Environmental Contamination: We Control the Future

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Former Director, Hospital Epidemiology, Occupational Health and Safety, UNC Health Care, Chapel Hill, NC (1979-2017)
DISCLOSURES
2022

• Consultations
  ■ PDI (Professional Disposables International)

• Honoraria
  ■ PDI

• Other
  ■ Kinnos, Ideate Medical
Objectives

- Role of environment in disease transmission
- Why we need continuous room decontamination
- Discuss continuous room decontamination technologies
- Evaluate a continuously active disinfectant
Objectives

- Role of environment in disease transmission
- Why we need continuous room decontamination
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- Evaluate a continuously active disinfectant
Environmental Contamination Leads to HAIs

Evidence environment contributes

- Role-MRSA, VRE, C. difficile
- Surfaces are contaminated—~25%
- EIP survive days, weeks, months
- Contact with surfaces results in hand contamination; contaminated hands transmit EIP to patients
- Disinfection reduces contamination
- Disinfection (daily) reduces HAIs
FREQUENCY OF ACQUISITION OF MRSA ON GLOVED HANDS AFTER CONTACT WITH SKIN AND ENVIRONMENTAL SITES

No significant difference on contamination rates of gloved hands after contact with skin or environmental surfaces (40% vs 45%; p=0.59)

Acquisition of EIP on Hands of Healthcare Providers after Contact with Contaminated Environmental Sites and Transfer to Other Patients
Acquisition of EIP on Hands of Patient after Contact with Contaminated Environmental Sites and Transfers EIP to Eyes/Nose/Mouth
Evidence environment contributes

- Role-MRSA, VRE, *C. difficile*
- Surfaces are contaminated~25%
- EIP survive days, weeks, months
- Contact with surfaces results in hand contamination; contaminated hands transmit EIP to patients
- Disinfection reduces contamination
- Disinfection (daily) reduces HAIs
- Rooms not adequately cleaned
Clean/Disinfect at Least Daily (surfaces not wiped thoroughly)
Thoroughness of Environmental Cleaning

P Carling. AJIC;2013:41:S20-S25

Mean = 32%

Objects

>110,000

Mean = 32%
Admission to Room Previously Occupied by Patient C/I with Epidemiologically Important Pathogen

- Results in the newly admitted patient having an increased risk of acquiring that pathogen by 39-353%
- For example, increased risk for *C. difficile* is 235% (11.0% vs 4.6%; Shaughnessy et al. ICHE 2011;32:201)
- Exposure to contaminated rooms confers a 5-6 fold increase in odds of infection, hospitals must adopt proven methods for reducing environmental contamination (Cohen et al. ICHE. 2018;39:541-546)
Surfaces should be hygienically clean (not sterile)-free of pathogens in sufficient numbers to prevent human disease
Environmental Contamination Leads to HAIs

- By contaminating hands/gloves via contact with the environment and transfer to patient or patient self inoculation
- Surfaces should be hygienically clean (not sterile)-free of pathogens in sufficient numbers to prevent human disease
- Two environmental surface concerns
  - Discharge/terminal-prevent infection to new patient in room
  - Daily room decontamination, suboptimal C/D
Key Pathogens Where Environmental Surfaces May Play a Role in Transmission

- MRSA
- VRE
- *Acinetobacter* spp.
- *Clostridium difficile*
- Norovirus
- Rotavirus
- SARS
A Bundle Approach to Surface Disinfection

- Develop policies and procedures
- Select cleaning and disinfecting products
- Educate staff-environmental services and nursing
- Monitor compliance (thoroughness of cleaning, product use) and feedback
- Implement “no touch” room decontamination technology and monitor compliance (and new strategies)
Effective Surface Decontamination Reduces Microbial Contamination (all touchable surfaces not just high-touch)

Product and Practice = Perfection
# LOW-LEVEL DISINFECTION FOR NONCRITICAL EQUIPMENT AND SURFACES


<table>
<thead>
<tr>
<th>Germicide</th>
<th>Use Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethyl or isopropyl alcohol</td>
<td>70-90%</td>
</tr>
<tr>
<td>Chlorine</td>
<td>100ppm (1:500 dilution)</td>
</tr>
<tr>
<td>Phenolic</td>
<td>UD</td>
</tr>
<tr>
<td>Iodophor</td>
<td>UD</td>
</tr>
<tr>
<td>Quaternary ammonium (QUAT)</td>
<td>UD</td>
</tr>
<tr>
<td>QUAT with alcohol</td>
<td>RTU</td>
</tr>
<tr>
<td>Improved hydrogen peroxide (HP)</td>
<td>0.5%, 1.4%</td>
</tr>
<tr>
<td>PA with HP, 4% HP, chlorine (C. difficile spores)</td>
<td>UD</td>
</tr>
</tbody>
</table>

