Update on Methods for Cleaning and Disinfection of Environmental Surfaces

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Topics for Discussion

- General principles for use of surface disinfectants
- Current options for surface disinfectants
  - Which one(s) should you choose
- Methods for application (towels, microfiber, wipes)
  - Things your Environmental Services department needs to know
- Automated "No-Touch" methods for surface disinfection
  - Ultra-violet light (UVC)
  - Hydrogen peroxide vapor and mist
  - 405 nm light
  - Others

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General Principles to Follow When Using Surface Disinfectants

- Use disinfectants approved by federal agencies (in USA, EPA)
- Use disinfectants at their recommended concentration or dilution
  - Do not overdilute products
- Use disinfectants for the recommended contact times
- Do not use antiseptic solutions for surface disinfection
- Follow recommended procedures for preparation of products
- Small-volume dispensers that are refilled from large-volume stock containers should be used until entirely empty, then rinsed with tap water and air-dried before they are refilled
- Store stock solutions as recommended by the manufacturer

Weber DJ, Rutala WA et al. Antimicrob Agents Chemother 2007;51:4217

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Choices of Surfaces Disinfectants

- Commonly used disinfectants in hospitals contain
  - Quaternary ammonium compounds +/- alcohol
  - Sodium hypochlorite (bleach), other chlorine-releasing products
  - Improved hydrogen peroxide products
  - Peracetic acid/hydrogen peroxide combinations
  - Alcohols
  - Phenolics
  - Aldehydes
  - Iodophors (not recommended for surface disinfection)
- Ideal disinfectant for all purposes and against all pathogens does not currently exist

Rutala WA et al. Infect Control Hosp Epidemiol 2014;35:855

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Quaternary Ammonium-Based Disinfectants

- Quaternary ammonium-based disinfectants (Quats) are widely for low-level disinfection of surfaces in healthcare facilities in the USA and a number of other countries

Advantages	Disadvantages
Inexpensive (in dilutable form) Good cleaning agents Compatible with many surfaces Persistent antimicrobial activity	Not sporicidal Not good for non-enveloped viruses Some products require use of PPE Affected by organic material Some products have long contact times Bind to cotton & cellulose wipes Outbreaks due to contaminated quats

Rutala WA et al. Infect Control Hosp Epidemiol 2014;35:855
Weber DJ et al. Am J Infect Control 2016;44 (5 Suppl):e85
Engelbrecht K et al. Am J Infect Control 2013;41:908

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Using Dilutable Quat Disinfectants

- A popular approach to surface disinfection in several countries:
  - Diluting concentrated quat disinfectant
  - Placing diluted disinfectant in a reusable bucket with disposable wipes

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Issues Related to Use of Dilutable Quats

- Recently, we tested disinfectant solutions obtained from 33 automated dispensing stations in a hospital
  - Quat concentration was tested using a simple strip test
- Results:
  - 2 stations delivered solutions with no detectable Quat
  - 7 stations yielded Quat disinfectant with < 200 ppm
  - 17 stations yielded solutions with 200-400 ppm
  - 6 stations delivered solutions with 400-600 ppm
  - 1 station was inoperative
- Differences in water pressure in parts of the hospital and design of concentrated jugs of disinfectant were responsible for delivery of inappropriate in-use concentrations
- Recommendation: consider periodic testing of diluted solutions to assure the in-use concentration is correct

Boyce JM et al. Infect Control Hosp Epidemiol 2015;37:340

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Contamination of Reusable Buckets used to Dispense Disinfectant Wipes

- Two studies in Germany assessed the frequency of contamination of reusable buckets used to dispense disinfectant wipes used for surface disinfection in multiple hospitals.
- In one study, 42.4% of buckets containing surface-active disinfectants (e.g. Quats, glucoprotamin) were heavily contaminated with bacteria (e.g., *Achromobacter* species)
- In a second study, 47% of reusable buckets were contaminated
- Failure to process reusable buckets according to manufacturer recommendations contributed to frequent contamination of disinfectant solutions

Kampf G et al.. BMC Infect Dis 2014;14:37
Kupfahl C et al. Infect Control Hosp Epidemiol 2015;36:1362

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Quat Disinfectants Are Prone to Contamination

Boyce JM Antimicrob Resist Infect Control 2016;5:10
Weber DJ et al. Antimicrob Agents Chemother 2007;51:4217
Kampf G et al.. BMC Infect Dis 2014;14:37

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Contamination of Quat Disinfectant

- Investigation revealed that the reusable bucket of quaternary ammonium disinfectant contained high concentrations of *Serratia marcescens*
- Testing of the disinfectant in the bucket showed that it still inhibited the growth of a sensitive strain of *Serratia*
- Whole genome sequencing of the contaminating strain of *Serratia* by collaborators revealed the presence of four Qac-resistance genes
- Recommendation: follow manufacturer's recommendations for how to clean/disinfect buckets before re-filling

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Sodium Hypochlorite and Other Chlorine-Releasing Disinfectants

- Frequently used when *Clostridium difficile*, Ebola virus, and Norovirus or other non-enveloped viruses are of concern

Advantages	Disadvantages
Bactericidal, tuberculocidal, virucidal, and sporicidal Fast efficacy Inexpensive (in dilutable forms) Not flammable Reduces biofilm on surfaces Relatively stable	Reaction hazard with acids and ammonias May be corrosive to metals Affected by organic matter Discolors/stains fabrics May have unpleasant odor Irritating in high concentrations Leaves salt residue

