

Novel Technologies for Infection Prevention

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DISCLOSURES

- Advanced Sterilization Products-consultant; honoraria
- Clorox-consultant
- CareFusion and 3M-honoraria

Novel Technologies for Infection Prevention

- Critique and review novel methods of providing infection prevention via disinfection and sterilization
 - UV light
 - Vaporized hydrogen peroxide
 - Copper
 - Silver
 - Steris System 1E

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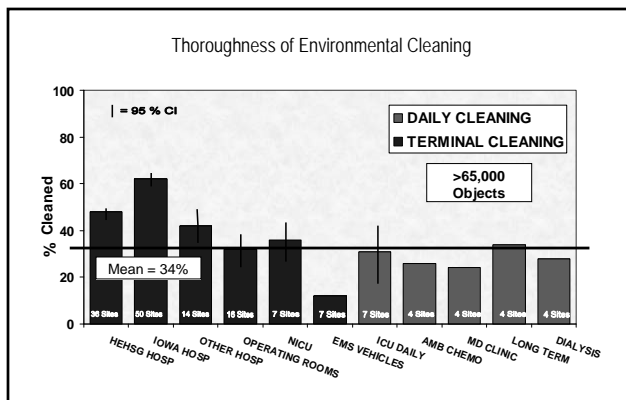
What's the Problem?

New Approaches to Room Decontamination

- Contaminated environmental surfaces can contribute to transmission of pathogens
- <50% of 14 objects in patient room are cleaned at terminal disinfection
- Inadequate terminal cleaning of rooms occupied by patients with MDR pathogens places the next patients in these rooms at increased risk of acquiring these organisms

Mean proportion of surfaces disinfected at terminal cleaning is <50%

Terminal cleaning methods ineffective (products effective practices deficient [surfaces not wiped]) in eliminating epidemiologically important pathogens



Risk of Acquiring MRSA, VRE, and *C. difficile* from Prior Room Occupants

- Admission to a room previously occupied by an MRSA-positive patient or VRE-positive patient significantly increased the odds of acquisition for MRSA and VRE (although this route is a minor contributor to overall transmission). Arch Intern Med 2006;166:1945.
- Prior environmental contamination, whether measured via environmental cultures or prior room occupancy by VRE-colonized patients, increases the risk of acquisition of VRE. Clin Infect Dis 2008;46:678.
- Prior room occupant with CDI is a significant risk for CDI acquisition. ICACC (K-4194) 2008. Shaughnessy et al.

New Approaches to Room Decontamination after Patient Discharge

Ultraviolet

- UV is electromagnetic radiation with wavelength shorter than visible light
- UV is found in sunlight but ozone layer blocks 98.7%
- 98.7% of the UV light that reaches earth's surface is UVA
- UVC (short wave or germicidal light) has a wavelength range of 280nm-100nm
- UVC photons damage DNA



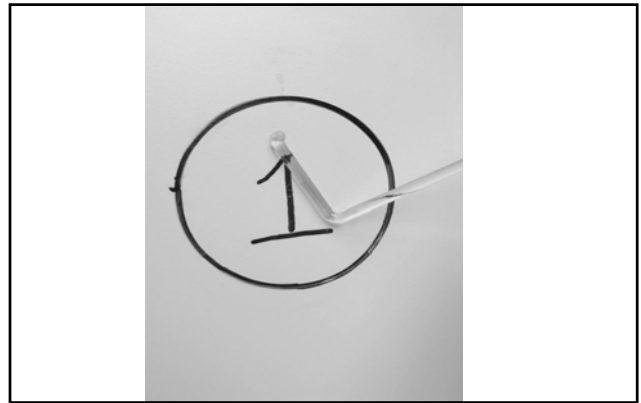
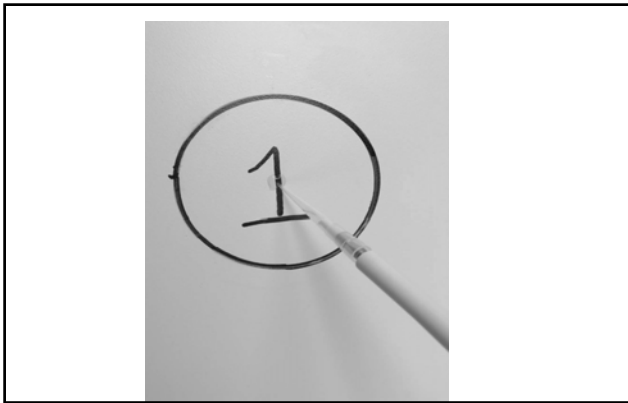
UVC Room Decontamination