UD=Manufacturer’s recommended use dilution; others in development/testing-electrolyzed water; polymeric guanidine; cold-air atmospheric pressure plasma (Boyce Antimicrob Res IC 2016. 5:10)
Clean/Disinfect at Least Daily
(surfaces should be wiped thoroughly)
These interventions (effective surface disinfection, thoroughness indicators) not enough to achieve consistent and high rates of cleaning/disinfection

No Touch
(supplements but do not replace surface cleaning/disinfection)
Enhanced Disinfection Leading to Reduction of Microbial Contamination and a Decrease in Patient Col/Infection

Anderson et al. Lancet 2017;289:805; Rutala et al. ICHE 2018;39:1118

<table>
<thead>
<tr>
<th></th>
<th>Standard Method</th>
<th>Enhanced Method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quat</td>
<td>Quat/UV</td>
</tr>
<tr>
<td>EIP (mean CFU per room)</td>
<td>60.8</td>
<td>3.4</td>
</tr>
<tr>
<td>Reduction (%)</td>
<td>94</td>
<td>81</td>
</tr>
<tr>
<td>Colonization/Infection (rate)</td>
<td>2.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Reduction (%)</td>
<td>35</td>
<td>17</td>
</tr>
</tbody>
</table>

All enhanced disinfection technologies were significantly superior to Quat alone in reducing EIPs. Comparing the best strategy with the worst strategy (i.e., Quat vs Quat/UV) revealed that a reduction of 94% in EIP (60.8 vs 3.4) led to a 35% decrease in colonization/infection (2.3% vs 1.5%). Our data demonstrated that a decrease in room contamination was associated with a decrease in patient colonization/infection. First study which quantitatively described the entire pathway whereby improved disinfection decreases microbial contamination which in-turn reduced patient colonization/infection.
Clinical Trials of “No Touch” Methods for Terminal Room Disinfection

<table>
<thead>
<tr>
<th>Year, author</th>
<th>Device/system</th>
<th>Study design</th>
<th>Setting</th>
<th>Selected results(^a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016, Vianna et al. [44]</td>
<td>UV-PX</td>
<td>Before–after</td>
<td>Community hospital</td>
<td>Facility wide:</td>
</tr>
<tr>
<td>2015, Horn and Otter [45]</td>
<td>HP vapor</td>
<td>Before–after</td>
<td>Hospital</td>
<td>CDI, VRE,</td>
</tr>
<tr>
<td>2015, Anderson et al. [46]</td>
<td>UV-C</td>
<td>RCT</td>
<td>9 hospitals</td>
<td>All MDROs (MRSA, VRE, CDI)</td>
</tr>
<tr>
<td>2015, Pegues et al. [47]</td>
<td>UV-C</td>
<td>Before–after</td>
<td>Academic center</td>
<td>CDI</td>
</tr>
<tr>
<td>2015, Nagaraja et al. [48]</td>
<td>UV-PX</td>
<td>Before–after</td>
<td>Academic center</td>
<td>CDI</td>
</tr>
<tr>
<td>2015, Miller et al. [49]</td>
<td>UV-PX</td>
<td>Before–after</td>
<td>Nursing home</td>
<td>CDI</td>
</tr>
<tr>
<td>2014, Mitchell et al. [50]</td>
<td>Dry HP vapor</td>
<td>Before–after</td>
<td>Hospital</td>
<td>MRSA colonization and infection</td>
</tr>
<tr>
<td>2014, Haas et al. [51]</td>
<td>UV-PX</td>
<td>Before–after</td>
<td>Academic center</td>
<td>CDI, MRSA, VRE, MDRO GNB, all MDROs</td>
</tr>
<tr>
<td>2013, Manian et al. [52]</td>
<td>HP vapor</td>
<td>Before–after</td>
<td>Community hospital</td>
<td>CDI</td>
</tr>
<tr>
<td>2013, Passaretti et al. [53]</td>
<td>HP</td>
<td>Prospective cohort</td>
<td>Academic center</td>
<td>VRE, all MDROs (MRSA, VRE, CDI)</td>
</tr>
<tr>
<td>2013, Levin et al. [54]</td>
<td>UV-PX</td>
<td>Before–after</td>
<td>Community hospital</td>
<td>CDI, VRE,</td>
</tr>
<tr>
<td>2011, Cooper et al. [55]</td>
<td>HP vapor</td>
<td>Before–after (2 cycles)</td>
<td>Hospitals</td>
<td>CDI (cases; incidence not significant)</td>
</tr>
<tr>
<td>2008, Boyce et al. [56]</td>
<td>HP vapor</td>
<td>Before–after</td>
<td>Community hospital</td>
<td>CDI</td>
</tr>
</tbody>
</table>

