Safer Healthcare Environments for Infection Prevention

William A. Rutala, Ph.D., M.P.H., C.I.C.
Director, Statewide Program for Infection Control and Epidemiology
and Professor of Medicine, University of North Carolina at Chapel Hill, NC, USA
Former Director, Hospital Epidemiology, Occupational Health and Safety, UNC Health Care, Chapel Hill, NC (1979-2017)
DISCLOSURES
2018

• Consultations
  ■ ASP (Advanced Sterilization Products), PDI

• Honoraria
  ■ PDI, ASP

• Scientific Advisory Board
  ■ Kinnos

• Grants
  ■ CDC, CMS
Safer Healthcare Environments for Infection Prevention

• Reprocessing reusable medical/surgical instruments

• Environmental Surface Disinfection
  ■ Ideal Disinfectant

• Water
Safer Healthcare Environments for Infection Prevention

• Reprocessing reusable medical/surgical instruments

• Environmental Surface Disinfection
  - Ideal Disinfectant

• Water
DISINFECTION AND STERILIZATION

• EH Spaulding believed that how an object will be disinfected depended on the object’s intended use
  ■ CRITICAL - objects which enter normally sterile tissue or the vascular system or through which blood flows should be sterile
  ■ SEMICRITICAL - objects that touch mucous membranes or skin that is not intact require a disinfection process (high-level disinfection[HLD]) that kills all microorganisms but high numbers of bacterial spores
  ■ NONCRITICAL - objects that touch only intact skin require low-level disinfection
Critical Medical/Surgical Devices
Rutala et al. ICHE 2014;35:883; Rutala et al. ICHE 2014;35:1068; Rutala et al. AJIC 2016;44:e47

- Critical
  - Contact: sterile tissue
  - Transmission: direct contact
  - Control measure: sterilization
  - Surgical instruments
    - Enormous margin of safety, rare outbreaks
    - ~85% of surgical instruments <100 microbes
    - Washer/disinfector removes or inactivates 10-100 million
    - Sterilization kills 1 trillion spores
Sterilization of “Critical Objects”

Steam sterilization

Hydrogen peroxide gas plasma

Ethylene oxide

Ozone and hydrogen peroxide

Vaporized hydrogen peroxide
Biological Indicators

- Select BIs that contain spores of \textit{B. atrophaeus} or \textit{Geobacillus stearothermophilus}

- Rationale: BIs are the only sterilization process monitoring device that provides a direct measure of the lethality of the process
30m or 24m Biological Indicator for HP Sterilizers
DISINFECTION AND STERILIZATION

• EH Spaulding believed that how an object will be disinfected depended on the object’s intended use
  ■ CRITICAL - objects which enter normally sterile tissue or the vascular system or through which blood flows should be sterile
  ■ SEMICRITICAL - objects that touch mucous membranes or skin that is not intact require a disinfection process (high-level disinfection\[HLD\]) that kills all microorganisms but high numbers of bacterial spores
  ■ NONCRITICAL - objects that touch only intact skin require low-level disinfection
Semicritical Medical Devices

Rutala et al. AJIC 2016;44:e47

- Semicritical
  - Transmission: direct contact
  - Control measure: high-level disinfection
  - Endoscopes top ECRI list of 10 technology hazards, >130 outbreaks (GI, bronchoscopes)
    - 0 margin of safety
      - Microbial load, $10^7$-$10^{10}$
      - Complexity
      - Biofilm
  - Other semicritical devices, rare outbreaks
    - ENT scopes, endocavitary probes (prostate, vaginal, TEE), laryngoscopes, cystoscopes
    - Reduced microbial load, less complex
Reprocessing Reusable Medical/Surgical Devices

- Shift from HLD to sterilization dependent on technology
- Most infections associated with endoscopes
- Perfuse channeled scopes
- Reprocessing laryngoscopes
- Endocavitary probes
- Ultrasound probe reprocessing
GI Endoscopes: Shift from Disinfection to Sterilization


Gastrointestinal Endoscopes
A Need to Shift From Disinfection to Sterilization?

William A. Rutala, PhD, MPH; David J. Weber, MD, MPH

More than 10 million gastrointestinal endoscopic procedures are performed annually in the United States for diagnostic purposes, therapeutic interventions, or both.¹ Because gastrointestinal endoscopes contact mucosal surfaces, use of a contaminated endoscope may lead to patient-to-patient transmission of potential pathogens with a subsequent risk of infection.¹

In this issue of JAMA, Epstein and colleagues² report findings from their investigation of a cluster of New Delhi metallo-β-lactamase (NDM)-producing Escherichia coli associated with gastrointestinal endoscopy that occurred from March 2013 to July 2013 in a single hospital in northeastern Illinois. During the 5-month period, 9 pa-

First, endoscopes are semicritical devices, which contact mucous membranes or nonintact skin, and require at least high-level disinfection.³ Four High-level disinfection achieves complete elimination of all microorganisms, except for small numbers of bacterial spores. Because flexible gastrointestinal endoscopic instruments are heat labile, only high-level disinfection with chemical agents or low-temperature sterilization technologies are possible.³ However, no low-temperature sterilization technology is US Food and Drug Administration (FDA)-cleared for gastrointestinal endoscopes such as duodenoscopes.

Second, more health care-associated outbreaks and clusters of infection have been linked to contaminated endoscopes than to any other medical device.⁴,⁵ However, until now,
Evidence-Based Recommendation for Sterilization of Endoscopes

(FDA Panel Recommendation for Duodenoscopes, May 2015; more peer-reviewed publications (>150) for the need for shifting from disinfection to sterilization than any other recommendation of AAMI, CDC [HICPAC], SHEA, APIC, SGNA, ASGE)

>130 plus endoscope-related outbreaks

GI endoscope contamination rates of 20-40% after HLD

Scope commonly have disruptive/irregular surfaces

>50,000 patient exposures involving HLD
Where are we?
Potential Future Methods to Prevent Endoscope-Related Outbreaks

• Optimize current low temperature sterilization methods or new LTST proving SAL $10^{-6}$ achieved (2 LTS technologies, FDA-cleared)
• Disposable sterile GI endoscopes/bronchoscopes (4 manufacturers)
• Steam sterilization for GI endoscopes (1 bronchoscope manufacturer)
• Use of non-endoscope methods to diagnosis or treat disease (e.g., capsule endoscopy, stool or blood tests to detect GI cancer, stool DNA test)
• Improved GI endoscope design (to reduce or eliminate reprocessing challenges-based on 50y of experience unlikely to resolve problem; closed channel duodenoscopes increased risk)
Reprocessing Reusable Medical/Surgical Devices

- Shift from HLD to sterilization dependent on technology
- Most infections associated with endoscopes
- Perfuse channeled scopes
- Reprocessing laryngoscopes
- Endocavitary probes
- Ultrasound probe reprocessing
### Infections/Outbreaks Associated with Semicritical Medical Devices

