

## DISCLOSURES

- Advanced Sterilization Products-consultant; honoraria
- CareFusion-honoraria
- Clorox-consultant

## Novel Methods of Room Disinfection

William A. Rutala, Ph.D., M.P.H.  
University of North Carolina (UNC) Health  
Care System and UNC at Chapel Hill, NC

## Novel Methods of Room Disinfection

- Critique and review novel methods of providing room disinfection that do not rely on surface disinfection (no-touch)
  - UV light
  - Vaporized hydrogen peroxide
  - Others
    - ◆ Low-level hydrogen peroxide gas
    - ◆ Ozone
    - ◆ Formaldehyde
    - ◆ Chlorine dioxide

## What's the Problem?

## New Approaches to Room Decontamination

- Contaminated environmental surfaces can contribute to transmission of pathogens
- About 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

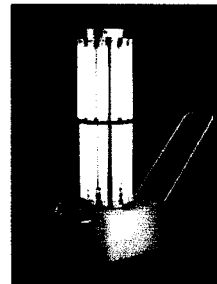
## Risk of Acquiring MRSA, VRE, and *C. difficile* from Prior Room Occupants

- 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). Huang et al. 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. Drees et al. Clin Infect Dis 2008;46:878.
- Prior room occupant with CDAD is a significant risk for CDAD acquisition. ICACC (K-4194) 2008. Shaughnessy et al.

## New Approaches to Room Decontamination after Patient Discharge

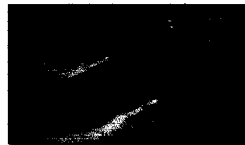
### Novel Methods of Room Disinfection

- Critique and review novel methods of providing room disinfection that do not rely on surface disinfection
  - UV light
  - Hydrogen peroxide (vapor and dry mist)
  - Others
    - ◆ Low level hydrogen peroxide gas
    - ◆ Ozone
    - ◆ Formaldehyde
    - ◆ Chlorine dioxide



### 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



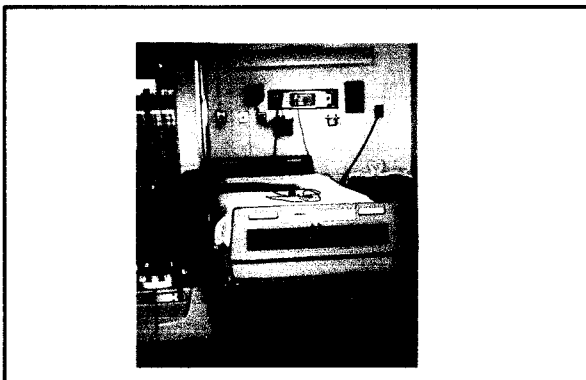
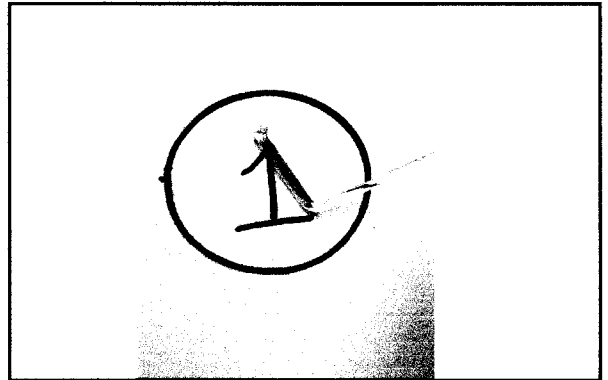
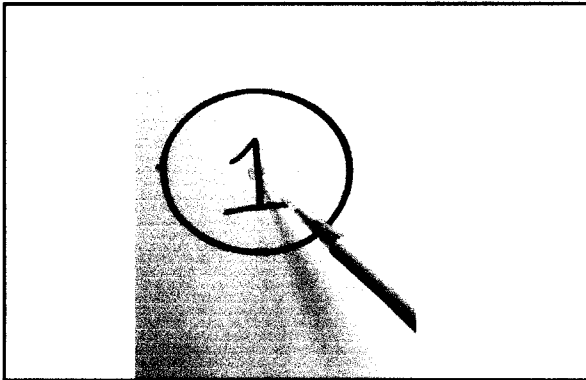
## UVC Room Decontamination

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 determine and targets highly-shadowed areas to deliver measured dose of UV energy
- After UV dose delivered (e.g., 36,000 $\mu$ W- $\text{e}/\text{cm}^2$  RD), will power-down and audibly notify the operator
- Reduces colony counts of pathogens by >99.9% within 15 minutes

## 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

## 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. 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.

## 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*	3.48 (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)

## 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 Rodac	384	19		
Pos Rodac/ Total Rodac			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  $\log_{10}$  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 Rodac (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 minutes) for vegetative bacteria
  - 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 capital 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 Methods of Room Disinfection

- Critique and review novel methods of providing room disinfection that do not rely on surface disinfection
  - UV light
  - Hydrogen peroxide vapor
  - Others
    - ◆ Low level hydrogen peroxide gas
    - ◆ Ozone
    - ◆ Formaldehyde
    - ◆ Chlorine dioxide

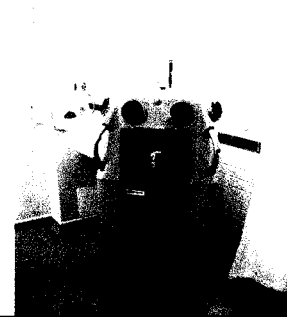
## Hydrogen Peroxide Vapor

- HPV is sporicidal, mycobactericidal, bactericidal
- Gaseous nature increases penetration to inaccessible areas
- Materials compatible and less toxic to human beings and environment
- Non-corrosive and biodegradable

