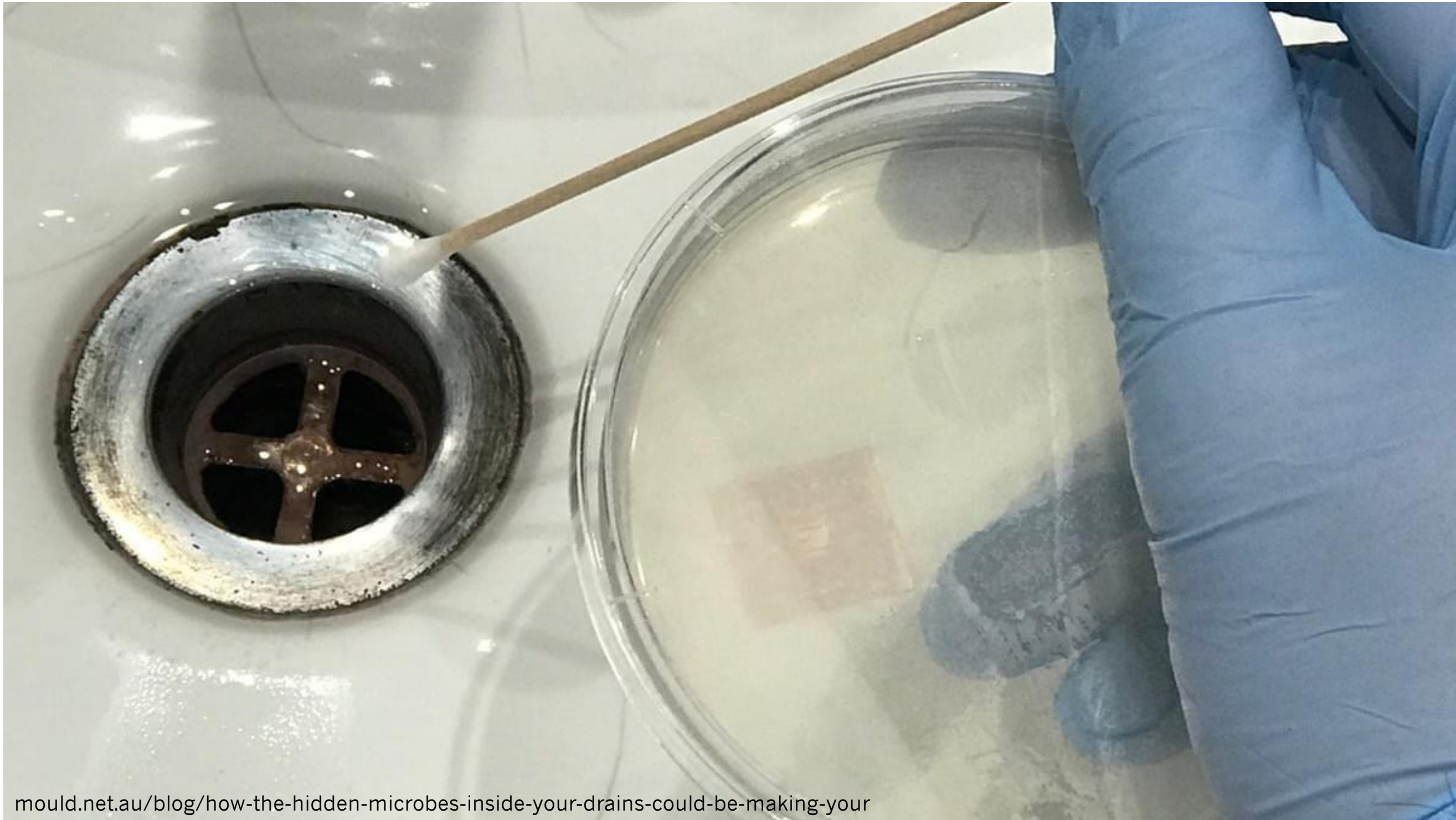
Standard room cleaning vs standard + UV-C disinfection, 4 cancer + 1 transplant ward, John Hopkins Hospital, Baltimore





# Water

[www.nbcnews.com/health/health-news/study-tracks-how-superbugs-splash-out-hospital-sink-drains-n725426](http://www.nbcnews.com/health/health-news/study-tracks-how-superbugs-splash-out-hospital-sink-drains-n725426)