Rutala, Weber, Gergen, ICHE, In press, 2010

- Fully automated, self calibrates, activated by hand-held remote
- Room ventilation does not need to be modified
- Uses UVC (254 nm range) to decontaminate surfaces
- Measures UV reflected from walls, ceilings, floors or other treated areas and calculates the operation time to deliver the programmed lethal dose for pathogens.
- UV sensors determines and targets highly-shadowed areas to deliver measured dose of UV energy
- After UV dose delivered (e.g., 36,000 μ Ws/cm² RD for spores), will power-down and audibly notify the operator

UVC Room Decontamination

- Phase 1-3x3" formica sheets contaminated with $\sim 10^{4-5}$ organisms (MRSA, VRE, MDR-*Acinetobacter*, *C. difficile* spores) were placed in a room, both in direct line-of-sight of the UV device and behind objects (indirect line-of-sight identified by using a laser pointer). Following timed exposure, the growth of the microbes was assessed.
- Phase 2-rooms that housed patients with MRSA or VRE had specified sites sampled before and after UVC irradiation. Following timed exposure, the growth of MRSA, VRE and total colony counts was assessed.



Formica Placement in the Patient Room

- Toilet seat
- Back of head-of-the-bed
- Back-of-computer
- Bedside table (far side)
- Side of sink
- Foot of bed, facing the door
- Bathroom door

Room Decontamination with UVC

(Rutala, Gergen, Weber, In press, ICHE, 2010)

Organism	Direct (log ₁₀ reduction)	Indirect (log ₁₀ reduction)	Total (log ₁₀ reduction)
MRSA (~15m)	4.31	3.85	3.94 (n=50)
VRE (~15m)	3.90	3.29*	3.46 (n=47)
MDR- <i>Acinetobacter</i> (~15m)	4.21	3.79	3.88 (n=47)
<i>C. difficile</i> (~50m)	4.04	2.43*	2.79 (n=45)

UVC Room Decontamination

- Phase 1-3x3" formica sheets contaminated with ~10⁴⁻⁵ organisms (MRSA, VRE, MDR-*Acinetobacter*, *C. difficile* spores) were placed in a room, both in direct line-of-sight of the UV device and behind objects. Following timed exposure, the growth of the microbes was assessed.
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Decontamination of Surfaces in Patient Rooms on Contact Precautions for MRSA

Overall Results	Before UV	After UV	Before UV	After UV
Mean Total CFU/5 Rodacs	384	19		
Pos Rodacs/ Total Rodacs			81/400	2/400
Mean MRSA/ Rodac			37	2

Summary

- UVC radiation was found to reduce >99.9% of vegetative bacteria within 15 minutes and 99.84% for *C. difficile* spores within 50 minutes.
- UVC was more effective when there was a direct line-of-sight to the contaminant but meaningful reduction (3.3-3.9 log₁₀ reduction for bacteria) occurred when the contaminant was not directly exposed to the UVC.
- In MRSA patient rooms, there was a significant reduction in total average CFU per 5 Rodacs (384 CFU pre and 19 CFU post); samples positive for MRSA (81/400 pre and 2/400 post); and the average MRSA per Rodac (37 pre- and 2 post-treatment)

