Reduce *C. difficile* Infection: Environmental Perspective

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Disclosure: Clorox

**LECTURE OBJECTIVES**

- Understand the epidemiology and impact of *C. difficile*
- Discuss how to prevent transmission of *C. difficile* via contaminated surfaces
- Identify effective preventive strategies
**CLOSTRIDIUM DIFFICILE**
**MICROBIOLOGY**

- Anaerobic bacterium
- Forms spores that persist
- Colonizes human GI tract
- Fecal-oral spread
- Toxins produce colitis
  - Diarrhea
  - More severe disease; death
- 2-steps to infection
  - New acquisition via transmission
  - Antibiotics result in vulnerability
- CDI due to BI/NAP1/027 carries high mortality and management remains problematic

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**C. difficile:**
**MICROBIOLOGY AND EPIDEMIOLOGY**

- Gram-positive bacillus: Strict anaerobe, spore-former
- Colonizes human GI tract
- Increasing prevalence and incidence
- New epidemic strain that hyperproduces toxins A and B
- Introduction of CDI from the community into hospitals
- High morbidity and mortality in elderly
- Asymptomatic *C. difficile* carriers may be reservoir in healthcare
- Inability to effectively treat fulminant CDI
- Absence of a treatment that will prevent recurrence of CDI
- Inability to prevent CDI
C. difficile Infection Rate, 2003-2013

C. difficile PATHOGENESIS

Handwashing and thorough cleaning of hospital rooms

Pathogenic spores are ingested

C. difficile spores germinate

Asymptomatic carrier

Patient undergoing antibiotic therapy

Protective immune response

Toxin production

Bacteria and spores in feces

Asymptomatic carrier

CDAD (Diarrhea and/or colitis)

CDC
FACTORS LEADING TO ENVIRONMENTAL TRANSMISSION OF CLOSTRIDIUM DIFFICILE

- Frequent contamination of the environment
- Stable in the environment
- Relatively resistant to disinfectants
- Low inoculating dose
- Common source of infectious gastroenteritis
- Susceptible population (limited immunity)

ENVIRONMENTAL CONTAMINATION

- 25% (117/466) of cultures positive (<10 CFU) for C. difficile. >90% of sites positive with incontinent patients. (Samore et al. AJM 1996;100:32)
- 31.4% of environmental cultures positive for C. difficile. (Kaatz et al. AJE 1988;127:1289)
- 9.3% (85/910) of environmental cultures positive (floors, toilets, toilet seats) for C. difficile. (Kim et al. JID 1981;143:42)
- 29% (62/216) environmental samples were positive for C. difficile. 29% (11/38) positive cultures in rooms occupied by asymptomatic patients and 49% (44/90) in rooms with patients who had CDAD. (NEJM 1989;320:204)
- 10% (110/1086) environmental samples were positive for C. difficile in case-associated areas and 2.5% (14/489) in areas with no known cases. (Fekety et al. AJM 1981;70:907)
C. difficile Environmental Contamination

- Frequency of sites found contaminated~10->50% from 13 studies—stethoscopes, bed frames/rails, call buttons, sinks, hospital charts, toys, floors, windowsills, commodes, toilets, bedsheets, scales, blood pressure cuffs, phones, door handles, electronic thermometers, flow-control devices for IV catheter, feeding tube equipment, bedpan hoppers
- C. difficile spore load is low—7 studies assessed the spore load and most found <10 colonies on surfaces found to be contaminated. Two studies reported >100; one reported a range of “1->200” and one study sampled several sites with a sponge and found 1,300 colonies C. difficile.

SURVIVAL
C. difficile

- Vegetative cells
  - Can survive for at least 24 h on inanimate surfaces

- Spores
  - Spores survive for up to 5 months. 10^6 CFU of C. difficile inoculated onto a floor; marked decline within 2 days. Kim et al. J Inf Dis 1981;143:42.
FREQUENCY OF ACQUISITION OF C. difficile ON GLOVED HANDS AFTER CONTACT WITH SKIN AND ENVIRONMENTAL SITES

Risk of hand contamination after contact with skin and commonly touched surfaces was identical (50% vs 50%)

FREQUENCY OF ENVIRONMENTAL CONTAMINATION AND RELATION TO HAND CONTAMINATION

- Study design: Prospective study, 1992
- Setting: Tertiary care hospital
- Methods: All patients with CDI assessed with environmental cultures
- Results
  - Environmental contamination frequently found (25% of sites) but higher if patients incontinent (>90%)
  - Level of contamination low (<10 colonies per plate)
  - Presence on hands correlated with prevalence of environmental sites