*Rutala, Weber, AJIC, In preparation*

<table>
<thead>
<tr>
<th>Medical Device</th>
<th>No. Outbreaks/Infections</th>
<th>No. Outbreaks/Infections with Bloodborne Pathogens</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vaginal Probes</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Ear-Nose-Throat Endoscopes</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Cystoscopes</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Hysteroscopes</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Laryngoscopes</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Ureteroscopes</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Prostate Probes</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>TEE-Transesophageal echocardiogram</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>GI Endoscopes/Bronchoscopes</td>
<td>~130</td>
<td>4 (HBV-1 GI; HCV-3 GI; HIV-0)</td>
</tr>
</tbody>
</table>
Infections/Outbreaks Associated with Semicritical Medical Devices
Rutala, Weber, AJIC, In preparation

- HBV and HCV transmission during endoscopy and use of semicritical medical devices can occur, but it is rare
- Four reports of HCV and HBV transmission related to breaches involved in GI endoscope reprocessing
- No articles related to possible transmission of HIV via medical device
- Greatest evidence of transmission associated with GI endoscopes/bronchoscopes (~130 outbreaks) likely due to microbial load and complexity.
- Other semicritical medical devices are rarely associated with infections related to inadequate reprocessing
High-Level Disinfection of “Semicritical Objects”

Exposure Time > 8m-45m (US), 20°C

<table>
<thead>
<tr>
<th>Germicide</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glutaraldehyde</td>
<td>&gt; 2.0%</td>
</tr>
<tr>
<td>Ortho-phthalaldehyde</td>
<td>0.55%</td>
</tr>
<tr>
<td>Hydrogen peroxide*</td>
<td>7.5%</td>
</tr>
<tr>
<td>Hydrogen peroxide and peracetic acid*</td>
<td>1.0%/0.08%</td>
</tr>
<tr>
<td>Hydrogen peroxide and peracetic acid*</td>
<td>7.5%/0.23%</td>
</tr>
<tr>
<td>Hypochlorite (free chlorine)*</td>
<td>650-675 ppm</td>
</tr>
<tr>
<td>Accelerated hydrogen peroxide</td>
<td>2.0%</td>
</tr>
<tr>
<td>Peracetic acid</td>
<td>0.2%</td>
</tr>
<tr>
<td>Glut and isopropanol</td>
<td>3.4%/26%</td>
</tr>
<tr>
<td>Glut and phenol/phenate**</td>
<td>1.21%/1.93%</td>
</tr>
</tbody>
</table>

*May cause cosmetic and functional damage; **efficacy not verified
Microbiological Disinfectant Hierarchy

Rutala WA, Weber DJ, HICPAC. www.cdc.gov

Most Resistant

Spores (C. difficile)
Mycobacteria (M. tuberculosis)
Non-Enveloped Viruses (norovirus, HAV, polio)
Fungi (Candida, Trichophyton)
Bacteria (MRSA, VRE, Acinetobacter)
Enveloped Viruses (HIV, HSV, Flu)

Most Susceptible
Reason for Endoscope-Related Outbreaks

• Margin of safety with endoscope reprocessing minimal or non-existent

• Microbial load
  ◆ GI endoscopes contain $10^7$-$10^{10}$
  ◆ Cleaning results in 2-6 $\log_{10}$ reduction
  ◆ High-level disinfection results in 4-6 $\log_{10}$ reduction
  ◆ Results in a total 6-12 $\log_{10}$ reduction of microbes
  ◆ Level of contamination after processing: 4$log_{10}$ (maximum contamination, minimal cleaning/HLD)

• Complexity of endoscope and endoscope reprocessing
• Biofilms-could contribute to failure of endoscope reprocessing
## Microbial Surveillance of GI Endoscopes


<table>
<thead>
<tr>
<th>Characteristics of Sample</th>
<th>Action Level (TCU&gt;100/scope) or EIP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gastroscope</td>
<td>26.6%</td>
</tr>
<tr>
<td>Colonoscope</td>
<td>33.7%</td>
</tr>
<tr>
<td>Duodenoscope</td>
<td>34.7%</td>
</tr>
<tr>
<td>Echo-endoscope</td>
<td>31.9%</td>
</tr>
<tr>
<td>AER</td>
<td>27.2%</td>
</tr>
<tr>
<td>Manual</td>
<td>39.3%</td>
</tr>
<tr>
<td>Age of endoscope &lt;2 years</td>
<td>18.9%</td>
</tr>
<tr>
<td>Age of endoscope &gt;2 years</td>
<td>38.8%</td>
</tr>
</tbody>
</table>
Visual Inspection of GI Endoscopes and Bronchoscopes

- All endoscopes (n=20) had visible irregularities (e.g., scratches)
- Researchers observed fluid (95%), discoloration, and debris in channels
- 60% scopes with microbial contamination

Bronchoscopes, Ofstead et al. Chest. 2018
- Visible irregularities were observed in 100% (e.g., retained fluid, scratches, damaged insertion tubes)
- Microbial contamination in 58%
- Reprocessing practices deficient at 2 of 3 sites
Bacteria will survive if the elevator lever was improperly positioned (in horizontal position instead of 45°) in AER

*E. faecalis* (7 log inoculum, 2-6 log recovered) and *E. coli* (0-3 log) survived disinfection of sealed and unsealed elevator wire channel duodenoscopes in 2 different AERs

Ensure proper lever position when placed in AERs with PA
Reprocessing Reusable Medical/Surgical Devices

- Shift from HLD to sterilization dependent on technology
- Most infections associated with endoscopes
- Perfuse channeled scopes
- Reprocessing laryngoscopes
- Endocavitary probes
- Ultrasound probe reprocessing
Reprocessing Channeled Endoscopes

Cystoscope- “completely immerse” in HLD (J Urology 2008.180:588)
Reprocessing Channeled Endoscopes

Cystoscope-HLD perfused through lumen with syringe (luer locks onto port and syringe filled and emptied until no air exits the scope nor air in barrel of syringe-syringe and lumen filled with HLD)
Reprocessing Channeled Endoscopes

<table>
<thead>
<tr>
<th>Exposure Method</th>
<th>CRE (K. pneumoniae) Inoculum before HLD (glutaraldehyde)</th>
<th>CRE (K. pneumoniae) Contamination after HLD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive HLD (immersed, not perfused)</td>
<td>3.2x10^8 1.9x10^9 4.1x10^8</td>
<td>3.1x10^8 4.6x10^8 1.0x10^8</td>
</tr>
<tr>
<td>Active HLD (perfused HLD into channel with syringe)</td>
<td>3.0x10^8 9.2x10^8 8.4x10^8</td>
<td>0 0 0</td>
</tr>
</tbody>
</table>