Rutala WA et al. Infect Control Hosp Epidemiol 2014;35:855

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Sodium Hypochlorite and Other Chlorine-Releasing Disinfectants

- Multiple studies have confirmed the effectiveness of sodium hypochlorite or other chlorine-releasing agents or wipes to reduce environmental surface contamination and/or *C. difficile* infection (CDI)
- Most effective if used for both daily and terminal disinfection of rooms occupied by patients with CDI

Kaatz GW et al. Am J Epidemiol 1998;127:1289
Mayfield JL et al. Clin Infect Dis 2000;31:995
Wilcox MH et al. J Hosp Infect 2003;54:109
McMullen KM et al. Infect Control Hosp Epidemiol 2007;28:205
Hacek PM et al. Am J Infect Control 2010;38:350
Orenstein R et al. Infect Control Hosp Epidemiol 2011;32:1137
Sitzlar B et al. Infect Control Hosp Epidemiol 2013;34:459

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Sodium Hypochlorite and Other Chlorine-Releasing Disinfectants

- Sodium hypochlorite or other chlorine-releasing products have been widely used to control outbreaks of Norovirus
- These surface disinfectants were widely used to prevent transmission of Ebola virus
  - CDC recommends using a disinfectant active against non-enveloped viruses as a special precaution
  - WHO suggests use of 0.5% chlorine solution

http://cdc.gov/hicpac/pdf/norovirus/Norovirus-Guideline-2011.pdf
http://cdc.gov/vhf/ebola/healthcare-us/cleaning/hospitals.html
Apps.who.int/iris/bitstream/10665/131828/1/WHO_EVD_Guidance_IPC_14.1_eng.pdf

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Improved Hydrogen Peroxide Surface Disinfectants

- In Canada, and to lesser degree in other countries, improved hydrogen peroxide (IHP) disinfectants are being used instead of Quat disinfectants for surface disinfection

Advantages	Disadvantages
Effective against many pathogens Fast efficacy Easy compliance with "wet times" Safe for workers Benign for the environment Good compatibility with surfaces Non-staining	More expensive than other disinfectants Not sporicidal in low concentrations

Omidbakhsh N et al. Am J Infect Control 2006;34:251
Rutala WA et al. Infect Control Hosp Epidemiol 2014;35:855

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Improved Hydrogen Peroxide (IHP) Surface Disinfectants

- A prospective study of a 0.5% IHP product significantly reduced *C. difficile* spores on toilet seats of CDI patients
- A laboratory-based study found that IHP liquid disinfectants containing 0.5% or 1.4% H_2O_2 were superior to or equal to the Quat tested
- A study using the ASTM E2967-15 standard for evaluating disinfectant wipes found that all wipes achieved > 4 log_{10} reduction of *S. aureus* and *Acinetobacter baumannii*
  - Only the IHP wipe containing 0.5% H_2O_2 prevented transfer of bacteria to another surface

Alfa MJ et al. BMC Infect Dis 2010;10:268
Rutala WA et al. Infect Control Hosp Epidemiol 2012;33:1159
Sattar SA et al. J Hosp Infect 2015;91:319

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Improved Hydrogen Peroxide (IHP) Surface Disinfectants

- A IHP wipe with 1.4% H_2O_2 used to disinfect 10 high-touch surfaces in 72 patient rooms resulted in 99% of surfaces having < 2.5 CFU/cm^2 (75% yielded no growth)
- A IHP spray product containing 1.4% IHP reduced microbial load on patient privacy curtains by 96.8%
- IHP wipes effectively disinfected surfaces in operating room
- A study of soft surfaces sprayed with a 1.4% IHP product or 1:10 dilution of household bleach found that both reduced MRSA and VRE by $\geq$ 6 log_{10} with a 1-min contact time

Boyce JM et al. Infect Control Hosp Epidemiol 2013;34:521
Rutala WA et al. Am J Infect Control 2014;42:426
Wiemken TL et al. Am J Infect Control 2014;42:1004
Cadnum JL et al. Am J Infect Control 2015;43:1357

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Improved Hydrogen Peroxide (IHP) Surface Disinfectants

- An hospital-based interrupted time series study compared
  - H_2O_2 cleaning agent
  - 0.5% IHP disposable wipe
- When > 80% of surfaces were wiped by housekeepers, use of IHP wipes was associated with a significant reduction in healthcare-associated infections caused by MRSA, VRE and *C. difficile*
- A 12-month prospective, cross-over controlled study involving 4 units in a hospital compared a Quat and 0.5% IHP wipes for daily and terminal room disinfection
  - IHP wipes yielded significantly lower colony counts after cleaning and significantly greater proportion of surfaces with no growth
  - There was a 23% reduction in a composite healthcare outcome that included MDRO acquisition and infection (p = 0.068, 95% CI 0.579 – 1.029)

Alfa MJ et al. Am J Infect Control 2015;43:141
Boyce JM et al. APIC 2016, Abstract #25

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Peracetic Acid/Hydrogen Peroxide Disinfectants

- Due to the continuing difficulties in preventing *C. difficile* infections, new sporicidal disinfectants have been introduced

Advantages	Disadvantages
Bactericidal, fungicidal, virucidal, and sporicidal Active in presence of organic matter Environmentally-friendly by-products (e.g., acetic acid, O_2, H_20) Surface compatible	Problems with stability Has potential to be incompatible with brass and copper More expensive than most other disinfectants Odor may be irritating

