Environmental Disinfection for Control of Healthcare-Associated Pathogens

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Disclosures
- Research support
  - Merck, Clorox, EcoLab, GOJO, AvidBiotics, Altapure
- 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:

Basic infection control practices

- Chlorhexidine bathing
- Hand hygiene, gloves, gowns
- Infected Patient
- Susceptible Patient
- Decolonization
- Environmental Cleaning

2. Patients shed pathogens before and after they are symptomatic

- Preemptive isolation
- Daily disinfection of high-touch surfaces
- Extend isolation until discharge

3. Antibiotics promote shedding of pathogens

- Effect of antibiotics on density of VRE in stool
  - Log_{10} VRE/g
  - WEEK
  - Antibiotics with potent activity against anaerobes
  - Antibiotics with minimal activity against anaerobes

References:
Increased burden of VRE in stool increases shedding into the environment


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

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

![Graph showing timing of onset of *C. difficile* infection after transfer from the hospital to long-term care.]


Proposed definitions

<table>
<thead>
<tr>
<th>Hospital-onset, Hospital-associated</th>
<th>Hospital-associated</th>
</tr>
</thead>
<tbody>
<tr>
<td>48 h</td>
<td>&lt; 30 days</td>
</tr>
<tr>
<td>LTCF-onset, Hospital-associated</td>
<td>&gt; 30 days</td>
</tr>
<tr>
<td>LTCF-associated</td>
<td></td>
</tr>
</tbody>
</table>

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

![Diagram showing 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)


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

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

<table>
<thead>
<tr>
<th>Ref</th>
<th>Setting</th>
<th>Effect on CDI rates</th>
<th>Monitoring to ensure efficacy of disinfection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Medical Ward</td>
<td>Outbreak ended</td>
<td>Surface contamination reduced to 28% of initial levels</td>
</tr>
<tr>
<td>2</td>
<td>Bone marrow transplant (BMT) unit, Medical Ward, ICU</td>
<td>Significant decrease on BMT unit, but not on the other 2 wards</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>2 medical wards</td>
<td>Decreased on 1 of 2 wards</td>
<td>No decrease in prevalence of environmental contamination with hypochlorite use</td>
</tr>
<tr>
<td>4</td>
<td>Medical and surgical ICUs</td>
<td>Decreased on both units</td>
<td>No</td>
</tr>
<tr>
<td>5</td>
<td>3 hospitals</td>
<td>48% decrease in prevalence density of CDI</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>2 medical wards</td>
<td>85% decrease in hospital acquired CDI</td>
<td>Yes (ATP bioluminescence)</td>
</tr>
</tbody>
</table>


Potential adverse effects of bleach

Mattress exposed to bleach versus quaternary ammonium disinfectant

Peracetic acid concentrations in 2 disinfectants

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


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

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


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

<table>
<thead>
<tr>
<th>Viral DNA (Cauliflower Mosaic Virus)</th>
<th>Live virus (Bacteriophage MS2)</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Viral DNA" /></td>
<td><img src="image2" alt="Live virus" /></td>
</tr>
</tbody>
</table>


Dissemination of a viral DNA surrogate marker on a LTCF ward

<table>
<thead>
<tr>
<th>Time after marker inoculation on TV remote</th>
<th>2 hours</th>
<th>1 day</th>
<th>2 days</th>
<th>3 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTCF resident’s hands</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Inside Room</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Personal items</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surfaces</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bathrooms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside Room on unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nurturing station</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Staff bathroom</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Recreation area/cafeteria</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portable equipment</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoking area outside building</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Alhmadi H, et al. Dissemination of a Nonpathogenic Viral DNA Surrogate Marker from High-Touch Surfaces in Residents 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


<table>
<thead>
<tr>
<th></th>
<th>Pre-intervention</th>
<th>Post-intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent contamination of fomites</td>
<td>52/105 (49%)</td>
<td>39/106 (32%)</td>
</tr>
<tr>
<td>Mean virus particles recovered</td>
<td>1,100,000</td>
<td>820</td>
</tr>
<tr>
<td>Hands</td>
<td>1500</td>
<td>2</td>
</tr>
</tbody>
</table>


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

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)

Organisms linked to sinks

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


Recovery of potential pathogens from hospital surfaces


From sink to patient

Improving room design to reduce risk for transmission from sinks

Before renovation

After renovation


Strategies to improve environmental disinfection

Improve standard cleaning and disinfection

New technologies
Process not product

Poor implementation


Environmental cleaning interventions

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


Fluorescent markers


Fluorescent marker on a toilet seat after housekeeping cleaning.
Improvement in cleaning based on fluorescent marker removal

Baseline Fluorescent marker intervention UV disinfection

C. difficile contamination in terminally cleaned CDI rooms

Baseline Fluorescent marker intervention UV disinfection

An environmental disinfection odyssey

Baseline Fluorescent markers UV device Enhanced daily & terminal cleaning

Limitations of fluorescent markers

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


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

Table top surface

Table hand grip

Fluorescent markers do not detect incorrect use of products

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

Bleach wipe after multiple uses

Fresh wet bleach wipe

Fluorescent markers do not detect defective products

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
- Rapid results can be used to provide immediate feedback to personnel


Low-cost fluorescent marker

Improved cleaning after providing education and feedback based on ATP readings

Automated UV-C Radiation Device

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

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

- Multiple quasi-experimental studies have reported reductions in CDI with UV-C
  2. Levin J. ACP 2015;14:746-8
  4. Haas JP. AJIC 2014;42:446-50
  7. Folkert C. ACP 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)

- Cluster randomized, multicenter, crossover study
  2. Levin J. ACP 2015;14:746-8
  4. Haas JP. AJIC 2014;42:446-50
  7. Folkert C. ACP 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)

- No decrease in CDI Incidence
  - Bleach: 30.4 cases/10,000 exposure days
  - Bleach+UV: 31.6 cases/10,000 exposure days

5. Levin J. ACP 2015;14:746-8
7. Haas JP. AJIC 2014;42:446-50
10. Folkert C. ACP 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)
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