TRANSMISSION MECHANISMS INVOLVING THE SURFACE ENVIRONMENT


ACQUISITION OF MRSA ON HANDS AFTER CONTACT WITH ENVIRONMENTAL SITES
ACQUISITION OF MRSA ON HANDS/GLOVES AFTER CONTACT WITH CONTAMINATED EQUIPMENT

TRANSFER OF MRSA FROM PATIENT OR ENVIRONMENT TO IV DEVICE AND TRANSMISSION OF PATHOGEN
ACQUISITION OF *C. difficile* ON PATIENT HANDS AFTER CONTACT WITH ENVIRONMENTAL SITES AND THEN INOCULATION OF MOUTH

Effective Surface Decontamination

Product and Practice = Perfection
Effective Surface Decontamination

*Product* and Practice = Perfection

### DECREASING ORDER OF RESISTANCE OF MICROORGANISMS TO DISINFECTANTS/STERILANTS

<table>
<thead>
<tr>
<th>Most Resistant</th>
<th>Most Susceptible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prions</td>
<td>Enveloped Viruses</td>
</tr>
<tr>
<td>Spores (\textit{C. difficile})</td>
<td></td>
</tr>
<tr>
<td>Mycobacteria</td>
<td></td>
</tr>
<tr>
<td>Non-Enveloped Viruses (norovirus)</td>
<td></td>
</tr>
<tr>
<td>Fungi</td>
<td></td>
</tr>
<tr>
<td>Bacteria (MRSA, VRE, \textit{Acinetobacter})</td>
<td></td>
</tr>
</tbody>
</table>
DISINFECTANTS AND ANTISEPSIS
*C. difficile* spores at 20 min, Rutala et al, 2006

- No measurable activity (1 *C. difficile* strain, J9)
  - CHG
  - Vesphene (phenolic)
  - 70% isopropyl alcohol
  - 95% ethanol
  - 3% hydrogen peroxide
  - Clorox disinfecting spray (65% ethanol, 0.6% QUAT)
  - Lysol II disinfecting spray (79% ethanol, 0.1% QUAT)
  - TBQ (0.06% QUAT); QUAT may increase sporulation capacity—Lancet 2000;356:1324
  - Novaplus (10% povidone iodine)
  - Accel (0.5% hydrogen peroxide)

DISINFECTANTS AND ANTISEPSIS
*C. difficile* spores at 10 and 20 min, Rutala et al, 2006

- ~4 log₁₀ reduction (3 *C. difficile* strains including BI-9)
  - Clorox, 1:10, ~6,000 ppm chlorine (but not 1:50)
  - Clorox Clean-up, ~19,100 ppm chlorine
  - Tilex, ~25,000 ppm chlorine
  - Steris 20 sterilant, 0.35% peracetic acid
  - Cidex, 2.4% glutaraldehyde
  - Cidex-OPA, 0.55% OPA
  - Wavicide, 2.65% glutaraldehyde
  - Aldahol, 3.4% glutaraldehyde and 26% alcohol
C. difficile Spores
EPA-Registered Products

- List K: EPA’s Registered Antimicrobials Products Effective Against C. difficile spores, April 2014
- [http://www.epa.gov/oppad001/list_k_clostridium.pdf](http://www.epa.gov/oppad001/list_k_clostridium.pdf)
- 34 registered products; most chlorine-based, some HP/PA-based, PA with silver

SURFACE DISINFECTION
Effectiveness of Different Methods

<table>
<thead>
<tr>
<th>Technique (with cotton)</th>
<th>C. difficile Log_{10} Reduction (1:10 Bleach)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saturated cloth</td>
<td>3.90</td>
</tr>
<tr>
<td>Spray (10s) and wipe</td>
<td>4.48</td>
</tr>
<tr>
<td>Spray, wipe, spray (1m), wipe</td>
<td>4.48</td>
</tr>
<tr>
<td>Spray</td>
<td>3.44</td>
</tr>
<tr>
<td>Spray, wipe, spray (until dry)</td>
<td>4.48</td>
</tr>
<tr>
<td>5500 ppm chlorine pop-up wipe</td>
<td>3.98</td>
</tr>
<tr>
<td>Non-sporicidal wipe</td>
<td>≥2.9</td>
</tr>
</tbody>
</table>

