What's New:
Strategies in Healthcare Environmental Infection Prevention

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DISCLOSURES

- Consultation (2017)
  - PDI
  - ASP
- Honoraria (2017)
  - PDI
- Grants to UNC or UNC Hospitals (2017)
  - CDC, CMS

What's New: Strategies in Healthcare Environmental Infection Prevention

- Role of environment in disease transmission
- Products and practices for surface disinfection
  - New issues
    - Inactivation of emerging pathogens (e.g., CRE, *C. auris*)
- Technologies for terminal room decontamination (not including technologies with limited data)
  - Ultraviolet light
  - Vaporized hydrogen peroxide
- Continuous room decontamination technologies
  - Light disinfection
  - Low-concentration hydrogen peroxide
  - Self-disinfecting surfaces
  - Other
- Other Healthcare Environment Issues
  - Water-Heater-cooler units

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Challenge

Prevent All Infectious Disease Transmission Associated with Surface Environment in 5 years (2021)

ENVIRONMENTAL CONTAMINATION LEADS TO HAIs

- There is increasing evidence to support the contribution of the environment to disease transmission
- This supports comprehensive disinfecting regimens (goal is not sterilization) to reduce the risk of acquiring a pathogen from the healthcare environment/equipment

KEY PATHOGENS WHERE ENVIRONMENTIAL SURFACES PLAY A ROLE IN TRANSMISSION

Weber, Rutala, Miller et al. AJIC 2010;38:S25

- MRSA
- VRE
- *Acinetobacter* spp.
- *Clostridium difficile*
- Norovirus
- Rotavirus
- SARS

Environmental Contamination Leads to HAIs

Weber, Kanamori, Rutala. Curr Op Infect Dis .2016.

- Evidence environment contributes
- Role-MRSA, VRE, *C. difficile*
- Surfaces are contaminated-~25%
- EIP survive days, weeks, months
- Contact with surfaces results in hand contamination; contaminated hands transmit EIP to patients
- Disinfection reduces contamination
- Disinfection (daily) reduces HAIs
- Rooms not adequately cleaned

Admission to Room Previously Occupied by Patient C/I with Epidemiologically Important Pathogen

- Results in the newly admitted patient having an increased risk of acquiring that pathogen by 39-353%
- For example, increased risk for *C. difficile* is 235% (11.0% vs 4.6%)

EVALUATION OF HOSPITAL ROOM ASSIGNMENT AND ACQUISITION OF CDI

- Study design: Retrospective cohort analysis, 2005-2006
- Setting: Medical ICU at a tertiary care hospital
- Methods: All patients evaluated for diagnosis of CDI 48 hours after ICU admission and within 30 days after ICU discharge
- Results (acquisition of CDI)
  - Admission to room previously occupied by CDI = 11.0%
  - Admission to room not previously occupied by CDI = 4.6% (p=0.002)

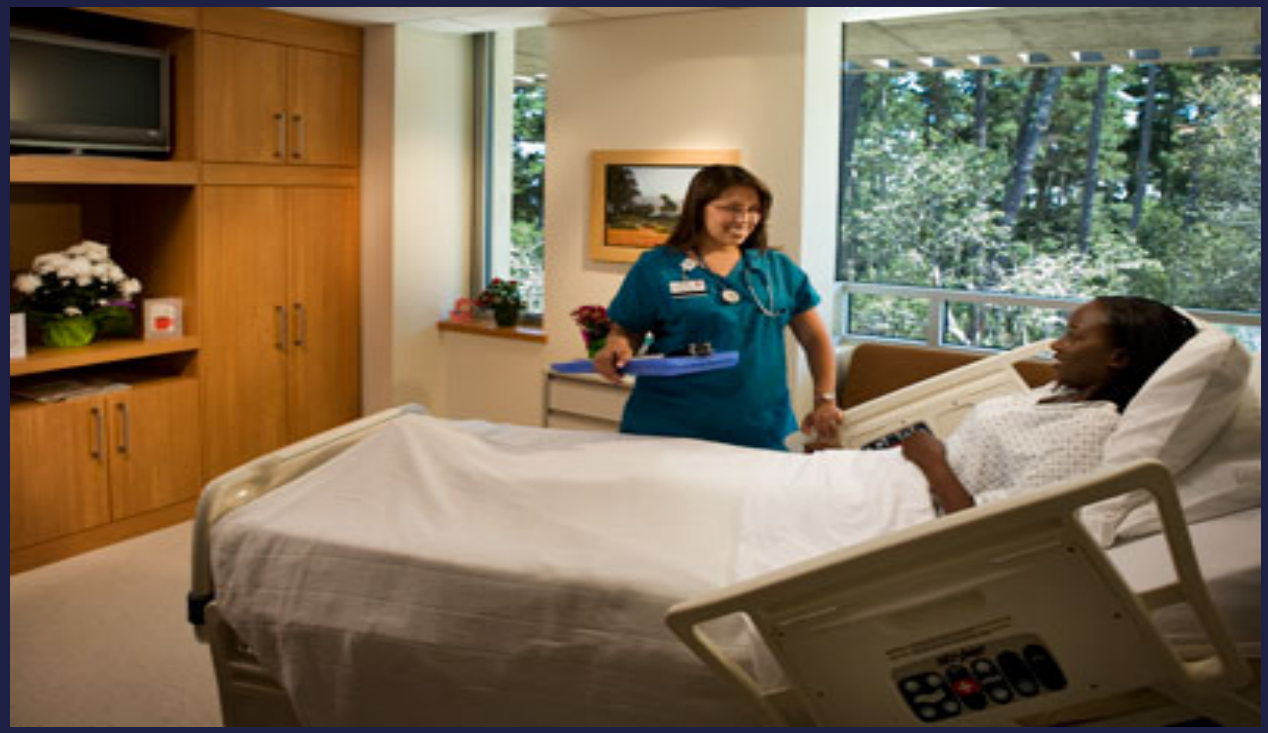
Shaughnessy MK, et al. ICHE 2011;32:201-206

TABLE 3. Multivariate Analysis of Risk Factors for Acquisition of *Clostridium difficile* Infection (CDI)

Risk factor	HR (95% CI)	*P*
Prior room occupant with CDI	2.35 (1.21–4.54)	.01
Greater age	1.00 (0.99–1.01)	.71
Higher APACHE III score	1.00 (1.00–1.01)	.06
Proton pump inhibitor use	1.11 (0.44–2.78)	.83
Antibiotic exposure		
Norfloxacin	0.38 (0.05–2.72)	.33
Levofloxacin	1.08 (0.67–1.73)	.75
Ciprofloxacin	0.49 (0.15–1.67)	.23
Fluoroquinolones	1.17 (0.72–1.91)	.53
Clindamycin	0.45 (0.14–1.42)	.17
Third- or fourth-generation cephalosporins	1.17 (0.76–1.79)	.48
Carbapenems	1.05 (0.63–1.75)	.84
Piperacillin-tazobactam	1.31 (0.82–2.10)	.27
Other penicillin	0.47 (0.23–0.98)	.04
Metronidazole	1.31 (0.83–2.07)	.24
Vancomycin		
Oral	1.38 (0.32–5.89)	.67
Intravenous	1.55 (0.88–2.73)	.13
Aminoglycosides	1.27 (0.78–2.06)	.35
Multiple (≥3 antibiotic classes)	1.28 (0.75–2.21)	.37

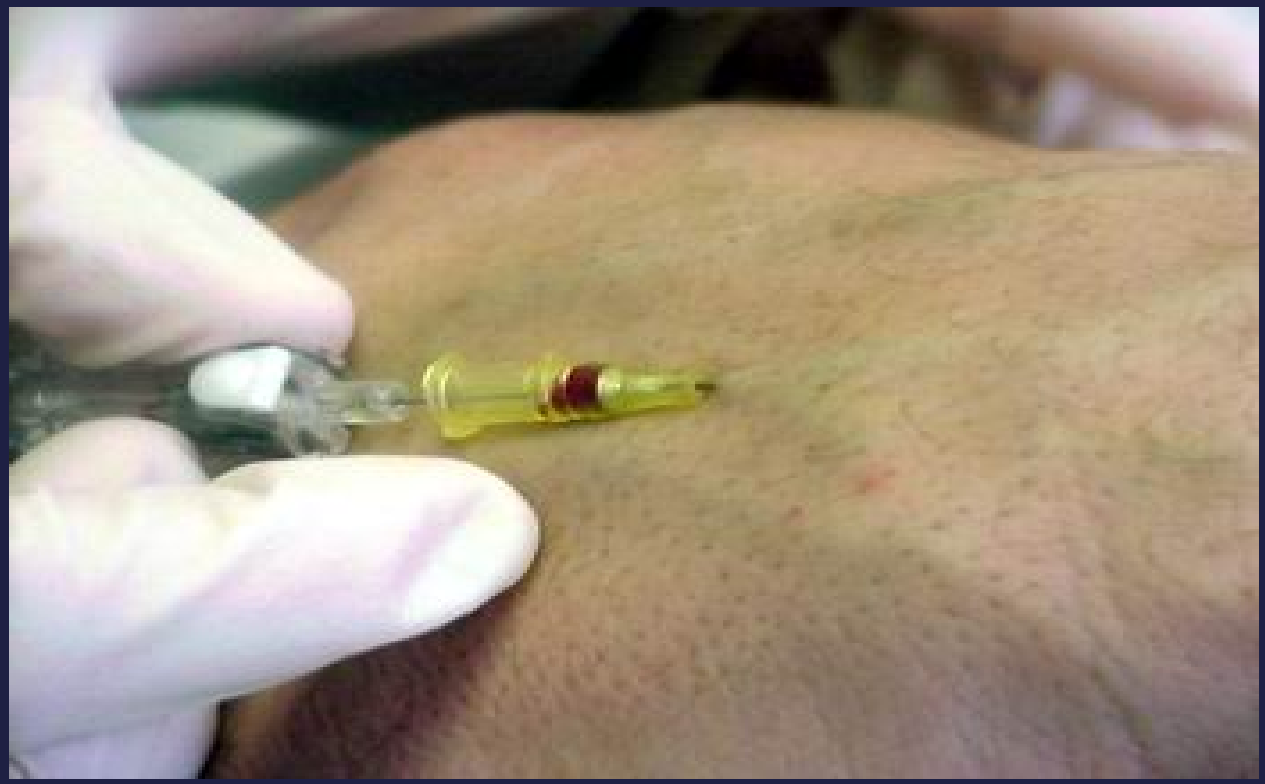
NOTE. APACHE, Acute Physiology and Chronic Health Evaluation; CI, confidence interval; HR, hazard ratio.