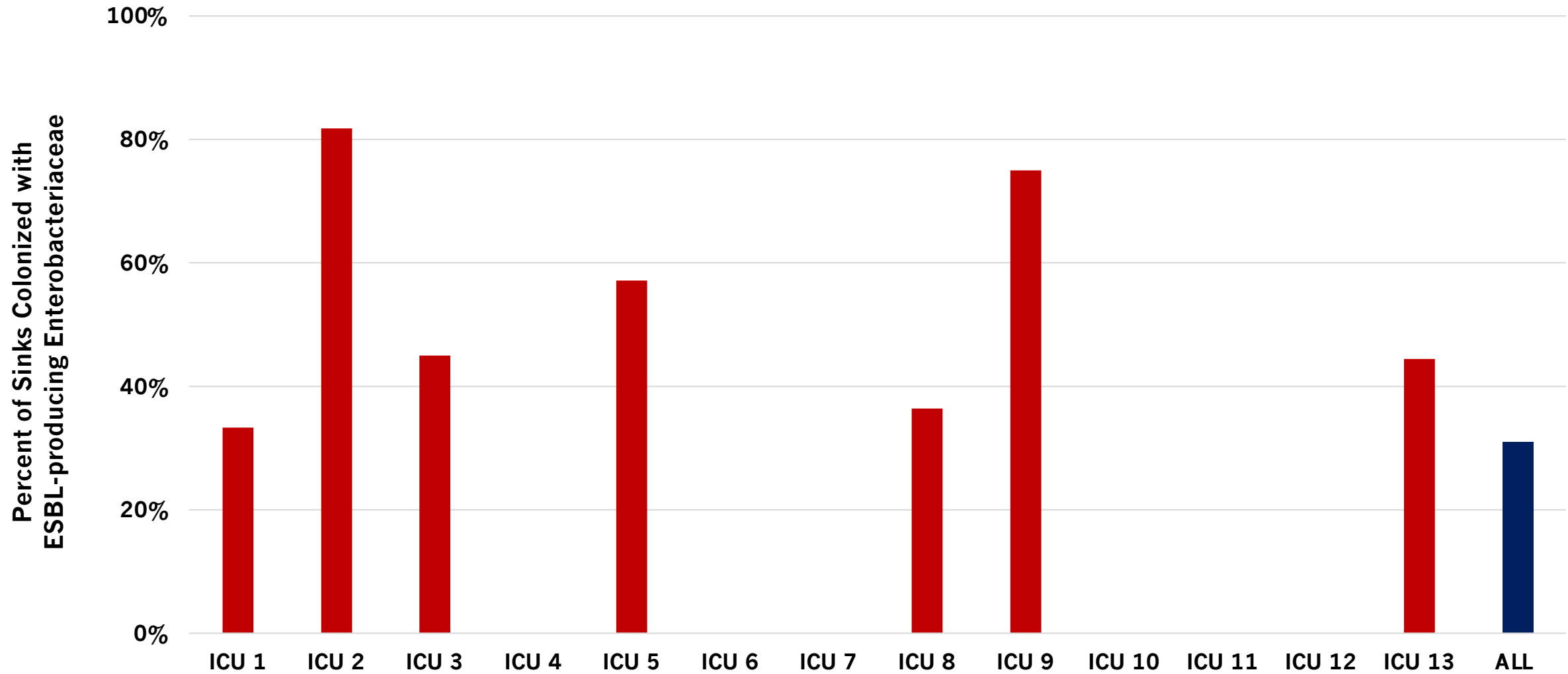
[mould.net.au/blog/how-the-hidden-microbes-inside-your-drains-could-be-making-your](http://mould.net.au/blog/how-the-hidden-microbes-inside-your-drains-could-be-making-your)

# Sink Drains

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- Sink and drains in ICUs are frequently colonized with multidrug resistant bacteria
  - Pseudomonas
  - Acinetobacter
  - Carbapenem resistant Enterobacteriaceae
  - Serratia...
  - Non-tuberculous mycobacteria
  - Mold

# Microbiological Survey of Sinks in 13 French ICUs





[globalhealthnewswire.com/public-health/2019/06/27/a-hidden-truth-hospital-faucets-are-often-home-to-slime-and-biofilm](https://globalhealthnewswire.com/public-health/2019/06/27/a-hidden-truth-hospital-faucets-are-often-home-to-slime-and-biofilm)



C.