Kundrapu S et al. Infect Control Hosp Epidemiol 2012;33:1039
Deshpande A Infect Control Hosp Epidemiol 2014;35:1414
Carling PC et al. Infect Control Hosp Epidemiol 2014;35:1349
Saha A et al. Am J Infect Control 2016 (Epub ahead of print)
Rutala WA et al. Infect Dis Clin N Am 2016;30:609

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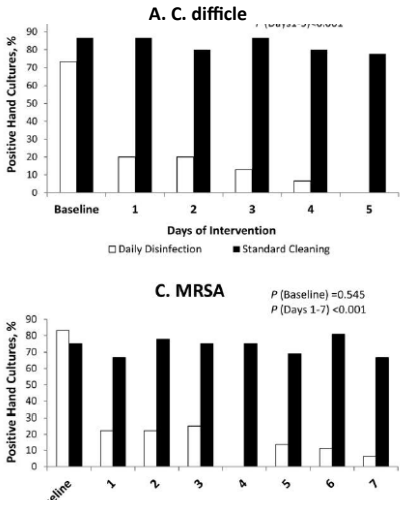
Peracetic Acid (PAA)-Based Disinfectant

- Prospective randomized trial in long-term care facility
- High-touch surfaces were cleaned
  - Only when visibly soiled
  - Daily with PAA-based disinfectant
- Daily cleaning with PAA-based product reduced frequency (and colony counts) of *C. difficile* and MRSA
- Reduced contamination of hands of healthcare personnel



Kundrapu S et al. Infect Control Hosp Epidemiol 2012;33:1039

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Peracetic Acid/Hydrogen Peroxide Disinfectants

- Peracetic acid (PAA)/Hydrogen peroxide disinfectant was as effective as bleach in killing MRSA, VRE and *C.difficile* spores in vitro, and was highly effective of removing the 3 pathogens from high-touch surfaces
- A comparison of a Quat and a PAA/Hydrogen peroxide disinfectant found no growth of bacteria after cleaning
  - 40% of surfaces with Quat disinfectant
  - 77% of surfaces with PAA/Hydrogen peroxide disinfectant

Deshpande A et al. Infect Control Hosp Epidemiol 2014;35:1414
Carling PC et al. Infect Control Hosp Epidemiol 2014;35:1349

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Peracetic Acid/Hydrogen Peroxide Disinfectants

- **Problems reported with PAA/Hydrogen peroxide products**
  - Odor of some products may be quite irritating to housekeepers
    - A few hospitals have discontinued use due to complaints about odor
  - At least some combination products require activation by mixing 2 components on site due to stability problems
  - One product was removed from market in 2015 due to insufficient activity against *C. difficile* spores of both unactivated and activated product

https://www.epa.gov/enforcement/stop-sale-use-or-removal-order-issued-sbiomed-llc

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Alcohols as Disinfectants

- **Because isopropanol & ethanol evaporate rapidly, they have not been recommended for disinfecting large surfaces**

Advantages	Disadvantages
Bactericidal, tuberculocidal, virucidal, fungicidal Fast acting Noncorrosive Nonstaining No toxic residue Used to disinfect small surfaces (e.g., medication vials)	Not sporicidal Affected by organic matter Poor cleaning properties Not EPA registered Damages some instruments (e.g. hard rubber, glue) Rapid evaporation makes contact time compliance difficult Flammable 1 pseudo-outbreak reported

Rutala WA et al. Infect Control Hosp Epidemiol 2014;35:855

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Alcohols as Disinfectants

- Alcohol concentrations of 60% - 90% have been used to disinfect small objects
- New alcohol-based formulation was recently marketed
  - Low concentration of alcohol plus other ingredients
  - Bactericidal, tuberculocidal, fungicidal, virucidal
    - Effective against Norovirus and enveloped viruses
  - Short contact time (30 seconds for 22 different microrganisms)
  - EPA registered for use on healthcare environmental surfaces
  - EPA Category IV (no personal protective equipment needed)
  - Can be used on food-contact surfaces
  - Not Sporicidal

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Phenolics as Disinfectants

Advantages	Disadvantages
Bactericidal, tuberculocidal, virucidal, fungicidal Inexpensive (in dilutable form) Nonstaining No toxic residue Not flammable	Not sporicidal Absorbed by porous materials, and residua may irritate tissue Some products cause skin depigmentation Can cause hyperbilirubinemia in infants if not used correctly

- Used on laboratory surfaces
- Extent of use in patient areas not clear

Rutala WA et al. Infect Control Hosp Epidemiol 2014;35:855

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Aldehydes as Disinfectants

- Aldehyde-based products are used for surface disinfection in some countries, especially in Europe, but are not used for this purpose in the United States

Advantages	Disadvantages
Bactericidal, tuberculocidal, fungicidal, virucidal (enveloped viruses) Short contact times Good cleaning ability Good material compatibility	Not all formulations are sporicidal Can cause skin and respiratory irritation Some concern over environmental impact

Khanna N et al. J Hosp Infect 2003;55:131
Meinke R et al. Infect Control Hosp Epidemiol 2012;33:1077
Kampf G et al. BMC Infect Dis 2014;14:37

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Methods Used to Apply Disinfectants to Surfaces

- Methods used to apply disinfectants to surfaces include:
  - Cotton towels or rags
  - Reusable microfiber cloths
  - Disposable cellulose-based wipes
  - Non-woven spunlace wipes
    Disposable meltblown polypropylene wipes
- Cotton and cellulose-based wipes, and to a lesser extent microfiber, can bind Quat disinfectants
  - Reduces the concentration of Quat delivered to surfaces
  - Impact of this phenomenon on reducing pathogens on surfaces requires further study

