New Approaches to Decontamination of Rooms After Patients Are Discharged

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Newer Approaches to Cleaning/Disinfection of Surfaces with Liquid Disinfectants

- Newer liquid disinfectants are available for cleaning/disinfection of environmental surfaces
  - Accelerated hydrogen peroxide liquid disinfectant
  - Peracetic acid/hydrogen peroxide
  - Activated hydrogen peroxide liquid/spray/wipes
    - Rapidly kills pathogenic bacteria and viruses
    - Yields low aerobic colony counts after cleaning
  - Electrolysed water disinfectant
- Impact on transmission of pathogens is unknown

Havill NL et al. APIC 2012
Meakin NS et al. J Hosp Infect 2012;80:122
No-Touch Room Decontamination Systems

- Hydrogen peroxide vapor technology
- Aerosolized hydrogen peroxide
- Gaseous ozone
- Saturated steam devices
- Alcohol-based fogging
- Peracetic acid fogging

- Mobile ultraviolet (UV) light devices
- Pulsed-xenon UV light system
- High-Intensity Narrow-Spectrum light
- Hydroxyl radical disinfection unit
Vapor-Based Hydrogen Peroxide Systems

• 2 major vapor-based hydrogen peroxide technologies are commercially available
  – Micro-condensation process (Bioquell)
  – “Dry gas” process (Steris)

• Despite differences in method of application, both technologies have been validated as effective

McAnoy AM: Vaporous Decontamination Methods, Australian Government DSTO 2006
Otter JA et al. ICHE 2009;30:574
Pottage T et al. J Hosp Infect 2010;24:55
Otter JA and Yezli S J Hosp Infect 2011;77:83
Vapor-Based Hydrogen Peroxide Systems

- Micro-condensation HPV system is highly effective in eradicating important pathogens
  - Methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), *Clostridium difficile*, *Klebsiella*, *Acinetobacter*, *Serratia*
  - *Mycobacterium tuberculosis*, fungi, viruses

- Laboratory and in-hospital studies document 6 log$_{10}$ reductions of a number of these pathogens

Hall L et al. Med Mycol 2008;46:189
Boyce JM et al. Infect Control Hosp Epidemiol 2008;29:723
Pottage T et al. J Hosp Infect 2010;24:55
Vapor-Based Hydrogen Peroxide Systems

• “Dry gas” vaporized hydrogen peroxide (VHP) system has been shown to be effective against
  – *Mycobacterium tuberculosis*, *Mycoplasma*, *Acinetobacter*, *Clostridium difficile*
  – *Bacillus anthracis*, viruses, prions

Heckert RA Appl Environ Microbiol 1997;63:3916
Ray A et al. Infect Control Hosp Epidemiol 2010;31:1236
Impact of Vapor-Based Hydrogen Peroxide Decontamination on Nosocomial Infections

• To date, most experience in healthcare facilities is with micro-condensation HPV system

• Decontamination of patient rooms using the micro-condensation HPV system has contributed to controlling several outbreaks
  – Cooper T et al. J Hosp Infect 2011;78:238

• “Dry gas” VHP system contributed to control of an outbreak in a long term care hospital
Micro-condensation HPV Process

• Several studies have shown that the micro-condensation HPV process has
  – Contributed to control of outbreaks caused by MRSA, *Serratia* and *C. difficile*, *Acinetobacter*
  – Associated with a significant reduction in incidence of nosocomial *C. difficile* infections
  – Been used to decontaminate a room previously occupied by a patient with Lassa fever
  – Feasible in hospital with high census levels

Boyce JM et al. Infect Control Hosp Epidemiol 2008;29:723
Otter JA et al. Infect Control Hosp Epidemiol 2009;30:574
Otter JA et al. J Hosp Infect 2010;75:325
Impact of Hydrogen Peroxide Vapor (HPV) Room Decontamination on Environmental Contamination and Nosocomial Transmission by *Clostridium difficile*