Power for  
sink motion  
sensor

Electronics  
unit for sink  
trap device

Sink trap heat &  
vibration device

## University of Virginia

Initiative to combat nosocomial acquisition of Carbapenem-resistant Enterobacteriaceae

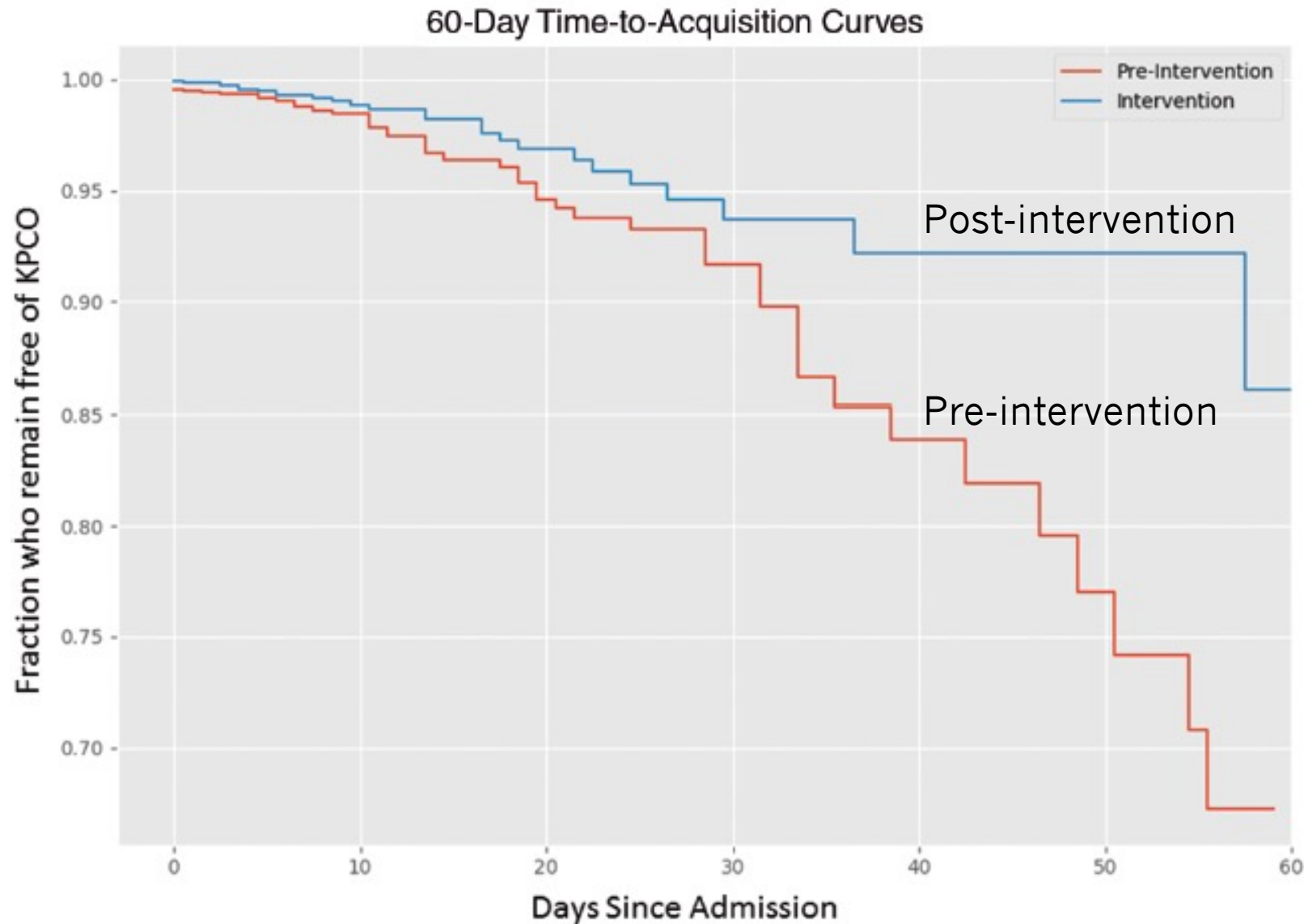
Installed sink trap heating & vibration devices in their ICUs