- Pathogens must have exposure to HLD for inactivation
- Immerse channeled flexible scope into HLD will not inactivate channel pathogens
- Completely immerse the endoscope in HLD and ensure all channels (e.g., hysteroscopes, cystoscopes) are perfused
- Air pressure in channel stronger than fluid pressure at fluid-air interface
Reprocessing Reusable Medical/Surgical Devices

- Shift from HLD to sterilization dependent on technology
- Most infections associated with endoscopes
- Perfuse channeled scopes
- Reprocessing laryngoscopes
- Endocavitary probes
- Ultrasound probe reprocessing
Disposable vs Reusable Laryngoscopes

- Many hospitals transitioning to disposable laryngoscopes
- Saves time
- Virtually eliminates risk of cross contamination
- Reduces likelihood on non-performing equipment
- Possibly cost-effective when considering reprocessing costs
Reprocessing of Rigid Laryngoscopes


- Limited guidelines for reprocessing laryngoscope’s blades and handles
- For years, many hospitals consider blade as semicritical (HLD) and handle as noncritical (LLD)
- Blades linked to HAIs; handles not directly linked to HAIs but contamination with microbes/blood/OPIM suggest its potential and blade and handle function together
- Ideally, clean then HLD/sterilize blades and handles (UNCH-blades and handles sterilized).
Contamination of Laryngoscope Handles

J Hosp Infect 2010;74:123
• 55/64 (86%) of the handles deemed “ready for patient use” positive for HA pathogens (S. aureus, enterococci, Klebsiella, Acinetobacter)

Anesth Analg 2009;109:479
• 30/40 (75%) samples from handles positive (CONS, Bacillus, Streptococcus, S. aureus, Enterococcus) after cleaning

AANA J 1997;65:241
• 26/65 (40%) of the handles and 13/65 (20%) of the blades were positive for occult blood. These blades and handles were identified as ready for patient use.
Reprocessing Reusable Medical/Surgical Devices

- Shift from HLD to sterilization dependent on technology
- Most infections associated with endoscopes
- Perfuse channeled scopes
- Reprocessing laryngoscopes
- Endocavitary probes
- Ultrasound probe reprocessing
Endocavitary Probes

- Probes—Transesophageal echocardiography probes, vaginal/rectal probes used in sonographic scanning
- Probes with contact with mucous membranes are semicritical
- Guideline recommends that a new condom/probe cover should be used to cover the probe for each patient and since covers may fail (1-80%), HLD (semicritical probes) should be performed
Endocavitary Probe Covers

• Sterile transvaginal probe covers had a very high rate pf perforations before use (0%, 25%, 65% perforations from three suppliers)

• A very high rate of perforations in used endovaginal probe covers was found after oocyte retrieval use (75% and 81% from two suppliers) but other investigators found a lower rate of perforations after use of condoms (0.9-2.0%)

• Condoms superior to probe covers for ultrasound probe (1.7% condom, 8.3% leakage for probe covers)
Reprocessing Reusable Medical/Surgical Devices

- Shift from HLD to sterilization dependent on technology
- Most infections associated with endoscopes
- Perfuse channeled scopes
- Reprocessing laryngoscopes
- Endocavitary probes
- Ultrasound probe reprocessing
Do ultrasound transducers used for placing peripheral or central venous access devices require HLD/sterilization?
Do ultrasound transducers used for placing peripheral or central venous access devices require HLD/sterilization?

A publication has interpreted CDC and AIUM recommendations differently than most hospitals (AJIC 2018:46:913-920): ultrasound guided CVC insertion (critical-sterilize or HLD with sterile sheath and sterile gel); scan across unhealthy skin (semicritical-HLD and use with clean sheath and clean gel)
Transducer Disinfection for Insertion of Peripheral and Central Catheters

Association of Vascular Access Guideline. June 2018; AIUM 2017

• “All transducers/probes used for peripheral VAD insertion will undergo, at a minimum, low-level disinfection. ...” Clean (step 1) the probe prior to disinfection (step 2).

• “During assessment, consider using a single-use condom or commercially manufactured transducer sheath (excluded: transparent dressing, gloves) during all use where there is the possibility of contact with blood/body fluids or non-intact skin”

• “Perform ALL ultrasound guided vascular access device insertions (PIV, Midline, PICC, CVC, arterial line) with the use of a sterile sheath and single-use sterile gel”.

  ■ After the procedure, the used sheath should be inspected for tears and the transducer inspected for potential compromise

  ■ Once inspected, the probe should be cleaned and then disinfected.
Transducer Disinfection for Insertion of Peripheral and Central Catheters

Association of Vascular Access (AVA) Guideline. June 2018; AIUM 2017

- All clinicians involved in ultrasound guidance should undergo comprehensive training on disinfection of the US transducers.

- The AVA recommendations are similar to guidelines from the American Institute for Ultrasound in Medicine (AIUM): that is, internal probes-HLD; “interventional percutaneous procedure probes that are used for percutaneous needle or catheter placement...should be cleaned using LLD and be used in conjunction with a single-use sterile probe cover”, if probe cover compromised HLD the probe.
Transducer Disinfection for Insertion of Peripheral and Central Catheters

Comments

• Blood contamination of probe is infrequent
• Sheath plus cleaning plus LLD should eliminate HBV, HCV, HIV
• Likelihood of transmission, even if probe still contaminated, very remote — would require contaminating virus gaining entry via contact with the actual injection site
• Transmission of HIV, HBV, HCV via a probe using on external body surface never demonstrated
• Only semicritical medical device to transmit HBV or HCV is GI endoscope (HIV not transmitted)
• If all devices that could contact non-intact skin or be blood contaminated require HLD prior to reuse that would include linen/mattresses (Burn Center), stethoscopes, BP cuffs, xray cassettes, etc
EH Spaulding believed that how an object will be disinfected depended on the object’s intended use.

- **CRITICAL** - objects which enter normally sterile tissue or the vascular system or through which blood flows should be sterile.
- **SEMICRITICAL** - objects that touch mucous membranes or skin that is not intact require a disinfection process (high-level disinfection [HLD]) that kills all microorganisms but high numbers of bacterial spores.
- **NONCRITICAL** - objects that touch only intact skin require low-level disinfection.
Safer Healthcare Environments for Infection Prevention

• Reprocessing reusable medical/surgical instruments

• Environmental Surface Disinfection
  ■ Ideal Disinfectant

• Water
Environmental Contamination Leads to HAI


- Evidence environment contributes
- Role: MRSA, VRE, C. difficile
- Surfaces are contaminated—~25%
- EIP survive days, weeks, months
- Contact with surfaces results in hand contamination
- Disinfection reduces contamination
- Disinfection (daily) reduces HAI
- Rooms not adequately cleaned
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 previous patient’s pathogen by 39-353%

• For example, increased risk for *C. difficile* is 235% (11.0% vs 4.6%)

• 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)
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
Environmental Contamination Leads to HAI's