ACQUISITION OF MRSA ON HANDS AFTER CONTACT WITH ENVIRONMENTAL SITES



ACQUISITION OF MRSA ON HANDS/GLOVES AFTER CONTACT WITH CONTAMINATED EQUIPMENT

TRANSFER OF MRSA FROM PATIENT OR ENVIRONMENT TO IV DEVICE AND TRANSMISSON OF PATHOGEN



ACQUISITION OF *C. difficile* ON PATIENT HANDS AFTER CONTACT WITH ENVIRONMENTAL SITES AND THEN INOCULATION OF MOUTH

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LOW-LEVEL DISINFECTION FOR NONCRITICAL EQUIPMENT AND SURFACES

Exposure time ≥ 1 min

Germicide	Use Concentration
Ethyl or isopropyl alcohol	70-90%
Chlorine	100ppm (1:500 dilution)
Phenolic	UD
Iodophor	UD
Quaternary ammonium (QUAT)	UD
QUAT with alcohol	RTU
Improved hydrogen peroxide (HP)	0.5%, 1.4%
Peracetic acid with HP (*C. difficile*)	UD

UD=Manufacturer's recommended use dilution; others in development/testing-electrolyzed water; polymeric guanidine; cold-air atmospheric pressure plasma (Boyce Antimicrob Res IC 2016. 5:10)

Issues Related to Disinfection Protocols

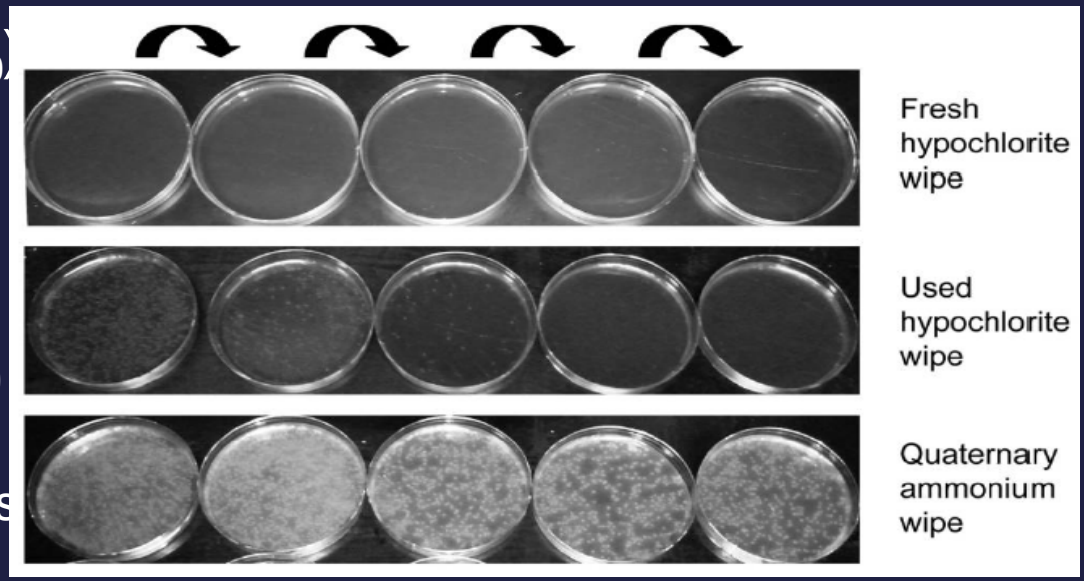
Boyce et al. ICHE 2016;37:340-342

- Inappropriate over-dilution of disinfectant solutions by housekeepers or by malfunctioning automated dilutions systems may result in applying disinfectants using inappropriate solutions
  - Audit of 33 automated dispensing stations that mix concentrated disinfectant with water to yield desired in-use QUAT conc of 800 ppm
  - QUAT solutions dispensed were tested with test strips, ~50% of stations delivered solutions with 200-400ppm
  - Several flaws in dispensing system

TRANSFER OF *C. DIFFICILE* SPORES BY NONSPORICIDAL WIPES AND IMPROPERLY USED HYPOCHLORITE WIPES

- Study design: *In vitro* study that assessed efficacy of different wipes in killing of *C. difficile* spores (5-$\log_{10}$)
  - Fresh hypochlorite wipes
  - Used hypochlorite wipes
  - Quaternary ammonium wipes
- Results (4th transfer)
  - Quat had no efficacy (3-$\log_{10}$ spores)
  - Fresh hypochlorite worked
  - Used hypochlorite transferred spores in lower concentration (0.4-$\log_{10}$ spores)

Practice + Product = Perfection



Cadnum JL, et al. ICHE 2013;34:441-2

PROPERTIES OF AN IDEAL SURFACE DISINFECTANT

Rutala WA, Weber DJ. Infect Control Hosp Epidemiol 2014;35:855-865

- Broad spectrum
- Fast acting
- Remains wet
- Not affected by environmental factors
- Nontoxic
- Surface compatibility
- Persistence
- Easy to use
- Acceptable odor
- Economical
- Solubility
- Stability
- Cleaner
- Nonflammable

Key Considerations for Selecting the Ideal Disinfectant for Your Facility

Rutala, Weber. Infect Control Hosp Epidemiol. 2014;35:855-865

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

Note: Consider the 5 components shown, give each product a score (1 is worst and 10 is best) in each of the 5 categories, and select the product with the highest score as the optimal choice (maximum score is 50).

Quaternary ammonium compounds

(e.g., didecyl dimethyl ammonium bromide, dioctyl dimethyl ammonium bromide)

Rutala, Weber. Am J Infect Control 2013;41:S36-S41

Advantages

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

Disadvantages

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

Alcohol

Rutala, Weber. Am J Infect Control 2013;41:S36-S41

Advantages

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

Disadvantages

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

Quat/Alcohol vs Quat

Rutala et al. Antimicrob Agents Chemother 2006. 50:1419-1424

- Adenovirus is a hardy virus that is relatively resistant to disinfectants
- Quat about <0.5 $\log_{10}$ reduction against adenovirus with 1m exposure time
- Accelerated hydrogen peroxide (0.5%) demonstrates ~0.7 $\log_{10}$ reduction against adenovirus with 1m exposure time
- Quat/Alcohol demonstrates a ~4 $\log_{10}$ reduction against adenovirus with 1m exposure time
- Chlorine (~5000ppm) demonstrates a ~5 $\log_{10}$ reduction against adenovirus with 1m exposure time
- Quat/Alcohol has improved virucidal activity compared to Quat and accelerated hydrogen peroxide

Improved Hydrogen Peroxide

Rutala, Weber. Am J Infect Control 2013;41:S36-S41

Advantages

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

Disadvantages

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

Sodium Hypochlorite

Rutala, Weber. Am J Infect Control 2013;41:S36-S41

Advantages

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

Disadvantages

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

Phenolics

Rutala, Weber. Am J Infect Control 2013;41:S36-S41

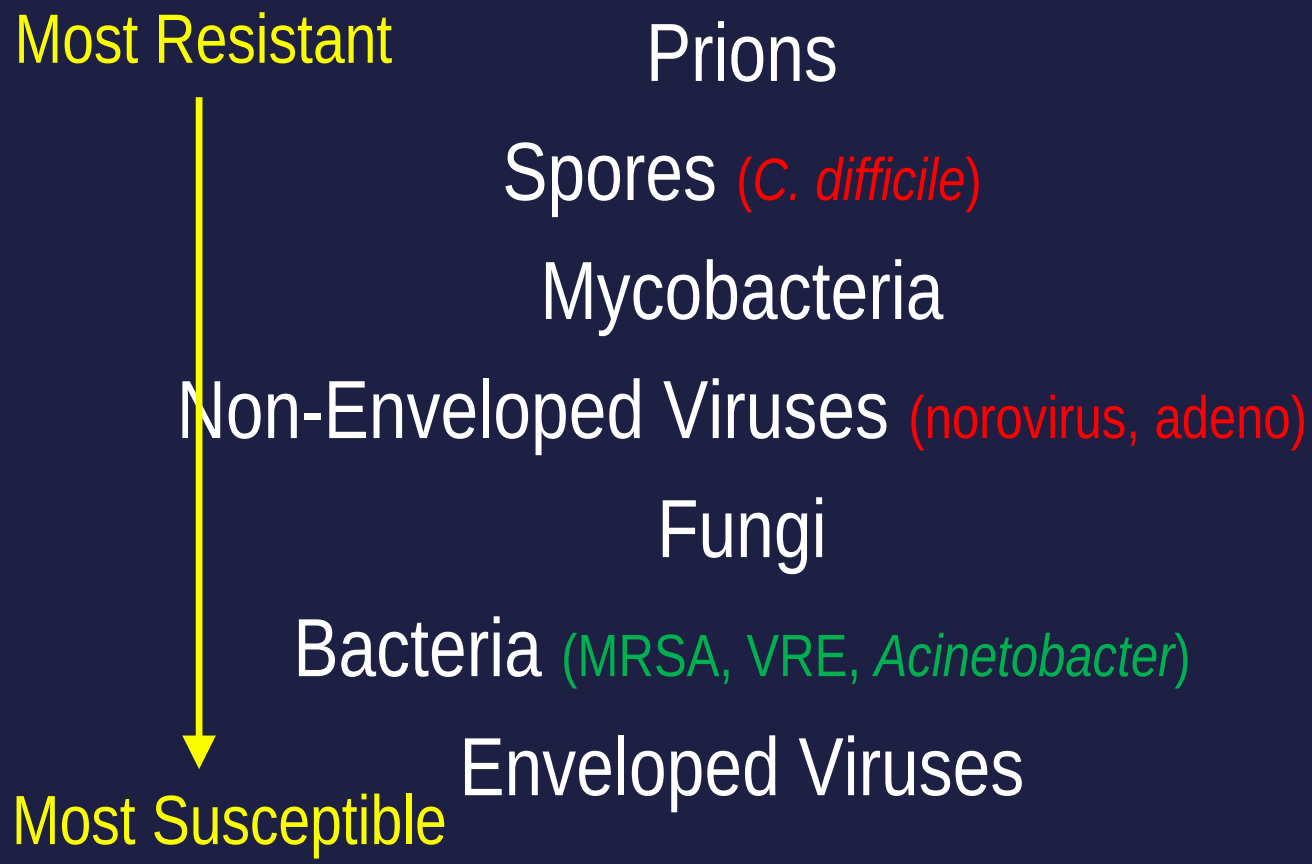
Advantages

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

Disadvantages

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

Decreasing Order of Resistance of Microorganisms to Disinfectants/Sterilants



Norovirus: Microbiology and Epidemiology

Weber, Rutala et al. AJIC 2010:38:S25-33

- Classified as a calicivirus: RNA virus, non-enveloped
- Prevalence
  - Causes an estimated 23 million infections per year in the US
  - Results in 50,000 hospitalizations per year (310 fatalities)
  - Accounts for >90% of nonbacterial and ~50% of all-cause epidemic gastroenteritis
- Infectious dose: 10-100 viruses (ID_{50} = 18 viruses)
- Fecal-oral transmission (shedding for up to 2-3 weeks)
  - Direct contact and via fomites/surfaces; food and water
- Droplet transmission? (via ingestion of airborne droplets of virus-containing particles)
- May cause chronic infection in transplant recipients

Why Chlorine for Norovirus?