Bloss R et al. J Hosp Infect 2010;75:56
Rutala WA et al. Am J Infect Control 2016;44:e69
Engelbrecht K et al. Am J Infect Control 2013;41:908
Boyce JM et al. Infect Control Hosp Epidemiol 2016;37:340

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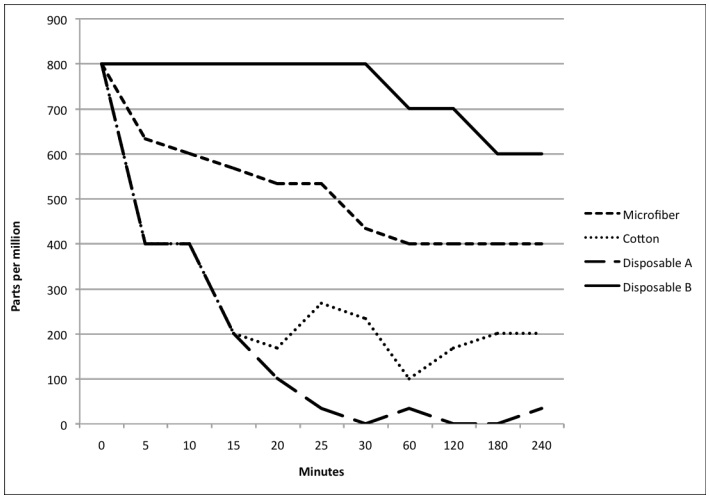
Quat Binding by Different Types of Wipes



Boyce JM et al. Infect Control Hosp Epidemiol 2016;37:340

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Cotton Towels and Microfiber Cloths

- Cotton towels and cloths are inexpensive
  - May still be contaminated even after being laundered
  - Can spread *C. difficile* spores to other surfaces
- Microfiber cloths
  - New cloths remove bacteria from surfaces better than cotton cloths
  - Commercially available microfiber cloths vary considerably in how well they remove bacteria from surfaces
  - Ability to clean surfaces is adversely affected
    - After laundering/drying multiple times at high temperatures
    - Exposure to sodium hypochlorite
  - Depending on method of use, may spread bacteria to surfaces

Sifuentes LY Am J Infect Control 2013;41:912
Trajtman AN Am J Infect Control 2015;43:686
Moore G et al. J Hosp Infect 2006 64:379
Diab-Elschahawi M et al. Am J Infect Control 38:289
Bergen LK et al. J Hosp Infect 2009;71:132

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Disposable Wipes

- **Advantages**
  - Eliminates need for laundering cotton and microfiber cloths
  - Ease of use
  - Ready-to-use pre-packaged wipes eliminate need for dilution/preparation of disinfectant by housekeepers
  - Personnel may prefer wipes vs bucket
  - Require less time to use than bucket method
- **Disadvantages**
  - More expensive than dilutable disinfectants
  - More waste disposal
  - Ability to remove bacteria may vary by type

Berendt AE et al. Am J Infect Control 2011;39:442
Wiemken TL et al. Am J Infect Control 2014;42:329
Sattar SA et al. J Hosp Infect 2015;91:319

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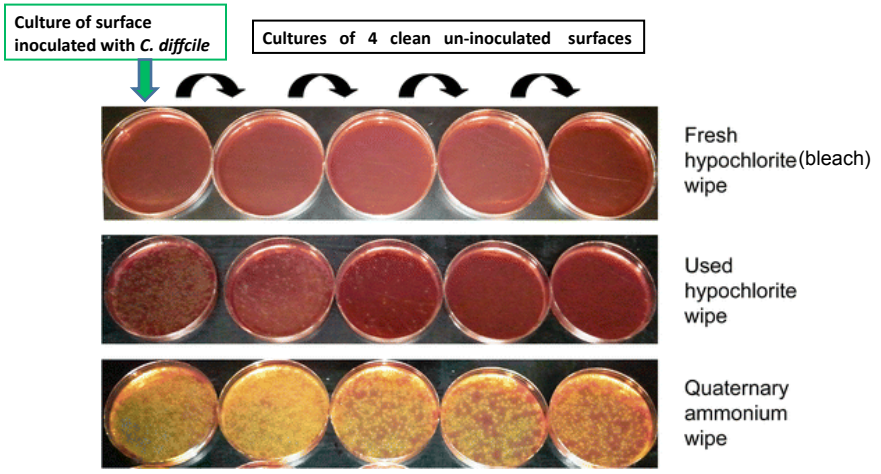
Follow Recommended Procedures

- Use recommended number of wipes per room
- Using too few wipes per room can spread bacteria



Cadnum JL Infect Control Hosp Epidemiol 2013;34:441

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Costs of Disinfectant Solutions and Wipes

- Few publications have reported the cost of disinfectants
- Dilutable Quats and bleach solutions are relatively inexpensive
- Acquisition costs of disposable wipes are higher, but avoid the costs of cotton towels, microfiber cloths, and laundering expenses

Cost comparison of wipes used in the study and control wards

Cost*	Quaternary ammonium compound (Tuffie 5†)	Alcohol wipes (Sani-Cloth 70‡)	Peracetic acid (Clinell Sporicidal§)
Per wipe	$0.03	$0.014	$0.47
Per pack	$3.59	$3.30	$11.73
A month's supply	$269.62	$16.48	$1,817.55
Total cost to the control ward (per mo): $286.09		Total cost to the study ward (per mo): $1,817.55	

