

Environmental Disinfection for Control of Healthcare- Associated Pathogens

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Disclosures

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- Advisory Board
 - 3M

Objectives

- To be aware of how contaminated surfaces contribute to pathogen transmission
- To learn strategies to improve environmental disinfection in healthcare facilities
- To appreciate challenges for achieving effective environmental disinfection in long-term care settings

General principles

1. Patients and the environment contribute to transmission



Contamination of hands with MRSA after contact with:

Patient



Environment

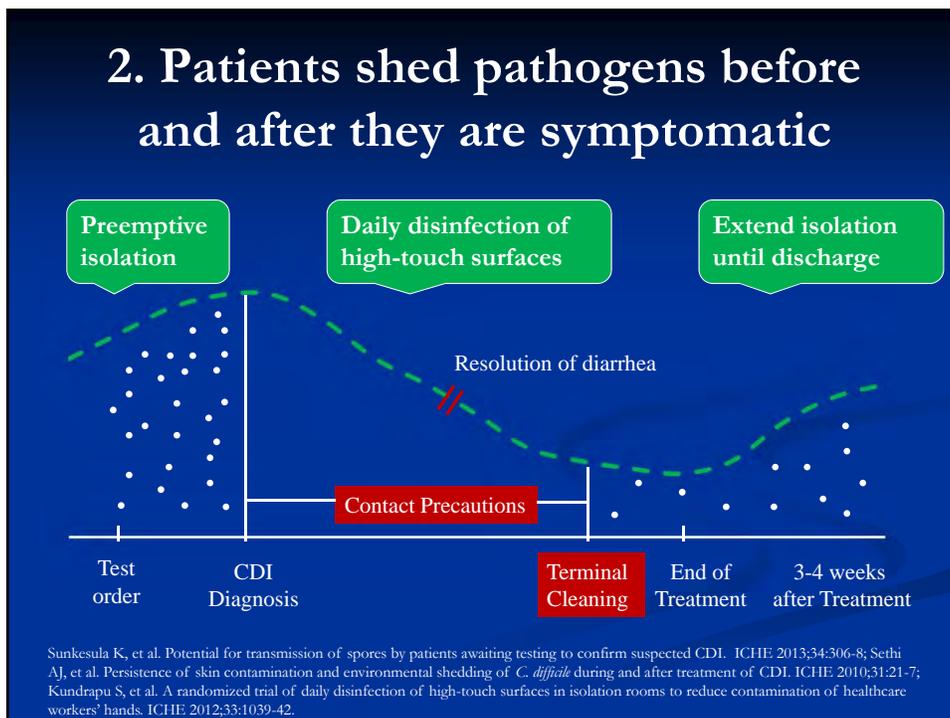


Donskey CJ, Eckstein B. N Engl J Med 2009;360:e3; Stiefel U, et al. Infect Control Hosp Epidemiol 2011;32:185-7

Basic infection control practices

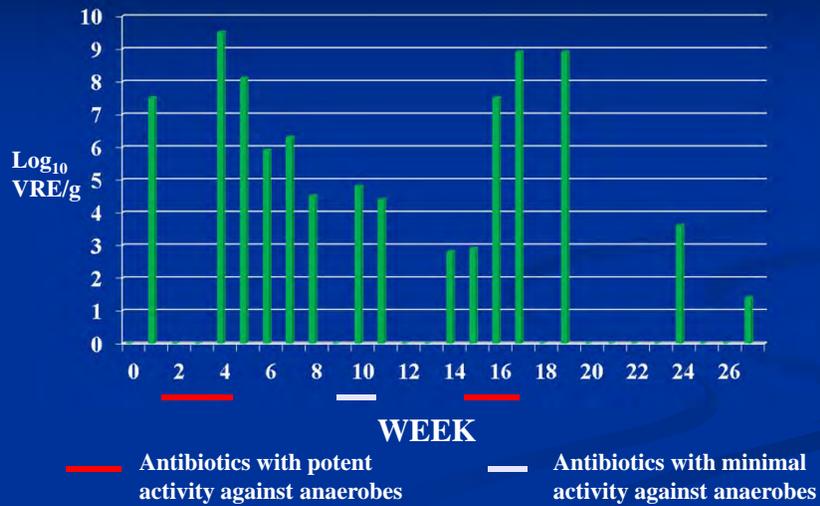


2. Patients shed pathogens before and after they are symptomatic



3. Antibiotics promote shedding of pathogens

Effect of antibiotics on density of VRE in stool



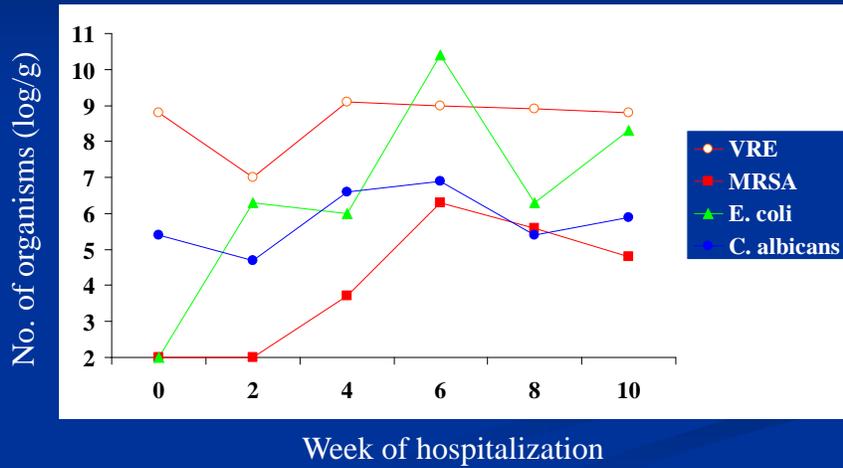
Donskey CJ, et al. N Engl J Med 2000;343:1925-32