CDI, Clostridium difficile infection; ESBL, extended spectrum beta-lactamase producers; GNB, Gram negative bacteria; HP, hydrogen peroxide; MDRO, multidrug-resistant organism; MRSA, methicillin-resistant Staphylococcus aureus; UV-C, ultraviolet light – C; UV-PX, ultraviolet light – pulsed xenon; VRE, vancomycin-resistant Enterococcus.

\(^a\)All listed results were statistically significant (see reference for more details).
This technology ("no touch"-e.g., UV/HP) should be used (capital equipment budget) for terminal room disinfection (e.g., after discharge of patients on Contact Precautions).
Best Practices in Disinfection of Noncritical Surfaces in the Healthcare Setting: A Bundle Approach

NL Havill AJIC 2013;41:S26-30; Rutala, Weber. AJIC 2019;47:A96-A105

A Bundle Approach to Surface Disinfection

- Develop policies and procedures
- Select cleaning and disinfecting products
- Educate staff-environmental services and nursing
- Monitor compliance (thoroughness of cleaning, product use) and feedback
- Implement “no touch” room decontamination technology and monitor compliance (and new strategies)
Objectives

• Role of environment in disease transmission
• **Why we need continuous room decontamination**
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• Evaluate a continuously active disinfectant
Environmental Contamination Leads to HAIs

- By contaminating hands/gloves via contact with the environment and transfer to patient or patient self inoculation
- Surfaces should be hygienically clean (not sterile)-free of pathogens in sufficient numbers to prevent human disease
- Two environmental surface concerns
  - Discharge/terminal-prevent infection to new patient in room
  - Daily room decontamination, suboptimal and recontamination
Environmental Contamination Leads to HAIs

• By contaminating hands/gloves via contact with the environment and transfer to patient or patient self inoculation
• Surface should be hygienically clean (not sterile)-free of pathogens in sufficient numbers to prevent human disease
• Two environmental surface concerns
  ■ Discharge/terminal-new patient in room
  ■ Daily room decontamination (referred to “trash and dash”) suboptimal and recontamination
Recontamination Rate with MRSA After Terminal Disinfection with HP System

Hardy et al. J Hosp Infect 2007;66:360-368

Figure 1: Number of environmental sites (■) contaminated with MRSA, and number of patients (□) colonized with MRSA on intensive care units on each screen.

*MRSA environmental samples all negative; †no patients colonized with MRSA. HP, hydrogen peroxide vapour; TC, terminal clean.
• **Purpose:** assess how much environmental sites (e.g., chair, bedrail, overbed table, stock cabinet, IV pump, etc.) become recontaminated with *Acinetobacter* over time after cleaning/disinfection.

• **Results:**
  - At baseline all environmental sites sampled except overbed table were contaminated with *Acinetobacter*.
  - No *Acinetobacter* were detected except bed rail just after cleaning/disinfection.
  - First time to recontamination with *Acinetobacter* was 3 hours at chair, 2 hours at overbed table, 3 hours at stock cabinet, and 2 hours at IV pump. No recontamination was observed at the monitor.
  - The level of *Acinetobacter* contamination on surfaces was occasionally high (e.g., when a stock cabinet was sampled at 5 hours, 75 of 96 CFU were *Acinetobacter*).  
  - The amount of recontamination with aerobes and *Acinetobacter* on some surfaces tended to increase over time.
Overall, the frequency of all environmental sites positive for EIP was 21% in all rooms.
In hospitals (outside patient rooms-ED, clinics, Radiology, waiting), 9.1% of surfaces were positive for 1 or more bacterial pathogens and 4% positive for \textit{Candida} spp.