- Chlorine is the most robust disinfectant against a wide range of pathogens including norovirus, rotavirus, adenovirus and *C. difficile*
- Types of isolation at UNC Hospitals: Contact Enteric and Contact. Contact we use Quat, Quat/Alc and Contact Enteric (*C. difficile*, norovirus) we use chlorine
- Use of two products simplifies training of healthcare providers regarding isolation signs and EVS training regarding the two disinfectants
- Additionally, when confronted with a norovirus outbreak (and possibly a closed unit), we recommend the most effective and proven control measures to terminate the outbreak
  - Hand hygiene with soap and water
  - Chlorine disinfection of surfaces

Accelerated Hydrogen Peroxide and QUAT Less Effective at 10m than Sodium Hypochlorite at 1m

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Major article

Efficacy of common disinfectant/cleaning agents in inactivating murine norovirus and feline calicivirus as surrogate viruses for human norovirus

Stephanie Chiu MSc [a,*], Brenton Skura PhD [a], Martin Petric PhD [b,c], Lorraine McIntyre MSc [d], Bruce Gamage ClC, BScN [e], Judith Isaac-Renton MD [b,c,d]

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Key Words:
Accelerated hydrogen peroxide
Contact time
Disinfectant
Norovirus
Quaternary ammonium compound
Sodium hypochlorite

Background: The efficacies of disinfection by sodium hypochlorite, accelerated hydrogen peroxide (AHP), and quaternary ammonium compound (QUAT) commonly used in health care facilities were determined using the surrogate viruses murine norovirus (MNV-1) and feline calicivirus (FCV).
Methods: A virus suspension of known concentration (with or without a soil load) was deposited onto stainless steel discs under wet or dry load conditions and exposed to defined concentrations of the disinfectant/cleaning agent for 1-, 5-, or 10-minute contact time using the quantitative carrier test (QCT-2) method. Virus inactivation was determined by plaque assay.
Results: At an exposure time of 1 minute, sodium hypochlorite at 2,700 ppm was able to inactivate MNV-1 and FCV with a >5 $\log_{10}$ reduction. After 10 minutes, MNV-1 was inactivated by AHP at 35,000 ppm, whereas FCV was inactivated at 3,500 ppm. MNV-1 was not inactivated by QUAT at 2,800 ppm. A QUAT-alcohol formulation containing 2,000 ppm QUAT and 70% ethanol was effective in inactivating MNV-1 after 5 minutes, but resulted in only a <3 $\log_{10}$ reduction of FCV after 10 minutes.
Conclusions: AHP and QUAT products were less effective than sodium hypochlorite for the inactivation of MNV-1 and FCV.

Accelerated Hydrogen Peroxide and QUAT Less Effective at 10m than Sodium Hypochlorite at 1m

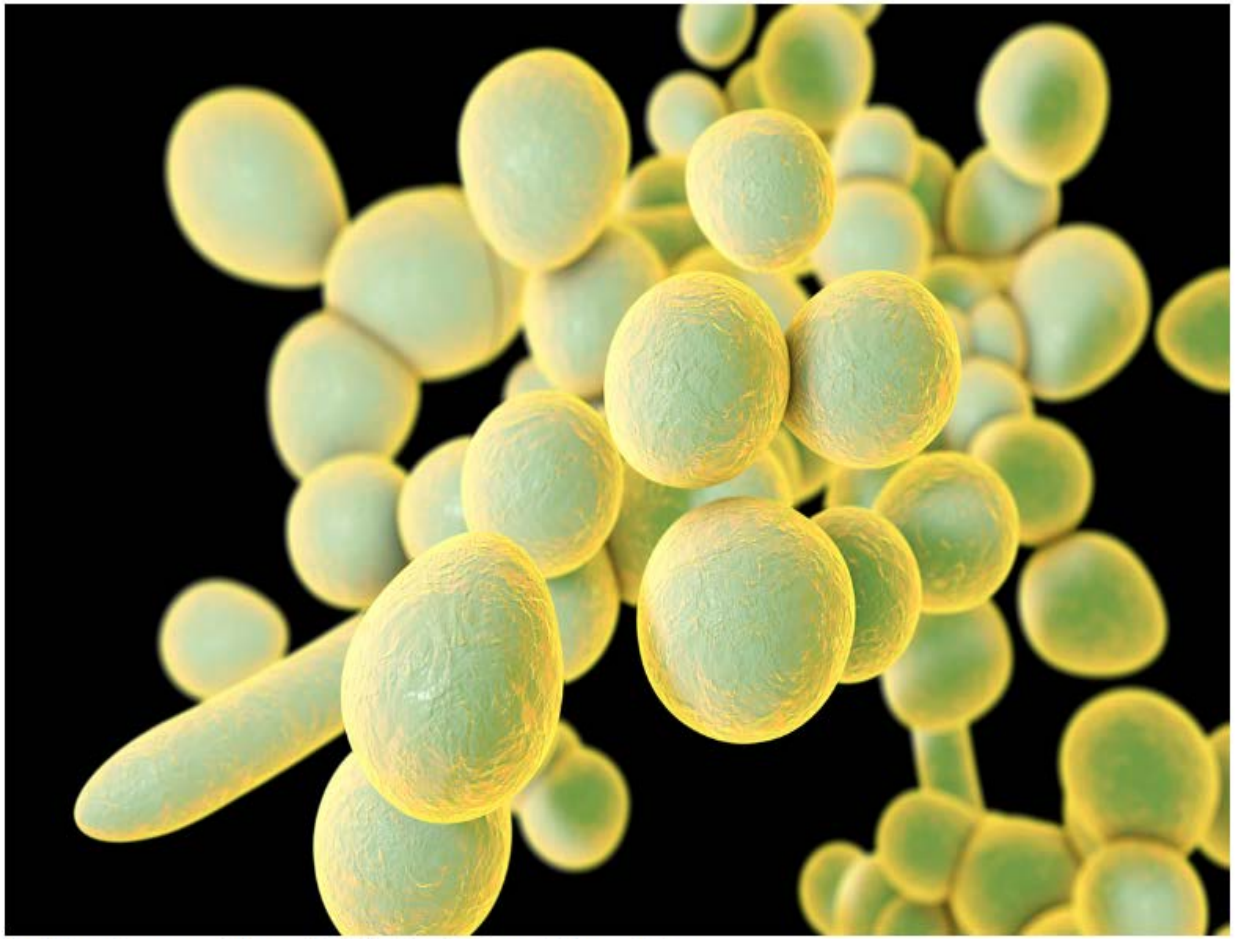
Table 1
Summary of the most effective concentrations and contact times of commonly used disinfectants against MNV-1 and FCV, with and without soil load

	MNV-1						FCV					
	Without soil load			With soil load			Without soil load			With soil load		
Disinfectant	Concentration (ppm)/contact time (min)	Wet and dry load mean* log_{10} reduction† Wet	Dry	Concentration (ppm)/contact time (min)	Wet and dry load mean* log_{10} reduction† Wet	Dry	Concentration (ppm)/contact time (min)	Wet and dry load mean* log_{10} reduction† Wet	Dry	Concentration (ppm)/contact time (min)	Wet and dry load mean* log_{10} reduction† Wet	Dry
Sodium hypochlorite	2700/1	**6.8**	**5.9**	5400/1	**6.4**	**6.7**	5400/1	**5.7**	**5.4**	2700/5	**5.3**	**4.8**
	1350/5	**6.0**	**5.5**	1350/5	**6.5**	**5.5**	1350/5	**4.6**	**4.9**	1350/10	**5.4**	**4.6**
	675/10	**6.4**	**5.6**				1350/10	**5.6**	**5.3**			
AHP	35,000/10	**6.5**	**5.6 (est)**	35,000/10	**6.3**	**5.6 (est)**	1750/5	**5.7**	**5.2**	7000/5	**5.1**	**4.8**
										3500/10	**5.1**	**4.8**
RTU AHP	5000/10	2.6	1.0	5000/10	0.8	0.9	5000/10	**6.0**	**5.5**	5000/10	**5.4**	**5.0**
QUAT	2800/10	2.0	3.2	NT		NT	2800/10	3.6	3.3	NT		NT
QUAT-alcohol (70% ethanol)	2000/5	**6.9**	**6.2 (est)**	NT		NT	2000/10	2.4	2.9	NT		NT

NT, not tested.
*Mean values from experimental trials performed in triplicate.
†Bold values indicate complete inactivation with no virus plaques observed.

A QUAT-alcohol containing 2000 ppm QUAT and 70% ethanol was effective in inactivating MNV after 5 minutes

Deadly, drug-resistant Candida yeast infection spreads in the US



Candida auris causes multidrug-resistant infections that can result in organ failure

Kateryna Kon/Science Photo Library

Efficacy of Disinfectants and Antiseptics against *Candida auris*

Rutala, Kanamori, Gergen, Sickbert-Bennett, Weber, 2017

- ≥3 $\log_{10}$ reduction (*C. auris*, 1m, 5% FCS, QCT)
  - 0.20% peracetic acid
  - 2.4% glutaraldehyde
  - 0.65% hydrogen peroxide, 0.14% peroxyacetic acid
  - 0.5% Quat, 55% isopropyl alcohol
  - Disinfecting spray (58% ethanol, 0.1% QUAT)
  - 28.7% isopropyl alcohol, 27.3% ethyl alcohol, 0.61% QAC
  - 0.07% o-phenylphenol, 0.06% p-tertiary amylphenol
  - 70% isopropyl alcohol
  - ~5,250 ppm chlorine
  - Ethanol hand rub (70% ethanol)
  - Accelerated hydrogen peroxide, 1.4%
  - Accelerated hydrogen peroxide, 2%

Efficacy of Disinfectants and Antiseptics against *Candida auris*

Rutala, Kanamori, Gergen, Sickbert-Bennett, Weber, 2017

- ≤3 $\log_{10}$ (most <2 $\log_{10}$) reduction (*C. auris*, 1m, 5% FCS, QCT)
  - 0.55% OPA
  - 3% hydrogen peroxide
  - Quat, (0.085% QACs)
  - 10% povidone-iodine
  - ~1,050 ppm chlorine
  - 2% Chlorhexidine gluconate-CHG
  - 4% CHG
  - 0.5% triclosan
  - 1% CHG, 61% ethyl alcohol
  - 1% chloroxylenol