Increased burden of VRE in stool increases shedding into the environment



Donskey CJ, et al. N Engl J Med 2000;343:1925-32

4. Pathogens often coexist



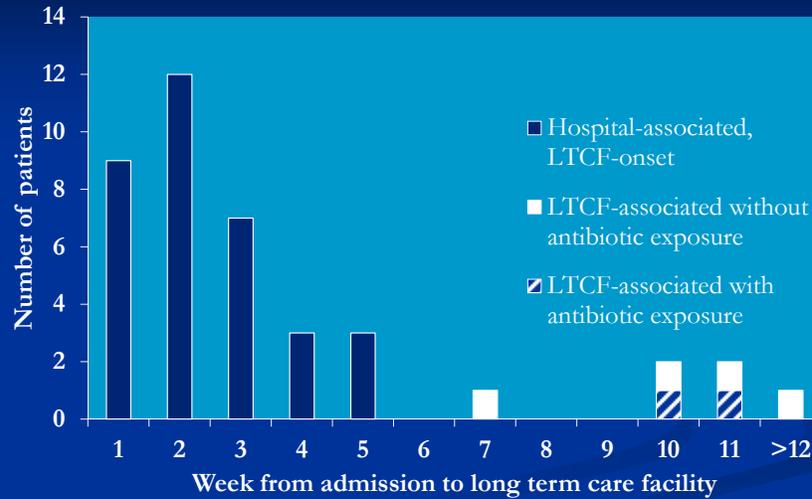
Donskey CJ. Clin Infect Dis 2004;39:219

Example 1. A LTCF resident is diagnosed with *C. difficile* infection (CDI) 1 week after admission



McDonald LC, et al. ICHE 2007;28:140-5; Mylotte JM. ICHE 2008;29:760-3

Timing of onset of *C. difficile* infection after transfer from the hospital to long-term care



- 1). Guerrero DM, et al. Infect Control Hosp Epidemiol 2011;32;
 2). Kim JH, et al. Infect Control Hosp Epidemiol 2011;32:656-60 (LTCF-onset CDI: 59% hospital-associated and 41% LTCF-associated)

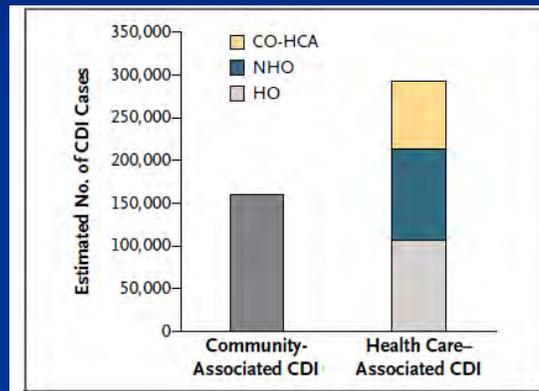
Proposed definitions ¹



LTCF-associated – onset more than 30 days after LTCF admission and no CDI in the previous 3 months

Mylotte JM. Infect Control Hosp Epidemiol 2008;29:760-3

Site of onset of *Clostridium difficile* infections



Only 24% of cases had onset in a hospital

Lessa FC, et al. NEJM 2015;372:825-33

SHEA Position Paper: *C. difficile* in LTCFs for the elderly

- Appropriate and prompt diagnostic testing (AII)
- Antimicrobial stewardship (AII)
- Education of providers about CDI (BIII)
- Environmental control measures
 - Use disposable single-use thermometers (AII)
 - Dedicated equipment for CDI patients (BIII)
 - Environmental disinfection with sporicidal agents (BII)
 - Private room for CDI patients with incontinence (BIII)

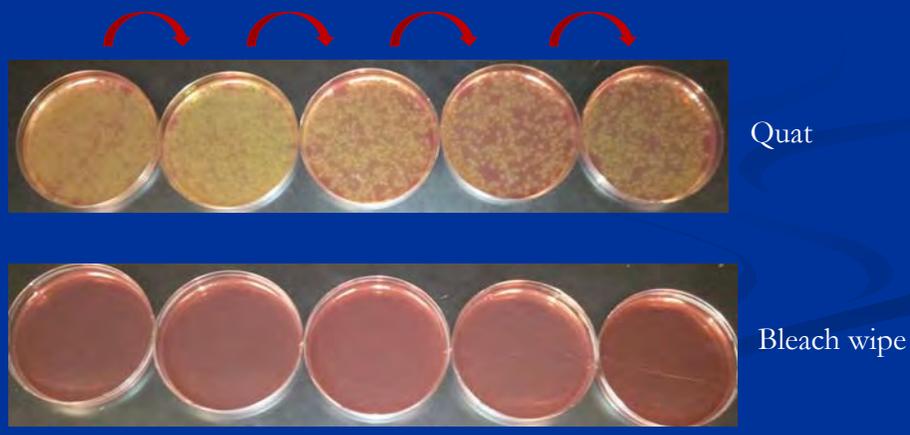
Simor AE, et al. SHEA Position Paper: *C. difficile* in long-term care facilities for the elderly. Infect Control Hosp Epidemiol 2002;23:696-703

Which disinfectants kill *C. difficile* spores?

- 1). Bleach
- 2). Quaternary ammonium compounds (e.g., lysol, Virex)
- 3). OxyCide (peracetic acid)
- 4). Oxivir (accelerated/improved hydrogen peroxide)

Why is a sporicidal disinfectant recommended?

Transfer of *C. difficile* spores by a non-sporicidal disinfectant



Substitution of hypochlorite for non-sporicidal cleaning agents to control *C. difficile*

Ref	Setting	Effect on CDI rates	Monitoring to ensure efficacy of disinfection
1	Medical Ward	Outbreak ended	Surface contamination reduced to 21% of initial levels
2	Bone marrow transplant (BMT) unit, Medical Ward, ICU	Significant decrease on BMT unit, but not on the other 2 wards	No
3	2 medical wards	Decreased on 1 of 2 wards	No decrease in prevalence of environmental contamination with hypochlorite use
4	Medical and surgical ICUs	Decreased on both units	No
5	3 hospitals	48% decrease in prevalence density of CDI	No
6	2 medical wards	85% decrease in hospital acquired CDI	Yes (ATP bioluminescence)

1). Katz G. Am J Epidemiol 1988;127:1289-94; 2). Mayfield JL. Clin Infect Dis 2000;31:995-1000; 3). Wilcox MH. J Hosp Infect 2003;54:109-114; 4). McMullen KM. Infect Control Hosp Epidemiol 2007;28:205-7; 5). Haeck DM. Am J Infect Control 2010;38:350-3; 6). Orenstein R. Infect Control Hosp Epidemiol 2011;32:1137-9

