Disinfection and Sterilization
Current Issues, New Research and New Technology

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Former Director, Hospital Epidemiology, Occupational Health and Safety, UNC Health Care, Chapel Hill, NC (1979-2017)
Disinfection and Sterilization
Current Issues, New Research and New Technologies

- Sterilization robustness
- *C. auris* susceptible to germicides and UV-C
- Continuously active disinfectant
- Sporicide in all discharge rooms
Sterilization of “Critical Objects”

Steam sterilization
Hydrogen peroxide gas plasma
Ethylene oxide
Ozone and hydrogen peroxide
Vaporized hydrogen peroxide
Steam formaldehyde
STERILIZATION

Factors affecting the efficacy of sterilization

- Bioburden
- Cleaning
- Pathogen type
- Protein and salt
- Biofilm accumulation
- Lumen length and diameter
- Restricted flow
Factors affecting the efficacy of sterilization

- Bioburden
- Cleaning
- Pathogen type
- Protein and salt
- Biofilm accumulation
- Lumen length and diameter
- Restricted flow
## Penicylinders Sterilized by Various Low-Temperature Sterilization Methods

<table>
<thead>
<tr>
<th>Challenge:</th>
<th>12/88</th>
<th>100%ETO</th>
<th>HCFC-ETO</th>
<th>HPGP</th>
</tr>
</thead>
<tbody>
<tr>
<td>10% Serum, 0.65% Salt</td>
<td>97%</td>
<td>60.3%</td>
<td>95.2%</td>
<td>37%</td>
</tr>
<tr>
<td>(7 organisms, N=63)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Serum or Salt,</td>
<td>100%</td>
<td>100%</td>
<td>96%</td>
<td>100%</td>
</tr>
<tr>
<td>(3 organisms, N=27)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SS Carriers Inoculated with Test Organisms
(to simulated inadequate cleaning, added 10% FCS and 0.52% salt; $10^4$-$10^6$ organisms)
Comparative Evaluation of the Microbicidal Activities of Sterilization Technologies in the Presence of Salt and Serum

Study conditions not representative of practice or manufacturer’s recommendations
Rutala, Gergen, Sickbert-Bennett, Weber. ICHE, 2019

<table>
<thead>
<tr>
<th>Organism</th>
<th>Steam</th>
<th>ETO</th>
<th>HPGP</th>
<th>VHP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetative Cells-Pa, Ec, VRE, Sa, Mt</td>
<td>0% (0/140)</td>
<td>3% (6/220)</td>
<td>3% (5/180)</td>
<td>72% (129/180)</td>
</tr>
<tr>
<td>Spores-Ba, Gs, Cd</td>
<td>0% (0/80)</td>
<td>0% (0/90)</td>
<td>0% (0/90)</td>
<td>86% (77/90)</td>
</tr>
<tr>
<td>Overall Total</td>
<td>0% (0/220)</td>
<td>2% (6/310)</td>
<td>2% (5/270)</td>
<td>76% (206/270)</td>
</tr>
</tbody>
</table>
Conclusions

• All LTST technologies have limitations
• LTST (ETO, HP gas plasma) demonstrate a significant number of failures in presence of serum or salt
• Salt and serum provide protection for spores and bacteria
• Steam sterilization is the most effective and had the largest margin of safety, followed by ETO and HPGP and lastly, VHP
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Deadly, drug-resistant Candida yeast infection spreads in the US

*Candida auris* causes multidrug-resistant infections that can result in organ failure

Kateryna Kon/Science Photo Library
Efficacy of Disinfectants and Antiseptics against *Candida auris*

Rutala, Kanamori, Gergen, Sickbert-Bennett, Weber, ICHE 2018

- ≥3 log<sub>10</sub> reduction (*C. auris*, 1m, 5% FCS, QCT)
  - 0.20% peracetic acid
  - 2.4% glutaraldehyde
  - 0.65% hydrogen peroxide, 0.14% peroxyacetic acid
  - 0.5% Quat, 55% isopropyl alcohol
  - Disinfecting spray (58% ethanol, 0.1% QUAT)
  - 28.7% isopropyl alcohol, 27.3% ethyl alcohol, 0.61% QAC
  - 0.07% o-phenylphenol, 0.06% p-tertiary amylphenol
  - 70% isopropyl alcohol
  - ~5,250 ppm chlorine
  - Ethanol hand rub (70% ethanol)
  - Accelerated hydrogen peroxide, 1.4%
  - Accelerated hydrogen peroxide, 2%
Efficacy of Disinfectants and Antiseptics against *Candida auris*