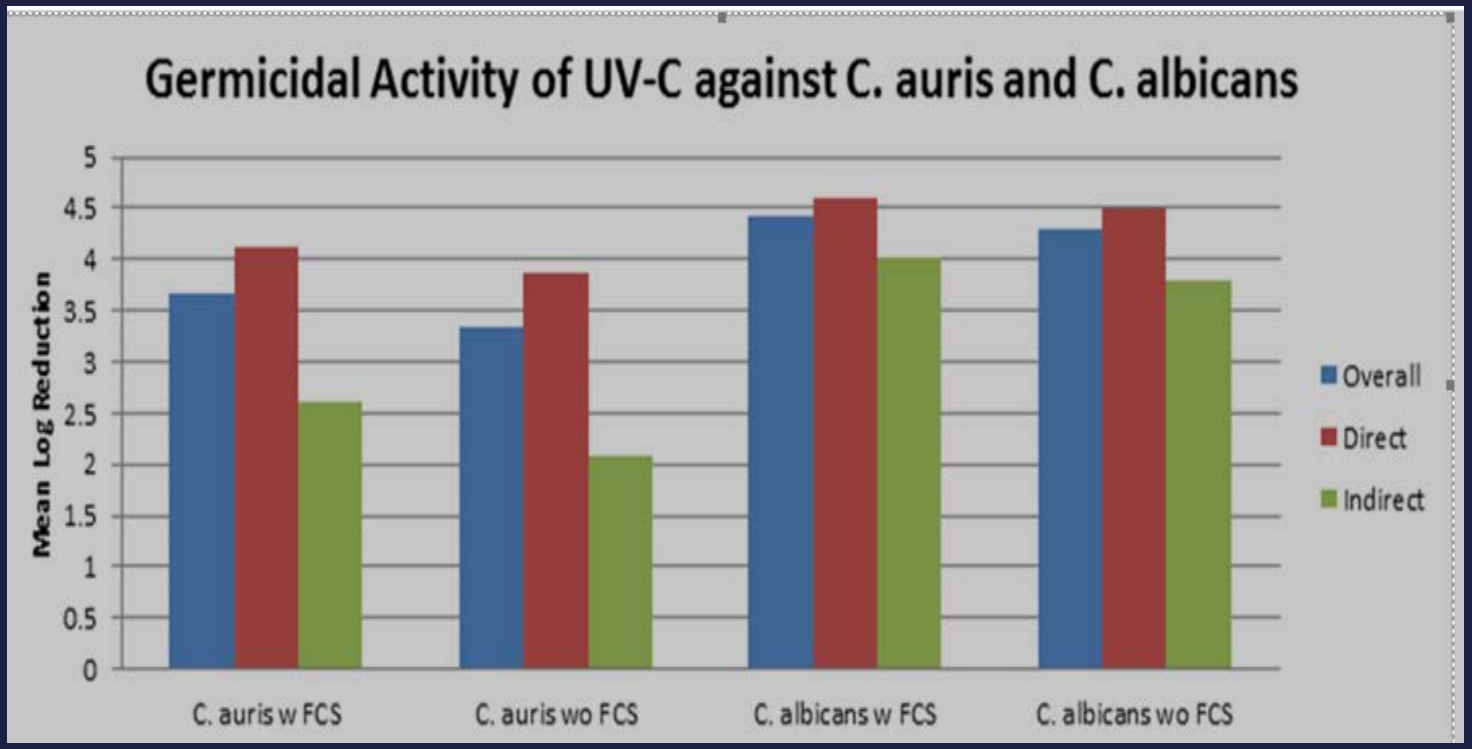
Efficacy of Disinfectants and Antiseptics against Carbapenem-Resistant *Enterobacteriacae*

Rutala, Kanamori, Gergen, Sickbert-Bennett, Weber, 2017

- ≥3 $\log_{10}$ reduction (CRE, 1m, 5% FCS, QCT)
  - 0.20% peracetic acid
  - 2.4% glutaraldehyde
  - 0.5% Quat, 55% isopropyl alcohol
  - 58% ethanol, 0.1% QUAT
  - 28.7% isopropyl alcohol, 27.3% ethyl alcohol, 0.61% QAC
  - 0.07% o-phenylphenol, 0.06% p-tertiary amylphenol
  - ~5,250 ppm chlorine
  - 70% isopropyl alcohol
  - Ethanol hand rub (70% ethanol)
  - 0.65% hydrogen peroxide, 0.15% peroxyacetic acid
  - Accelerated hydrogen peroxide, 1.4% and 2.0%
  - Quat, (0.085% QACs; not *K. pneumoniae*)

Germicidal Activity of UV-C Against *C. auris* and *C. albicans*

UNC Hospitals, 2017



Very good inactivation of *Candida auris* by UV. Used Tru-D bacteria cycle (17-19 minute cycle, 12,000µWs/cm^2).

ALL “TOUCHABLE” (HAND CONTACT) SURFACES SHOULD BE WIPED WITH DISINFECTANT

“High touch” objects only recently defined (no significant differences in microbial contamination of different surfaces) and “high risk” objects not epidemiologically defined. Cleaning and disinfecting is one-step with disinfectant-detergent. No pre-cleaning necessary unless spill or gross contamination.

CDC Guideline for Disinfection and Sterilization

Rutala, Weber, HICPAC. November 2008. www.cdc.gov

Guideline for Disinfection and Sterilization in Healthcare Facilities, 2008

William A. Rutala, Ph.D., M.P.H.[1,2], David J. Weber, M.D., M.P.H.[1,2], and the Healthcare Infection Control Practices Advisory Committee (HICPAC)[3]

It appears that not only is disinfectant use important but how often is important

Daily disinfection vs clean when soiled

Daily Disinfection of High-Touch Surfaces

Kundrapu et al. ICHE 2012;33:1039

Daily disinfection of high-touch surfaces (vs cleaned when soiled) with sporicidal disinfectant (PA) in rooms of patients with CDI and MRSA reduced acquisition of pathogens on hands after contact with surfaces and of hands caring for the patient

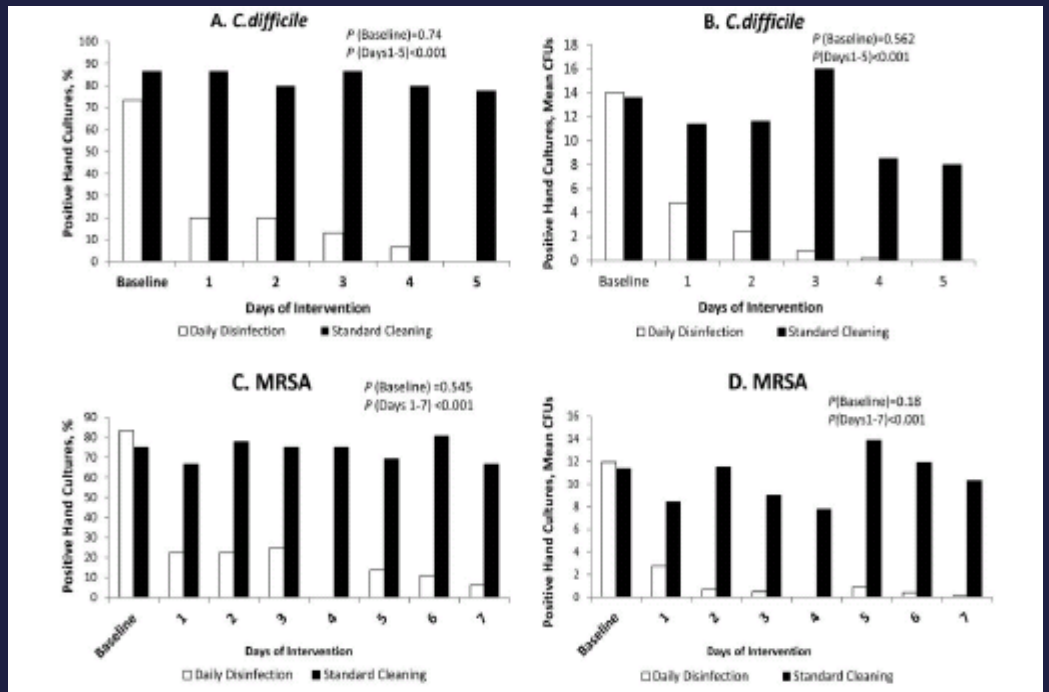


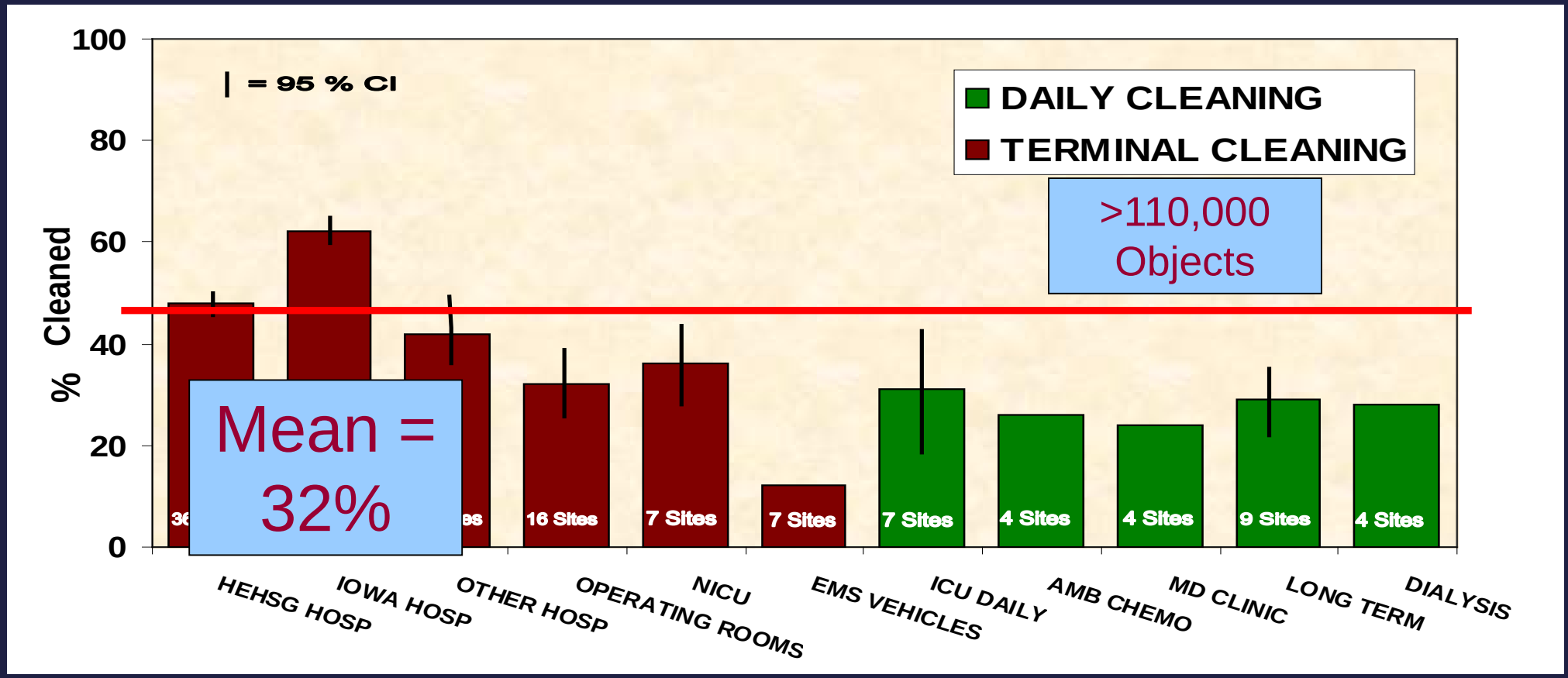
FIGURE 1. Effect of daily disinfection of high-touch environmental surfaces on acquisition of *Clostridium difficile* and methicillin-resistant *Staphylococcus aureus* (MRSA) on gloved hands of investigators after contact with the surfaces. *A*, Percentage of positive *C. difficile* cultures; *B*, mean number of *C. difficile* colony-forming units acquired; *C*, percentage of positive MRSA cultures; *D*, mean number of MRSA colony-forming units acquired.

