

Strategies for Improving Cleaning and Disinfection of Environmental Surfaces in Healthcare Facilities

John M. Boyce, MD
Infectious Diseases Section
Hospital of Saint Raphael
and
Clinical Professor of Medicine
Yale University School of Medicine
New Haven, CT

Disclosures: Consultant to Soap and Detergent Association, Clorox Corporation, 3M Corporation, Advanced Sterilization Products, BIOQUELL PLC; Research support from 3M Corporation; honoraria from Advanced Sterilization Products



Environmental Contamination

- Patients with pathogens such as MRSA, VRE, *C. difficile* and *Acinetobacter* frequently contaminate environmental surfaces in their immediate vicinity
- These organisms can remain viable in the environment for weeks or months



Cleaning Practices Are Often Suboptimal

- Daily cleaning of surfaces near patients is often performed poorly
- Terminal cleaning of rooms after patient discharge is often inadequate
 - Carling et al. found that only 47% of surfaces targeted for terminal cleaning had been cleaned



VRE on call button after cleaning

Carling PC et al. Clin Infect Dis 2006;42:385
Eckstein BC et al. BMC Infect Dis 2007;7:61



Contaminated Surfaces Can Contribute to Transmission

- Contaminated environmental surfaces can contribute to transmission of pathogens
 - By serving as a source from which healthcare workers contaminate their hands or gloves
- Contaminated medical equipment that comes into direct contact with the patient can serve as a source of transmission

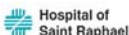
Boyce JM et al. Infect Control Hosp Epidemiol 1997;28:1142
Bhalla A et al. Infect Control Hosp Epidemiol 2004;25:164
Hayden MK et al. Infect Control Hosp Epidemiol 2008;29:149



Contaminated Surfaces Can Contribute to Transmission

- Patients admitted to a room formerly occupied by a patient with VRE or MRSA are at increased risk of acquiring the organism, suggesting that
 - terminal cleaning of rooms is inadequate
 - patients acquire the organism
 - directly from contaminated surfaces
 - from HCWs who contaminate their hands in the room

Martinez JA et al. Arch Intern Med 2003;163:1905
Huang SS et al. Arch Intern Med 2006;166:1945
Drees M et al. Clin Infect Dis 2008;46:678



Reducing Environmental Contamination Reduces VRE Transmission

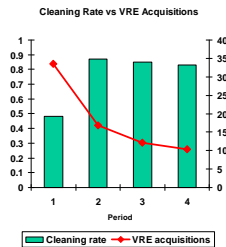
- Prospective, 9-month study in an MICU included
 - Admission and daily screening of patients
 - Environmental and HCW hand cultures twice weekly
- Study design included
 - Baseline period (1)
 - Education/monitoring/feedback for housekeepers (2)
 - Wash-out period with no specific intervention (3)
 - Multimodal hand hygiene intervention (4)

Hayden MK et al. Clin Infect Dis 2006;42:1552



Reducing Environmental Contamination Reduces VRE Transmission

- Environmental cleaning rate increased significantly
- VRE environmental contamination decreased significantly
- VRE acquisitions by patients decreased significantly
- Other factors analyzed could not explain decreased VRE acquisition rate



Hayden MK et al. Clin Infect Dis 2006;42:1552



Evidence That Environmental Disinfection Reduces Transmission of *C. difficile*

- CDAD transmission decreased significantly on a high incidence ward after changing from quaternary ammonium to 1:10 solution of sodium hypochlorite (bleach)
- Incidence rose to initial level after a switch back to quaternary ammonium
- 1:10 hypochlorite did not reduce CDAD incidence on low-incidence wards

Mayfield JL et al. Clin Infect Dis 2000;31:995



Evidence That Environmental Disinfection Reduces Transmission of *C. difficile*

- Hypochlorite disinfection was used in 2 ICUs with increased incidence of CDAD
 - Hypochlorite used in all patient rooms in one ICU
 - Hypochlorite was used in only rooms of patients with CDAD in the other ICU
- Incidence of CDAD decreased in both ICUs, and remained low for 1.5 years

McMullen KM et al. Infect Control Hosp Epidemiol 2007;28:205



Improving Cleaning/Disinfection Practices

- Based on increasing evidence,
 - CDC's Healthcare Infection Control Practices Advisory Committee (HICPAC)
 - SHEA/IDSA Healthcare-Associated Infections Task Force
- Have recommended that healthcare facilities pay greater attention to cleaning and disinfection of equipment and the environment