Potential adverse effects of bleach

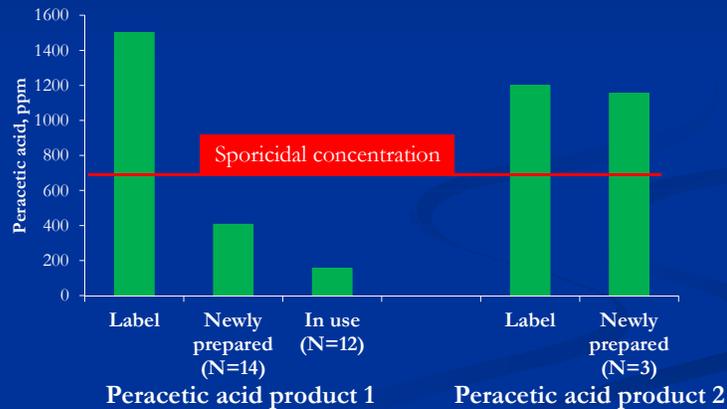
Mattress exposed to bleach versus quaternary ammonium disinfectant

Quat Bleach Bleach
 wiper 1:10



Cadnum JL, et al. SHEA 2017

Peracetic acid concentrations in 2 disinfectants

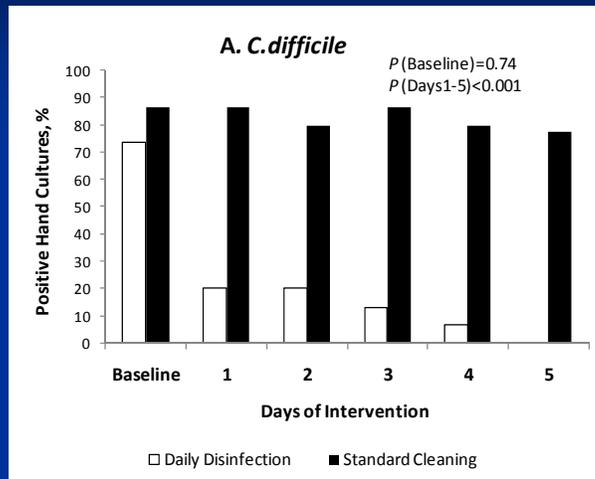


Cadnum JL, et al. ICHE 2016

Why is daily cleaning recommended?

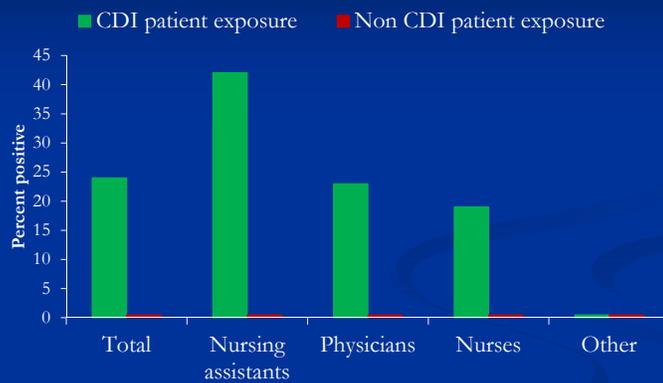
- An elderly person in your household develops diarrhea that is diagnosed as an infectious viral illness. There are young children in the household who interact regularly with the ill person. Do you:
 1. Wait 10 days until the illness has completely resolved before cleaning the bathroom and other objects that the person contacts
 2. Disinfect surfaces daily or after each use of the bathroom to prevent transmission

Daily disinfection of high-touch surfaces



Kundrapu S, et al. Daily disinfection of high-touch surfaces in isolation rooms to reduce contamination of healthcare workers' hands. *Infect Control Hosp Epi* 2012 33:1039-42

Contamination of hands with *C. difficile* spores despite contact precautions



Independent risk factors: high-risk contact and ≥ 1 contact without gloves

Landelle C. *ICHE* 2014;35:10-15; Shrestha SK. *ICHE* 2016;37:475-7 (16% hand contamination after care of CDI patients); Tomas ME. *AJIC* 2015;43:1366-7 (hand contamination decreased after an intervention to improve PPE technique)

Technical difficulty

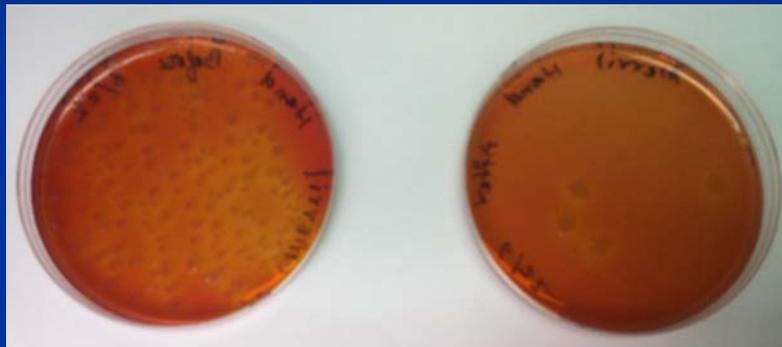
Daily cleaning?