ENVIRONMENTAL CONTAMINATION LEADS TO HAIs

- There is increasing evidence to support the contribution of the environment to disease transmission
- This supports comprehensive disinfecting regimens (goal is not sterilization) to reduce the risk of acquiring a pathogen from the healthcare environment/equipment

Thoroughness of Environmental Cleaning

Carling et al. ECCMID, Milan, Italy, May 2011



MONITORING THE EFFECTIVENESS OF CLEANING

Cooper et al. AJIC 2007;35:338

- Visual assessment-not a reliable indicator of surface cleanliness
- ATP bioluminescence-measures organic debris (each unit has own reading scale, <250-500 RLU)
- Microbiological methods-<2.5CFUs/cm^2-pass; can be costly and pathogen specific
- Fluorescent marker-transparent, easily cleaned, environmentally stable marking solution that fluoresces when exposed to an ultraviolet light (applied by IP unbeknown to EVS, after EVS cleaning, markings are reassessed)

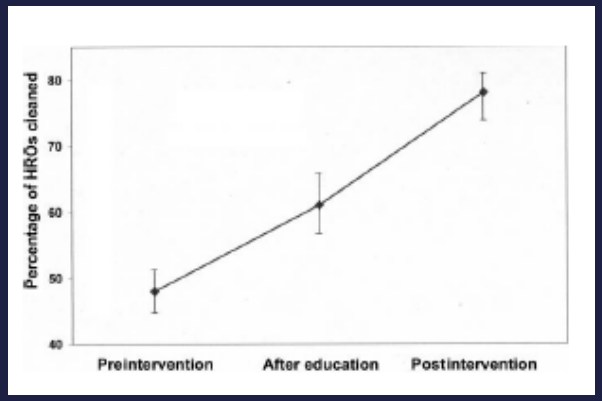
DAZO Solution (AKA – Goo)

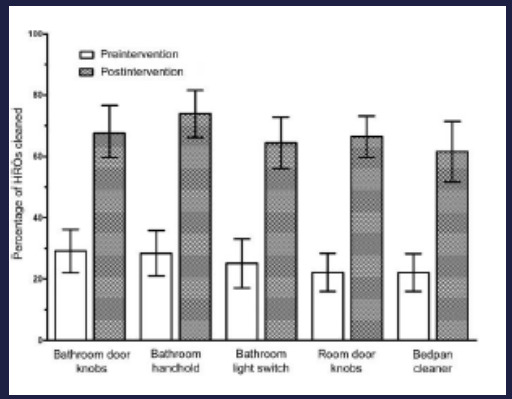
TARGET ENHANCED

TERMINAL ROOM CLEANING: DEMONSTRATION OF IMPROVED CLEANING

- Evaluated cleaning before and after an intervention to improve cleaning
- 36 US acute care hospitals
- Assessed cleaning using a fluorescent dye
- Interventions
  - Increased education of environmental service workers
  - Feedback to environmental service workers

†Regularly change “dotted” items to prevent targeting objects



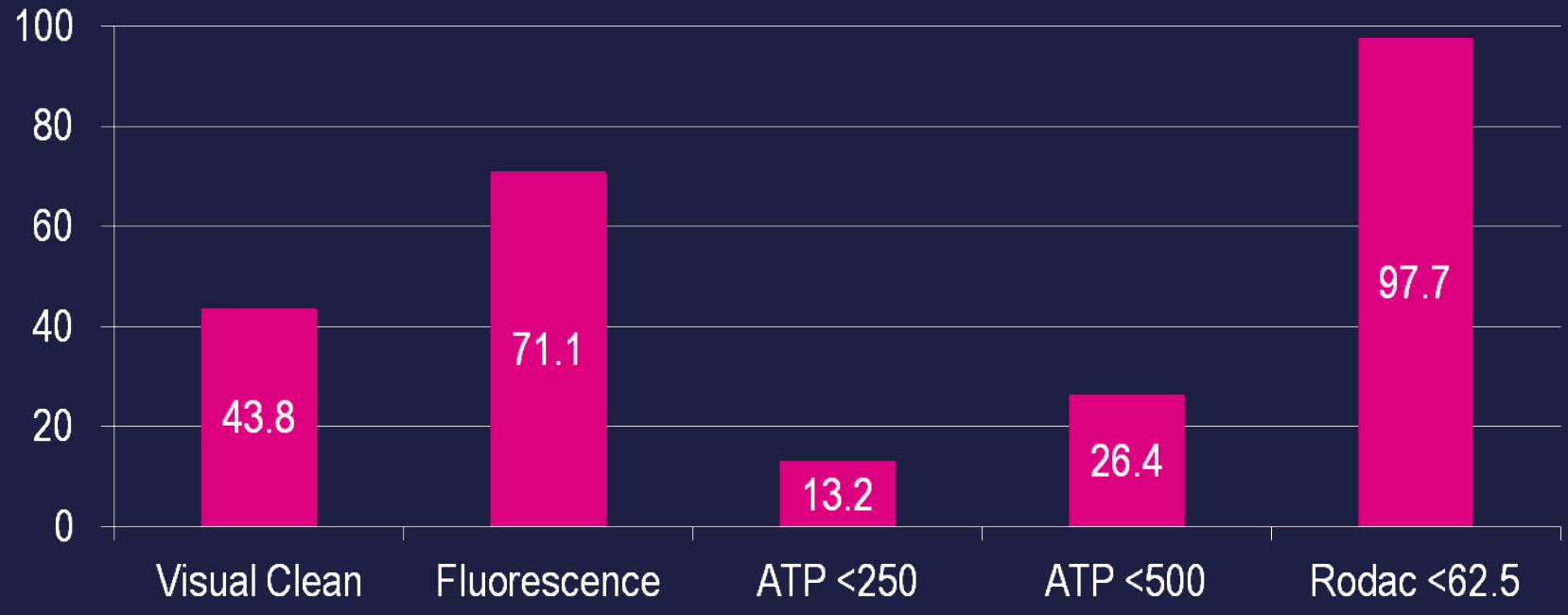


Carling PC, et al. ICHE 2008;29:1035-41

Percentage of Surfaces Clean by Different Measurement Methods

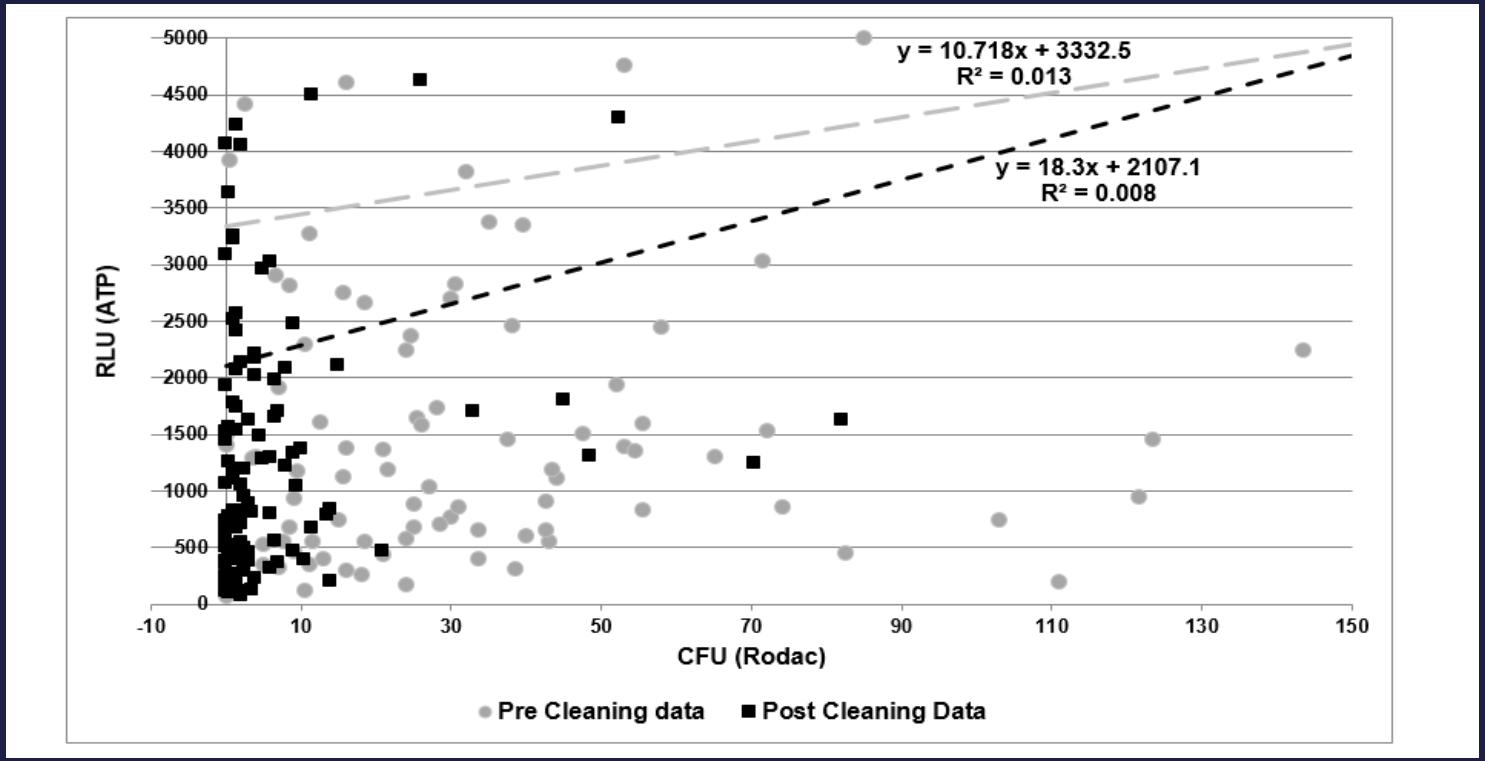
Rutala, Kanamori, Gergen, Sickbert-Bennett, Huslage, Weber. APIC 2017.