Siegel JD et al. Am J Infect Control 2007; 35(10 Suppl 2):S165
Yokoe DS et al. Infect Control Hosp Epidemiol 2008;29:S12



Improving Cleaning/Disinfection Practices

- Develop written protocols for daily and terminal cleaning and disinfection of patient rooms
- Routinely assess adherence to protocols and the adequacy of cleaning
- Pay close attention to cleaning and disinfection of "high-touch" surfaces in patient-care areas
- Provide appropriate training for personnel

Calfee DP et al. Infect Control Hosp Epidemiol 2008;29(Suppl 1):S62



Factors Contributing to Suboptimal Cleaning/Disinfection Practices

- Housekeepers and nursing staff often do not agree on who should clean what
- Housekeepers do not always understand
 - Which detergent/disinfectant to use
 - What concentration should be used
 - How often to change cleaning cloths/mop heads
- Other contributing factors
 - Demands for fast room "turnaround times"
 - Staff shortages and frequent turnover of personnel



TYPE OF CLEANING	RESPONSIBLE SERVICE	ITEMS TO BE CLEANED	PRODUCTS USED TO CLEAN	COMMENTS
ROUTINE DAILY CLEANING OF PATIENT ROOM	Environmental Services	1.dust window ledge 2.spot clean furniture (chairs) 3.wipe down over-bed table 4.wipe down side rails 5.wipe down TV control 6.wipe down bathroom fixtures (faucets, grab bar, shelf, etc.) 7.clean sink and toilet 8.wipe down door handles (room and bathroom) 9.sweep bathroom and patient floor 10.remove trash	1. - 9. EPA/ICC hosp quat* or 1. - 8. EPA/ICC hosp bleach wipe** for Contact CD and Enteric Precautions 9. EPA/ICC hosp quat*	8 Step daily cleaning process
TRANSFER/DISCHARGE CLEANING OF PATIENT ROOM AND ANY PATIENT ROOM AT NURSES' REQUEST (WHEN ROOM IS EMPTY)	Environmental Services	1.clean bed frame, side rails, mattress (after nursing has stripped bed of all linen) 2.clean bedside table, over bed table, phone, call bell, TV control 3.wipe down flow meters 4.wipe down regulators 5.dust/clean lighting fixtures 6.clean outside canister (clean) of suction container 7.clean and wipe down IV poles and pumps that need to remain on the unit, apply sani-strip** 8.wipe down furniture 9.dust all ledges 10.clean around sharps containers and glove boxes 11.wipe down step stools 12.wipe down walkers 13.wipe down cans 14.clean bedside commode, (once emptied by nursing) apply sani-strip** 15.clean bathroom fixtures, sink, shower, and toilet apply sani-strip** 16.sweep bathroom and patient floor 17.pull trash 18.change out privacy curtains if soiled or on request	1. - 16. EPA/ICC hosp quat* or 1-15. EPA/ICC hosp bleach wipe** for Contact CD and Enteric Precautions 16. EPA/ICC hosp quat* ** see cleaning instructions provided by Clinical Engineering, below *** apply sani-strip, see notes below	8 Step Discharge cleaning process

Monitoring Housekeeping Practices

- Were important surfaces wiped with appropriate disinfectant or detergent?
 - Checklist to be completed by housekeeper
 - Fluorescent dye marker placed by supervisor
- Is surface “clean”?
 - Visual assessment: does the surface look clean?
 - Aerobic colony counts
 - Time consuming; results available in 48 hrs
 - Adenosine triphosphate (ATP) bioluminescence assay
 - Results available immediately

Malik RE et al. Am J Infect Control 2003;31:181
 Sherlock O et al. J Hosp Infect 2009

High-Touch Surface Checklist For Daily Cleaning

Bedrails, bed frame	<input type="checkbox"/>
Overbed table	<input type="checkbox"/>
TV remote control	<input type="checkbox"/>
Nurse call button	<input type="checkbox"/>
Telephone	<input type="checkbox"/>
Bathroom: grab bars	<input type="checkbox"/>
toilet seat	<input type="checkbox"/>
faucet handles	<input type="checkbox"/>
Light switches	<input type="checkbox"/>
Door handles	<input type="checkbox"/>

Fluorescent Dye Marker System for Monitoring Cleaning Practices

- Prospective study conducted in 3 hospitals
- 12 high-touch objects in patient rooms were marked with invisible fluorescent solution after terminal cleaning
 - Marks moistened by disinfectant spray could be removed by wiping surface for 5 seconds with light pressure



Carling PC et al Clin Infect Dis 2006;42:385.