Heats the sink trap to 75-85°C

Added covers to disposal hoppers



# Impact on CRE Acquisition



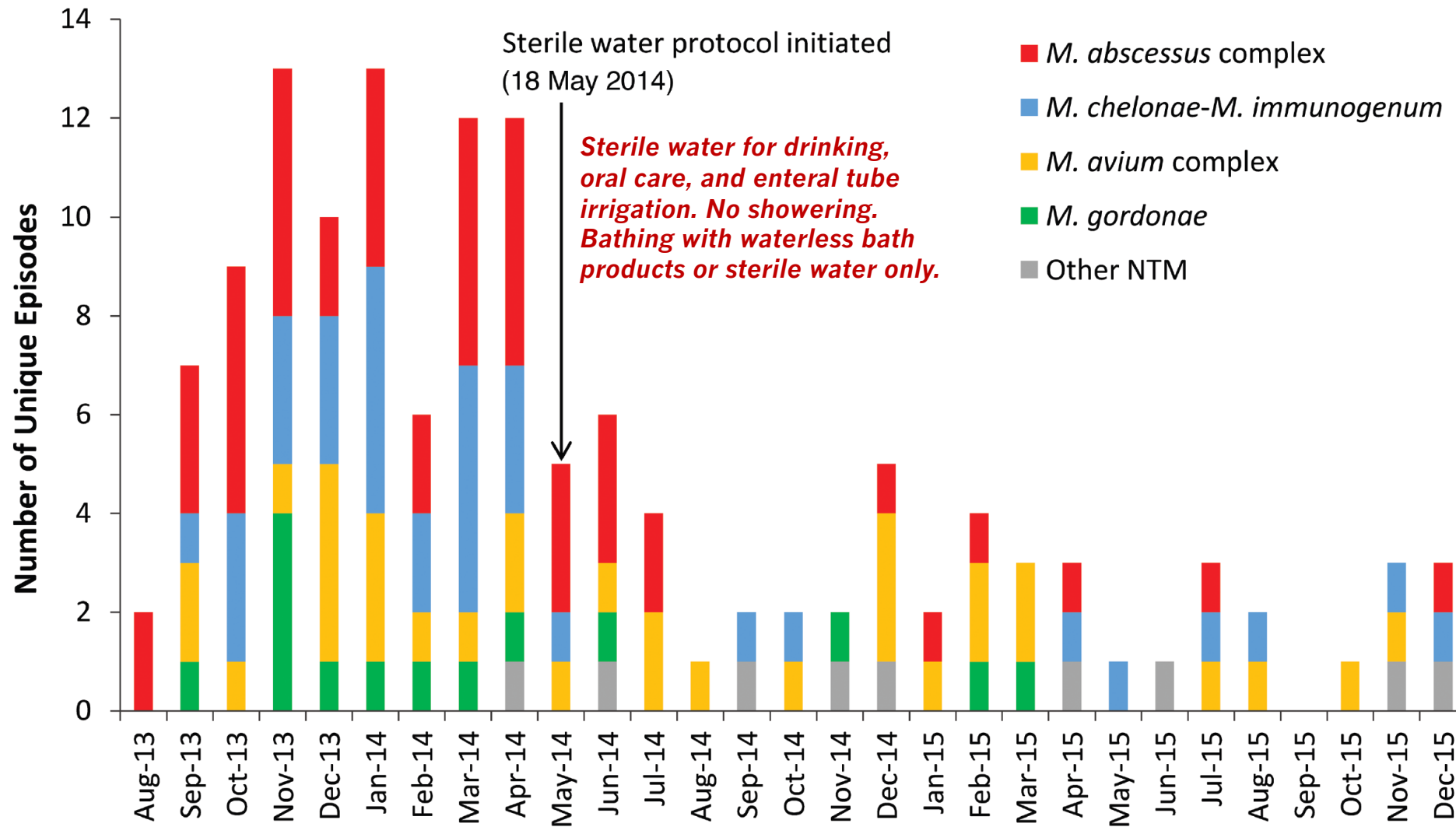
**50% Decrease  
CRE Colonization**  
OR 0.51  
(95% CI 0.31-0.81)

**70% Decrease  
CRE Infection**  
OR 0.29  
(95% CI 0.17-0.48)



# Eliminating tap water associated with drop in NTM infections

Count of patients with new non-tuberculous mycobacteria cultures, 3 ICUs & 1 step-down, Duke University Hospital