Fluorescent marker is a useful tool in determining how thoroughly a surface is wiped and mimics the microbiological data better than ATP



Scatterplot of ATP Levels (less than 5000 RLUs) and Standard Aerobic Counts (CFU/Rodac)

Rutala, Kanamori, Gergen, Sickbert-Bennett, Huslage, Weber. APIC 2017

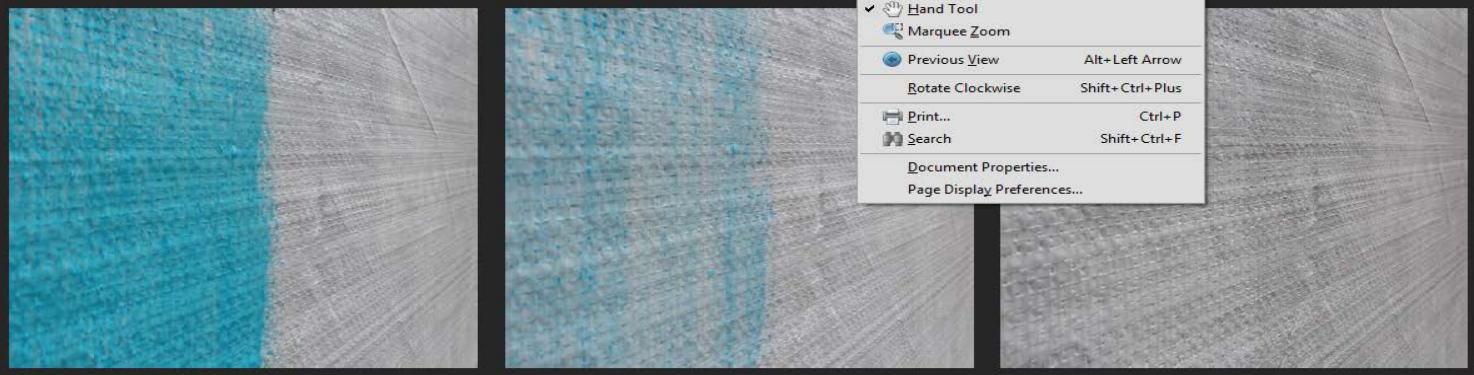


There was no statistical correlation between ATP levels and standard aerobic plate counts.

Future Methods to Ensure Thoroughness

Future May Have Methods to Ensure Thoroughness

Solution: Highlight®



0 min 5 min 10 min

- Color-fading time can be matched to contact kill time for a disinfectant --> **enforces compliance**
- Prevents staining on permanent structures + reusable materials
- Provides **real-time feedback** when a surface is safe to touch

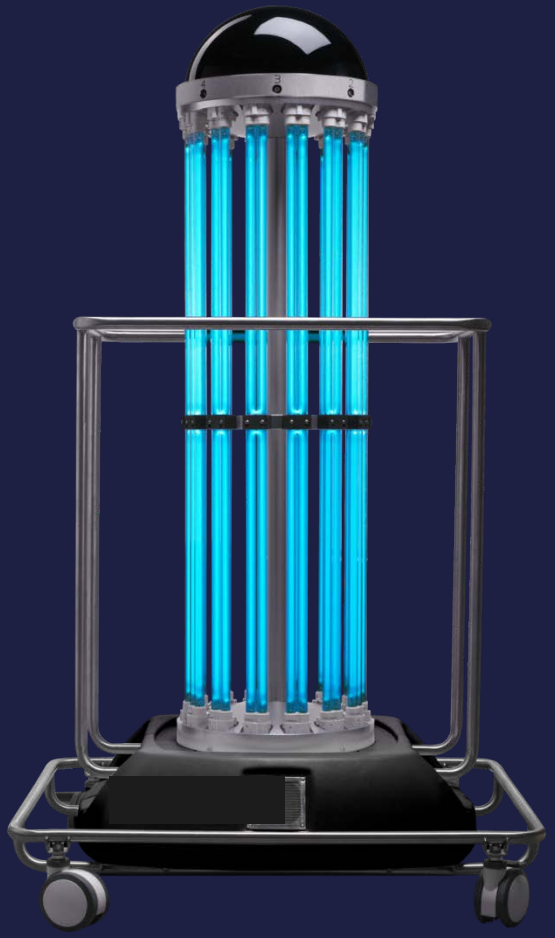
What's New: Strategies in Healthcare Environmental Infection Prevention

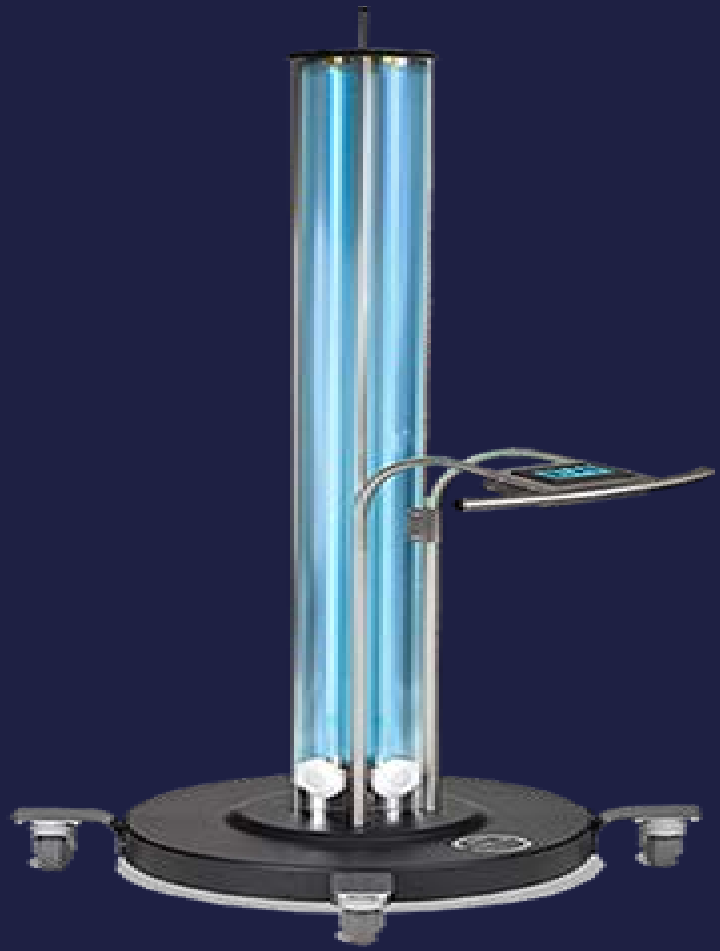
- Role of environment in disease transmission
- Products and practices for surface disinfection
  - New issues
    - Inactivation of emerging pathogens (e.g., CRE, *C. auris*)
- Technologies for terminal room decontamination (not including technologies with limited data)
  - Ultraviolet light
  - Vaporized hydrogen peroxide
- Continuous room decontamination technologies
  - Light disinfection
  - Low-concentration hydrogen peroxide
  - Self-disinfecting surfaces
  - Other
- Other Healthcare Environment Issues
  - Water-Heater-cooler units

“NO TOUCH” APPROACHES TO ROOM DECONTAMINATION

(will not discuss technology with limited data)

Rutala, Weber. Infect Control Hosp Epidemiol. 2013;41:S36-S41





Touch (Wiping) vs No-Touch (Mechanical)

No Touch

(supplements but do not replace surface cleaning/disinfection)

New Technologies for Room/Surface Decontamination
Assessment Parameters

- Safe
- Microbicidal
- Reduction of HAIs
- Cost-effective

EFFECTIVENESS OF UV DEVICES ON REDUCING MDROs ON CARRIERS

Author, year	UV system	MDROs	Time (min)	Energy ($\mu W/cm^2$)	Log_{10} reduction direct (indirect)
Rutala, 2010[27]	UV-C, Tru-D	MRSA, VRE, A	~15	12,000	4.31 (3.85), 3.90 (3.25), 4.21 (3.79)
Rutala, 2010[27]	UV-C, Tru-D	Cd	~50	36,000	4.04 (2.43)
Boyce, 2011[28]	UV-C, Tru-D	Cd	67.8 (1 stage)	22,000	1.7-2.9
Havill, 2012[29]	UV-C, Tru-D	Cd	73 (mean)	22,000	2.2
Rutala, 2013[30]	UV-C, Tru-D	MRSA	25	12,000	4.71 (4.27)
Rutala, 2013[30]	UV-C, Tru-D	Cd	43	22,000	3.41 (2.01)
Mahida, 2013[31]	UV-C, Tru-D	OR: MRSA, VRE	49	12,000	≥4.0 (≥4.0), 3.5 (2.4)
Mahida, 2013[31]	UV-C, Tru-D	Single patient room: VRE, A, As	23-93	12,000	≥4.0 (>2.3), ≥4.0 (1.7), ≥4.0 (2.0)
Rutala, 2014[32]	UV-C, Optimum	MRSA	5	NS	4.10 (2.74)
Rutala, 2014[32]	UV-C, Optimum	Cd	10	NS	3.35 (1.80)
Nerandzic, 2015[33]	UV, PX, Xenon	Cd, MRSA, VRE	10 at 4 ft (2 cycles)	NS	0.55, 1.85, 0.6

A, *Acinetobacter* spp; *As*, *Aspergillus*; *Cd*, *Clostridium difficile*; *MDRO*, multidrug-resistant organism; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *NS*, not stated; *OR*, operating room; *PX*, pulsed xenon; *UV*, ultraviolet light; *VRE*, vancomycin-resistant enterococci.