Saha A et al. Am J Infect Control 2016 (Epub ahead of print)

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No-Touch Room Decontamination Methods

- In many facilities, ≤ 50% of high-touch surfaces are wiped by housekeepers at the time of terminal room cleaning
- In response, "no-touch" automated systems have been developed to decontaminate patient rooms after discharge
- Examples include:
  - Aerosolized hydrogen peroxide
  - Hydrogen peroxide vapor systems
  - Gaseous ozone
  - Saturated steam systems
  - Mobile ultraviolet and pulsed-Xenon light devices
  - High-Intensity Narrow-Spectrum light

Carling PC et al. Am J Infect Control 2010;38 (5 Suppl 1):S41
Otter JA et al. J Hosp Infect 2013;83:1

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Aerosolized Hydrogen Peroxide Dry Mist Systems

- Portable units aerosolize hydrogen peroxide
- 5-6% hydrogen peroxide +/- 50-60 ppm silver plus stabilisers
- Aerosolized (droplets – not gas) have particle size of 0.5-12 µm
- Systems use passive aeration. Hydrogen peroxide is left to degrade naturally
- Cycle time >2 hr for a single room

Examples of hydrogen peroxide aerosol systems

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Aerosolized Hydrogen Peroxide

- Generally reduces indicator spores by ≤ 4 logs
- 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
- One system has sporicidal claim from EPA in USA

Andersen BM et al. J Hosp Infect 2006;62:149
Shapey S et al. J Hosp Infect 2008;70:136
Bartels MD et al. J Hosp Infect 2008;70:35
Barbut F et al. Infect Control Hosp Epidemiol 2009;30:515
Piskin N et al. Am J Infect Control 2011;39:757
Landelle *et al. ICHE* 2013;34:119-124
Mitchell BG et al. BMJ Open 2014;4: doi: 10.1136/bmjopen-2013-004522

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Aerosolized Hydrogen Peroxide

- More recently, an aerosolized hydrogen peroxide system which emits 7.5% H_20_2 was tested for activity against spores on *G. stearothermophilus* and 2 strains of *C. difficile* on carriers located 80 cm from device
- After a 1-hr exposure in a ½-open drawer,
  - few *C. difficile* spores were killed
  - a 10^5 log reduction of *G. stearothermophilus* spores occurred
- After 3-hr exposure,
  - no viable *C. difficile* spores were recovered
  - A 5-log reduction of both *C. difficile* strains occurred

Steindl G et al. Wiener Klinische Wochenschrift 2014
DOI 10.1007/s00508-014-0682-6

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Impact of Aerosolized Hydrogen Peroxide Systems on Healthcare-Associated Infections

- One Before/After study compared
  - Aerosolized hydrogen peroxide system
  - Use of detergent for room cleaning
- Results: aerosolized hydrogen peroxide system
  - Was associated with a significant reduction in MRSA acquisition
  - Some reduction in MRSA infection
- No randomized controlled trials of the impact on healthcare-associated infections

Mitchell BG et al. BMJ Open 2014;4: doi: 10.1136/bmjopen-2013-004522

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Vaporized Hydrogen Peroxide System

- "Dry gas" vaporized hydrogen peroxide (VHP) system that utilizes ~30% H_2O_2 has been shown to be effective against
  - *Mycobacterium tuberculosis*, *Mycoplasma, Acinetobacter, Clostridium difficile, Bacillus anthracis*, viruses, prions
- In Before/After studies ,"dry gas" VHP system, when combined with other infection control measures, appeared to contribute to control of outbreaks of *Acinetobacter*
  In long-term acute care facility and in two ICUs in a hospital
- No randomized controlled trials of impact on HAIs

Fichet G et al. Lancet 2004;364:521
Heckert RA Appl Environ Microbiol 1997;63:3916
Rogers JV et al. J Appl Microbiol 2005;99:739
Pottage T et al. J Hosp Infect 2010;74:55
Ray A et al. Infect Control Hosp Epidemiol 2010;31:1236
Galvin S et al. J Hosp Infect 2012;80:67
Chmielarczyk A et al. J Hosp Infect 2012;81:239

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Hydrogen Peroxide Vapor System

- Micro-condensation HPV system, which utilizes 35% H_2O_2 is 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 significant reductions (often log 10^6) of a number of these pathogens, with 92% to 100% reduction of pathogens on surfaces

French GL et al. J Hosp Infect 2004;57:31
Bates CJ et al. J Hosp Infect 2005;61:364
Hall L et al. J Clin Microbiol 2007;45:810
Otter JA et al. J Hosp Infect 2007;67:182
Hall L et al. Med Mycol 2008;46:189
Boyce JM et al. Infect Control Hosp Epidemiol 2008;29:723
Otter JA et al. J Clin Microbiol 2009;47:205
Pottage T et al. J Hosp Infect 2010;24:55
Manian FA et al. Infect Control Hosp Epidemiol 2011;32:667
Barbut F et al. Burns 2013;39:395
Landelle et al. Infect Control Hosp Epidemiol 2013;34:119

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Impact of Microcondensation Hydrogen Peroxide Vapor (HPV) Room Decontamination on Risk of Acquiring MDROs