- A 10-month prospective trial in community-teaching hospital
- Before/After intervention study design
- After patients were discharged, environmental surfaces were cultured for *C. difficile*, MRSA and VRE
- Rooms were decontaminated using hydrogen peroxide vapor (HPV) microcondensation technology
- Same surfaces in decontaminated rooms were cultured for *C. difficile*, MRSA and VRE
  - Swab cultures processed at hospital
  - Sponge cultures processed at CDC

Boyce JM et al. Infect Control Hosp Epidemiol 2008;29:723
## Microbiologic Efficacy of HPV Decontamination

<table>
<thead>
<tr>
<th></th>
<th>Before HPV</th>
<th>After HPV</th>
</tr>
</thead>
<tbody>
<tr>
<td># of Swab Cultures</td>
<td>165</td>
<td>155</td>
</tr>
<tr>
<td># Cultures (+) for Cdiff</td>
<td>4 (2.4%)</td>
<td>0</td>
</tr>
<tr>
<td>MRSA</td>
<td>9 (5%)</td>
<td>0</td>
</tr>
<tr>
<td>VRE</td>
<td>23 (14%)</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th># of Sponges Cultured</th>
<th># of Sponges (+) for Cdiff</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>43</td>
<td>11 (25.6%)</td>
</tr>
</tbody>
</table>

Hospital of Saint Raphael
Impact of HPV Decontamination on Incidence of New Nosocomial CDAD Cases

Reduction in rate: 39%

Reduction in rate: 53%

Analysis only for months when epidemic strain was present

Boyce JM et al. ICHE 2008;29:723
Impact of Hydrogen Peroxide Vapor (HPV) Room Decontamination on Risk of Acquiring VRE or MRSA

- Prospective study on 3 intervention wards
- Rooms cultured for VRE and MRSA
- Rooms were decontaminated with HPV whenever possible
- Incidence of VRE and MRSA acquisition determined among patients who were subsequently admitted to the rooms

Passaretti CL et al. 48th ICAAC, Oct 2008, Abstr K-4214b
Impact of Hydrogen Peroxide Vapor (HPV) Room Decontamination on Risk of Acquiring VRE or MRSA

• Rooms were classified as:
  – **Missed**: preceding room occupant known to have VRE or MRSA, but room NOT decontaminated with HPV
  
  – **Not Done**: preceding room occupant NOT known to be colonized or infected with VRE or MRSA, and room NOT decontaminated with HPV
  
  – **HPV**: preceding room occupant known to be colonized or infected with VRE or MRSA; room was decontaminated with HPV
## Impact of Hydrogen Peroxide Vapor Room Decontamination on Risk of Acquiring VRE or MRSA

<table>
<thead>
<tr>
<th></th>
<th>Acquisition rate (# of acquisitions/1000 patient-days)</th>
<th>Adjusted Incidence Rate Ratio</th>
<th>P - Value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>VRE</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missed Not Done HPV</td>
<td>10.2, 6.9, 2.0</td>
<td>1.0, 0.59, 0.22</td>
<td>0.08, 0.02</td>
</tr>
<tr>
<td><strong>MRSA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missed Note Done HPV</td>
<td>3.4, 2.4, 0.6</td>
<td>1.0, 0.62, 0.18</td>
<td>0.26, 0.11</td>
</tr>
</tbody>
</table>

Passaretti CL et al. 48th ICAAC, Oct 2008, Abstr K-4214b
Terminal Room Disinfection Using Dilute Bleach Followed by Hydrogen Peroxide Vapor (HPV)

• Before-After study in 900-bed hospital

• Intervention included terminal disinfection of rooms vacated by patients with MDR *Acinetobacter*
  – 10% bleach disinfection, repeated 4 times (132 rooms)
  – 10% bleach disinfection x 1 before & after HPV treatment using microcondensation process (37 rooms)
  – 10% bleach x 1 followed by HPV (134 rooms)

• Cultures for *Acinetobacter* & MRSA were obtained after terminal disinfection/decontamination