Patient hand washing to reduce spore contamination

Before hand wash

After hand wash



Kundrapu S, et al. A Randomized Trial of Soap and Water Hand Wash Versus Alcohol Hand Rub for Removal of *C. difficile* Spores from Hands of Patients. ICHE 2014;35:204-6; Jury LA, et al. Effectiveness of routine patient bathing to reduce the burden of spores on skin of patients with CDI. ICHE 2011;32:181-4

Example 2. Three LTCF residents and 2 staff members develop nausea and vomiting

- 1). *C. difficile* infection
- 2). Norovirus
- 3). Staphylococcal food poisoning

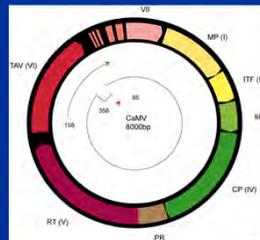
Environmental cleaning for Norovirus outbreaks

- Increase frequency of routine cleaning and disinfection of isolation rooms, shared equipment, and high traffic areas (2-3 times/day)
- Clean from areas of low to high contamination
- Use an EPA-approved disinfectant
- Consider changing privacy curtains upon discharge and transfer

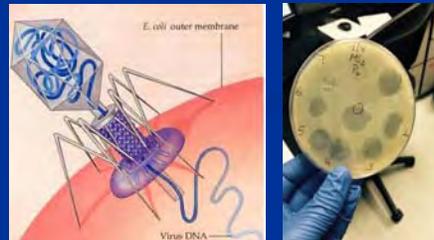
cdc.gov; Kambhampati A. J Hosp Infect 2015;89:296-301; Barker JD. J Hosp Infect 2004;58:42-49 (surfaces cleaned with a detergent spread Norovirus to uncontaminated sites)

Use of benign surrogate markers to study virus transmission in LTCFs

Viral DNA
(Cauliflower Mosaic Virus)



Live virus
(Bacteriophage MS2)



Sassi HP, et al. Control of the spread of viruses in a LTCF using hygiene protocols. AJIC 2015;43:702-6;
Alhmidi H, et al. Dissemination of a Nonpathogenic Viral DNA Surrogate Marker from High-Touch Surfaces in Rooms of LTCF Residents. AJIC in press

Dissemination of a viral DNA surrogate marker on a LTCF ward

	Time after marker inoculation on TV remote			
	2 hours	1 day	2 days	3 days
LTCF resident's hands	+	-	-	-
Inside Room				
Personal Items	+	+	-	+
Surfaces	+	+	+	+
Bathroom	+	+	-	-
Outside Room on unit				
Nursing stations	-	+	-	+
Staff bathroom	-	+	-	-
Recreation area/cafeteria	+	-	-	+
Laundry Room	+	-	-	-
Portable equipment	-	-	+	+
Smoking area outside building	-	-	-	+

Alhmidi H, et al. Dissemination of a Nonpathogenic Viral DNA Surrogate Marker from High-Touch Surfaces in Rooms of LTCF Residents. AJIC in press

Control of the spread of a benign virus in a LTCF using hygiene protocols

- The benign virus bacteriophage MS2 inoculated onto hands of 1 staff member
- Comparison of environmental and staff hand contamination before and after an intervention
- Intervention: education, increase availability of hand sanitizer for staff and patients and disinfectant wipes

Sassi HP, et al. Control of the spread of viruses in a LTCF using hygiene protocols. AJIC 2015;43:702-6

Control of the spread of a benign virus in a LTCF using hygiene protocols

	Pre-intervention	Post-intervention
Percent contamination of fomites	52/105 (49%)	39/106 (32%)
Mean virus particles recovered		
Fomites	1,100,000	820
Hands	1500	2

Sassi HP, et al. Control of the spread of viruses in a LTCF using hygiene protocols. AJIC 2015;43:702-6

Does the environment contribute to spread of respiratory viruses?

- Enveloped respiratory viruses (e.g., influenza, RSV) viable for hours to days on surfaces
- Respiratory viruses (e.g., influenza, RSV) can be recovered from surfaces and in some cases have been linked to transmission
- CDC: for influenza use standard cleaning and disinfection procedures

cdc.gov Prevention strategies for seasonal influenza in healthcare settings; Boone SA, Gerba CP. Significance of fomites in the spread of respiratory and enteric viral disease. *Appl Environ Microbiol* 2007;73:1687-96; Hall CB, et al. Infectivity of RSV by various routes of inoculation. *Infect Immunol* 1981;33:779-783; Morens DM, Rash VM. Lessons from a nursing home outbreak of influenza A. *ICHE* 1995;16:275-80.

Paramyxovirus outbreak in a long-term care facility

- RSV and human metapneumovirus outbreak on a dementia ward
- 30 of 41 (73%) residents and multiple personnel affected
- Lack of on-site testing delayed recognition
- Prevention of future outbreaks: active surveillance for cases during respiratory virus season

Schaeffer Spires S, et al. *ICHE* 2017:1-6

Example 3. Two LTCF residents are colonized with multidrug-resistant *Pseudomonas*. Which is increasingly linked to transmission?

- A. Contaminated stool softener
- B. Contaminated sinks
- C. Physicians' ties
- D. Dirty laundry

Example 3. Two LTCF residents are colonized with multi-resistant *Pseudomonas*. Which is increasingly linked to transmission?

- A. Contaminated stool softener (*Burkholderia*)
- B. Contaminated sinks
- C. Physicians' ties
- D. Dirty laundry (*Zygomycoses*)

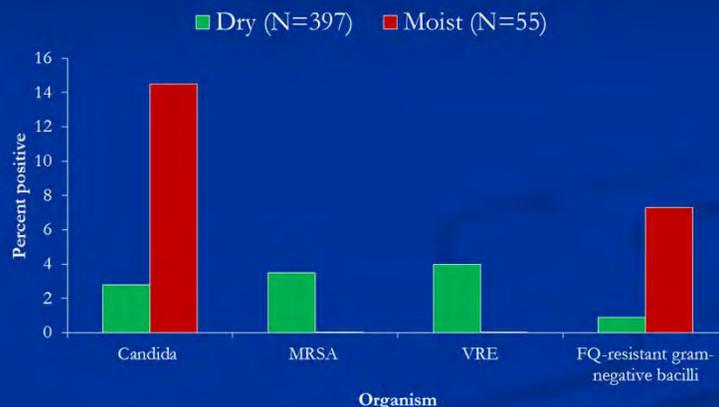
Marquez L, et al An outbreak of *Burkholderia cepacia* complex infections associated with contaminated liquid docusate. *ICHE* 2017;1-7; Cheng VCC, et al. Hospital outbreak of pulmonary and cutaneous zygomycosis due to contaminated linen items from substandard laundry. *Clin Infect Dis* 2016;62:714-20 (Hong Kong); Duffy J, et al. Mucormycosis outbreak associated with hospital linens. *Pediatr Infect Dis J* 2014;33:472-6 (Louisiana); ID Week 2016. Zygomycosis associated with contaminated laundry (*Rhizopus* spp. and *Lichtheimia* (*Absidia*) *corymbifera*)