<table>
<thead>
<tr>
<th>Organism</th>
<th>Hospital 1 (N=327)</th>
<th>Hospital 2 (N=291)</th>
<th>Hospital 3 (N=300)</th>
<th>Hospital 4 (N=277)</th>
<th>Total Hospitals (N=1,195)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any MRSA, VRE, \textit{C. difficile}, GNB\textsuperscript{a}</td>
<td>36 (11.0)</td>
<td>16 (5.5)</td>
<td>15 (5.0)</td>
<td>42 (15.2)</td>
<td>109 (9.1)</td>
</tr>
<tr>
<td>MRSA</td>
<td>15 (4.6)</td>
<td>1 (0.3)</td>
<td>4 (1.3)</td>
<td>10 (3.6)</td>
<td>30 (2.5)</td>
</tr>
<tr>
<td>VRE</td>
<td>10 (3.1)</td>
<td>2 (0.7)</td>
<td>2 (0.7)</td>
<td>3 (1.1)</td>
<td>17 (1.4)</td>
</tr>
<tr>
<td>\textit{C. difficile}</td>
<td>5 (1.5)</td>
<td>8 (2.7)</td>
<td>5 (1.7)</td>
<td>5 (1.8)</td>
<td>23 (1.9)</td>
</tr>
<tr>
<td>GNB\textsuperscript{a}</td>
<td>10 (3.1)</td>
<td>9 (3.1)</td>
<td>5 (1.7)</td>
<td>29 (10.5)</td>
<td>53 (4.4)</td>
</tr>
<tr>
<td>\textit{Candida} spp</td>
<td>17 (5.2)</td>
<td>13 (5.9)</td>
<td>10 (3.3)</td>
<td>8 (2.9)</td>
<td>48 (4.0)</td>
</tr>
</tbody>
</table>

Note. GNB, gram-negative bacilli; MRSA, methicillin-resistant \textit{Staphylococcus aureus}; \textit{C. difficile}, \textit{Clostridioides difficile}; VRE, vancomycin-resistant enterococci.

\textsuperscript{a}GNB included \textit{Enterobacteriaceae}, \textit{Pseudomonas aeruginosa}, \textit{Acinetobacter baumannii}, and \textit{Stenotrophomonas maltophilia}.
In outpatient facilities, 6.2% of sites were positive for 1 or more bacterial pathogens.

Table 3. Environmental Contamination in Outpatient Clinics

<table>
<thead>
<tr>
<th>Organism</th>
<th>Clinic 1 (N=104)</th>
<th>Clinic 2 (N=66)</th>
<th>Clinic 3 (N=55)</th>
<th>Clinic 4 (N=55)</th>
<th>Surgery Center (N=205)</th>
<th>Total Samples (N=485)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any MRSA, VRE, C. difficile, GNB</td>
<td>16 (15.4)</td>
<td>4 (6.1)</td>
<td>5 (9.1)</td>
<td>1 (1.9)</td>
<td>4 (2.0)</td>
<td>30 (6.2)</td>
</tr>
<tr>
<td>MRSA</td>
<td>3 (2.9)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>1 (0.5)</td>
<td>4 (0.8)</td>
</tr>
<tr>
<td>VRE</td>
<td>5 (4.8)</td>
<td>0 (0)</td>
<td>1 (1.9)</td>
<td>0 (0)</td>
<td>0 (0)</td>
<td>6 (1.2)</td>
</tr>
<tr>
<td>C. difficile</td>
<td>5 (4.8)</td>
<td>0 (0)</td>
<td>2 (3.6)</td>
<td>1 (1.9)</td>
<td>1 (0.5)</td>
<td>9 (1.9)</td>
</tr>
<tr>
<td>GNB^</td>
<td>3 (2.9)</td>
<td>4 (6.1)</td>
<td>2 (3.6)</td>
<td>0 (0)</td>
<td>2 (1.0)</td>
<td>11 (2.3)</td>
</tr>
<tr>
<td>Candida spp</td>
<td>22 (21.2)</td>
<td>5 (7.6)</td>
<td>4 (7.3)</td>
<td>6 (10.9)</td>
<td>8 (3.9)</td>
<td>45 (9.3)</td>
</tr>
<tr>
<td>Marker removal (%), no. removed/no. placed (%)</td>
<td>4/54 (7.4)</td>
<td>35/98 (35.7)</td>
<td>21/61 (34.4)</td>
<td>28/44 (63.6)</td>
<td>82/99 (82.8)</td>
<td>170/367 (46.3)</td>
</tr>
</tbody>
</table>

Note. GNB, gram-negative bacilli; MRSA, methicillin-resistant Staphylococcus aureus; C. difficile, Clostridioides difficile; VRE, vancomycin-resistant enterococci.