Manian F et al. ICHE 2011;32:667
Terminal Room Disinfection Using Dilute Bleach Followed by Hydrogen Peroxide Vapor

- After 4 rounds of bleach cleaning
  - 27% of rooms had > 1 culture-positive site
  - 16% of rooms yielded MDR *Acinetobacter*; 14% grew MRSA

- After 1 round of bleach cleaning before/after HPV
  - Significant reduction in number of room sites (+) for *Acinetobacter* and for MRSA

- After 1 round of bleach cleaning followed by HPV
  - All culture-positive rooms were negative for *Acinetobacter* and MRSA after cleaning and HPV decontamination

Manian F et al. ICHE 2011;32:667
Aerosolized Hydrogen Peroxide (aHP) Dry Mist System

- Formerly Sterinis, now Advanced Sterilization Products
- Aerosol produced contains 8-12 micron particles
  - 5% hydrogen peroxide, < 50 ppm silver ions, < 50 ppm phosphoric acid, < 1ppm Arabica gum and 95% bi-osmotic water
- Cultures obtained before/after cycles have demonstrated significant reductions in bacterial (including spore) counts in laboratory settings and patient care areas
  - Did not completely eradicate *C. difficile* spores in 2 studies

Shapey S et al. J Hosp Infect 2008;70:136
Bartels MD et al. J Hosp Infect 2008;70:35
Aerosol Hydrogen Peroxide (aHP) “Dry Mist” Disinfection System

- *In vitro* study with MRSA and *Acinetobacter*
- Organisms inoculated onto stainless steel disks
  - With and without 5% sterile serum
  - Placed on surfaces, partly closed drawers, covered Petri dish
  - On upper side and underside of horizontal surfaces
- Log reductions achieved
  - ~ 4.5 $\log_{10}$ if no barrier present
  - 1.5 $\log_{10}$ to 3.5 $\log_{10}$ if in partly closed drawer

- Conclusions:
  - Effective in disinfecting open areas of test room
  - Poor activity in semi-closed or closed areas

Hydrogen Peroxide Vapor (HPV) vs Aerosolized Hydrogen Peroxide (aHP)

- Comparison of 1 HPV generator versus 2 aHP machines

- $6 \log_{10} Geobacillus\ stearothermophilus$ biologic indicator (BI) spore strips in multiple locations

- All biological indicators (BIs) were inactivated by HPV, compared to 10% to 79% by aHP
  - Cycle times: HPV = 3 hrs. aHP = 3.5 hrs

- Conclusion: 1 HPV generator was more effective than 2 aHP machines in inactivating BIs

Holmdahl T et al. Infect Control Hosp Epidemiol 2011;32:831
Hydrogen Peroxide Vapor vs Aerosolized Hydrogen Peroxide

- 2nd head-to-head comparison of HPV and aHP
- 4- and 6-log *G. stearothermophilus* BIs and test discs with MRSA, *Acinetobacter* or *C. difficile*
- Doors were sealed during HPV cycles, but not during aHP cycles (recommended by company)
- Detection of leakage of HP from rooms was performed with hand held detector

Fu TY et al. J Hosp Infect 2012;80:199
Hydrogen Peroxide Vapor vs Aerosolized Hydrogen Peroxide

- HPV generally yielded 6-log reduction, while aHP generally achieved < 4-log reduction on BIs and discs
- Culture results suggested that distribution of aHP was uneven, but this was not true for HPV
- HP leakage occurred from room when door was not sealed during aHP cycles, and levels of HP in room after aHP cycles exceeded short-term exposure limit x 2 hrs
- Conclusion: HPV was safer, faster and more effective than aHP for biological inactivation

Fu TY et al. J Hosp Infect 2012;80:199
Other Aerosol-Based Hydrogen Peroxide Systems

- Aerosol “dry fog” system with heating and ionizing turbine
  - 6% hydrogen peroxide
  - 30 ppm colloidal silver
  - Average particle size – 5 microns

- Surfaces inoculated with VRE yielded 1.0 – 1.7 \( \log_{10} \) reduction after treatment