Organisms linked to sinks

- *Pseudomonas aeruginosa*
- *Klebsiella pneumoniae* and *K. oxytoca*
- *Enterobacter cloacae*
- *Elizabethkingia meningoseptica*
- *Acinetobacter baumannii*
- *Stenotrophomonas maltophilia*

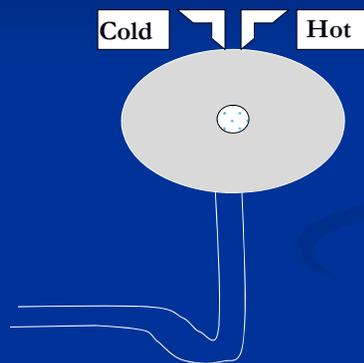
Kanamori H, et al. Clin Infect Dis 2016;62:1423-35 (review on waterborne transmission in healthcare facilities); Hota S, et al. ICHE 2009;30:25-33; Ambrogi V, et al. J Hosp Infect 2016;92:27-9; Wolf I, et al. J Hosp Infect 2014;87:126-30; Roux D, et al. J Hosp Infect 2013;85:106-11; Zhou Z, et al. J Infect Chemother 2016; Aspelund AS, et al. J Hosp Infect 2016;94:13-20; Leitner E, et al. Antimicrob Agents Chemother 2015;59:714-16; Chapuis A, et al. Frontiers Microbiol 2016;7:1-9; Amoureux L, et al. Emerg Infect Dis 2017;23:304-7; Clarivet B, et al. Euro Surveill 2016;21; Knoester M, et al. Clin Microbiol Infect 2014;20:0207-0215; Vergara-Lopez S, et al. Clin Microbiol Infect 2013;19:E490-8; Fusch C, et al. Acta Paediatrica 2015;104:e344-e349; Lowe C, et al. Emerg Infect Dis 2012;18:1242-7;

Recovery of potential pathogens from hospital surfaces

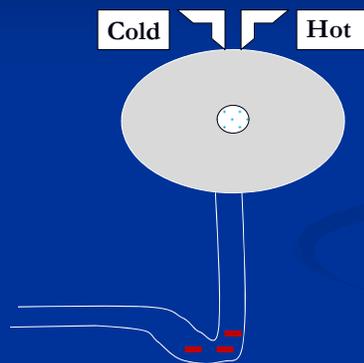


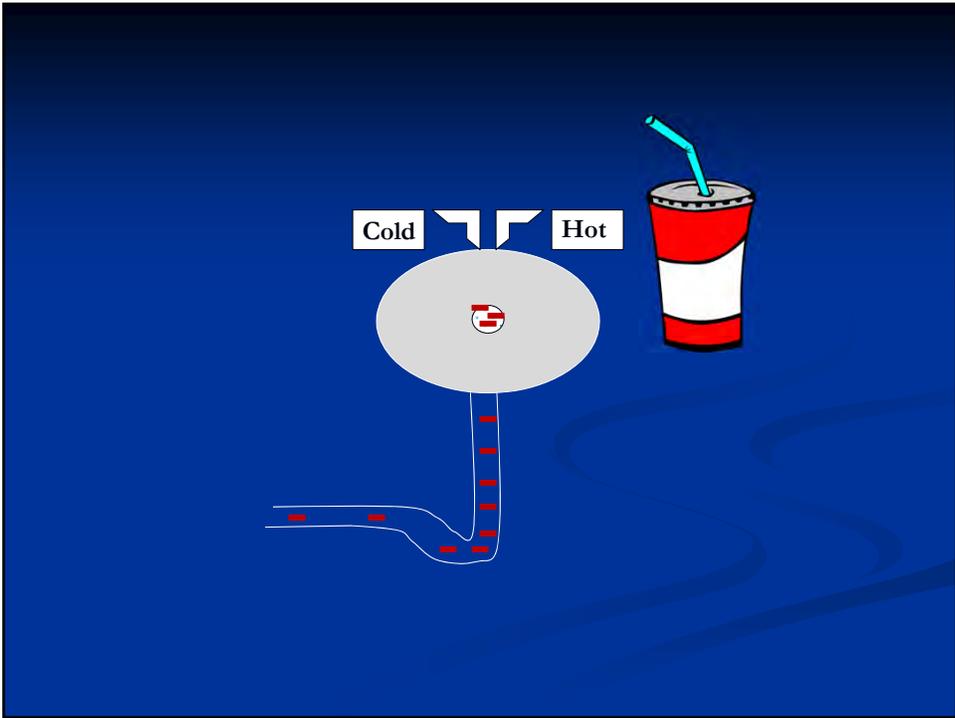
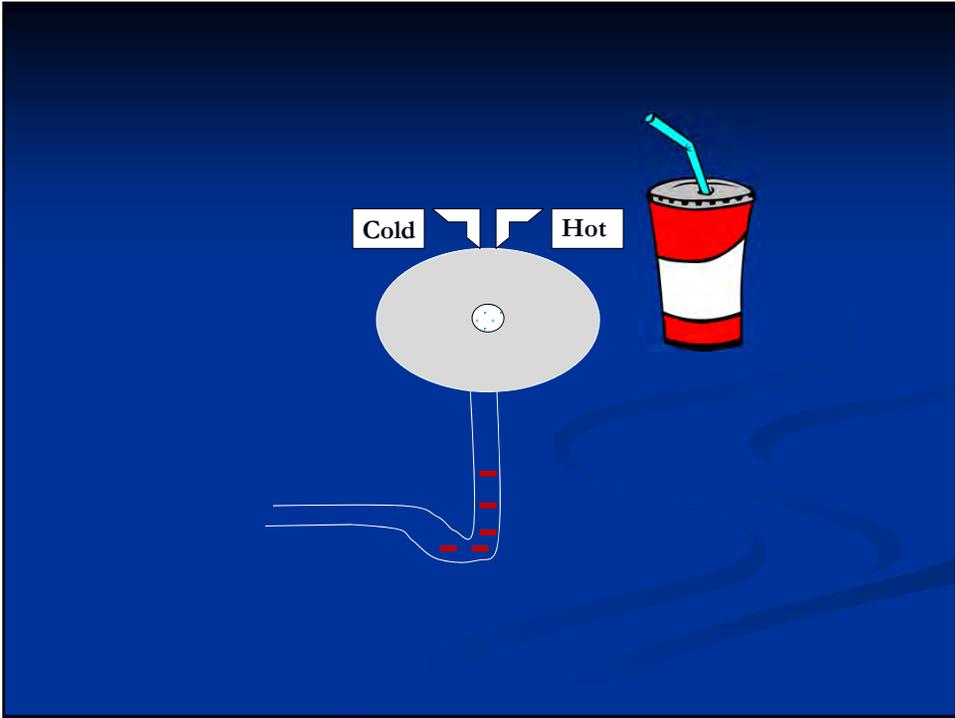
Piedrahita C, et al. Environmental Surfaces in Healthcare Facilities are a Potential Source for Transmission of *Candida auris* and other *Candida* species. SHEA 2017 abstract 8997; manuscript submitted.