Rutala, Kanamori, Gergen, Sickbert-Bennett, Weber, ICHE 2018

- $\leq 3 \log_{10}$ (most $< 2 \log_{10}$) reduction (*C. auris*, 1m, 5% FCS, QCT)
  - 0.55% OPA
  - 3% hydrogen peroxide
  - Quat, (0.085% QACs)
  - 10% povidone-iodine
  - ~1,050 ppm chlorine
  - 2% Chlorhexidine gluconate-CHG
  - 4% CHG
  - 0.5% triclosan
  - 1% CHG, 61% ethyl alcohol
  - 1% chloroxylenol
Inactivation of *C. auris* and *C. albicans* by UV-C

(UV-C device delivered a dose of 12,000µWs/cm², vegetative bacterial cycle, 17-19m)

Rutala, Kanamori, Gergen, Sickbert-Bennett, Weber, 2019
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To reduce microbial contamination

Continuous Room Decontamination Technology
Relationship Between Microbial Burden and HAIs


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>
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<tr>
<th>Standard Method</th>
<th>Enhanced method</th>
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<tbody>
<tr>
<td></td>
<td>Quat</td>
</tr>
<tr>
<td>EIP (mean CFU per room)$^a$</td>
<td>60.8</td>
</tr>
<tr>
<td>Reduction (%)</td>
<td>94</td>
</tr>
<tr>
<td>Colonization/Infection (rate)$^b$</td>
<td>2.3</td>
</tr>
<tr>
<td>Reduction (%)</td>
<td>35</td>
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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 cm$^2$. 
Continuous Room Decontamination Technologies for Disinfection of the Healthcare Environment

- Visible light disinfection through LEDs
- Low concentration hydrogen peroxide
- Self-disinfecting surfaces
- Continuously active disinfectant (CAD) or persistent disinfectant that provides continuous disinfection action
  - Allows continued disinfection (may 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”

Abrasion Tester

Test Surface

Abrasion Boat
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 ($10^3$, 30min dry) over 24hr
- At the end of the study and at least 24 hours later, the ability of the test surface to kill microbes (99.9%) within 5 min is measured using the last inoculation ($10^6$)
4-5 log₁₀ reduction in 5min over 24hr for most pathogens; ~99% reduction with Klebsiella and CR Enterobacter.

<table>
<thead>
<tr>
<th>Test Pathogen</th>
<th>Mean Log₁₀ Reduction , 95% CI n=4</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>S.aureus</em></td>
<td>4.4 (3.9, 5.0)</td>
</tr>
<tr>
<td><em>S.aureus</em> (Formica)</td>
<td>4.1 (3.8, 4.4)</td>
</tr>
<tr>
<td><em>S.aureus</em> (stainless steel)</td>
<td>5.5 (5.2, 5.9)</td>
</tr>
<tr>
<td>VRE</td>
<td>≥4.5</td>
</tr>
<tr>
<td><em>E.coli</em></td>
<td>4.8 (4.6, 5.0)</td>
</tr>
<tr>
<td><em>Enterobacter sp.</em></td>
<td>4.1 (3.5, 4.6)</td>
</tr>
<tr>
<td><em>Candida auris</em></td>
<td>≥5.0</td>
</tr>
<tr>
<td><em>K pneumoniae</em></td>
<td>1.5 (1.4, 1.6)</td>
</tr>
<tr>
<td>CR <em>E.coli</em></td>
<td>3.0 (2.6, 3.4)</td>
</tr>
<tr>
<td>CR <em>Enterobacter</em></td>
<td>2.0 (1.6, 2.4)</td>
</tr>
<tr>
<td>CR <em>K pneumoniae</em></td>
<td>2.1 (1.8, 2.4)</td>
</tr>
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*Test surface glass unless otherwise specified*
## Comparison of CAD with Three Disinfectants Using EPA Method and *S. aureus*