^GNB included Enterobacteriaceae, Pseudomonas aeruginosa, Acinetobacter baumannii, and Stenotrophomonas maltophilia.
Increasing Bioburden Associated with Increasing HAIs and Decreasing Bioburden Associated with Deceased HAIs

Table 1. Epidemiologically-important pathogens (EIP) by intervention and contamination in 92 patient rooms during the benefits of enhanced terminal room disinfection study.

<table>
<thead>
<tr>
<th>Room type</th>
<th>Pathogen</th>
<th>Quat (N=21 rooms)</th>
<th>Quat/UV (N=28 rooms)</th>
<th>Bleach (N=23 rooms)</th>
<th>Bleach/UV (N=20 rooms)</th>
<th>Quat vs Quat/UV</th>
<th>Quat vs Bleach</th>
<th>Quat vs Bleach/UV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient room only</td>
<td>MDR-Acinetobacter</td>
<td>8.76</td>
<td>0.18</td>
<td>0.39</td>
<td>0.25</td>
<td>0.013</td>
<td>0.013</td>
<td>0.013</td>
</tr>
<tr>
<td></td>
<td><em>C. difficile</em></td>
<td>0</td>
<td>0.07</td>
<td>0.04</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MRSA</td>
<td>2.83</td>
<td>0.11</td>
<td>2.13</td>
<td>0.05</td>
<td>0.018</td>
<td>0.032</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td>VRE</td>
<td>6.62</td>
<td>0.07</td>
<td>0.78</td>
<td>0.35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EIP</td>
<td>19.71</td>
<td>0.43</td>
<td>3.35</td>
<td>0.65</td>
<td>0.013</td>
<td>0.032</td>
<td>0.045</td>
</tr>
<tr>
<td>Bathroom only</td>
<td>MDR-Acinetobacter</td>
<td>0.19</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0.008</td>
<td>0.032</td>
<td>0.045</td>
</tr>
<tr>
<td></td>
<td><em>C. difficile</em></td>
<td>3.76</td>
<td>2.79</td>
<td>4.43</td>
<td>3.25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MRSA</td>
<td>6.19</td>
<td>0</td>
<td>2.26</td>
<td>0.80</td>
<td>0.044</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>VRE</td>
<td>30.95</td>
<td>0.14</td>
<td>1.65</td>
<td>1.55</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EIP</td>
<td>41.10</td>
<td>2.93</td>
<td>8.35</td>
<td>5.60</td>
<td>0.013</td>
<td>0.035</td>
<td></td>
</tr>
<tr>
<td>Patient/Bathroom^2</td>
<td>MDR-Acinetobacter</td>
<td>6.55</td>
<td>0.18</td>
<td>0.39</td>
<td>0.25</td>
<td>0.017</td>
<td>0.032</td>
<td></td>
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<tr>
<td></td>
<td><em>C. difficile</em></td>
<td>3.76</td>
<td>2.86</td>
<td>4.48</td>
<td>3.25</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>MRSA</td>
<td>9.52</td>
<td>0.11</td>
<td>4.39</td>
<td>0.85</td>
<td>0.032</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>VRE</td>
<td>39.57</td>
<td>0.21</td>
<td>2.43</td>
<td>1.90</td>
<td>0.034</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EIP</td>
<td>60.81</td>
<td>3.36</td>
<td>11.70</td>
<td>6.25</td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Relationship between microbial reduction of epidemiologically-important pathogens (EIP) and colonization/infection in a patient subsequently admitted to a room of a patient colonized/infected with an EIP by decontamination method.

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
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</tr>
<tr>
<td>EIP (mean CFU per room)^1</td>
<td>60.8</td>
<td>3.4</td>
</tr>
<tr>
<td>Reduction (%)</td>
<td>94</td>
<td>94</td>
</tr>
<tr>
<td>Colonization/Infection (rate)^2</td>
<td>2.3</td>
<td>1.5</td>
</tr>
<tr>
<td>Reduction (%)</td>
<td>35</td>
<td>35</td>
</tr>
</tbody>
</table>

Figure 2. Quartile distribution of healthcare-acquired infections (HAIs) stratified by microbial burden measured in the intensive care unit (ICU) room during the patient’s stay. There was a significant association between burden and HAI risk (P = .038), with 89% of HAIs occurring among patients cared for in a room with a burden of more than 500 colony-forming units (CFUs)/100 cm².