• 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
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-prevent infection to new patient in room
  - Daily room decontamination
“No Touch” Approaches To Room Decontamination
(UV/VHP~20 microbicidal studies, 12 HAi reduction studies; will not discuss technology with limited data)
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;38:1118-1121

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.
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”)

Evidence That All Touchable Room Surfaces Are Equally Contaminated

<table>
<thead>
<tr>
<th>Surface (no. of samples)</th>
<th>Mean CFUs/RODAC (95% CI)</th>
<th>Pre-cleaning</th>
<th>Post-cleaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>High (n = 40)</td>
<td></td>
<td>71.9 (46.5–97.3)</td>
<td>9.6 (3.8–15.4)</td>
</tr>
<tr>
<td>Medium (n = 42)</td>
<td></td>
<td>44.2 (28.1–60.2)</td>
<td>9.3 (1.2–17.5)</td>
</tr>
<tr>
<td>Low (n = 37)</td>
<td></td>
<td>56.7 (34.2–79.2)</td>
<td>5.7 (2.01–9.4)</td>
</tr>
</tbody>
</table>

**Note.** CFU, colony-forming unit; CI, confidence interval.
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>
<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>

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 HAI's occurring among patients cared for in a room with a burden of more than 500 colony-forming units (CFUs)/100 cm$^2$. 
To reduce microbial contamination

Continuous Room Decontamination Technology
Continuous Room Decontamination Technologies for Disinfection of the Healthcare Environment

• Visible light disinfection through LEDs
• Low concentration hydrogen peroxide
• Self-disinfecting surfaces
• Persistent (or continuously active) disinfectant that provides continuous disinfection action
Evaluation of a Persistent Surface Disinfectant

“EPA Protocol for Residual Self-Sanitizing Activity of Dried Chemical Residuals on Hard, Non-Porous Surfaces”

Abrasion Tester
Efficacy of a Persistent Surface Disinfectant
Rutala WA, Gergen M, Sickbert-Bennett E, Anderson D, Weber D. ID Week 2018

4-5 log₁₀ reduction in 5min over 24hr for most pathogens; ~99% reduction with Klebsiella and CRE Enterobacter.

<table>
<thead>
<tr>
<th>Test Pathogen</th>
<th>Mean Log₁₀ 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>

*Test surface glass unless otherwise specified
Effective Surface Decontamination

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

Exposure time > 1 min

<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>Peracetic acid with HP (C. difficile)</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)
Microbiological Disinfectant Hierarchy

Most Resistant

- Spores (C. difficile)
- Mycobacteria (M. tuberculosis)
- Non-Enveloped Viruses (norovirus, HAV, polio)
- Fungi (Candida, Trichophyton)
- Bacteria (MRSA, VRE, Acinetobacter)
- Enveloped Viruses (HIV, HSV, Flu)
TABLE 2
Disinfectant Activity Against Antibiotic-Susceptible and Antibiotic-Resistant Bacteria

<table>
<thead>
<tr>
<th>Product</th>
<th>VSE</th>
<th>VRE</th>
<th>MSSA</th>
<th>MRSA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.5 min</td>
<td>5 min</td>
<td>0.5 min</td>
<td>5 min</td>
</tr>
<tr>
<td>Vesphene IIse</td>
<td>&gt;4.3</td>
<td>&gt;4.3</td>
<td>&gt;4.8</td>
<td>&gt;4.8</td>
</tr>
<tr>
<td>Clorox</td>
<td>&gt;5.4</td>
<td>&gt;5.4</td>
<td>&gt;4.9</td>
<td>&gt;4.9</td>
</tr>
<tr>
<td>Lysol Disinfectant</td>
<td>&gt;4.3</td>
<td>&gt;4.3</td>
<td>&gt;4.8</td>
<td>&gt;4.8</td>
</tr>
<tr>
<td>Lysol Antibacterial</td>
<td>&gt;5.5</td>
<td>&gt;5.5</td>
<td>&gt;5.5</td>
<td>&gt;5.5</td>
</tr>
<tr>
<td>Vinegar</td>
<td>0.1</td>
<td>5.3</td>
<td>1.0</td>
<td>3.7</td>
</tr>
</tbody>
</table>

Abbreviations: MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *S aureus*; VRE, vancomycin-resistant *Enterococcus*; VSE, vancomycin-susceptible *Enterococcus*.

Data represent mean of two trials (n=2). Values preceded by “>” represent the limit of detection of the assay. Assays were conducted at a temperature of 20°C and a relative humidity of 45%. Results were calculated as the log of Nd/No, where Nd is the titer of bacteria surviving after exposure and No is the titer of the control.
PROPERTIES OF AN IDEAL SURFACE DISINFECTANT


- Broad spectrum
- Fast acting
- Remains wet
- Not affected by environmental factors
- Nontoxic
- Surface compatibility
- Persistence
- Easy to use
- Acceptable odor
- Economical
- Solubility
- Stability
- Cleaner
- Nonflammable
## Key Considerations for Selecting the Ideal Disinfectant for Your Facility


<table>
<thead>
<tr>
<th>Consideration</th>
<th>Question to Ask</th>
<th>Score (1-10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kill Claims</td>
<td>Does the product kill the most prevalent healthcare pathogens</td>
<td></td>
</tr>
<tr>
<td>Kill Times and Wet-Contact Times</td>
<td>How quickly does the product kill the prevalent healthcare pathogens. Ideally, contact time greater than or equal to the kill claim.</td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td>Does the product have an acceptable toxicity rating, flammability rating</td>
<td></td>
</tr>
<tr>
<td>Ease-of-Use</td>
<td>Odor acceptable, shelf-life, in convenient forms (wipes, spray), water soluble, works in organic matter, one-step (cleans/disinfects)</td>
<td></td>
</tr>
<tr>
<td>Other factors</td>
<td>Supplier offers comprehensive training/education, 24-7 customer support, overall cost acceptable (product capabilities, cost per compliant use, help standardize disinfectants in facility</td>
<td></td>
</tr>
</tbody>
</table>

Note: Consider the 5 components shown, give each product a score (1 is worst and 10 is best) in each of the 5 categories, and select the product with the highest score as the optimal choice (maximum score is 50).
Quaternary ammonium compounds
(e.g., didecyl dimethyl ammonium bromide, dioctyl dimethyl ammonium bromide)

Advantages
- Bactericidal, fungicidal, virucidal against enveloped viruses (e.g., HIV)
- Good cleaning agents
- EPA registered
- Surface compatible
- Persistent antimicrobial activity when undisturbed
- Inexpensive (in dilutable form)
- Not flammable

Disadvantages
- Not sporicidal
- In general, not tuberculocidal and virucidal against non-enveloped viruses
- High water hardness and cotton/gauze can make less micbicidal
- A few reports documented asthma as result of exposure to benzalkonium chloride
- Affected by organic matter
- Multiple outbreaks ascribed to contaminated benzalkonium chloride
Alcohol