Rutala, Gergen, Weber. ICHE 2012;33:1255-58
Disinfectant Product Substitutions
Donskey CJ. AJIC. May 2013

- Six of the 7 interventions were quasi-experimental studies in which rates were compared before and after interventions with no concurrent control group
- Confounding factors not reported (e.g., hand hygiene or Contact Precaution compliance)
- Decrease in the incidence in 6 of 7 studies

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>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Medical Ward</td>
<td>Outbreak ended</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>
</tr>
<tr>
<td>3</td>
<td>2 medical wards (crossover study)</td>
<td>Decreased on 1 of 2 wards</td>
</tr>
<tr>
<td>4</td>
<td>Medical and surgical ICUs</td>
<td>Decreased on both units</td>
</tr>
<tr>
<td>5</td>
<td>3 hospitals</td>
<td>48% decrease in prevalence density of CDI</td>
</tr>
<tr>
<td>6</td>
<td>2 medical wards</td>
<td>85% decrease in hospital acquired CDI</td>
</tr>
</tbody>
</table>

Effect of Environmental Disinfection with 10% Bleach on CDI Rates
(results suggest greater impact when baseline incidence is high)


Increased CDI Incidence on BMT Unit after Switch Back to Quaternary Ammonium Product

ALL “TOUCHABLE” (HAND CONTACT) SURFACES SHOULD BE WIPED WITH DISINFECTANT

“High touch” objects only recently defined (no significant differences in microbial contamination of different surfaces) and “high risk” objects not epidemiologically defined.

Effective Surface Decontamination

Product and Practice = Perfection
Thoroughness of Environmental Cleaning
Carling P. AJIC 2013;41:S20-S25

Mean proportion of surfaces disinfected at terminal cleaning is 32%

Terminal cleaning methods ineffective (products effective practices deficient [surfaces not wiped]) in eliminating epidemiologically important pathogens
EVALUATION OF HOSPITAL ROOM ASSIGNMENT AND ACQUISITION OF CDI

- Study design: Retrospective cohort analysis, 2005-2006
- Setting: Medical ICU at a tertiary care hospital
- Methods: All patients evaluated for diagnosis of CDI 48 hours after ICU admission and within 30 days after ICU discharge
- Results (acquisition of CDI)
  - Admission to room previously occupied by CDI = 11.0%
  - Admission to room not previously occupied by CDI = 4.6% (p=0.002)

Shaughnessy MK, et al. ICHE 2011;32:201-206

MONITORING THE EFFECTIVENESS OF CLEANING
Cooper et al. AJIC 2007;35:338; Carling P AJIC 2013;41:S20-S25

- Visual assessment - not a reliable indicator of surface cleanliness
- ATP bioluminescence - measures organic debris (each unit has own reading scale, <250-500 RLU)
- Microbiological methods - <2.5CFUs/cm²-pass; can be costly and pathogen specific
- Fluorescent marker - transparent, easily cleaned, environmentally stable marking solution that fluoresces when exposed to an ultraviolet light (applied by IP unbeknown to EVS, after EVS cleaning, markings are reassessed)
TERMINAL ROOM CLEANING: DEMONSTRATION OF IMPROVED CLEANING

- Evaluated cleaning before and after an intervention to improve cleaning
- 36 US acute care hospitals
- Assessed cleaning using a fluorescent dye
- Interventions
  - Increased education of environmental service workers
  - Feedback to environmental service workers
  †Regularly change “dotted” items to prevent targeting objects

Carling PC, et al. ICHE 2008;29:1035-41

SURFACE EVALUATION USING ATP BIOLUMINESCENCE

Swab surface → luciferase tagging of ATP → Hand held luminometer

Used in the commercial food preparation industry to evaluate surface cleaning before reuse and as an educational tool for more than 30 years.
Wipes
Cotton, Disposable, Microfiber, Cellulose-Based, Nonwoven Spunlace

Wipe should have sufficient wetness to achieve the disinfectant contact time (e.g. >1 minute)

Daily Disinfection of High-Touch Surfaces
Kundrapu et al. ICHE 2012;33:1039

Daily disinfection of high-touch surfaces (vs cleaned when soiled) with sporicidal disinfectant in rooms of patients with CDI and MRSA reduced acquisition of pathogens on hands after contact with surfaces and of hands caring for the patient
REDUCTION IN CDI INCIDENCE WITH ENHANCED ROOM DISINFECTION