Monitoring Cleaning Practices

- After at least 2 patients had occupied the rooms and rooms had been terminally cleaned, target surfaces were evaluated using a portable UV light to see if the marker had been wiped off
- Education and feedback given to cleaning staff

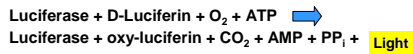
Monitoring Cleaning Practices

- 1404 objects were evaluated before the intervention
- 744 objects were evaluated after the intervention
- Proportion of objects cleaned
 - Before intervention: 47%
 - After interventions: 76 - 92%
- Technique improved in all hospitals ($p < 0.001$)
- Technique has been adopted in numerous hospitals

Carling PC et al. Clin Infect Dis 2006;42:385
 Carling PC et al. Infect Control Hosp Epidemiol 2008;29:1

Monitoring Cleaning Practices

- ATP bioluminescence methods have been used for years to monitor adequacy of cleaning procedures
 - in beverage and food processing industries
- Methods detect ATP from bacteria, human secretions, food



- Amount of light is proportional to concentration of ATP present

Griffith CL et al. J Hosp Infect 2000;45:19
Malik RE et al. Am J Infect Control 2003;31:181



3M BioTrace ATP Bioluminescence Method



- Step 1 Use special swab to sample surface
Step 2 Place swab in reaction tube
Step 3 Place tube in luminometer
Results: Relative Light Units

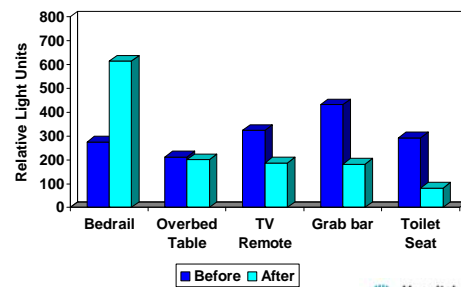


Trial of ATP Bioluminescence Assay System

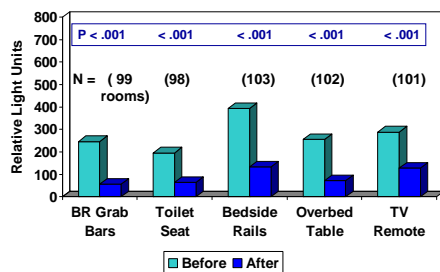
- Prospective trial in community-teaching hospital
- Phase I: ATP bioluminescence method was used to sample 5 high-touch surfaces before/after daily cleaning in 20 rooms
 - Housekeepers were unaware that cleaning was being monitored
- Phase II: ATP readings were obtained from same 5 high-touch surfaces before/after daily cleaning in 101 patient rooms on randomly selected nursing units hospital-wide
 - Goal was to determine the range of ATP readings that could be achieved with reasonably good cleaning technique
 - Housekeepers were told in advance that the room they were about to clean would be tested before and after daily cleaning



Median ATP Readings (RLUs) for 5 High-Touch Surfaces, Before and After Daily Cleaning in 20 Rooms



Median Relative Light Unit Readings, Before & After Daily Cleaning in Patient Rooms, Phase II



Boyce JM et al. Infect Control Hosp Epidemiol (in press) Hospital of Saint Raphael

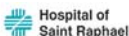
Common Cleaning/Disinfection Methods

- Liquid disinfectants, or detergents
 - Spray disinfectant on surface or cleaning cloth & wipe
 - Soak clean cloth in disinfectant and wipe surface
 - Use disinfectant-impregnated wipes
 - “Bucket method”; cloth is soaked in disinfectant, used to drench surfaces, which are kept wet x 10 min; surfaces are wiped dry with clean cloth