Advantages
- Bactericidal, tuberculocidal, fungicidal, virucidal
- Fast acting
- Non-corrosive
- Non-staining
- Used to disinfect small surfaces such as rubber stoppers on medication vials
- No toxic residue

Disadvantages
- Not sporicidal
- Affected by organic matter
- Slow acting against non-enveloped viruses (e.g., norovirus)
- No detergent or cleaning properties
- Not EPA registered
- Damage some instruments (e.g., harden rubber, deteriorate glue)
- Flammable (large amounts require special storage)
- Evaporates rapidly making contact time compliance difficult
- Not recommended for use on large surfaces
- Outbreaks ascribed to contaminated alcohol
Improved Hydrogen Peroxide


Advantages

- Bactericidal, tuberculocidal, fungicidal, virucidal
- Fast efficacy
- Easy compliance with wet-contact times
- Safe for workers (lowest EPA toxicity category, IV)
- Benign for the environment
- Surface compatible
- Non-staining
- EPA registered
- Not flammable

Disadvantages

- More expensive than most other disinfecting actives
- Not sporicidal at low concentrations
## Sodium Hypochlorite


### Advantages

- Bactericidal, tuberculocidal, fungicidal, virucidal
- Sporidical
- Fast acting
- Inexpensive (in dilutable form)
- Not flammable
- Unaffected by water hardness
- Reduces biofilms on surfaces
- Relatively stable (e.g., 50% reduction in chlorine concentration in 30 days)
- Used as the disinfectant in water treatment
- EPA registered

### Disadvantages

- Reaction hazard with acids and ammonias
- Leaves salt residue
- Corrosive to metals (some ready-to-use products may be formulated with corrosion inhibitors)
- Unstable active (some ready-to-use products may be formulated with stabilizers to achieve longer shelf life)
- Affected by organic matter
- Discolors/stains fabrics
- Potential hazard is production of trihalomethane
- Odor (some ready-to-use products may be formulated with odor inhibitors). Irritating at high concentrations.
Phenolics

Advantages
- Bactericidal, tuberculocidal, fungicidal, virucidal
- Inexpensive (in dilutable form)
- Non-staining
- Not flammable
- EPA registered

Disadvantages
- Not sporicidal
- Absorbed by porous materials and irritate tissue
- Depigmentation of skin caused by certain phenolics
- Hyperbilirubinemia in infants when phenolic not prepared as recommended
Quat/Alcohol vs Quat

- Adenovirus is a hardy virus that is relatively resistant to disinfectants
- Quat about $<0.5 \log_{10}$ reduction against adenovirus with 1m exposure time
- Accelerated hydrogen peroxide (0.5%) demonstrates $\sim 0.7 \log_{10}$ reduction against adenovirus with 1m exposure time
- Quat/Alcohol demonstrates a $\sim 4 \log_{10}$ reduction against adenovirus with 1m exposure time
- Chlorine ($\sim 5000$ppm) demonstrates a $\sim 5 \log_{10}$ reduction against adenovirus with 1m exposure time
- Quat/Alcohol has improved virucidal activity compared to Quat and accelerated hydrogen peroxide
The term “wetness” is controversial. Based on EPA test for wipes/sprays, treatment time is the kill time and includes a wet time via wiping as well as the undisturbed time. Duration of wet time is not relevant.
Risk Assessment Worksheet
Justifies to TJC/CMS Off-Label Use for Surface Disinfection
www.disinfectionandsterilization.org

Issue: Off-label use for undisturbed time after environmental disinfection

Assessment Date: March 5, 2018

Scoring: Low = 1 Moderate = 3 High = 5

Team Members:

Meeting Actions: Team members evaluated the evidence and determined that off-label use of undisturbed time was sufficient to disinfect noncritical environmental surfaces and noncritical patient care equipment in a healthcare environment.

<table>
<thead>
<tr>
<th>Suggested Questions</th>
<th>Benefit</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the truth about disinfectant contact time?</td>
<td>Most manufacturers suggest the user maintain wetness for the duration of the contact time. The method used to assess efficacy of disinfectant wipes by the EPA is the Disinfectant Towelette Test. The procedure involves using one towelette to wipe ten carriers/slides. The area of the towelette used for wiping is folded and rotated so as to expose a new surface of the towelette for each carrier. To generate test cultures, carriers are inoculated using pathogens <em>Staphylococcus aureus, Pseudomonas aeruginosa, and Salmonella enteric</em>. The test procedure involves wiping the slide back and forth for a total of six passes across the inocula for 15 seconds of</td>
<td>There is no risk to utilizing a treatment time instead of a wet time for the given contact time of a disinfectant. Score = 1</td>
</tr>
</tbody>
</table>
Bactericidal (*S. aureus*) Efficacy of EPA-Registered Towelettes
West, Teska, Oliver, AJIC, 2018

- Drying time curve based on surface wetness; bold-contact time (180s); dashed-dry (~260s)

- Wet time is not crucial for complete disinfection (wet or dry ~4.5 log$_{10}$ reduction); 30s for log$_{10}$ reduction
Effective Surface Decontamination

Product and Practice = Perfection
Thoroughness of Environmental Cleaning
Carling et al. ECCMID, Milan, Italy, May 2011

Mean = 32%

>110,000 Objects

<table>
<thead>
<tr>
<th>Mean = 32%</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAILY CLEANING</td>
</tr>
<tr>
<td>TERMINAL CLEANING</td>
</tr>
<tr>
<td>HEHSG HOSP</td>
</tr>
<tr>
<td>IOWA HOSP</td>
</tr>
<tr>
<td>OTHER HOSP</td>
</tr>
<tr>
<td>OPERATING ROOMS</td>
</tr>
<tr>
<td>NICU</td>
</tr>
<tr>
<td>EMS VEHICLES</td>
</tr>
<tr>
<td>ICU DAILY</td>
</tr>
<tr>
<td>AMB CHEMO</td>
</tr>
<tr>
<td>MD CLINIC</td>
</tr>
<tr>
<td>LONG TERM</td>
</tr>
<tr>
<td>DIALYSIS</td>
</tr>
</tbody>
</table>

| 14 Sites |
| 16 Sites |
| 7 Sites |
| 7 Sites |
| 7 Sites |
| 4 Sites |
| 4 Sites |
| 9 Sites |
| 4 Sites |
MONITORING THE EFFECTIVENESS OF CLEANING
Cooper et al. AJIC 2007;35:338

• 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)
Fluorescent marker is a useful tool in determining how thoroughly a surface is wiped and mimics the microbiological data better than ATP.
Colorized Disinfectant
Future May Have Methods to Ensure Thoroughness Such as Colorized Disinfectant

- Color-fading time matched to disinfectant contact time --> enforces compliance
- Provides real-time feedback when disinfection is complete
- Trains staff on importance of contact time as they use the 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.
Safer Healthcare Environments for Infection Prevention