- Before-after study of CDI incidence rates in two hyperendemic wards at a 1,249 bed hospital
- Intervention: Change from cleaning rooms with QUAT to bleach wipes (0.55% Cl) for both daily and terminal disinfection
- Results: CDI incidence dropped 85% from 24.2 to 3.6 cases per 10,000 pt-days (p<0.001); prolonged median time between HA CDI from 8 to 80 days

Orenstein R, et al
ICHE 2011;32:1137

Effective Surface Decontamination
Practice and Product
CONTROL MEASURES
* C. difficile Disinfection *

- In units with high endemic C. difficile infection rates or in an outbreak setting, use dilute solutions of 5.25-6.15% sodium hypochlorite (e.g., 1:10 dilution of bleach) or an approved sporicidal product for environmental decontamination of rooms of patients with CDI. (Dubberke et al. SHEA 2014).

- We now use chlorine solution in all CDI rooms for routine daily and terminal cleaning. One application of an effective product covering all hand contact surfaces (chlorine not used on floors) to allow a sufficient wetness for > 1 minute contact time. Chlorine solution normally takes 1-3 minutes to dry.

- For semicritical equipment, glutaraldehyde (20m), OPA (12m) and peracetic acid (12m) kills C. difficile spores using normal exposure times

NEW “NO TOUCH” APPROACHES TO ROOMDECONTAMINATION
Supplement Surface Disinfection
### EFFECTIVENESS OF UV ROOM DECONTAMINATION


### EFFECTIVENESS OF UV-C FOR ROOM DECONTAMINATION (Inoculated Surfaces)

<table>
<thead>
<tr>
<th>Pathogens</th>
<th>Dose*</th>
<th>Mean log_{10} Reduction Line of Sight</th>
<th>Mean log_{10} Reduction Shadow</th>
<th>Time</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRSA, VRE, MDR-A</td>
<td>12,000</td>
<td>3.90-4.31</td>
<td>3.25-3.85</td>
<td>~15 min</td>
<td>Rutala W, et al.¹</td>
</tr>
<tr>
<td>C. difficile</td>
<td>36,000</td>
<td>4.04</td>
<td>2.43</td>
<td>~50 min</td>
<td>Rutala W, et al.¹</td>
</tr>
<tr>
<td>MRSA, VRE</td>
<td>12,000</td>
<td>&gt;2-3</td>
<td>NA</td>
<td>~20 min</td>
<td>Nerandzic M, et al.²</td>
</tr>
<tr>
<td>C. difficile</td>
<td>22,000</td>
<td>&gt;2-3</td>
<td>NA</td>
<td>~45 min</td>
<td>Nerandzic M, et al.²</td>
</tr>
<tr>
<td>C. difficile</td>
<td>22,000</td>
<td>2.3</td>
<td>overall</td>
<td>67.8 min</td>
<td>Boyce J, et al.³</td>
</tr>
<tr>
<td>MRSA, VRE, MDR-A, Asp</td>
<td>12,000</td>
<td>3.5-4.0</td>
<td>1.7-4.0</td>
<td>30-40 min</td>
<td>Mahida N, et al.⁴</td>
</tr>
<tr>
<td>MRSA, VRE, MDR-A, Asp</td>
<td>22,000</td>
<td>&gt;4.0°</td>
<td>1.0-3.5</td>
<td>60-90 min</td>
<td>Mahida N, et al.⁴</td>
</tr>
<tr>
<td>C. difficile, G. stear spore</td>
<td>22,000</td>
<td>2.2 overall</td>
<td></td>
<td>73 min</td>
<td>Havill N et al.⁵</td>
</tr>
<tr>
<td>VRE, MRSA, MDR-A</td>
<td>12,000</td>
<td>1.61</td>
<td>1.18</td>
<td>25 min</td>
<td>Anderson et al.⁶</td>
</tr>
</tbody>
</table>

¹ICHE 2010:31:1025; ²BMC 2010:10:197; ³ICHE 2011:32:737; ⁴JHI 2013:84:323; ⁵ICHE 2012:33:507-12 ⁶ICHE 2013:34:466 * μWs/cm²; min = minutes; NA = not available
**USE OF HPV TO REDUCE RISK OF ACQUISITION OF MDROs**