Liquid Disinfectants

- Traditional liquid disinfectants
 - Quaternary ammonium compounds (most commonly used)
 - Phenolics
 - Alcohols or alcohol-based mixtures
 - Chlorine-releasing products
- New or experimental liquid disinfectants
 - Accelerated hydrogen peroxide
 - Superoxidized water
 - Silver ion zeolite technology
 - Immobilized polymeric biocide + insoluble silver salt
 - Organosilane formulation
 - Cationic ingredient + chlorhexidine
 - Copper-based disinfectants

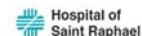


Disinfection Methods for *C.difficile* and Norovirus outbreaks

- In units with high rate of *C. difficile*-associated disease, use 1:10 dilution of household bleach for routine environmental disinfection
 - Currently, no products are EPA-registered specifically for inactivating *C. difficile* spores
 - EPA is evaluating a sodium hypochlorite product for use against *C. difficile* spores, and will likely approve
 - 4.5% accelerated hydrogen peroxide liquid has activity against *C. difficile* spores (DIN registered in Canada)

www.cdc.gov/ncidod/dhqp/pdf/guidelines/Disinfection_Nov_2008.pdf

- Common surfaces disinfectants have poor activity against Norovirus
 - Dilute household bleach solution is recommended



Accelerated hydrogen peroxide

- Accelerated hydrogen peroxide liquid formulation
- Bactericidal and virucidal in 1 min and mycobactericidal and fungicidal in 5 min
- More desirable side effects profile than quaternary ammonium-based disinfectants; is more expensive
- Gained popularity in Canada
 - Used by 24 % of hospitals in one small Canadian survey

Perez J et al. Am J Infect Control 2005;33:320
Omidbakhsh N et al. Am J Infect Control 2006;34:251
Gravel D et al. Am J Infect Control 2009;37:9



Vapor-Phase Disinfectants (Fumigants)

- Vapor-phase disinfectants
 - β -propiolactone
 - Ethylene oxide
 - Methyl bromide
 - Ozone
 - Formaldehyde gas *
 - Chlorine dioxide gas *
 - Hydrogen peroxide vapor *



* Used for remediation (decontamination) of equipment or buildings after 2001 anthrax attack

McAnoy AM: Vaporous Decontamination Methods
Australian Government DSTO 2006



Hydrogen Peroxide Vapor

- 2 main hydrogen peroxide vapor technologies are commercially available
 - Micro-condensation process (BIOQUELL)
 - "Dry gas" process (Steris)
- Despite differences in method of application, both technologies have been validated as effective
 - Most experience in healthcare settings is with the micro-condensation process

McAnoy AM: Vaporous Decontamination Methods,
Australian Government DSTO 2006
Fisher J et al. Pharmaceutical Technology 2004, pg. 68



Hydrogen Peroxide Vapor Micro-Condensation Process

- Hydrogen peroxide vapor micro-condensation process (Bioquell) has been used in hospitals with epidemic or endemic problems with MRSA, VRE, *C. difficile*, *Acinetobacter* or other multidrug-resistant Gram negative pathogens
- Effective against a broad range of healthcare-associated pathogens including *C. difficile* spores

French GL et al. J Hosp Infect 2004;57:31
Jeanes A et al. J Hosp Infect 2005;61:85
Passaretti C et al. 2008 IDSA/CAAC meeting, Abstr K-4124b
Dryden M et al. J Hosp Infect 2008;68:190
Otter JA et al. J Clin Microbiol 2009;47:205



Impact of Hydrogen Peroxide Vapor (HPV) Room Decontamination on Environmental Contamination and Nosocomial Transmission by *Clostridium difficile*

- A 10-month prospective trial at Hospital of Saint Raphael
- Collaborators: CDC and BIOQUELL PLC
- Pre- and post-intervention study design
- HPV was injected into sealed patient rooms using HPV generators until a c. 1micron film of HPV was applied
- HPV is then catalytically converted to oxygen and water vapor by an aeration unit
- Cycle time: 12 hrs for entire ward or 3 - 4 hrs for a patient room; current cycle times are 2.3 to 3 hrs