Decontamination with UVC

- Advantages
 - Reliable biocidal activity against a wide range of pathogens
 - Surfaces and equipment decontaminated
 - Room decontamination is rapid (~15-17 minutes) for vegetative bacteria (3-4 log₁₀ reduction)
 - HVAC system does not need to be disabled and the room does not need to be sealed
 - It is residual free and does not give rise to health and safety concerns
 - No consumable products so costs are equipment and staff time
 - Good distribution in the room of UV energy via an automated monitoring system

Decontamination with UVC

- Disadvantages
 - Do not know if use decreases the incidence of HAIs
 - Only done at terminal disinfection (i.e., not daily cleaning)
 - Rapid recontamination of the environment likely
 - All patients and staff must be removed from the room/area
 - Capital equipment costs are substantial
 - Does not remove dust and stains which are important to patient/visitors
 - Sensitive use parameters (e.g., UV dose delivered)

Novel Technologies for Infection Prevention

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Hydrogen Peroxide Vapor

- "Microcondensation"-one system forms condensation (from a gas to a liquid phase) that is often invisible to the naked eye. Use 30-35% hydrogen peroxide to generate particles $<1 \mu$.
- "Dry mist"-system produces an aerosol composed of particles $<10 \mu$ containing 5% hydrogen peroxide, <50 ppm phosphoric acid (stabilizer) and <50 ppm silver cations.

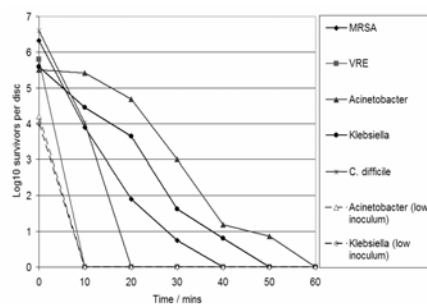
Vaporized Hydrogen Peroxide Decontamination

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- Barbut et al. ICHE 2009;30:517. *C. difficile*
- Bartels MD et al. J Hosp Infect 2008;70:35. MRSA
- Boyce JM et al. ICHE 2008;29:723. *C. difficile*
- Shapey S et al. J Hosp Infect 2008;70:136. *C. difficile*
- Hardy KJ et al. J Hosp Infect 2007;66:360. MRSA
- Hall L et al. J Clin Microbiol 2007;45: 810. *M. tuberculosis*

Vaporized Hydrogen Peroxide Decontamination

- Bates CJ, Pearse R. J Hosp Infect 2005;61:364. *S. marcescens*
- Johnston MD et al. J Microbiol Methods 2005;60:403. *C. botulinum*
- French GL et al. J Hosp Infect 2004;57:31. MRSA
- Heckert RA et al. Appl Environ Microbiol 1997;63:3916. Viruses
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HPV *in vitro* Efficacy



Otter and French. J Clin Microbiol 2009;47:205-207.

Decontamination by Hydrogen Peroxide Vapor

French GL et al. J Hosp Infect 2004;57:31

- 74% of swabs taken before cleaning yielded MRSA
- After detergent cleaning 66% yielded MRSA
- After HPV, only 1.2% (1/85) yielded MRSA
- Conclusion: HPV is a highly effective method of eradicating MRSA from rooms, furniture and equipment

Decontamination with Hydrogen Peroxide Vapor

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

- MRSA was isolated from 11.2% of environmental sites in ICU
- MRSA from environment similar to those colonizing patients
- After terminal cleaning, MRSA was isolated from 5 sites (17.2%)
- After HPV decontamination, MRSA was not isolated from the environment
- 24 hours after readmitting patients (including MRSA patients), MRSA was isolated from 5 sites
- In 8 weeks after VHP, the environment was sampled and MRSA isolated from 16.3%
- Conclusion: VHP is effective in eliminating bacteria, but rapid rate of recontamination suggest it is not a effective means of maintaining low levels of environmental contamination

Decontamination with Hydrogen Peroxide Vapor

Bates, Pearse. J Hosp Infect 2005;61:364

- Used HPV to eradicate *Serratia marcescens* from neonatal ICU during outbreak
- Although environmental contamination with *Serratia* was not extensive, concerned that even low numbers posed a risk of the outbreak recurring from an environmental reservoir
- After VHP treatment, no further babies were colonized with *S. marcescens*