- **Design:** 30 mo prospective cohort study with hydrogen peroxide vapor (HPV) intervention to assess risks of colonization or infection with MDROs
- **Methods:** 12 mo pre-intervention phase followed by HPV use on 3 units for terminal disinfection
- **Results**
  - Prior room occupant colonized or infected with MDRO in 22% of cases
  - Patients admitted to HPV decontaminated rooms 64% less likely to acquire any MDRO (95% CI, 0.19-0.70) and 80% less likely to acquire VRE (95% CI, 0.08-0.52)
  - Risk of *C. difficile*, MRSA and MDR-GNRs individually reduced but not significantly
  - Proportion of rooms environmentally contaminated with MDROs significantly reduced (RR, 0.65, P=0.03)
- **Conclusion:** HPV reduced the risk of acquiring MDROs compared to standard cleaning

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<table>
<thead>
<tr>
<th>Author, Year</th>
<th>HP Syst</th>
<th>Pathogen</th>
<th>Before HPV</th>
<th>After HPV</th>
<th>% Reduct</th>
</tr>
</thead>
<tbody>
<tr>
<td>French, 2004</td>
<td>VHP</td>
<td>MRSA</td>
<td>61/85-72%</td>
<td>1/85-1%</td>
<td>98</td>
</tr>
<tr>
<td>Bates, 2005</td>
<td>VHP</td>
<td><em>Serratia</em></td>
<td>2/42-5%</td>
<td>0/24-0%</td>
<td>100</td>
</tr>
<tr>
<td>Jeanes, 2005</td>
<td>VHP</td>
<td>MRSA</td>
<td>10/28-36%</td>
<td>0/50-0%</td>
<td>100</td>
</tr>
<tr>
<td>Hardy, 2007</td>
<td>VHP</td>
<td>MRSA</td>
<td>7/29-24%</td>
<td>0/29-0%</td>
<td>100</td>
</tr>
<tr>
<td>Dryden, 2007</td>
<td>VHP</td>
<td>MRSA</td>
<td>8/29-28%</td>
<td>1/29-3%</td>
<td>88</td>
</tr>
<tr>
<td>Otter, 2007</td>
<td>VHP</td>
<td>MRSA</td>
<td>18/30-60%</td>
<td>1/30-3%</td>
<td>95</td>
</tr>
<tr>
<td>Boyce, 2008</td>
<td>VHP</td>
<td><em>C. difficile</em></td>
<td>11/43-26%</td>
<td>0/37-0%</td>
<td>100</td>
</tr>
<tr>
<td>Bartels, 2008</td>
<td>HP dry mist</td>
<td>MRSA</td>
<td>4/14-29%</td>
<td>0/14-0%</td>
<td>100</td>
</tr>
<tr>
<td>Shapey, 2008</td>
<td>HP dry mist</td>
<td><em>C. difficile</em></td>
<td>48/203-24%; 7</td>
<td>7/203-3%; 0.4</td>
<td>88</td>
</tr>
<tr>
<td>Barbut, 2009</td>
<td>HP dry mist</td>
<td><em>C. difficile</em></td>
<td>34/180-19%</td>
<td>4/180-2%</td>
<td>88</td>
</tr>
<tr>
<td>Otter, 2010</td>
<td>VHP</td>
<td>GNR</td>
<td>10/21-48%</td>
<td>0/63-0%</td>
<td>100</td>
</tr>
</tbody>
</table>
During the UV period (pulsed Xenon), significant decrease in HA MDRO plus *C. difficile*. UV used for 76% of Contact Precaution discharges. 20% decrease in HA MDRO plus *C. difficile* during the 22-m UV period compared to 30-m pre-UV period.

This technology should be considered (capital equipment budget) for terminal room disinfection (e.g., after discharge of patients under CP, during outbreaks) if studies continue to demonstrate a benefit.
LECTURE OBJECTIVES

- Understand the epidemiology and impact of *C. difficile*
- Discuss how to prevent transmission of *C. difficile* via contaminated surfaces
- Identify effective preventive strategies

Reduce *C. difficile* Infections: Environmental Perspective

- Contaminated environment likely important for *C. difficile*
- Sodium hypochlorite (diluted 1:10 with water) or EPA-registered sporicidal products are effective but surfaces must be thoroughly wiped to eliminate environmental contamination
- Monitor the effectiveness of room cleaning (e.g., fluorescent dye)
- Inadequate terminal cleaning of rooms occupied by patients with *C. difficile* pathogens places the next patients in these rooms at increased risk of acquiring these organisms
- Eliminating the environment as a source for transmission of nosocomial pathogens requires: adherence to proper room cleaning and disinfection protocols (thoroughness), effective product (EPA-registered sporicide), and "no touch" technology if studies continue to demonstrate a benefit.
THANK YOU!
www.disinfectionandsterilization.org