Weber DJ, Rutala WA, et al. Am J Infect Control 2016;44:e77-e84

EFFECTIVENESS OF UV DEVICES ON REDUCING MDROs IN CONTAMINATED PATIENT ROOMS

Author, year	UV system	MDROs	Time (min); energy ($\mu W/cm^2$)	Positive sites (before and after) (%)	Log_{10} reduction
Rutala, 2010[27]	UV-C, Tru-D	MRSA	~15; 12,000	20.2, 0.5	1.30
Nerandzic, 2010[34]	UV-C, Tru-D	MRSA, VRE	20; 12,000	10.7, 0.8; 2.7, 0.38	0.68; 2.52
Nerandzic, 2010[34]	UV-C, Tru-D	Cd	45; 22,000	3.4, 0.38	1.39;
Stibich, 2011[35]	UV, PX, Xenex	VRE	12; NS	8.2, 0	1.36
Anderson, 2013[36]	UV-C, Tru-D	All, VRE, A	25; 12,000	NS; 11, 1; 13, 3	1.35; 1.68; 1.71
Anderson, 2013[36]	UV-C, Tru-D	Cd	45; 22,000	10, 5	1.16
Jinadatha, 2015[37]	UV, PX, Xenex	MRSA	15 (3 cycles of 5 min), NS	70, 8	2.0
Nerandzic, 2015[33]	UV, PX, Xenex	MRSA, VRE, Cd	10 (2 cycles of 5 min); NS	10, 2; 4, 0.9; 19, 8	0.90, 1.08, NS
Jinadatha, 2015[37]	UV-PX, Xenex	MRSA	15 (3 cycles of 5 min); NS	NS, NS	0.63

A, *Acinetobacter* spp; *All*, all target organisms; *Cd*, *Clostridium difficile*; *MDRO*, multidrug-resistant organism; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *NS*, not stated; *PX*, pulsed xenon; *UV*, ultraviolet light; *VRE*, vancomycin-resistant enterococci.

Weber DJ, Rutala WA, et al. Am J Infect Control 2016;44:e77-e84

Clinical Trials Using UV for Terminal Room Decontamination to Reduce HAIs

Weber, Rutala et al. Am J Infect Control. 2016;44:e77-e84.

Author, Year	Design	Pathogens	Reduction in HAIs
Levin, 2013	Before-After, Pulsed Xenon	CDI	Yes
Hass, 2014	Before-After, Pulsed Xenon	CDI, MRSA, VRE, MDRO-GNR	Yes
Miller, 2015	Before-After, Pulsed Xenon	CDI	Yes
Nagaraja, 2015	Before-After, Pulsed Xenon	CDI	Yes (p=0.06)
Pegues, 2015	Before-After, Optimum	CDI	Yes
Anderson, 2017	Randomized-controlled trial, Tru-D	MRSA, VRE, CDI	Yes

Enhanced terminal room disinfection and acquisition and infection caused by multidrug-resistant organisms and *Clostridium difficile* (the Benefits of Enhanced Terminal Room Disinfection study): a cluster-randomised, multicentre, crossover study

Deverick J Anderson, Luke F Chen, David J Weber, Rebekah W Moehring, Sarah S Lewis, Patricia F Triplett, Michael Blocker, Paul Becherer, J Conrad Schwab, Lauren P Knelson, Yuliya Lokhnygina, William A Rutala, Hajime Kanamori, Maria F Gergen, Daniel J Sexton; for the CDC Prevention Epicenters Program

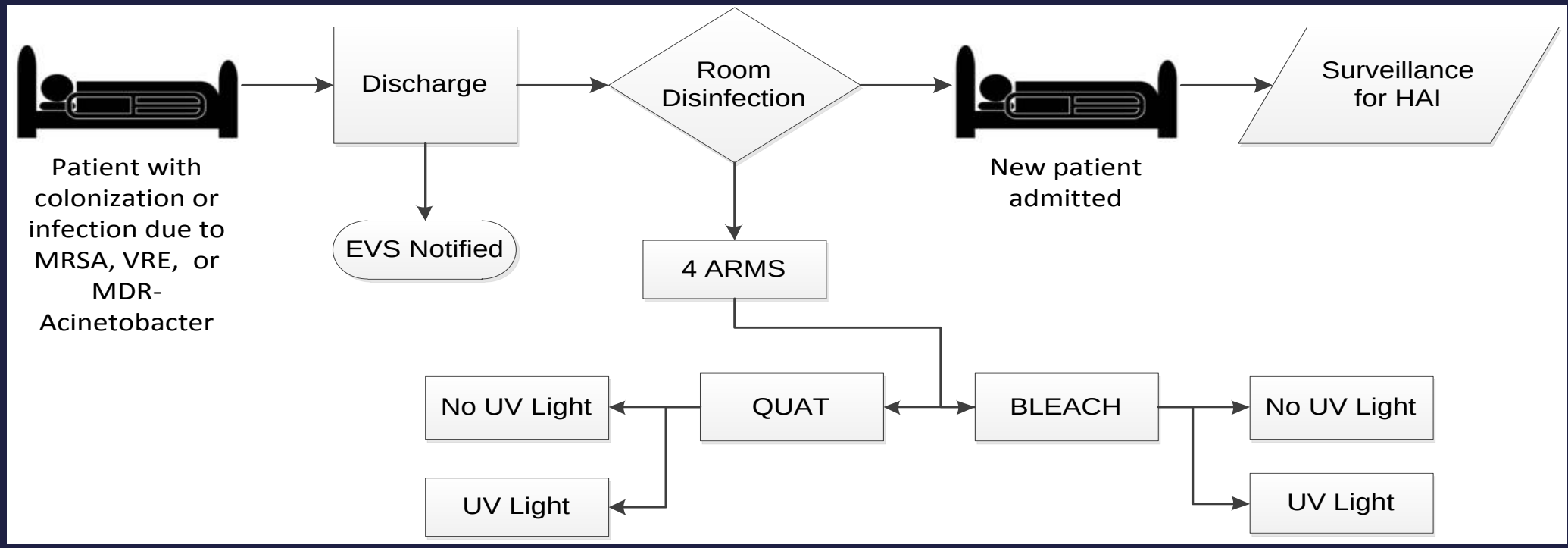
Anderson DJ, et al. Lancet (epub ahead of print)

2x2 Factorial Design

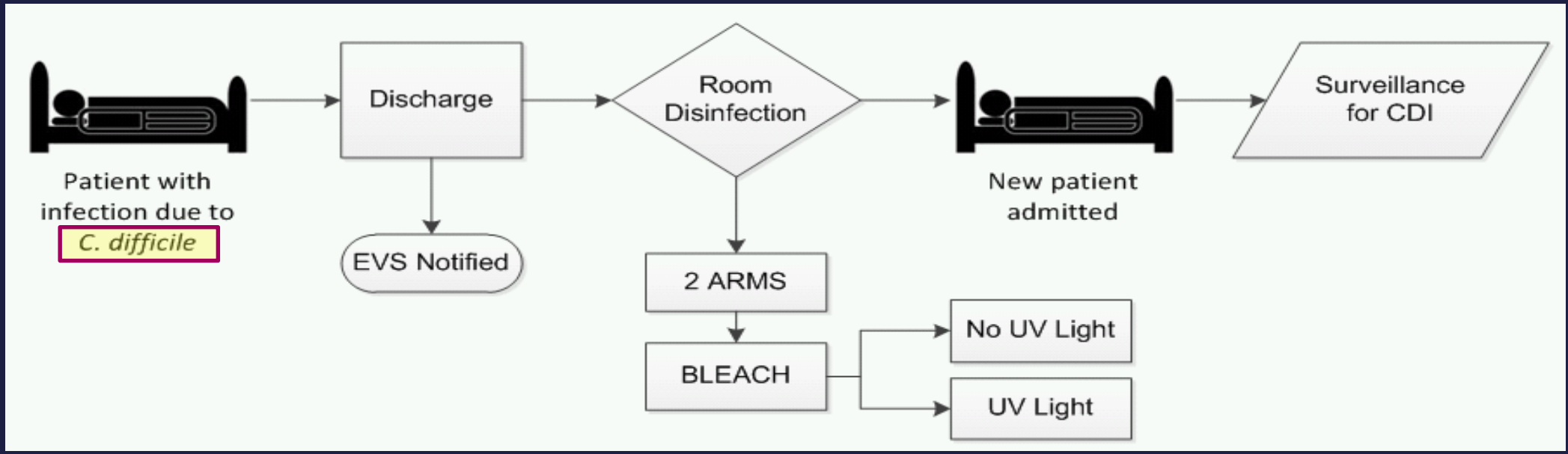
	No UV Light	UV Light
Quat*	A	B
Bleach	C	D

*NOTE: Bleach always used in rooms of patients with suspected or confirmed *C. difficile*

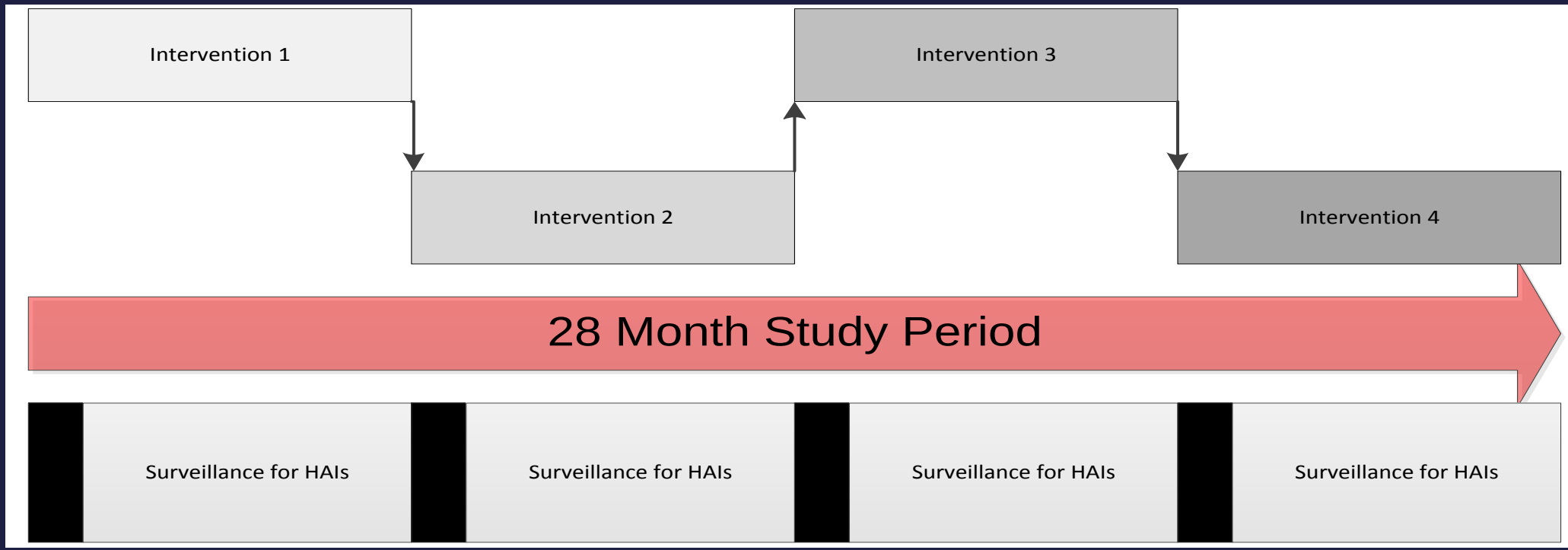
DUKE/UNC BETR-D STUDY: MRSA, VRE, *MDR-Acinetobacter*