Decontamination with Hydrogen Peroxide Vapor

Boyce et al: ICHE 2008;29:723

- 5 wards with a high incidence of *C. difficile*
- HPV was injected into sealed wards and individual patient rooms using generators until approx 1 micron film of HP was achieved on the surface
- 11/43 (25.6%) surface samples yielded *C. difficile* compared to 0/27 (0%) after HPV decontamination
- The incidence of nosocomial CDI was significantly lower during the intervention period (2.28 to 1.28/1000 patient days)
- Conclusion: HPV was efficacious in eradicating *C. difficile* from contaminated surfaces

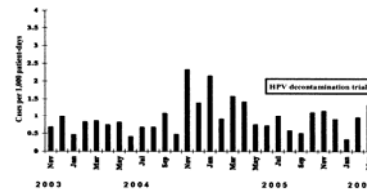


FIGURE 1. Hospital-wide incidence of nosocomial *Clostridium difficile*-associated disease, November 2003 through March 2006. HPV, hydrogen peroxide vapor.

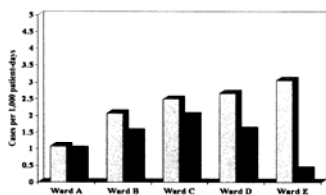


FIGURE 2. Incidence of nosocomial *Clostridium difficile*-associated disease on 5 wards (A-E) that underwent intensive hydrogen peroxide vapor decontamination, during the preintervention period (gray bars; June 2004 through March 2005) and the intervention period (black bars; June 2005 through March 2006).

Feasibility of Routinely Using HPV

Otter et al: ICHE 2009;30:574

- Used HPV to decontaminate selected rooms (e.g., MRSA, VRE, *C. difficile* [70% of rooms], norovirus, *Acinetobacter*, other MDROs)
- HPV requires room be vacated, cleaned of dirt (effectiveness reduced by dirt), and sealed
- 1656 rooms decontaminated with HPV over 22 month; 1194 "missed rooms" (58% staff not in hospital; 21% lack of notification)
- Total time from room vacated until ready for the next patient was 270 min (cycle 140 min) for HPV and 67 min for bleach cleaning
- Despite the greater time for decontamination, HPV decontamination is feasible in a busy hospital

Summary

- HPV systems significantly reduced the contamination with *C. difficile* and other pathogens
- Studies done with concentration of pathogens (6-7 log₁₀ CFU) considerably higher than encountered in the hospital environment
- Equipment or surfaces difficult to disinfect or escapes disinfection can be effectively decontaminated
- Studies shown benefits in controlling outbreaks and reducing infections
- HPV provides an alternative to traditional decontamination methods such as surface disinfection

Decontamination with Hydrogen Peroxide Vapor

- Advantages
 - Efficacious (reliable biocidal activity) against wide range of pathogens (6 log₁₀ reduction of spores)
 - Surfaces and equipment decontaminated
 - Decrease incidence of disease (*C. difficile*).
 - Residue free and does not give rise to health and safety concerns (aeration units convert HPV into oxygen and water)
 - Uniform distribution via an automated dispersal system
 - Useful for disinfecting complex equipment and furniture
 - Materials compatible and less toxic to human beings and environment

Decontamination with Hydrogen Peroxide Vapor

- Disadvantages
 - Only done at terminal disinfection (not daily cleaning)
 - Rapid recontamination of the environment
 - All patients must be removed from the area
 - Decontamination takes approx 3-5 hours (bed turnover time-72m)
 - HVAC disabled to prevent unwanted dilution of HPV during the exposure; room sealed with tape
 - Cost
 - Does not remove dust and stains which are important to patients/visitors
 - Sensitive parameters-for example, gas 280ppm, temp 26-28C, RH 48-57%
 - Long-term use exposure damage from microcondensation (sensitive electronics)?