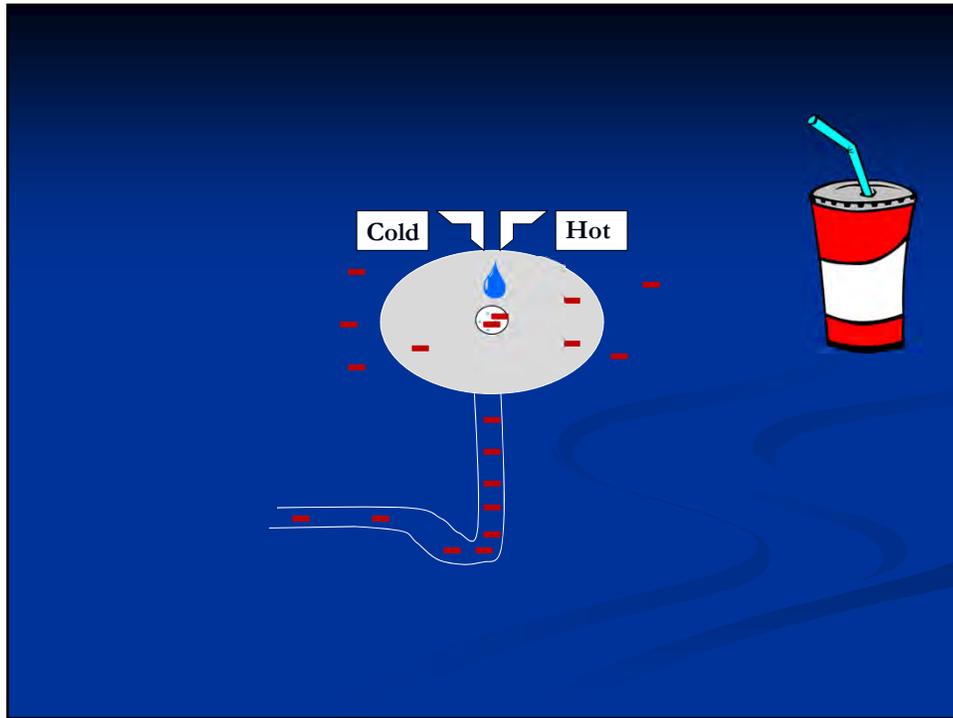
From sink to patient



Kotay S, et al. Spread from the sink to the patient: in situ study using GFP expressing *E. coli* to model bacterial dispersion from sink trap reservoirs. *Appl Env Microbiol* Feb. 2017







Improving room design to reduce risk for transmission from sinks

Before renovation



After renovation



Hota S, et al. Outbreak of multidrug-resistant *P. aeruginosa* colonization and infection secondary to imperfect intensive care unit room design. *ICHE* 2009;30:25-33.

Strategies to improve environmental disinfection

Improve standard cleaning and disinfection

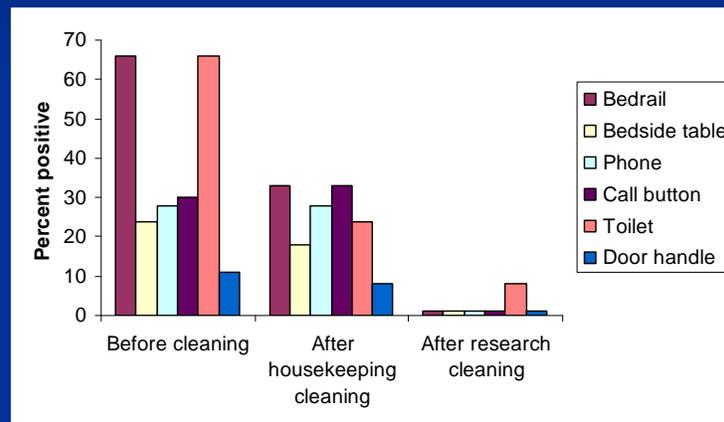


New technologies



Process not product

Poor implementation



Eckstein B, et al. Reduction of *C. difficile* and VRE contamination after an intervention to improve cleaning methods BioMed Central Infect Dis 2007;7:61

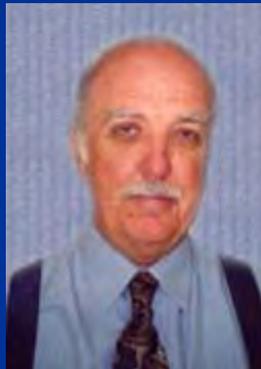
Environmental cleaning interventions

- Education
- Monitoring and feedback
- Standardized policies and procedures
- Recognition of environmental services personnel

Carling P. Am J Infect Control 2013;41:520-5; Havill NL. Am J Infect Control 2013;41:S26-S30