- 30-month prospective cohort study on 3 intervention wards and 3 control units in a tertiary hospital
- Environmental contamination by, and patient acquisition of VRE, MRSA, *C difficile* and MDR GNRs were studied in rooms decontaminated with HPV vs standard cleaning
- **Results:** Patients admitted to rooms decontaminated with HPV were 64% less likely to acquire an MDRO ($p < 0.001$), and 80% less likely to acquire VRE ($p < 0.001$))
  - Fewer patients acquired MRSA, C difficile and MDR GNR, but the reduction was not statistically significant
- The percent of rooms contaminated with MDROs was reduced significantly on HPV units, but not control units

Passaretti CL et al. Clin Infect Dis 2013;56:27

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Impact of Microcondensation HPV System on Healthcare-Associated Infections

- In Before/After trials, when used in conjunction with other measures, HPV appears to have contributed to control of outbreaks caused by MRSA, resistant Gram-negative bacteria, and *C. difficile*
  - 37% - 60% reductions in incidence density of *C. difficile*
- Has been used to decontaminate rooms previously occupied by patients with Lassa fever and Ebola virus infection
- No randomized, controlled trials of impact on HAIs

Jeanes *et al. J Hosp Infect* 2005;61:85-86
Bates & Pearse. *J Hosp Infect* 2005;61:364-366
Dryden et al. *J Hosp Infect* 2008;68:190-192
Boyce JM et al. Infect Control Hosp Epidemiol 2008;29:723
Otter *et al. Am J Infect Cont* 2011;38:754-756
Cooper *et al. J Hosp Infect* 2011;78:238-240
Snitkin *et al. Sci Transl Med* 2012;4:148ra116
Manian FA Amer J Infect Control 2013;41:537
Gopinath *et al. Infect Control Hosp Epidemiol* 2013;34:99-100
McCord J et al. ID Week 2014,Poster 1648

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Hydrogen Peroxide Vapor vs Aerosolized Hydrogen Peroxide

- HPV and aerosolized HP are different processes with differing effectiveness in eliminating pathogens
- 2 head-to-head comparisons of one aerosolized hydrogen peroxide system vs microcondensation HPV system revealed:
  - HPV was significantly more effective than aerosolized H_2O_2 system against spores
  - Cycle times were similar for the 2 processes
- Conclusion: HPV is significantly more effective in eradicating spores than the aerosol H_2O_2 system tested

Otter JA et al. ICHE 2010;31:1201
Holmdahl T et al. ICHE 2011;32:831
Fu TY et al. J Hosp Infect 2012;80:199

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Concerns Regarding Vapor-Based Hydrogen Peroxide Systems

- Need to seal air vents and doors increases cycle times
- Total cycle times (room prep/decontamination/breakdown)
  - Micro-condensation process: 2 – 2.3 hrs, less with newer equipment
  - Dry Gas process: 8 hrs
- Micro-condensation HPV process is feasible in hospitals with high census levels
- Level of training and expertise of operators is greater than with other no-touch systems such as mobile UV-C light units
- No randomized, controlled trials of impact on infection rates

Otter JA et al. Infect Control Hosp Epidemiol 2009;30:574
Ray A et al. Infect Control Hosp Epidemiol 2010;31:1236

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UVC Light Room Decontamination 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 has been performed
- Some units can be set to kill vegetative bacteria (12,000 uWs/cm^2) or to kill spores (22,000 uWs/cm^2)

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UV-C Light Room Decontamination Systems

- Cultures obtained from surfaces inoculated with *C. difficile*, MRSA, VRE were obtained before/after UVC light decontamination
  - 3-5 $\log_{10}$ reduction of MRSA and VRE and 1-3 $\log_{10}$ reduction of *C. difficile* under experimental conditions
  - Significant reduction, without complete eradication of pathogens
- Less effective in "shadowed" areas, in several studies
- Efficacy is affected by cycle time, distance from device, and presence of organic material

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
Havill NL et al. ICHE 2012;33:507
Anderson DJ et al. ICHE 2013;34:466
Mahida N et al. J Hosp Infect 2013;84:332
Nerandzic MM et al. PLoS One 2014;9:e107444

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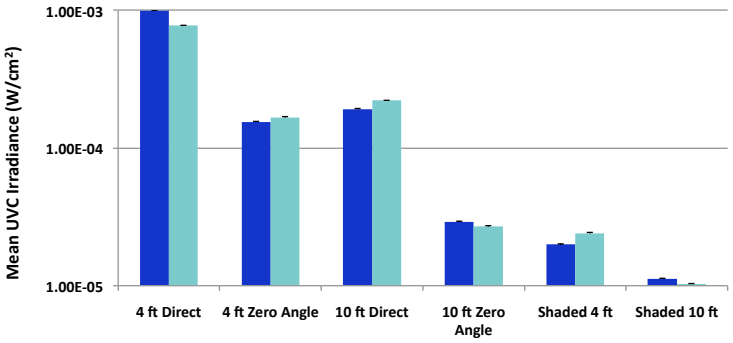
Parameters Effecting UV-C Effectiveness

- UV-C irradiance and antimicrobial efficacy are effected by test methods
  - Area over which the inoculum is spread on test surfaces
  - Distance and orientation of test surfaces relative to the UV-C device
  - Types of organic load used in tests



Cadnum JL et al. Infect Control Hosp Epidemiol 2016;37:555
Boyce JM et al. Infect Control Hosp Epidemiol 2016;37:667

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Impact of UV-C Decontamination Systems on Healthcare-Associated Infections