Novel Technologies for Infection Prevention

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Copper

- Copper is recognized as having antimicrobial activity (copper sheathing of boat hulls in 1750s)
- Limited published data on antimicrobial activity of copper-containing disinfectants
- Antimicrobial activity property of copper recently applied in a clinical setting

Role of Copper in Reducing Hospital Environmental Contamination

Casey et al. 2010: 74:72-77



Role of Copper in Reducing Environmental Contamination

- Toilet seat (~70% Cu), brass tap handles (60% Cu) and brass door push (70% Cu) each containing copper were sampled for microorganisms and compared to equivalent standard, non-copper-containing items
- Sampled once weekly for 10 weeks (at 5 weeks interchanged)

Role of Copper in Reducing Environmental Contamination

- Median numbers of microorganisms harbored by copper-containing items were 90 to 100% lower than controls
 - Toilet seat: 87 v 2/cm²
 - Push plate 2 v 0/cm²
 - Hot water tap handle 7.5 v 0/cm²
- Copper has the potential to reduce microorganisms in the hospital environment (MRSA, VRE, *C. difficile*) but not likely to reduce HAIs as copper items not high-touch items and too many other sources of pathogens (contaminated items)

Copper Ions and Inorganic Copper-Based Biocide

- Copper-silver ionization used successfully in hospitals for controlling *Legionella* and other waterborne pathogens (such as *P. aeruginosa*, *S. maltophilia*, and *A. baumannii*)
- One copper compound, CuWB50, which is a water-based formulation of copper sulfate, ammonium chloride and hydrochloric acid is compatible with fabrics (100ppm) and has antimicrobial activity in 30m-1 hour (slow); but efficacy compromised by hard water

Inorganic Copper

- In preliminary studies, copper paints (range of cuprous oxide contents both exterior and interior latex) also shown capable of reducing some organism counts to negligible levels but similar noncopper paints (with fungicide).

Silver-Containing Disinfectants



Silver-Containing Disinfectants

- Silver used for prophylactic treatment of burns and water disinfection
- Biomaterials coated or impregnated with silver or silver nanoparticles will not be discussed
- Limited published data on antimicrobial activity of silver-containing disinfectants
- A silver-containing disinfectant has demonstrated antimicrobial activity (e.g., silver dihydrogen citrate)

Silver Dihydrogen Citrate (SDC)

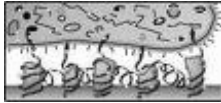
- SDC is a stabilized silver ion with a shelf life of several years
- SDC is non-toxic (EPA Category IV, lowest toxicity), non-caustic, colorless, tasteless, and does not produce toxic fumes
- SDC is effective against a broad spectrum of microbes

Silver Dihydrogen Citrate v Other Disinfectants (log₁₀ reductions in 1 minute); Rutala et al, unpublished 2010

Organism	Quat	Phenolic	Bleach 1:10	SDC
<i>A. baumannii</i>	>5	>5	>5	>5
ESBL <i>Kp</i>	>5	>5	>5	-4
MRSA	>5	>5	>5	-2
<i>P. aeruginosa</i>	>5	>5	>5	>5
<i>S. maltophilia</i>	>5	>5	>5	>5

Silver Iodide (SI)

- Silver iodide incorporated into surface-immobilized coating (PHMB) that reacts with bacterial membrane
- The intimate microbial contact with the surface results in transfer of the silver
- Bacteria accumulate silver until the toxicity threshold is exceeded



Effect on VRE Survival of Wiping Silver Iodide on a Treated Surface Over an Extended Time

Rutala, Weber, Emerg Infect Dis 2001; 7:349

Surface	Intervention	Day 1	Day 6	Day 13
Formica	Control	50	95	120
	Treated	0 (100%)	0 (100%)	0 (100%)
	Treated & Wiped	0 (100%)	0 (100%)	0 (100%)

Silver Iodide (SI)

- Preliminary results show that the treated surfaces result in excellent elimination of VRE inoculated directly on various surfaces at challenge levels of 100 CFU/sq inch for at least 13 days
- Antimicrobial activity is retained when the surface is subjected to repeated dry wiping or wiping with the QUAT
- The coating can be applied to surfaces by dipping, brushing, or spraying without prior surface treatment

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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.