- In a trial conducted in 8 hospital rooms, 33.3% of surfaces yielded no growth after treatment

# Relative Efficacy of No-Touch Hydrogen Peroxide Decontamination Systems

<table>
<thead>
<tr>
<th>Reduction in Bacterial Levels</th>
<th>Micro-condensation HPV Bioquell</th>
<th>Dry Gas Vaporized HP Steris</th>
<th>Dry Mist Aerosol HP Sterinis (ASP)</th>
<th>Dry Fog Aerosol HP Oxypharm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log Reduction Vegetative Bacteria</td>
<td>$10^6$</td>
<td>$10^6$</td>
<td>$10^3 - 10^{4.5}$</td>
<td>$10^1 - 10^{1.7}$</td>
</tr>
<tr>
<td>Log Reduction Bacterial Spore strips</td>
<td>$10^6$</td>
<td>$10^6$</td>
<td>$\sim 10^1 - &lt; 10^4$</td>
<td>??</td>
</tr>
<tr>
<td>Log Reduction <em>C. difficile</em> Spores</td>
<td>$10^6$</td>
<td>$10^6$</td>
<td>$10^4$</td>
<td>??</td>
</tr>
</tbody>
</table>

Ultraviolet Light Systems

- Automated mobile UV light units that emit UV-C (254 nm range) can be placed in patient rooms after patient discharge and terminal cleaning had been performed.
- Units can be set to kill vegetative bacteria or to kill spores.
- Significantly reduce bacterial counts in patient rooms.
- Easy to use and require relatively short cycle times.
Automated Ultraviolet Light Systems

- Cultures obtained from surfaces inoculated with *C. difficile*, MRSA, VRE or *S. warneri* were obtained before/after UVC light decontamination

- UV-C light decontamination produced
  - 3-4 log$_{10}$ reductions with MRSA & VRE
  - 2-3 log$_{10}$ reductions of *C. difficile* on various surfaces

- Median of 2 log$_{10}$ reduction of *C. difficile* spores inoculated on stainless steel disk carriers

Nerandzic M et al. BMC Infect Dis 2010;10:197
Rutala WA et al. ICHE 2010;31:1025
Boyce JM et al. ICHE 2011;32:737
Comparison of HPV vs Mobile UV Light System

• Prospective study in 500-bed hospital

• 15 rooms were each decontaminated once with HPV and UV-C light processes, at intervals > 2 months apart

• 5 high-touch surfaces in each room were sampled before/after decontamination & aerobic colony counts (ACCs) were determined

• Carrier disks with $10^6$ C. difficile spores and BIs with $10^4$ and $10^6$ G. stearothermophilus spores were placed in 5 sites in each room before decontamination

Havill NL & Boyce JM  ICHE 2012;33:507
Comparison of HPV vs Mobile UV Light System

- Of sites which had (+) ACCs before decontamination
  - 93% yielded no growth after HPV treatment
  - 52% yielded no growth after UV-C light treatment

- Mean *C. difficile* log reductions
  - > 6 logs for HPV vs ~ 2 logs for UV-C

- Proportion of $10^4$ BIs yielded no growth after Rx
  - 100% after HPV, compared to 22% after UV-C

- Proportion of $10^6$ BIs yielded no growth after Rx
  - 99% after HPV, compared to 0% after UV-C

Havill NL & Boyce JM  ICHE 2012;33:507
Comparison of HPV vs Mobile UV Light System

• Sites out of direct line of sight were significantly more likely to show growth after UV-C than after HPV

• Mean cycle times
  - 153 min for HPV vs 73 min for UV-C

• Conclusions: Both HPV and UV-C reduced bacterial contamination in patient rooms
• HPV was significantly more effective in rendering surfaces culture-negative; more effective vs spores
• UV-C was faster and easier to use