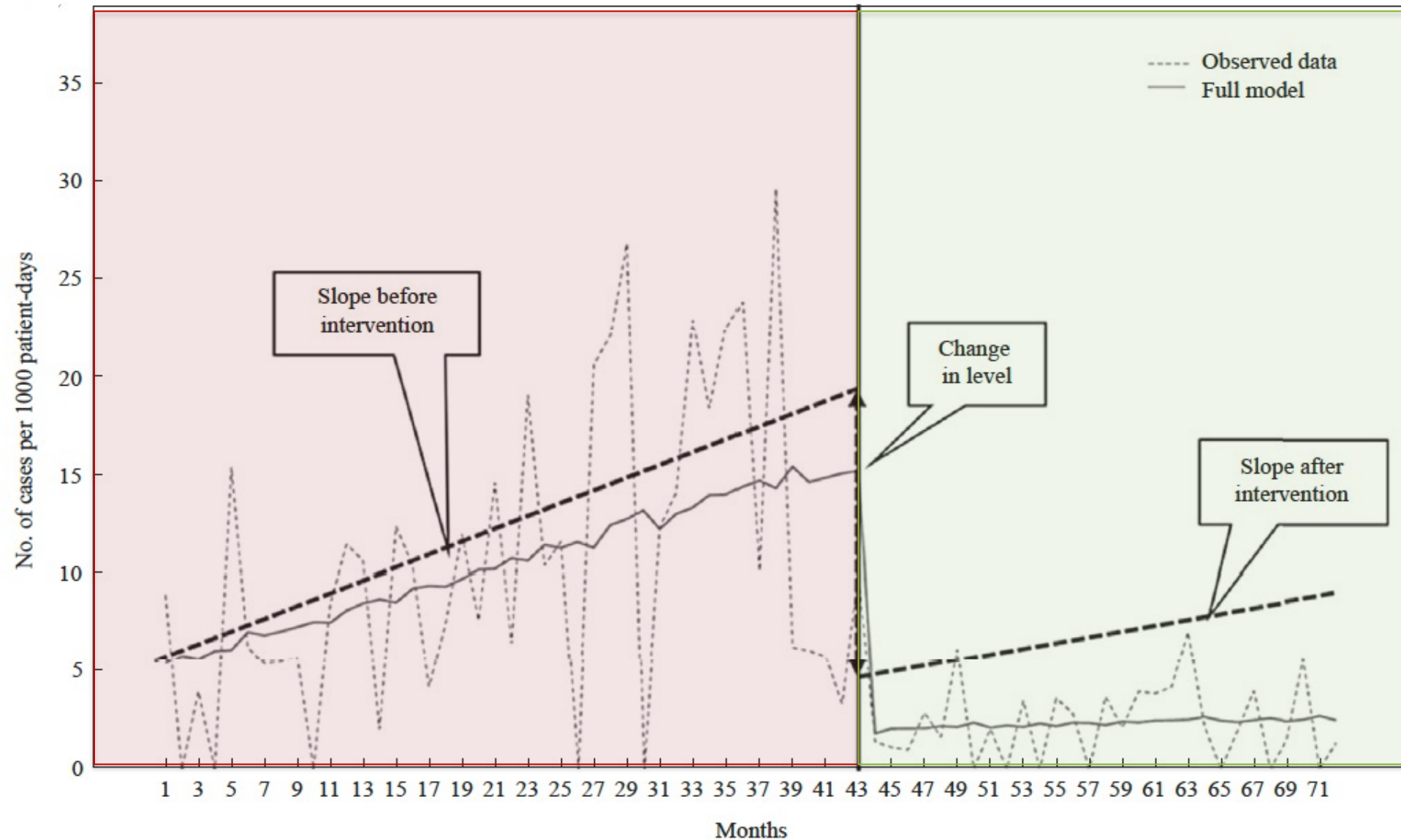


# Control of endemic multidrug-resistant Gram-negative bacteria after removal of sinks and implementing a new water-safe policy in an intensive care unit

E. Shaw<sup>a,b,\*</sup>, L. Gavaldà<sup>c</sup>, J. Càmarà<sup>d</sup>, R. Gasull<sup>e</sup>, S. Gallego<sup>e</sup>, F. Tubau<sup>d,f</sup>,  
R.M. Granada<sup>e</sup>, P. Ciercoles<sup>a</sup>, M.A. Dominguez<sup>d,b,g</sup>, R. Mañez<sup>e</sup>,  
J. Carratalà<sup>a,b,g</sup>, M. Pujol<sup>a,b</sup>



# Drop in MDR Gram Negatives After Sink Removal



# Summary: Design Considerations Affect Infection Risk

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- **Surface contamination**
    - Single rooms strongly preferred
    - Consider microbe-resistant surfaces
  - **Airborne contamination**
    - Single rooms +/- Airborne Infection Isolation Rooms
    - Protected Environments
    - Upper room germicidal UV?
  - **Water contamination**
    - Careful sink design
    - Waterless ICU
-

# Thank You!

## For all the lives we touch

Clean hands protect our patients.

Always perform hand hygiene  
and help others do the same.



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