Rutala WA, Gergen M, Sickbert-Bennett E, Anderson D, Weber D. ICHE 2019

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<thead>
<tr>
<th>Test Disinfectant</th>
<th>Mean Log$_{10}$ Reduction</th>
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<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>
Efficacy of a Continuously Active Disinfectant

Summary

• Preliminary studies with a new continuously active disinfectant are promising (e.g., $4-5 \log_{10}$ reduction in 5min over 24hr)

• Unclear why 99% reduction with *Klebsiella* and CR *Enterobacter* (another researcher [Donskey] found a $4 \log_{10}$ reduction; most surfaces have $<100$ CFU/Rodac

• Continuously active disinfectants may reduce or eliminate the problem of recontamination.
The CAD (disinfectant 1, red-24h sample) was able to significantly control bioburden on bed rails, a critical touch surface.
Why do we need to consider continuous room decontamination technology?

To reduce microbial contamination
(associated with suboptimal CD practices and recontamination)
Evaluation of Three Disinfectants for Ability to Limit Establishment of Bioburden After Disinfection

- The use of a continuously active disinfectant (CAD) offers the infection prevention community a new opportunity to limit the re-establishment of bacteria on touch surfaces in the hospital environment.
- Several studies (Salgado et al., Anderson et al, Rutala et al) were able to demonstrate that when the microbial bioburden of a patient room was kept low, the risk of acquisition of HAIs was reduced.
Relationship Between Microbial Burden and HAIs

Rutala WA et al. ICHE 2018;38:1118-1121; Salgado CD, et al. ICHE 2013;34:479-86

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.

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<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>
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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.
Environmental Disinfection in Health Care Facilities

Recommendations

- Decontaminate **surfaces in patient room** that are touched by health care workers and patients (daily, terminal)
- Decontaminate **portable equipment** that is shared among patients such as medication carts, wheelchairs, portable x-ray machines, etc. **after each patient use**
Environmental Disinfection in Health Care Facilities

- Environmental disinfection is suboptimal
  - Patient rooms are contaminated due to suboptimal cleaning/disinfection and recontamination
  - Portable equipment not decontaminated per policy
  - Outbreaks and environmental-mediated infections occur
Environmental Disinfection in Healthcare Facilities

- Continuously active disinfectants reduces bioburden
- 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
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Asymptomatic carriers contribute to *C. difficile* transmission

1. Curry SR. Clin Infect Dis 2013 (29% of hospital-associated CDI cases linked to carriers by MLVA); 2. Blixt T. Gastroenterol 2017;152:1031 (exposure to carriers increased CDI risk); 3. Longtin Y. JAMA Int Med 2016 (screening for and isolating carriers reduced CDI by 63%); 4. Samore MH. Am J Med 1996;100:32 (only 1% of cases linked to asymptomatic carriers - roommates and adjacent rooms - by PFGE/REA); 5. Eyre DW. PLOS One 2013;8:e78445 (18 carriers: no links to subsequent CDI cases); 6. Lisenmyer K. Clin Infect Dis 2018 (screening and isolation of carriers associated with control of a ward outbreak); 7. Paquet-Bolduc B. Clin Infect Dis 2018 (unit-wide screening and isolation of carriers not associated with shorter outbreak durations vs historical controls); 8. Donskey CJ. Infect Control Hosp Epidemiol 2018 (14% of healthcare-associated CDI cases linked to LTCF asymptomatic carriers); 9. Kong LY. Clin Infect Dis 2018 (23% of healthcare-associated CDI linked to carriers vs 42% to CDI patient).
Interventions focused on CDI rooms

CDI rooms

Non-CDI rooms

Sporicidal disinfection only in CDI rooms

Interventions addressing CDI cases and asymptomatic carriers

Sporicidal disinfection in CDI and non-CDI rooms
Use of Sporicidal Disinfectant on *C. difficile* spore Contamination in non-*C. difficile* Infection Rooms

Wong et al. AJIC. 2019;47:843-845

The percentage of rooms contaminated with *C. difficile* was significantly reduced during the period with a sporicidal product was used 5% vs 24%. Results suggest sporicidal disinfectant in all postdischarge rooms could potentially be beneficial in reducing the risk for *C. difficile* transmission from contaminated surfaces.
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