Rutala WA et al. ICHE 2018;39:1118-1121

Salgado CD, et al. ICHE 2013;34:479-86
Objectives

- Role of environment in disease transmission
- Why we need continuous room decontamination
- **Discuss continuous room decontamination technologies**
- Evaluate a continuously active disinfectant
Rationale for Continuous Room Decontamination Methods

- Key issues in daily room disinfection and rationale for improving daily room disinfection
  - Environmental contamination leads to HAIs
  - Suboptimal disinfection
  - Rapid recontamination of surface occurs after disinfection
  - EIP are present on environmental surfaces (via prevalence survey, after terminal disinfection)
  - All touchable surfaces are equally contaminated
  - Increased surface bioburden is associated with an increased rate of HAIs and decreasing the bioburden (terminal disinfection) reduces HAIs

- Need to evaluate continuous room disinfection
Continuous Room Decontamination Technologies for Disinfection of the Healthcare Environment


- Visible light disinfection through LEDs
- Dry/dilute hydrogen peroxide; hydroxyl radicals, free reactive oxygen
- Self-disinfecting surfaces (e.g., heavy metals-copper, silver)
- Far UV 222 nm
- Bipolar ionization
- Multijet cold air plasma
- Continuously active disinfectant (CAD) or persistent disinfectant that provides continuous disinfection action
  - Allows continued disinfection and may eliminate the problem of recontamination
  - Patients, staff and visitors can remain in the room
Surfaces should be hygienically clean (not sterile)-free of pathogens in sufficient numbers to prevent human disease
Continuous Room Decontamination Technologies for Disinfection of the Healthcare Environment

- Visible light disinfection through LEDs
- Dry/dilute hydrogen peroxide; hydroxyl radicals, free reactive oxygen
- Self-disinfecting surfaces (e.g., heavy metals-copper, silver)
- Far UV 222 nm
- Bipolar ionization
- Multijet cold air plasma
- Continuously active disinfectant (CAD) or persistent disinfectant that provides continuous disinfection action
  - Allows continued disinfection and may eliminate the problem of recontamination
  - Patients, staff and visitors can remain in the room
Antimicrobial Activity of a Continuous Visible Light Disinfection System

- Visible Light Disinfection uses the blue-violet range of visible light in the 400-450nm region generated through light-emitting diodes (LEDs)
- Initiates a photoreaction with endogenous porphyrin found in microorganisms which yield production of reactive oxygen species inside microorganisms, leading to microbial death
- Overhead illumination systems can be replaced with Visible Light Disinfection counterparts
Visible Light Disinfection in a Patient Room
(automatic switching between modes performed by wall-mounted controls)

White light ~0.12 mW/cm²-0.16 mW/cm²

Blue light ~0.34-0.44 mW/cm²; increase kill
Blue and white light significantly reduced the three test bacteria (MRSA, VRE, MDR-A), and blue significantly reduced C. difficile spores.

• Safe

• Could augment episodic disinfection

• Could be considered for several healthcare decontamination applications
**Time to Specified Percent Reductions (Hours) of Epidemiologically-Important Pathogens with “Blue” Light and “White” Light**

Rutala et al. Infect Control Hosp Epidemiol 2018;39:1250-1253

<table>
<thead>
<tr>
<th>Treatment</th>
<th>25%</th>
<th>50%</th>
<th>90%</th>
<th>100%</th>
<th>Max Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blue</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MRSA</td>
<td>3</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>100</td>
</tr>
<tr>
<td>VRE</td>
<td>5</td>
<td>24</td>
<td>24</td>
<td>48</td>
<td>100</td>
</tr>
<tr>
<td>MDR-Acinet</td>
<td>1</td>
<td>5</td>
<td>NA</td>
<td>NA</td>
<td>88</td>
</tr>
<tr>
<td>C. difficile</td>
<td>5</td>
<td>72</td>
<td>NA</td>
<td>NA</td>
<td>65</td>
</tr>
<tr>
<td><strong>White</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MRSA</td>
<td>7</td>
<td>24</td>
<td>48</td>
<td>72</td>
<td>100</td>
</tr>
<tr>
<td>VRE</td>
<td>24</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>47</td>
</tr>
<tr>
<td>MDR-Acinet</td>
<td>6</td>
<td>24</td>
<td>48</td>
<td>72</td>
<td>100</td>
</tr>
<tr>
<td>C. difficile</td>
<td>5</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>25</td>
</tr>
</tbody>
</table>

NA-not achieved

MRSA, VRE, and MDR-*Acinetobacter* were reduced on Formica surfaces but slowly (>90% at 24-48h, 25-50% in 3-5h)
Continuous Room Decontamination Technologies for Disinfection of the Healthcare Environment