• Reprocessing reusable medical/surgical instruments

• Environmental Surface Disinfection
  ■ Ideal Disinfectant

• Water
Water and Healthcare
Multiple Uses
Water-Related Pathogens and Their Disease Transmission Pathways

Exner et al. AJIC 33:S26-40; 2005
Healthcare Outbreaks Associated With a Water Reservoir and Infection Prevention Strategies

Hajime Kanamori, David J. Weber, and William A. Rutala

Division of Infectious Diseases, University of North Carolina School of Medicine, and Hospital Epidemiology, University of North Carolina Health Care, Chapel Hill

Hospital water may serve as a reservoir of healthcare-associated pathogens, and contaminated water can lead to outbreaks and severe infections. The clinical features of waterborne outbreaks and infections as well as prevention strategies and control measures are reviewed. The common waterborne pathogens were bacteria, including Legionella and other gram-negative bacteria, and nontuberculous mycobacteria, although fungi and viruses were occasionally described. These pathogens caused a variety of infections, including bacteremia and invasive and disseminated diseases, particularly among immunocompromised hosts and critically ill adults as well as neonates. Waterborne outbreaks occurred in healthcare settings with emergence of new reported reservoirs, including electronic faucets (Pseudomonas aeruginosa and Legionella), decorative water wall fountains (Legionella), and heater-cooler devices used in cardiac surgery (Mycobacterium chimaera). Advanced molecular techniques are useful for achieving a better understanding of reservoirs and transmission pathways of waterborne pathogens. Developing prevention strategies based on water reservoirs provides a practical approach for healthcare personnel.

Keywords. waterborne outbreaks; healthcare-associated infections; water; outbreaks.
**Table 2. Summary of Key Issues and Infection Prevention Strategies Against Waterborne Outbreaks by Major Water Reservoir in Healthcare Settings**

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Key Issues</th>
<th>Infection Prevention Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potable water, tap water, and hospital water systems</td>
<td>- Potable water is not sterile, and pathogenic waterborne organisms may exist in potable water at acceptable levels of coliform bacteria (&lt;1 coliform bacterium/100 mL). Healthcare-associated outbreaks have been linked to contaminated potable water. Some studies describe a transmission link between a colonized sink and infected patients. Some studies describe that multidrug-resistant gram-negative bacilli are associated with contaminated sinks. Gram-negative bacilli can survive wet environments, including sinks, for a long time (&gt;250 days). Transmission can be caused by splashing of water droplet from contaminated sinks to hands of healthcare personnel, followed by transient colonization of hands. Common pathogens include gram-negative bacilli (e.g., Pseudomonas aeruginosa, Legionella, NTM).</td>
<td>- Follow public health guidelines. Hot water temperature at the outlet at the highest temperature allowable, preferably &gt;51°C. Water disruptions; post signs and do not drink tap water. Maintain standards for potable water (&lt;1 coliform bacterium/100 mL). Rinse semicircular equipment with sterile water, filtered water, or tap water followed by alcohol rinse. Some experts have recommended periodic monitoring of water samples for growth of Legionella. Legionella eradication can be technically difficult, temporary, and expensive. Potential methods of eradication include filtration, ultraviolet, ozonation, heat inactivation (&gt;60°C), hyperchlorination, and copper-silver ionization (&gt;0.4 ppm and &gt;0.04 ppm, respectively).</td>
</tr>
<tr>
<td>Sinks</td>
<td>- Colonization of sinks with gram-negative bacilli has been reported. Some studies demonstrate a transmission link between a colonized sink and infected patients. Some studies describe that multidrug-resistant gram-negative bacilli are associated with contaminated sinks. Gram-negative bacilli can survive wet environments, including sinks, for a long time (&gt;250 days). Transmission can be caused by splashing of water droplet from contaminated sinks to hands of healthcare personnel, followed by transient colonization of hands. Common pathogens include gram-negative bacilli (e.g., Pseudomonas, Acinetobacter, Seratia).</td>
<td>- Use separate sinks for handwashing and disposal of contaminated fluids. Decontaminate or eliminate sinks as a reservoir if epidemic spread of gram-negative bacteria via sinks is suspected.</td>
</tr>
<tr>
<td>Faucet aerators</td>
<td>- Faucet aerators may serve as a platform for accumulation of waterborne pathogens. Potential pathogens include Pseudomonas, Stenotrophomonas, and Legionella.</td>
<td>- Routine screening and disinfection or permanent removal of all aerators are not warranted at present. No precautions necessary at present. For Legionella outbreaks, clean and disinfect faucet aerators in high-risk patient areas periodically, or consider removing them in the case of additional infections.</td>
</tr>
<tr>
<td>Showers</td>
<td>- Some outbreaks are linked to contaminated shower heads or inhalation of aerosols. Potential pathogens include Legionella, Pseudomonas, NTM, group A Streptococcus, and Aspergillus.</td>
<td>- Prohibit use of showers in neutropenic patients. Control Legionella colonization of potable water.</td>
</tr>
<tr>
<td>Ice and ice machines</td>
<td>- Patients can acquire pathogens by sucking on ice, ingesting iced drinks, or use of contaminated ice for cooling medical procedure and patients' skin. Large outbreaks occurred when ice machines have become contaminated and ice used for cooling drinking water. Common pathogens include Pseudomonas, Enterobacter,</td>
<td>- Do not handle ice by hand. Do not store pharmaceuticals or medical solutions on ice for consumption. Use automatic dispensers rather than open chest storage compartments in patient areas. Clean and disinfect ice-storage chests regularly.</td>
</tr>
</tbody>
</table>
# Healthcare Outbreaks Associated with Water Reservoir


<table>
<thead>
<tr>
<th>Stationary and portable eyewash stations may not be used for months or years. The water source may stand in the incoming pipes at room temperature for a long period. Pathogens, including <em>Pseudomonas, Legionella</em>, amoebae, and fungi, could be transmitted.</th>
<th>Use sterile water for eye flush or regularly (e.g., monthly) flush eyewash stations.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potable water usually supplies dental units. Water delivered to dental devices (e.g., dental handpieces and air/water syringes) as well as dental unit water lines may be contaminated. Immuno compromised patients may be at risk for infection. Pathogens, including <em>Sphingomonas, Pseudomonas, Acinetobacter, Legionella</em>, and NTM, have been recovered from water supplies in dental units.</td>
<td>Clean dental water systems. Flush with water and disinfectant solution, or use of clean-water systems that put sterile water into the dental unit. Flush dental instruments with water and air for 20–30 sec from any dental device connected to the dental water system that enters the patient’s mouth (e.g., handpieces). Ensure that water in dental unit meets standards (&lt;500 CFU/mL).</td>
</tr>
<tr>
<td>Excessive levels of gram-negative bacilli in the dialysate were responsible for pyrogenic reactions in patients or bacteremia, which was caused by bacteria or endotoxin entry into the blood from the contaminated dialysate.</td>
<td>Follow AAMI standards for quality assurance performance of dialysis devices. Disinfect water distribution system on a regular basis. Perform microbiological testing and endotoxin testing for water in dialysis settings regularly. Maintain dialysis water (input) &lt;200 CFU/mL and dialysate (output) &lt;200 CFU/mL per CMS.</td>
</tr>
<tr>
<td>Contaminated water baths were used to thaw or warm blood products (fresh plasma, cryoprecipitate) or peritoneal dialysate bottles, followed by contamination of the infusates occurred during preparation. Contaminated ice baths were used to cool syringes or bottles of saline in measuring cardiac output. Potential pathogens include <em>Pseudomonas, Acinetobacter, Burkholderia, Staphylococcus</em>, and <em>Ewingella</em>.</td>
<td>Consider routine cleaning, disinfection, and changing of water in water baths. Add germicide to water bath or use plastic overwrap of blood products and keep the surfaces dry. Use sterile water in ice baths (or at room temperature) used for thermodilution catheters.</td>
</tr>
</tbody>
</table>
# Healthcare Outbreaks Associated with Water Reservoir