Boyce JM et al. *Infect Control Hosp Epidemiol* 2008;29:723



Microbiologic Efficacy of HPV Decontamination

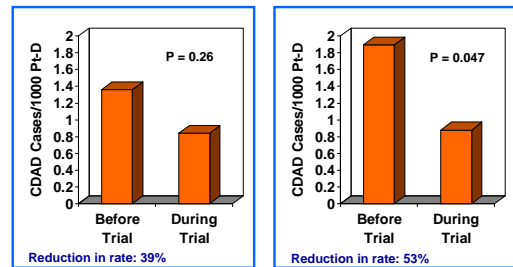
Before HPV				After HPV			
# of Swab Cultures	# Cultures (+) for Cdiff	# Cultures (+) for MRSA	# Cultures (+) for VRE	# of Cultures	# of Cultures (+) for Cdiff	# of Cultures (+) for MRSA	# of Cultures (+) for VRE
165	4 (2.4%)	9 (5%)	23 (14%)	155	0	0	0

# of Sponges Cultured	# of Sponges (+) for Cdiff	# of Sponges Cultured	# of Sponges (+) for Cdiff
43	11 (25.6%)	37	0

Conclusion: HPV is efficacious in eradicating Cdiff, MRSA and VRE from environmental surfaces



Impact of HPV Decontamination on Incidence of New Nosocomial CDAD Cases



Boyce JM et al. *Infect Control Hosp Epidemiol* 2008;29:723



Hydrogen Peroxide “Dry-Mist” System

- Hydrogen peroxide “dry mist” system (Sterinis) injects particles of 8 – 12 microns into room
- Disinfectant contains 5% H₂O₂ + silver ions + phosphoric acid
- Has shown reduction in bacterial contamination in experimental and actual hospital rooms
- Appears to be less efficacious against *C. difficile* spores than hydrogen peroxide vapor

Andersen BM et al. *J Hosp Infect* 2006;62:149
 Bartels MD et al. *J Hosp Infect* 2008;70:35
 Shapey S et al. *J Hosp Infect* 2008;70:136



Alcohol/Quaternary Ammonium Mist System

- Disinfectant is sprayed onto surfaces; evaporates quickly so no wiping of surfaces is required
- Disinfectant contains 58.6% alcohol + 4-chain quaternary ammonium suspended in carbon dioxide carrier (Biomist); non-flammable
- Significantly reduced VRE and MRSA on hospital surfaces
 - No data on *C. difficile* spores
- Not as consistently effective as 1:10 solution of bleach



Jury LA et al. 2009 SHEA meeting, abstr 278



Other Area Decontamination Strategies

- Ultraviolet Light Surface Decontamination (Lumalier Tru-D)
- Gaseous ozone
 - Berrington AW J Hosp Infect 1998
 - Sharma M et al. AJIC 2008;36:559
- Super-oxidized water fogging
 - Clark J et al. J Hosp Infect 2006;64:386
- Quaternary ammonium "dry mist" system (Zimex)
 - No published studies or data on *C. difficile* spores



Summary

- Improving cleaning/disinfection practices in hospitals requires
 - Developing detailed protocols, educating housekeepers
 - Monitoring cleaning, providing feedback to housekeepers
- Methods of monitoring the adequacy of cleaning
 - Checklists
 - Using fluorescent markers
 - ATP bioluminescence methods
 - Surface cultures (colony counts)
- New liquid disinfectants, some with persistent activity, are becoming available and warrant further evaluation
- Hydrogen peroxide vapor, mobile UV light systems, and other new area decontamination systems warrant further evaluation to determine their effectiveness and impact on transmission of healthcare-associated pathogens

Summary

- Issues to consider when evaluating liquid disinfectants or area decontamination systems
 - Effectiveness against
 - bacteria, including *C. difficile* spores
 - viruses, including non-enveloped viruses like Norovirus
 - Ease of application
 - Speed of action or room turn-around time
 - Materials compatibility
 - Adverse effects on housekeepers, patients, environment
 - Impact on pathogen transmission
 - Cost

Selected Guidelines

- HICPAC Environmental guideline
www.cdc.gov/ncidod/dhqp/pdf/guidelines/Enviro_guide_03.pdf
- HICPAC MDRO guideline
www.cdc.gov/ncidod/dhqp/pdf/ar/MDROGuideline2006.pdf
- HICPAC Disinfection and Sterilization guideline
www.cdc.gov/ncidod/dhqp/pdf/guidelines/Disinfection_Nov_2008.pdf
- Canadian Hand Hygiene, Disinfection & Sterilization guideline
www.phac-aspc.gc.ca/publicat/ccdr-rmtc/98/pdf/cdr24s8e.pdf