Fluorescent markers

Phil Carling

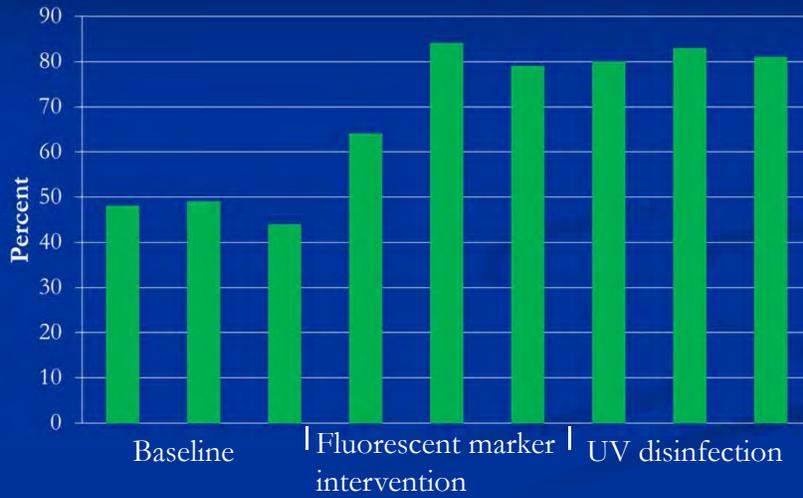


Fluorescent marker on a toilet seat after housekeeping cleaning

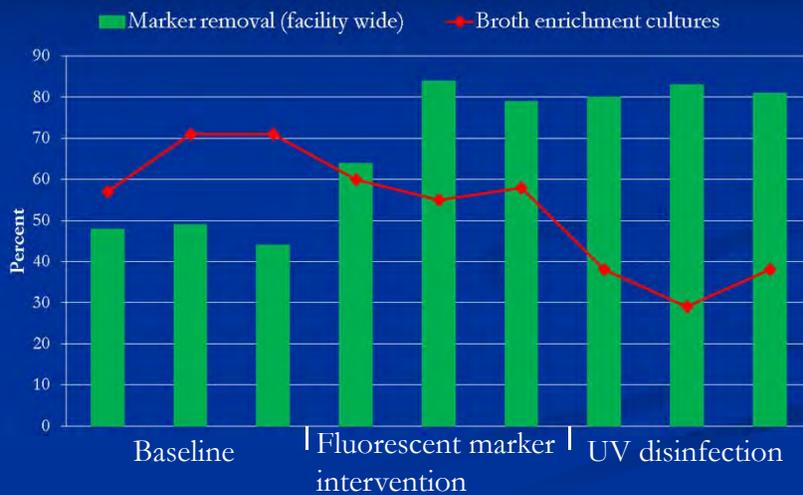


1. Carling PC, et al. Clin Infect Dis 2006;42:385-8; 2. Carling P, et al. Infect Control Hosp Epidemiol 2008;29:1035-41; 3. Carling P. Am J Infect Control 2013;41:520-525

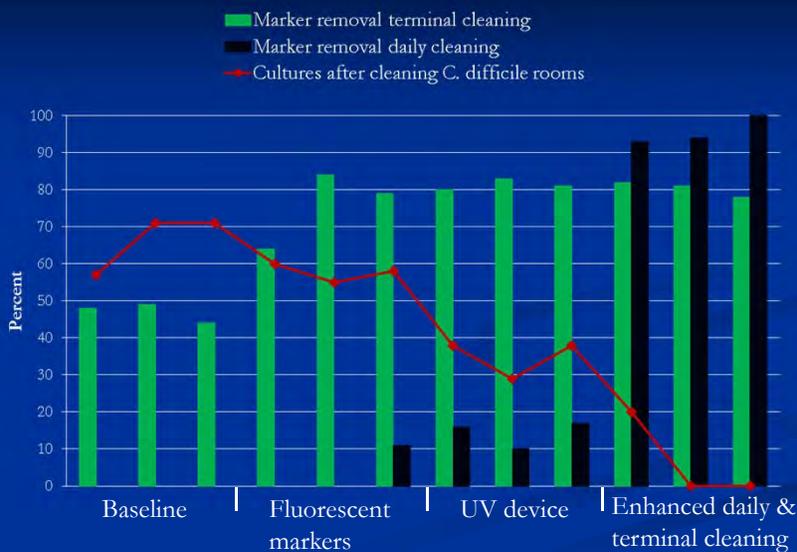
Improvement in cleaning based on fluorescent marker removal



C. difficile contamination in terminally cleaned CDI rooms



An environmental disinfection odyssey



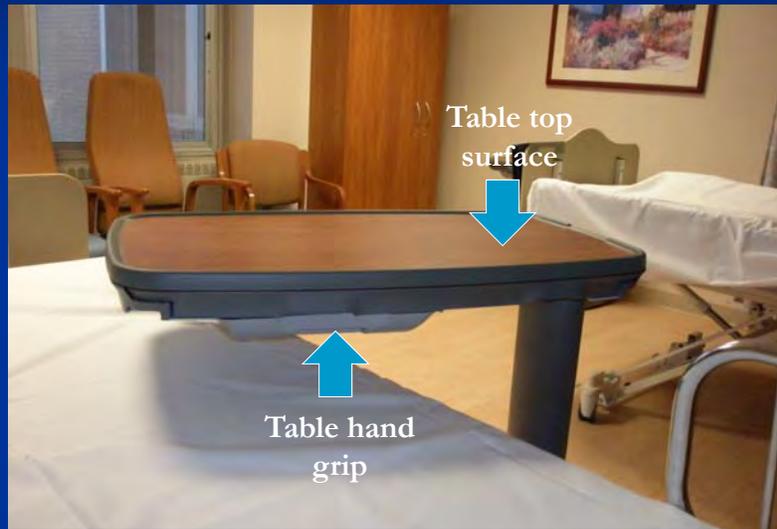
Sitzlar B, et al. Infect Control Hosp Epidemiol 2013;34:459-65

Limitations of fluorescent markers

Ref	Fluorescent marker method culture results
1	Despite intervention, 27% of rooms contaminated with MRSA or VRE after cleaning (versus 45% at baseline)
2	33% of toilet seats in CDI rooms with complete marker removal grew <i>C. difficile</i>
3	21% of sites with complete marker removal not clean based on aerobic colony counts

1. Goodman ER et al. Infect Control Hosp Epidemiol 2008;29:593-9; 2. Alfa MJ, et al. BMC Infect Dis 2008;8:64; 3. Boyce JM, et al. Infect Control Hosp Epidemiol 2011;32:1187-93