- Currently, limited published data on impact of UV-C light systems on incidence of healthcare-associated infections
- Multicenter prospective, cluster-randomized crossover trial of UV-C light for terminal disinfection of hospital rooms has been completed in nine hospitals, comparing
  - Standard quat disinfectant alone
  - Standard quat disinfectant + UV-C
  - Sodium hypochlorite (bleach) alone
  - Sodium hypochlorite + UV-C
- Outcome measures
  - Colonization or infection among patients exposed to rooms previously occupied by a patient with MRSA, VRE or C. difficile

Anderson DJ et al. IDWeek 2015, Abstract
Weber DJ et al. Curr Opin Infect Dis 2016;29:424

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Impact of UV-C Decontamination Systems on Healthcare-Associated Infections

- **Results**
  - **Bleach and/or UV-C enhanced room decontamination decreased the clinical incidence of MRSA, VRE and *C. difficile* by 10% to 30% (p = 0.036)**

Anderson DJ et al. IDWeek 2015, Abstract
Weber DJ et al. Curr Opin Infect Dis 2016;29:424

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Issues to Address When Considering Mobile Ultraviolet Light Systems

- **Ease of use**
- **Duration of cycle times recommended by manufacturer**
- **Evidence of microbiological efficacy published by independent investigators**
- **Cost per device ($40,000 - $125,000)**
- **Cost of replacement bulbs/service contracts**
- **Availability of digital recording, storage & retrieval of data**

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Comparison of HPV vs Mobile UV Light System

- Prospective study involving 15 rooms, each decontaminated once with HPV and UV-C light processes, at intervals ≥ 2 months
- 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
- Mean cycle times: 153 min for HPV vs 73 min for UV-C
- 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

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Hydrogen Peroxide Vapor vs Ultraviolet Light Systems

- Choice between hydrogen peroxide vapor and ultraviolet light systems will depend on a number of factors, including its intended use and practicalities of application

Variable	Continuous UV-C or Pulsed-Xenon UV	Hydrogen Peroxide Vapor
Intended use	Decontaminate a relatively large proportion of rooms	Decontaminate primarily rooms with difficult-to-kill or highly virulent pathogens
Level of efficacy needed	Significant reduction of pathogens	Near-total or total eradication of pathogen
Cycle times	15 min – 45 min	2 – 2.3 hrs

Havill NL et al. Infect Control Hosp Epidemiol 2012;33:507
Otter JA et al. J Hosp Infect 2013;83:1

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Pulsed-Xenon UV Light System

- System uses pulsed-xenon instead of mercury bulbs to produce UV light
- Emits flashes of UV light in the 200-320nm range
- Manufacturer recommends placing device in 3 locations in a room with 5-7 min cycles
- Several studies have shown significant reduction of pathogens in patient rooms

Stibich *et al. Infect Control Hosp Epidemiol* 2011;32:286-288
Levin *et al. Am J Infect Control* 2013;41:746-748
Jinadatha *et al. BMC Infect Dis* 2014;14:187
Ghantoji SS et al. J Med Microbiol 2015;64:191

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Comparison of Continuous UV-C vs Pulsed-Xenon UV Light System

Device	Pathogen	Log_{10} Reduction Per cm^2
Pulsed-Xenon UV	*C. difficile*	0.55
	MRSA	1.85
	VRE	0.6
Continuous UV-C	*C. difficile*	1.0
	MRSA	~3.1
	VRE	~3.6

- Both systems reduced pathogens on surfaces
- UV-C showing greater log reductions

Nerandzic MM Infect Control Hosp Epidemiol 2015;36:192

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Concerns Regarding Mobile UV-C and Pulsed Xenon Room Decontamination Devices

- Currently, no randomized controlled trials of the impact of Pulsed Xenon system on healthcare-associated infection rates
- Number of systems currently being marketed, often with limited documentation of effectiveness, makes choice of device difficult
- There are substantial differences between systems regarding
  - Recommended cycle times
  - Up-front and maintenance costs
- Odor generated by use of UV-C devices is initially of concern to some healthcare workers
  - To date, no evidence that odor is harmful

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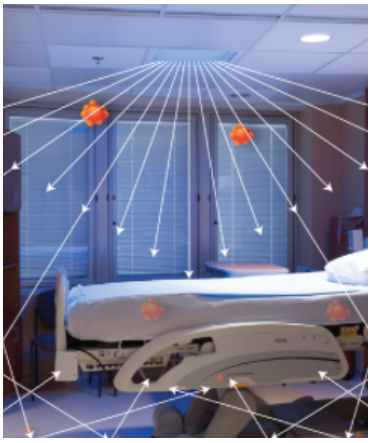
High-Intensity, Narrow Spectrum Light (405 nm)

- High-Intensity, narrow spectrum light system emits visible light in 405 nm range
- Light can be set to blue color or white color
- Can be left on when patients or personnel are in room
- Has been shown to reduce staphylococci on surfaces
- Further data are needed to determine its role in air and surface disinfection



Maclean M et al. J Hosp Infect 2010;76:247
Bache SE et al. Burns 2012;38:69
Maclean M et al. J Hosp Infect 2014;88:1

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Health-Economic Evaluation of New Disinfection Methods