Steris System 1

Has been used as a chemical sterilization process



Steris System 1 (SS1)

- May 2008, based on significant changes from 1988 to 2002, FDA notified Steris that SS1 "adulterated and misbranded" and FDA has not determined it is safe and effective for label claims.
- January 2009, Steris advised customers about steps it was taking in response to FDA concerns (stopped selling SS1 in the US but support it for 2 years)
- December 2009, FDA not satisfied with transition of Steris customers to replacements for SS1 issued a notice to healthcare organizations recommending they transition to legally marketed processes within 3-6 months (later extended to 18 months)

Steris System 1

- February 2010, FDA tells manufacturers (e.g., endoscope) that they must change labeling that their devices can be processed by SS1. Revise labeling to identify legally-marketed devices.
- "Hospitals using SS1 should be figuring out what their next sterilizer will be and how quickly they can switch over" Steven Silverman, Office of Compliance, FDA
- Steris submitted to FDA an updated SS1 in January 2009 but not FDA-cleared

Steris System 1E

FDA cleared 6 April 2010
(available 2nd Qtr FY2011)

Steris System 1E (SS1E)

- SS1E is a liquid chemical sterilant processing system which can be used to reprocess heat-sensitive reusable critical and semicritical medical devices. FDA, April 2010
- Since the rinse water is tap water that has been filtered and exposed to UV, it is not sterile. Therefore, the final processed devices are not considered sterile (or cannot be assured to be sterile). FDA, April 2010
- Since the CDC guidelines (and other guidelines) require critical items to be sterile, the SS1E should not be used on critical devices since, by definition, they need to be sterile.

Steris System 1E (SS1E)

- Thus, heat-sensitive critical devices should be sterilized by other validated, FDA-cleared, sterilization processes (i.e., ETO, HP gas plasma, VHP, ozone)
- If the heat-sensitive critical device truly cannot be reprocessed by any other modality than SS1E, the user is left with the decision between not using the device at all or reprocessing it in a SS1E liquid chemical sterilant processing system

UNC Health Care Policy-SS1E

- UNC Health Care will eliminate the use of SS1 over the next several months
- We will use the replacement reprocessor, SS1E, for reprocessing semicritical items that require high-level disinfection
- As a general rule, the Steris System 1E will not be used to reprocess critical items as critical items should be sterile and with SS1E the final processed device is not considered sterile

UNC Health Care Policy-SS1E

- Thus, heat-sensitive critical devices will be sterilized by other validated, FDA-cleared, sterilization processes such as HP gas plasma, ETO, VHP and ozone
- If a heat-sensitive critical device truly cannot be processed by any other modality than SS1E, then we are left with the decision between not using the device at all or reprocessing it in a SS1E.

UNC Health Care Policy-SS1E

- The decision to use SS1E for a heat-sensitive critical item that cannot be processed by an alternative sterilization process will be made on a case-by-case basis in collaboration with Hospital Epidemiology and Risk Management

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Novel Technologies for Infection Prevention Summary

- UV and HPV are effective and significantly reduced the contamination with *C. difficile*, MRSA, VRE, MDROs and other pathogens
- UV and HPV offer an option for room decontamination at patient discharge (daily cleaning still a problem)
- HPV studies have shown benefits in controlling outbreaks and reducing infections

Novel Technologies for Infection Prevention Summary

- Since contamination of surfaces is common, even after surface disinfection, UV and HPV technology should be considered in selected patient rooms and care areas when the environmental mode of transmission is significant.
- Copper and silver have antimicrobial activity but currently, clinical applications and benefits are limited

Novel Technologies for Infection Prevention Summary

- The Steris System 1E should not be used on critical devices since, by definition, they need to be sterile and with SS1E the final processed devices are not considered sterile.

Thank you

disinfectionandsterilization.org

Questions?

References

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