Removal of marker may not correlate with cleaning of alternate sites on the same surface



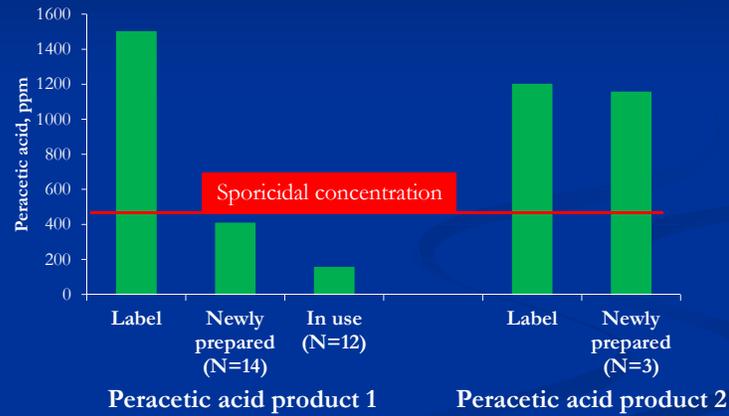
Fluorescent markers do not detect incorrect use of products

Transfer of *C. difficile* spores by a bleach wipe¹



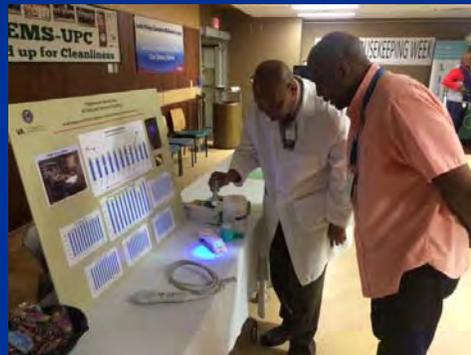
1. Cadnum JL, et al. Infect Control Hosp Epidemiol 2013;34:441-2; 2. Manian FA, et al. Infect Control Hosp Epidemiol 2011;32:667-72 (Suspected transfer of MRSA and Acinetobacter from dirty to clean sites during room cleaning)

Fluorescent markers do not detect defective products



Cadnum JL, et al. An Increase in Healthcare-Associated CDI Associated with Use of a Defective Peracetic Acid-Based Surface Disinfectant. *Infect Control Hosp Epidemiol* 2017;38:300-305.

Low-cost fluorescent marker

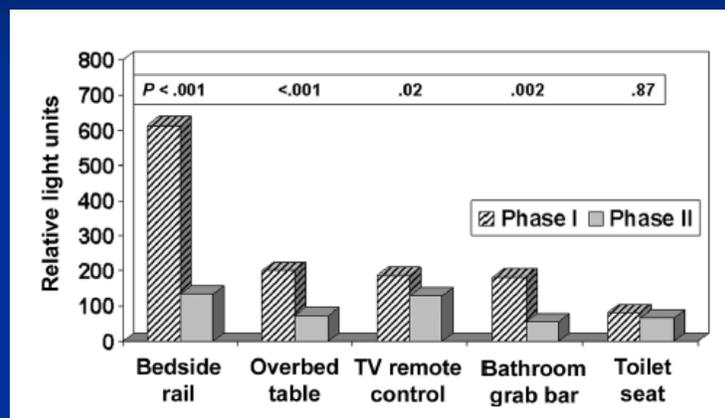


ATP bioluminescence

- Quantitative measurement of organic material (bacteria, food, bodily secretions)
- Expressed as relative light units (RLUs)
- No established benchmark for defining clean
- ATP readings may correlate with aerobic colony counts^{3, 5}
- Rapid results can be used to provide immediate feedback to personnel

1. Boyce JM. ICHE 2009;30:678-84; 2. Boyce JM. ICHE 2011;32:1187-93; 3. Luick L. Am J Infect Control 2013;41:751-2; 4. Amodio E, Dino C. J Infect Public Health 2014;7:92-8; 5. Huang Y. AJIC 2015;43:882-6

Improved cleaning after providing education and feedback based on ATP readings¹



1. Boyce JM. Monitoring effectiveness of hospital cleaning practices by use of an ATP bioluminescence assay. ICHE 2009;30:678-84; 2. Branch-Elliman W. Direct feedback with the ATP luminometer as a process improvement tool for terminal cleaning of patient rooms. AJIC 2014;42:195-7

Automated UV-C Radiation Device



- Mobile, automated, easy to use
- Kills *C. difficile* spores (2-3 log reduction)
- ~1 hour for *C. difficile* rooms

Nerandzic MM. BMC Infect Dis 2010;10:197; Nerandzic MM. PLOS One 2010; Rutala WA, et al. Infect Control Hosp Epidemiol 2010;31:1025-31; Boyce JM, et al. Infect Control Hosp Epidemiol 2011;32:1016-28; Stübich M, et al. Infect Control Hosp Epidemiol 2011;32:286-8; Havill NL, et al. Infect Control Hosp Epidemiol 2012;33:507-12

Impact of UV-C radiation devices on healthcare-associated CDI

- Multiple quasi-experimental studies have reported reductions in CDI with UV-C ¹⁻⁷
- Cluster randomized, multicenter, crossover study⁸
 - No decrease in CDI Incidence
 - Bleach: 30.4 cases/10,000 exposure days
 - Bleach+UV: 31.6 cases/10,000 exposure days

1. Miller R. AJIC 2015;43:1350-3; 2. Levin J. AJIC 2013;41:746-8; 3. Nagaraja A. AJIC. 4. Vianna PG. AJIC 2016;44:299-303; 5. Haas JP. AJIC 2014;42:586-90; 6. Nagaraja A. AJIC 2015, July 6; 7. Folkert C. APIC Annual Meeting 2016 (UV used for 85% of all discharges; significant reduction in CDI on 3 UV-C wards in comparison to 3 control wards); 8. Anderson D, et al. ID Week 2015

Can we minimize transmission of pathogens while maintaining a “home-like” environment?



Summary

- Contaminated environmental surfaces are an important source for transmission of bacterial and viral pathogens
- Monitoring and feedback is essential in order to improve cleaning and disinfection
- Direct observation of practices is useful
- Monitoring and feedback can have a positive impact on EVS programs