<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Key Issues</th>
<th>Infection Prevention Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bathing, tub immersion,</td>
<td>Tub immersion used in hospitals for physical hydrotherapy and for</td>
<td>Adhere strictly to proper disinfection of tub between patients.</td>
</tr>
<tr>
<td>and hydrotherapy</td>
<td>cleaning of burn wounds can cause cross-transmission,</td>
<td>Drain and clean tanks and tubs after use of each patient, and disinfect surfaces and</td>
</tr>
<tr>
<td></td>
<td>transmission from environmental reservoirs, or</td>
<td>components according to the manufacturer’s instructions.</td>
</tr>
<tr>
<td></td>
<td>autotransmission.</td>
<td>Add disinfectant to the water: 15 ppm in small hydrotherapy tanks and 2-5 ppm in whirlpools per</td>
</tr>
<tr>
<td></td>
<td>Skin infections such as folliculitis and cellulitis occurred related to</td>
<td>CDC.</td>
</tr>
<tr>
<td></td>
<td>water immersion.</td>
<td>Disinfect after using tub liners.</td>
</tr>
<tr>
<td></td>
<td>Water contamination of central venous catheters during bathing was</td>
<td>Cover catheter sites with transparent occlusive dressing.</td>
</tr>
<tr>
<td></td>
<td>related to bloodstream infection.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potential pathogens include Pseudomonas, Enterobacter,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Citrobacter, Acinetobacter, Legionella, Alcaligenes, and NTM.</td>
<td></td>
</tr>
<tr>
<td>Toilets</td>
<td>Transmission can be caused by aerosolization of fecal bacteria via</td>
<td>Facilitate good handwashing practices.</td>
</tr>
<tr>
<td></td>
<td>flushing or surface contamination by fecal bacteria.</td>
<td>Maintain clean surfaces with disinfectants.</td>
</tr>
<tr>
<td></td>
<td>Transmission could happen in healthcare facilities caring for</td>
<td>Clean bowl with a scouring powder and a brush.</td>
</tr>
<tr>
<td></td>
<td>mentally or neurologically impaired patients, or children.</td>
<td>No reason to pour disinfectant into bowl.</td>
</tr>
<tr>
<td></td>
<td>Potential pathogens include enteric bacteria, Pseudomonas,</td>
<td>Separate toilet bowl from clean hospital surfaces.</td>
</tr>
<tr>
<td></td>
<td>Clostridium difficile, and norovirus.</td>
<td></td>
</tr>
<tr>
<td>Flowers and vases</td>
<td>Flower vases and potted plants are heavily colonized with potential</td>
<td>Prohibit fresh flowers and potted plants in the rooms of immunocompromised and ICU patients.</td>
</tr>
<tr>
<td></td>
<td>pathogens, including Acinetobacter, Klebsiella, Enterobacter,</td>
<td>Or add antimicrobial agent to vase water and disinfect vases after use.</td>
</tr>
<tr>
<td></td>
<td>Pseudomonas, Serratia, Burkholderia cepacia, Aeromonas</td>
<td></td>
</tr>
<tr>
<td></td>
<td>hydrophila, and Flavobacterium.</td>
<td></td>
</tr>
<tr>
<td>Electronic faucets</td>
<td>Electronic faucets were likely to be contaminated by several</td>
<td>Electronic faucets need to be designed so that they do not promote the growth of microorganisms.</td>
</tr>
<tr>
<td></td>
<td>waterborne pathogens than handle-operated faucets.</td>
<td>No guideline but some authors have recommended to remove electronic faucets from high-risk</td>
</tr>
<tr>
<td></td>
<td>Issues associated with electronic faucets include a longer distance</td>
<td>patient care areas (eg, BMTU). Some have recommended periodic monitoring of water samples for</td>
</tr>
<tr>
<td></td>
<td>between the valve and the tap, resulting in a longer column of</td>
<td>growth of Legionella.</td>
</tr>
<tr>
<td></td>
<td>stagnates, warm water, which favors production of biofilms; reduced</td>
<td></td>
</tr>
<tr>
<td></td>
<td>water flow; reduced flushing effect (growth favored);</td>
<td></td>
</tr>
<tr>
<td></td>
<td>valves and pipes made of plastic enhances adhesion of *P.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>aeruginosa.</td>
<td></td>
</tr>
<tr>
<td>Decorative water wall</td>
<td>Legionella pneumophilia cases associated with decorative water</td>
<td>Avoid installation, especially in healthcare facilities serving</td>
</tr>
<tr>
<td>fountains</td>
<td>fountain were reported.</td>
<td>immunocompromised patients or in areas caring for high-risk patients.</td>
</tr>
<tr>
<td></td>
<td>There is an unacceptable risk in hospitals serving</td>
<td>Perform maintenance regularly and monitor water safety strictly unless removed.</td>
</tr>
<tr>
<td></td>
<td>immunocompromised patients (even with standard maintenance and</td>
<td></td>
</tr>
<tr>
<td></td>
<td>sanitizing methods).</td>
<td></td>
</tr>
<tr>
<td>Heater-cooler units</td>
<td>Healthcare-associated <em>Mycobacterium chimaera</em> outbreak due to</td>
<td>Ensure that heater-cooler units are safe and properly maintained</td>
</tr>
<tr>
<td></td>
<td>heater-cooler units during cardiac surgeries as a water source</td>
<td>According to the manufacturer’s instructions.</td>
</tr>
<tr>
<td></td>
<td>has been recently reported.</td>
<td>Enhance vigilance for NTM infections in patients after cardiac surgeries using heater-cooler</td>
</tr>
<tr>
<td></td>
<td>Airborne transmission from contaminated heater-cooler unit water tanks.</td>
<td>Devices.</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>Potential reservoirs include distilled water or containers (outlets</td>
<td>Consider control measures based on risk assessment by each reservoir when available.</td>
</tr>
<tr>
<td></td>
<td>with Enterobacter cloacae and <em>B. cepacia</em>, wash basins</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Salmonella enterica, <em>Trichosporon asahii</em> infection,</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Legionella pneumophilia</em>, intraaortic balloon pump (<em>B. cepacia</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>balanitis; humidifier water in ventilator systems (Acinetobacter</td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>kiliense</em> postoperative endophthalmitis), water cooler (<em>Pseudomonas</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>baumannii</em> infection), deonized water (<em>Escherichia</em> jeanesnkoelii</td>
<td></td>
</tr>
<tr>
<td></td>
<td>fungemia), water-damaged plaster (<em>mucormycosis</em>), water birth</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Legionella pneumophilia), water-saving device (<em>P. aeruginosa</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td>infection), rinse water during endoscope reprocessing (gram-</td>
<td></td>
</tr>
<tr>
<td></td>
<td>negative bacteria).</td>
<td></td>
</tr>
</tbody>
</table>
Water Wall Fountains and Electronic Faucets
Water Walls Linked to Legionnaires’