- Visible light disinfection through LEDs
- **Dry/dilute hydrogen peroxide; hydroxyl radicals; free reactive oxygen**
- Self-disinfecting surfaces (e.g., heavy metals-copper, silver)
- Far UV 222 nm
- Bipolar ionization
- Multijet cold air plasma
- Continuously active disinfectant (CAD) or persistent disinfectant that provides continuous disinfection action
  - Allows continued disinfection and may eliminate the problem of recontamination
  - Patients, staff and visitors can remain in the room
Dilute Hydrogen Peroxide Technology

UV activates the catalyst which creates H ion and hydroxyl radical and free electron, hydroxyl radicals removed from catalyst and combine to form HP; also H₂ and O₂ and electron make HP.
Evaluation of a Dilute HP System for Continuous Room Decontamination

Rutala et al. 2019; Infect Control Hosp Epidemiol. 40:1438-1439

Methods
- HPH units were installed in ceilings of a model room and the hallway in front of the room.
- An estimated 100-500 CFU for each test organisms was inoculated and spread on each Formica sheet then exposed to the DHP gas released into the room air.
- Triplicate samples were collected at times 0, 1, 3, 5, 6, 7, 24, 48 hrs

Results
- There were no statistical differences in survival between the DHP intervention and control groups except for very few time points.
- Our preliminary study using DHP demonstrated inconsistent microbicidal activity against MDRO on room surfaces, likely because we were unable to generate sufficient germicidal level under our test conditions. Requires further evaluation.
Objectives

- Role of environment in disease transmission
- Why we need continuous room decontamination
- Discuss continuous room decontamination technologies
- Evaluate a continuously active disinfectant
Continuous Room Decontamination Technologies for Disinfection of the Healthcare Environment

- Visible light disinfection through LEDs
- Dry/dilute hydrogen peroxide; hydroxyl radicals, free reactive oxygen
- Self-disinfecting surfaces (e.g., heavy metals-copper, silver)
- Far UV 222 nm
- Bipolar ionization
- Multijet cold air plasma
- Continuously active disinfectant (CAD) or persistent disinfectant that provides continuous disinfection action (polymer that retains Quat to surface)
  - Allows continued disinfection and may reduce or eliminate the problem of recontamination
  - Patients, staff and visitors can remain in the room
Evaluation of a Continuously Active Disinfectant
“EPA Protocol for Residual Self-Sanitizing Activity of Dried Chemical Residuals on Hard, Non-Porous Surfaces”

- Test surface inoculated ($10^5$), treated with test disinfectant, allowed to dry.
- Surface will undergo “wears” (abraded under alternating wet and dry conditions [24 passes, 12 cycles]) and 6 re-inoculations ($10^{\geq3.75}$, 30min dry) over 48hr
- At the end of the study and at least 48 hours later, the ability of the test surface to kill microbes (99.9%) within 1 min is measured using the last inoculation ($10^6$)
# Efficacy of a Continuously Active Disinfectant Against Healthcare Pathogens

Rutala WA et al. ICHE 2019;40:1284; Redmond et al. ICHE 2021, [https://doi.org/10.1017/ice.2021.66](https://doi.org/10.1017/ice.2021.66)

**4-5 log\(_{10}\) reduction in 5 min over 24hr for HA pathogens; ~99% reduction with Klebsiella and CRE Enterobacter. Redmond et al. found 5 log\(_{10}\) reduction for CRE Enterobacter, K. pneumoniae, MRSA, VRE, and C. auris**

<table>
<thead>
<tr>
<th>Test Pathogen</th>
<th>Mean Log(_{10}) Reduction , 95% CI n=4</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.aureus*</td>
<td>4.4 (3.9, 5.0)</td>
</tr>
<tr>
<td>S.aureus (formica)</td>
<td>4.1 (3.8, 4.4)</td>
</tr>
<tr>
<td>S.aureus (stainless steel)</td>
<td>5.5 (5.2, 5.9)</td>
</tr>
<tr>
<td>VRE</td>
<td>≥4.5</td>
</tr>
<tr>
<td>E.Coli</td>
<td>4.8 (4.6, 5.0)</td>
</tr>
<tr>
<td>Enterobacter sp.</td>
<td>4.1 (3.5, 4.6)</td>
</tr>
<tr>
<td>Candida auris</td>
<td>≥5.0</td>
</tr>
<tr>
<td>K pneumoniae</td>
<td>1.5 (1.4, 1.6)</td>
</tr>
<tr>
<td>CRE E.coli</td>
<td>3.0 (2.6, 3.4)</td>
</tr>
<tr>
<td>CRE Enterobacter</td>
<td>2.0 (1.6, 2.4)</td>
</tr>
<tr>
<td>CRE K pneumoniae</td>
<td>2.1 (1.8, 2.4)</td>
</tr>
</tbody>
</table>
Comparison of CAD with Three Disinfectants Using EPA Method and *S. aureus*