HPV



HPV



HPV



## 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.

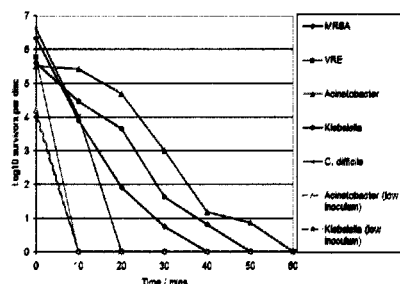
## Hydrogen Peroxide Vapor Decontamination

- Otter, French. J Clin Microbiol 2009;47:205. Spores/bacteria
- 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*

## Hydrogen Peroxide Vapor 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
- Klapes NA et al. Appl Environ Microbiol 1990;56:503. *Bacillus* spores/Prototype HPV generator

## 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 CDAD 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

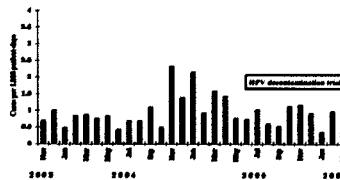


FIGURE 1. Hospital-wide incidence of nosocomial *Clostridium difficile*-associated disease, November 2003 through March 2006. HPV, hydrogen peroxide vapor.

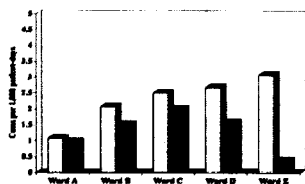


FIGURE 2. Incidence of nosocomial *Clostridium difficile*-associated disease on 5 wards (A-E) that underwent intensive hydrogen peroxide vapor decontamination, during the preintervention period (gray bars; June 2004 through March 2005) and the intervention period (black bars; June 2005 through March 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
- 1858 rooms decontaminated with HPV over 22 months; 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

## Comparison of HPV and Chlorine with *C. difficile*

(Barbut et al. Infect Control Hosp Epidemiol 2000;26:347)

Treatment	Before Treatment	After Treatment	% Reduction
Hydrogen peroxide mist	19% (34/180)	2% (2/180)	91% (p<.001)
Chlorine	24% (46/194)	12% (23/194)	50% (p<.002)

## Comparison of HPV and Chlorine with *C. difficile*

(Barbut et al. Infect Control Hosp Epidemiol 2000;26:347)

- This study showed HP dry-mist disinfection system was significantly more effective than 0.5% sodium hypochlorite solution at eradicating *C. difficile* spores
- The mean reduction was 4.32 log<sub>10</sub> CFU after 10 minutes for hypochlorite and 4.18 after 1 cycle of HP
- HPV method delivers the disinfectant vapor uniformly over exposed surfaces of the room. In contrast to cleaning which relies on the operator to wipe all surfaces (must be applied to work).

## Summary

- HPV systems significantly reduced the contamination with *C. difficile* and other pathogens
- Studies done with concentration of pathogens (6-7 log<sub>10</sub> 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
  - 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 3-6 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 200ppm, temp 26-28C, RH 48-57%
  - Long-term use exposure damage from microcondensation (sensitive electronics)?

## Novel Methods of Room Disinfection

- Critique and review novel methods of providing room disinfection that do not rely on surface disinfection
  - UV light
  - Vaporized hydrogen peroxide
  - Others
    - ◆ Low level hydrogen peroxide gas
    - ◆ Ozone
    - ◆ Paraformaldehyde
    - ◆ Chlorine dioxide

## Low Level HP Gas Generating Unit



## Hydrogen Peroxide Gas Technology

- Catalytically produces HP gas (non-vapor) from water and oxygen in the air
- Concentration 0.2ppm
- Potentially suitable for continuous use in occupied spaces to provide continuous antimicrobial activity in patient room
- Promising but effectiveness evaluations are incomplete





## Ozone

- Ozone is a powerful oxidizing agent; corrosive; cheap to generate
- Well-documented bactericidal properties
- Only few studies describe medical use; respiratory irritant (.1ppm)
- Although toxic, rapidly disassociates to oxygen
- One prototype ozone generator produced a bactericidal conc of ozone (25 ppm) with a short exposure (20 min). 3 log<sub>10</sub> reduction of test bacteria (AJIC 2008;38:559)
- Rooms sealed off during treatment; scrubber removes gas
- More research needed

## Chlorine Dioxide

- Sporicidal properties at concentrations as low as 10mg/L
- Used in the *B. anthracis* bioterrorism threat is 2001
- ClO<sub>2</sub> used to fumigate the Hart Senate Office Building, 750 ppm, 75% RH, 75°F for 12 hours
- Applications are limited because of deleterious effect on many materials

## Formaldehyde

- Formaldehyde gas is often used for space decontamination (e.g., BSCs); generated by heating para-formaldehyde; humidity must be controlled
- Highly effective on all surfaces
- Toxicity issues

## Novel Methods of Room Disinfection



## Novel Methods of Room Disinfection Summary

- UV and HPV are effective and significantly reduced the contamination with *C. difficile*, MRSA, VRE, MDROs and other pathogens
- 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
- Since contamination of surfaces is common, even after surface disinfection, this technology should be considered in selected patient rooms and care areas when the environmental mode of transmission is significant.
- Further investigations needed to evaluate new technologies, identify the role of these technologies in terminal (and daily) disinfection and whether they could be useful for reducing the incidence of other nosocomial pathogens.

## Novel Methods of Room Disinfection

- Critique and review novel methods of providing room disinfection that do not rely on surface disinfection
  - UV light
  - Vaporized hydrogen peroxide
  - Others
    - ◆ Low level hydrogen peroxide gas
    - ◆ Ozone
    - ◆ Formaldehyde
    - ◆ Chlorine dioxide

**disinfectionandsterilization.org**

**Thank you**