- Palmore et al. ICHE 2009;30:764
  - 2 immunocompromised patients exposed to decorative fountain in radiation oncology; isolates from patients and fountain identical; disinfection with ozone, filter and weekly cleaning

- Houpt et al. ICHE 2012;33:185
  - Lab-confirmed Legionnaires disease was dx in 8 patients; 6 had exposure to decorative fountain (near main entrance to hospital); high counts of *Legionella pneumophila* 1 despite disinfection and maintenance
Water Walls and Decorative Water Fountains

Present unacceptable risk in hospitals serving immunocompromised patients (even with standard maintenance and sanitizing methods)
Electronic Faucets
A Possible Source of Nosocomial Infection?
Electronic Faucets

• Conserve water
• Conserve energy
• Hygienic
• Hands free
• Barrier free
Electronic (E) vs Handle-Operated (HO) Faucets

- 100% E vs 30% HO *Legionella* (no cases). Halabi et al. JHI 2001;49:117
- Significant difference HPC levels between brand A (32%) and B (8%) E compared to HO (11%). Hargreaves et al. 2001; 22:202
- No difference in *P. aeruginosa*. Assadian et al. ICHE. 2002;23:44.
- 73% E samples did not meet German water standard vs 0% HO. Chaberny et al. ICHE 2004;25:997
- 39% of water samples from E and 1% from HO yielded *P. aeruginosa*. Merrer et al. Intensive Care Med 2005;31:1715
- 95% E grew *Legionella* compared to 45% HO (water-disruption events). Syndor et al. ICHE 2012; 33:235
Issues Associated with Electronic Faucets

- A longer distance between the valve and the tap, resulting in a longer column of stagnant, warm water, which favors production of biofilms
- Reduced water flow; reduced flushing effect (growth favored)
- Valves and pipes made of plastic (enhances adhesion of P. aeruginosa)
Prevention Measures

• Electronic faucets constructed so they do not promote the growth of microorganisms

• A potential source of nosocomial pathogens but more data are needed to establish role in HAI

• No guideline (but some have recommended) to remove electronic faucets from at-risk patient care areas (BMTU)

• Some have recommended periodic monitoring of water samples for growth of *Legionella*
WORLDWIDE OUTBREAK OF *M. chimaera* DUE TO CONTAMINATED HCU

- Since 2003, >200 cases of *M. chimaera* prosthetic valve endocarditis and disseminated disease reported
- Outbreak linked to intrinsically contaminated heater-cooler unit (HCU) – Stockert 3T HCU (Sorin)
- Internal water channels/tanks intrinsically contaminated; transmission from device to patients via aerosols
- Error = Failure to use disposable channels/tanks; intrinsic contamination and/or inability to disinfect/sterilize internal water tanks
- Problem = Presence of biofilm
- Risk = 0.4-16 per 10,000 Pt-years

Sommerstein R, et al. ICHE 2017;38:103;
Schreiber PW, Sax H. Curr Opin ID 2017;30:388;
CLINICAL FEATURES AND COURSE OF
*M. chimaera* HCU-ASSOCIATED INFECTIONS

- **Study goal:** Assess HCU associated infections, UK
- **Results (30 patients):**
  - 28/30 had prosthetic material; prosthetic valve endocarditis (14/30), sternal wound infection (2/30), aortic graft infection (4/30), and disseminated infection (10/30)
  - Mean presentation time = 14 mo (max 5 yrs)
  - 18/30 patients died (60%), a median of 30 mo after initial surgery and 9 mo after initiation of therapy

US FDA GENERAL GUIDANCE

• Strictly adhere to the cleaning and disinfection instructions provided in the manufacturer’s device labeling.
• DO NOT use tap water to rinse, fill, refill or top-off heater-cooler water tanks since this may introduce NTM organisms. Use only sterile water or water that has been passed through a filter of less than or equal to 0.22 microns.
• Direct and/or channel the heater-cooler’s exhaust vent(s) away from the surgical field and toward an operating room exhaust vent to mitigate the risk of aerosolized heater-cooler tank water reaching the sterile field.
• Immediately remove from service heater-cooler devices that show discoloration or cloudiness in the fluid lines/circuits.
• Consider performing environmental, air, and water sampling and monitoring if heater-cooler contamination is suspected.
• Healthcare facilities should follow their internal procedures for notifying and culturing patients if they suspect infection associated with heater-cooler devices.

http://www.fda.gov/MedicalDevices/ProductsandMedicalProcedures/CardiovascularDevices/Heater-CoolerDevices/ucm492583.htm
Safer Healthcare Environments for Infection Prevention

New Technologies and Future Challenges

• Reprocessing reusable medical/surgical instruments

• Hospital surfaces

• Water
CONCLUSIONS

• In general, sterilization, high-level disinfection and low-level disinfection technologies, practices, and products are effective.

• Endoscopes (and semicritical items) represent an infection risk. Urgent need to understand the gaps in endoscope reprocessing. Reprocessing guidelines must be followed to prevent exposure to pathogens that may lead to infection. Endoscopes have narrow margin of safety and manufacturers should be encouraged to develop practical sterilization technology.

• The contaminated surface environment in hospital rooms is important in the transmission of healthcare-associated pathogens (MRSA, VRE, *C. difficile*).

• Effective surface disinfection (excellent products, suboptimal practices) essential to eliminate the environment as a source for transmission of HA pathogens.

• New methods of reducing transmission of these pathogens may include: improved room cleaning/disinfection, “no-touch” methods (e.g., UV, HP), and continuous room decontamination.

• Water reservoirs of HA pathogens (e.g., water walls) may present unacceptable risk to high-risk patients.
THANK YOU!
www.disinfectionandsterilization.org