<table>
<thead>
<tr>
<th>Test Disinfectant</th>
<th>Mean $\log_{10}$ Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuously Active Disinfectant</td>
<td>4.4</td>
</tr>
<tr>
<td>Quat-Alcohol</td>
<td>0.9</td>
</tr>
<tr>
<td>Improved hydrogen peroxide</td>
<td>0.2</td>
</tr>
<tr>
<td>Chlorine</td>
<td>0.1</td>
</tr>
</tbody>
</table>
Comparison of *S. aureus* and enterococci recovered from PME at baseline, 1, 4, 7 days

The percentage of sites positive for *S. aureus* and/or enterococci was significantly reduced on days 1-7 in the continuously active group (3 of 93, 3%) versus both the no treatment group (20 of 97, 21%) and the Quat group (11 of 97, 11%)
The continuously active disinfectant was able to significantly reduce bioburden on bed rails, a critical touch surface.

Bioburden samples (bed rails) were collected before disinfection (gray) and at 1, 6, and 24 hours. Each disinfectant significantly controlled bioburden for the first hour. In comparison, the CAD (Disinfectant 1) was found superior for all time points compared to two other Quats.
Will the continuously active disinfectant kill viruses like coronaviruses?
A novel disinfectant studied using an EPA protocol (wears/re-inoculations) demonstrated excellent continuous antiviral activity (i.e., \(>4.5\log_{10}\) reduction) in 1 minute after 48 hours for SARS-CoV-2 and human coronavirus, 229E.

**Table 1. Inactivation of SARS-CoV-2 and the Human Coronavirus 229E by a Continuously Active Disinfectant Following a 48-Hour Period of Wear and Abrasion Exposure**

<table>
<thead>
<tr>
<th>Carrier Treatment with Wears and Re-inoculations</th>
<th>Contact Time</th>
<th>Mean Viral Recovery Titer per Carrier (Log(_{10}))</th>
<th>HCoV 229E Log(_{10}) Reduction</th>
<th>SARS-CoV-2 Log(_{10}) Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control (sterile ND water, n=3)</td>
<td>1 min</td>
<td>(\geq 2)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Continuously active disinfectant, n=3</td>
<td>1 min</td>
<td>(1.50 \pm 0.00)</td>
<td>&gt;4.50</td>
<td>&gt;4.22</td>
</tr>
</tbody>
</table>

*Note. NA, not available.*
Efficacy of a Continuously Active Disinfectant

Summary

A continuously active disinfectant may reduce or eliminate the problem of recontamination of environmental surfaces and the role of contaminated environmental surfaces and equipment in transmission of healthcare pathogens including SARS-CoV-2.
Environmental Disinfection in Healthcare Facilities

• Continuously active disinfectants reduces bioburden
• CAD shows promise and could reduce the risk of infections associated with devices (portable medical equipment) and surfaces
• Whether a CAD translates in a reduction of HAIs remains to be determined
• Continuously active disinfectants should not alter the frequency of cleaning and disinfection as one of the purposes of routine cleaning and disinfection is to remove dirt and debris in addition to the reduction of microbial contamination
Objectives

- Role of environment in disease transmission
- Why we need continuous room decontamination
- Continuous room decontamination technologies
- Evaluate a continuously active disinfectant
How Will We Prevent Infections Associated with the Environment?

Summary

• Implement evidence-based practices for surface disinfection
  ■ Evidence-based policies (product, practice, train, compliance, “no touch”)
  ■ Ensure use of safe and effective (against emerging pathogens such as *C. auris*, SARS-CoV-2 and CRE) low-level disinfectants
  ■ Ensure thoroughness of cleaning

• Use “no touch” room decontamination technology proven to reduce microbial contamination on surfaces and reduction of HAIs at terminal/discharge cleaning (e.g., Contact Precautions)

• Continuous room decontamination technology (e.g., continuously active disinfectants, $5 \log_{10}$ reduction in 5 min) shows promise and could reduce the risk of infections associated with devices (portable equipment) and surfaces
THANK YOU!
www.disinfectionandsterilization.org