Havill NL & Boyce JM  ICHE 2012;33:507
Pulsed-Xenon UV Light System

• Pulsed-xenon UV (PX-UV) device was studied in 12 rooms of VRE pts

• High-touch sites were cultured
  • 14 samples taken before manual cleaning & after PX-UV treatment
  • 14 samples taken after routine terminal room cleaning
  • 7 samples were taken before cleaning, after standard terminal cleaning, and after PX-UV treatment

• Swab cultures were placed in D-E neutralizing broth and shipped to lab

Stibich M et al. ICHE 2011;32:286
Pulsed-Xenon UV Light System

- 12-min multi-position treatment cycle was used

- Before cleaning
  - 78% of samples yielded growth; 23% were VRE-positive

- After standard terminal cleaning
  - 64% of samples yielded growth; 8% were VRE-positive

- After PX-UV treatment
  - 36% of samples yielded growth; none were VRE-positive
  - Median ACCs were reduced from 33/cm² to 1.2/cm²

- Conclusion: PX-UV system showed significant reduction in microbial load and eliminated VRE on sampled surfaces

Stibich M et al.  ICHE 2011;32:286
Other Novel No-Touch Room Decontamination Systems

• Gaseous ozone

• Saturated steam vapor system

• High-Intensity Narrow-spectrum light
  – Bache SE et al. Burns 2012;38:69

• Hydroxyl radical disinfection units
Summary

• New liquid products for disinfection of environmental surfaces include:
  – New hypochlorite-based products effective against *C. difficile* spores
  – Liquid accelerated/activated hydrogen peroxide products

• New area decontamination processes:
  • Require more time than cleaning by housekeeper
  • Are more expensive than cleaning by housekeepers
  • Reduce or eliminate pathogens on surfaces more reliably than standard cleaning by housekeepers
  • Vapor-based hydrogen peroxide systems are more effective at eradicating pathogens on surfaces
  • More data are needed on relative effectiveness of various systems on reducing transmission of pathogens
Traditional Room Disinfection After Patient Discharge

- Hospital room disinfection is most commonly performed by using liquid disinfectants
  - Spraying and wiping surfaces
  - Wiping surfaces with a mop, cloth or wipe containing disinfectant

- Traditional liquid disinfectants used for surface disinfection
  - Quaternary ammonium compounds
  - Phenolics
  - Bleach (l’eau de javel)
  - Alcohols
  - Chlorine dioxide
  - Aldehydes
Newer Approaches to Cleaning/Disinfection of Surfaces with Liquid Disinfectants

- Newer liquid surface disinfectants are effective at reducing surface contamination

- Few data are available on the impact of newer surface disinfectants on transmission of healthcare-associated pathogens

Meakin NS et al. J Hosp Infect 2012;80:122
Alfa MJ et al. BMC Infect Dis 2010;10:268
Newer Approaches to Cleaning/Disinfection of Surfaces with Liquid Disinfectants

• Sodium hypochlorite (dilute bleach) is recommended for disinfection of surfaces potentially contaminated with *C. difficile* or Norovirus
  – Rutala WA et al. CDC Disinfection & Sterilization Guideline, 2008

• New hydrogen peroxide-based liquid disinfectant/cleaners are active against *C. difficile* spores
  – Offer alternative to sodium hypochlorite (bleach) for disinfecting surfaces contaminated with *C. difficile*
Micro-condensation Hydrogen Peroxide Vapor (HPV) System

• In healthcare facilities, most experience with vapor-based hydrogen peroxide decontamination has been with the micro-condensation system by (Bioquell)

• The Bioquell micro-condensation HPV process has been used for room or area decontamination
  – in healthcare facilities in 20 countries around the world
  – In life sciences facilities in 45 countries
Micro-condensation HPV Process

- HPV generator and catalytic converter are placed in room or area to be decontaminated
- Air vents and door are sealed with tape
- Generator is turned on to deliver vapor to room
- When adequate hydrogen peroxide has been delivered to room, generator is turned off
- Catalytic converter is turned on, changes hydrogen peroxide vapor to oxygen and water vapor
- Tape and equipment removed from room
- Average total time for cycle: 2 to 2.5 hrs