- Very few data are available on the cost-effectiveness of new "no-touch" room disinfection technologies
- In one hospital, *C. difficile* disease incidence density decreased from 11.8/10,000 Pt-Days during 10 months before use of HPV to 8.7/10,000 Pt-Days during 10 months use of HPV (39% reduction)
  - Estimated number of *C. difficile* cases prevented in 10 mo = 33
  - 33 prevented cases x $6522/case = projected cost saving in 10 mo of $215,000 ($258,000 annually)
  - Cost of HPV implant team was less than projected cost saving
- A study of using HPV to decontaminate disposable medical supplies that are usually discarded at patient discharge revealed an potential annual cost saving of $387,000

Otter JA et al. Infect Control Hosp Epidemiol 2013;34:472

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Costs of "No-Touch" Room Disinfection Systems

- HPV technology costs vary, depending on whether devices are purchased by hospital vs paying for services of an "implant team" from the manufacturer
- Mobile UV-C light and pulsed-xenon devices vary in price from $40,000 to $125,000/device
  - Service contracts and bulb replacement costs must be considered
- Further studies of the cost-effectiveness of HPV and UV-C and pulsed-xenon systems are needed.

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Other Gaseous or Fogging Technologies

- Gaseous ozone has been proposed as a method of room decontamination, but few clinical studies are available
  - Sharma M Am J Infect Control 200836:559
  - Moat J et al. Can J Microbiol 2009;55:928
- Alcohol-based fogging system was shown to be less effective than bleach
  - Jury LA et al. Am J Infect Control 2010;38:234
- Chlorine dioxide fogging is promoted for room decontamination, but few published studies in hospital settings are available
  - Lowe JJ et al. J Occup Environ Hyg 2013;10:533
- Hydrogen peroxide/peracetic acid fogging showed significant log reductions of spores in laboratory setting
  - Wood JP et al. J Hazardous Materials 2013;250:61

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Summary

- There are an increasing number of newer surface disinfectants available for use in healthcare facilities
  - No disinfectant is ideal for every situation
- Greater attention should be devoted to making sure that disinfectants are used as recommended
  - To Assure that the product will be effective
  - Avoid contamination
- Wipes/cloths should be compatible with disinfectant used
- There is increasing evidence that "No-Touch" room decontamination systems can be used in conjunction with manual disinfection processes to reduce the risk of healthcare-associated infections

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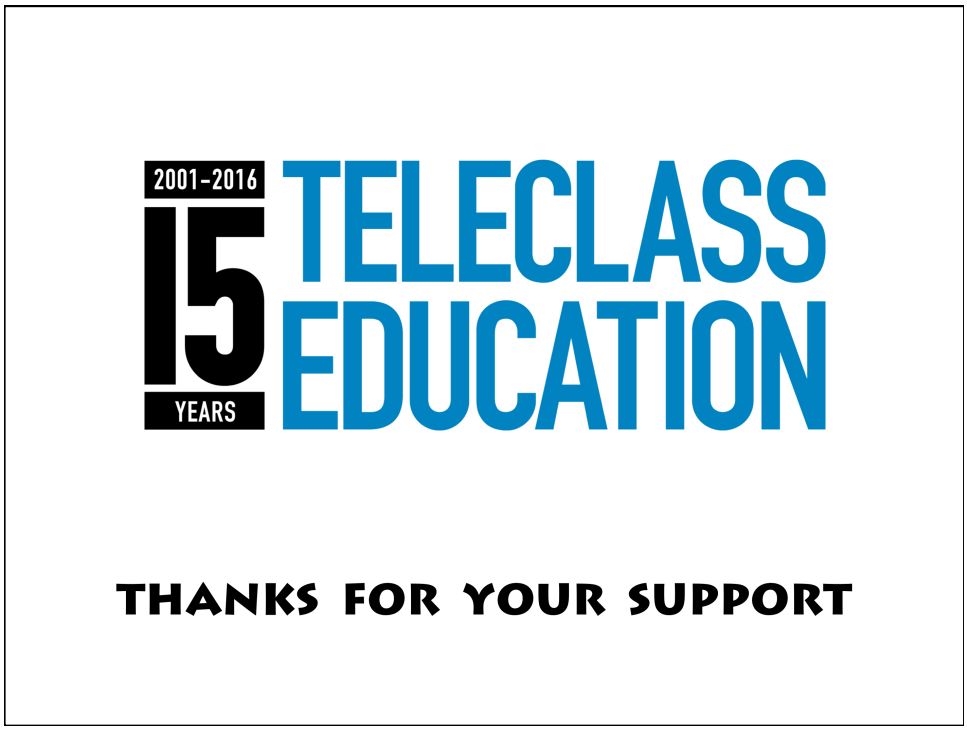
Coming Soon
October 19 (South Pacific Teleclass)
TECHNOLOGY FOR MONITORING HAND HYGIENE IN THE 21ST CENTURY – WHY ARE WE USING IT?
Prof. Mary-Louise McLaws, University of New South Wales, Australia
October 20 (FREE Teleclass)
THE HISTORY OF CBIC AND WHY CERTIFICATION IS STILL IMPORTANT TODAY
Certification Board of Infection Control
October 27 ANTIMICROBIAL ENVIRONMENTAL SURFACES IN HEALTHCARE SETTINGS – CAN THEY REALLY BE BENEFICIAL?
Prof. Jean-Yves Maillard, Cardiff University, Wales
November 10 NOROVIRUSES AND HEALTHCARE FACILITIES: HOW TO KEEP THE VIRUS OUT AND WHAT TO DO WHEN IT GETS IN
Dr. Ben Lopman, Centers for Disease Control and Prevention, and
Prof. Miren Ituriza-Gomara, University of Liverpool
www.webbertraining.com/schedulep1.php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