DUKE/UNC BETR-D STUDY: CDI



DUKE/UNC BETR-D STUDY: DESIGN



Anderson DJ, et al. Lancet (epub ahead of print)

BETR RESULTS: INTENTION-TO-TREAT ANALYSIS

Conclusion: Enhanced terminal room disinfection strategies decreased the clinical incidence of target MDROs by 10-30%

	Reference	Quat + UV group	Bleach group	Bleach + UV group
Exposed patients	4916	5178	5438	5863
Incidence cases (%)	115 (2.3%)	76 (1.5%)	101 (1.9%)	131 (2.2%)
Exposure days	22,426	22,289	24,261	28,757
Rate (per 10,000 exposure-days)	51.3	33.9	41.6	45.6
Risk reduction	Reference	17.4	9.7	5.7
RR (p value)	Reference	0.70 (0.036)	0.85 (0.116)	0.91 (0.303)

Anderson DJ et al. Lancet (epub ahead of print)

Enhanced Disinfection Leading to Reduction of Microbial Contamination and a Decrease in Patient Col/Infection

Rutala, Kanamori, Gergen et al. 2017

	Standard Method	Enhanced method		
	Quat	Quat/UV	Bleach	Bleach/UV
EIP (mean CFU per room)[a]	60.8	3.4	11.7	6.3
Reduction (%)		94	81	90
Colonization/Infection (rate)[a]	2.3	1.5	1.9	2.2
Reduction (%)		35	17	4

All enhanced disinfection technologies were significantly superior to Quat alone in reducing EIPs. Comparing the best strategy with the worst strategy (i.e., Quat vs Quat/UV) revealed that a reduction of 94% in EIP (60.8 vs 3.4) led to a 35% decrease in colonization/infection (2.3% vs 1.5%). Our data demonstrated that a decrease in room contamination was associated with a decrease in patient colonization/infection. First study which quantitatively described the entire pathway whereby improved disinfection decreases microbial contamination which in-turn reduced patient colonization/infection.

UV ROOM DECONTAMINATION: ADVANTAGES AND DISADVANTAGES

Rutala WA, Weber DJ. Am J Infect Control 2013;41:S36

- Advantages
  - Reliable biocidal activity against a wide range of pathogens
  - Surfaces and equipment decontaminated
  - Room decontamination is rapid (5-25 min) for vegetative bacteria (*C. difficile* spores 10-50m)
  - HVAC system does not need to be disabled and room does not need to be sealed
  - UV is residual free and does not give rise to health and safety concerns
  - No consumable products so operating costs are low (key cost = acquisition)
  - Studies show use of UV reduces HAIs
- Disadvantages
  - Can only be done for terminal disinfection (i.e., not daily cleaning)
  - All patients and staff must be removed from room
  - Substantial capital equipment costs
  - Does not remove dust and stains which are important to patients/visitors
  - Sensitive use parameters (e.g., UV dose delivered)

HP Systems for Decontamination of the Hospital Environment

Falagas et al. J Hosp Infect. 2011;78:171

Author, Year	HP System	Pathogen	Before HPV	After HPV	% Reduction
French, 2004	VHP	MRSA	61/85-72%	1/85-1%	98
Bates, 2005	VHP	*Serratia*	2/42-5%	0/24-0%	100
Jeanes, 2005	VHP	MRSA	10/28-36%	0/50-0%	100
Hardy, 2007	VHP	MRSA	7/29-24%	0/29-0%	100
Dryden, 2007	VHP	MRSA	8/29-28%	1/29-3%	88
Otter, 2007	VHP	MRSA	18/30-60%	1/30-3%	95
Boyce, 2008	VHP	*C. difficile*	11/43-26%	0/37-0%	100
Bartels, 2008	HP dry mist	MRSA	4/14-29%	0/14-0%	100
Shapey, 2008	HP dry mist	*C. difficile*	48/203-24%; 7	7/203-3%; 0.4	88
Barbut, 2009	HP dry mist	*C. difficile*	34/180-19%	4/180-2%	88
Otter, 2010	VHP	GNR	10/21-48%	0/63-0%	100

Clinical Trials Using HP for Terminal Room Disinfection to Reduce HAIs

Weber, Rutala et al. Am J Infect Control. 2016;44:e53-e62

Author, Year	Design	Pathogen	Reduction in HAIs
Boyce, 2008	Before-After	CDI	Yes
Cooper, 2011	Before-After	CDI	Decrease cases (incidence not stated)
Passaretti, 2013	Prospective cohort	MRSA, VRE, CDI	Yes, in all MDROs
Manian, 2013	Before-After	CDI	Yes
Mitchell, 2014	Before-After	MRSA	Yes
Horn, 2015	Before-After	CDI, VRE, ESBL GNR	Yes

HP ROOM DECONTAMINATION: ADVANTAGES AND DISADVANTAGES

Rutala WA, Weber DJ. Am J Infect Control 2013;41:S36

- Advantages
  - Reliable biocidal activity against a wide range of pathogens
  - Surfaces and equipment decontaminated
  - Demonstrated to decrease disease incidence (*C. difficile*)
  - Residual free and does not give rise to health and safety concerns (aeration units convert HPV into oxygen and water)
  - Useful for disinfecting complex equipment and furniture
  - Does not require direct or indirect line of sight
- Disadvantages
  - Can only be done for terminal disinfection (i.e., not daily cleaning)
  - All patients and staff must be removed from room
  - Decontamination takes approximately 1.5-5 hours
  - HVAC system must be disabled and the room sealed with tape
  - Substantial capital equipment costs
  - Does not remove dust and stains which are important to patients/visitors
  - Sensitive use parameters (e.g., HP concentration)

This technology (“no touch”-UV/HP) should be used (capital equipment budget) for terminal room disinfection (e.g., after discharge of patients on Contact Precautions).

Selection of a UV or HP Device

Weber, Rutala et al. Am J Infect Control. 2016;44:e77-e84.

- Since different UV and hydrogen peroxide systems vary substantially, infection preventionists should review the peer-reviewed literature and choose only devices with demonstrated bactericidal capability as assessed by carrier tests and/or the ability to disinfect actual patient rooms
- Ideally, one would select a device that has demonstrated bactericidal capability and the ability to reduce HAIs

What's New: Strategies in Healthcare Environmental Infection Prevention

- Role of environment in disease transmission
- Products and practices for surface disinfection
  - New issues
    - Inactivation of emerging pathogens (e.g., CRE, *C. auris*)
- Technologies for terminal room decontamination (not including technologies with limited data)
  - Ultraviolet light
  - Vaporized hydrogen peroxide
- Continuous room decontamination technologies
  - Light disinfection
  - Low-concentration hydrogen peroxide
  - Self-disinfecting surfaces
  - Other
- Other Healthcare Environment Issues
  - Water-Heater-cooler units

How Will We Prevent Infections Associated with the Environment?

- Implement evidence-based practices for surface disinfection
  - Ensure use of safe and effective (against emerging pathogens such as *C. auris* and CRE) low-level disinfectants
  - Ensure thoroughness of cleaning (new thoroughness technology)
- Use “no touch” room decontamination technology proven to reduce microbial contamination on surfaces and reduction of HAIs at terminal/discharge cleaning
- Use new continuous room decontamination technology that continuously reduces microbial contamination

Continuous Room Decontamination-Continuous Microbial Reduction

Hygienically clean (not sterile)-free of pathogens in sufficient numbers to prevent human disease

Continuous Room Decontamination Technology

- Advantages
  - Allows continued disinfection (may eliminate the problem of recontamination)
  - Patients, staff and visitors can remain in the room
  - Does not require an ongoing behavior change or education of personnel
  - Self-sustaining once in place
  - Once purchased might have low maintenance cost
  - Technology does not give rise to health or safety concerns
  - No (limited) consumable products

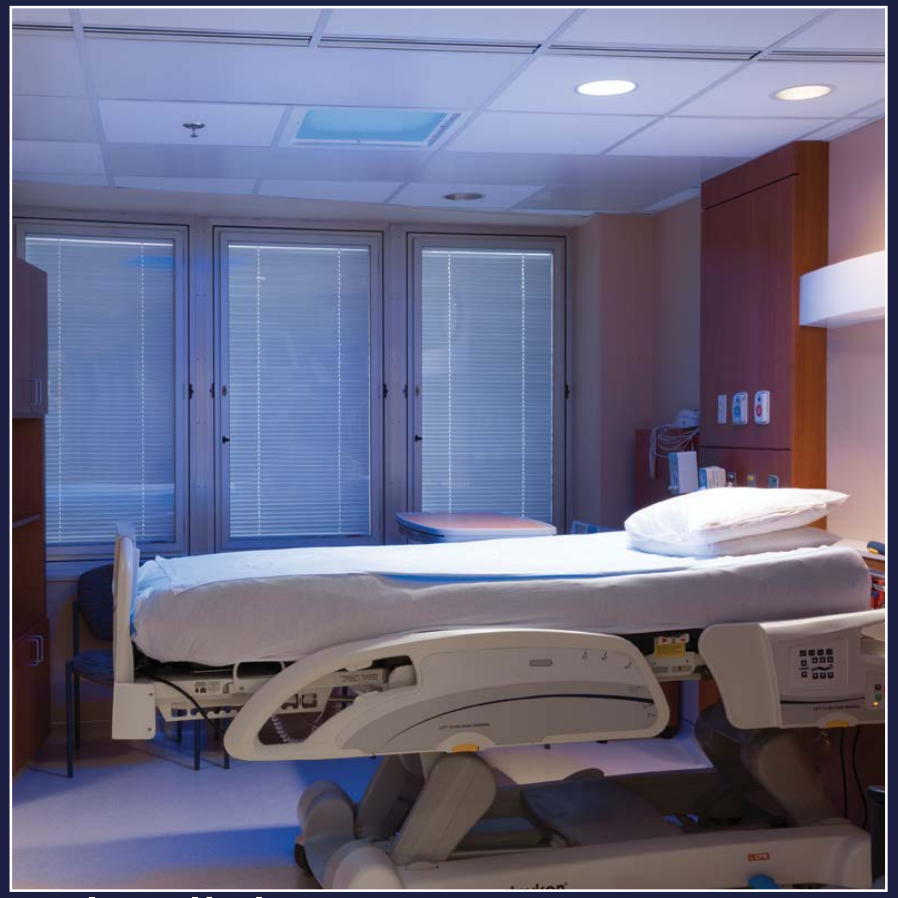
Continuous Room Decontamination Technology

- Disadvantages
  - Room decontamination/biocidal activity is slow
  - Capital equipment costs are substantial
  - Does not remove dust, dirt, stains that are important to patients and visitors
  - Studies have not shown whether the use will decrease HAIs
  - May cause patient dissatisfaction (e.g., lights on 24/7)

Visible Light Disinfection in a Patient Room

(automatic switching between modes performed by wall-mounted controls)

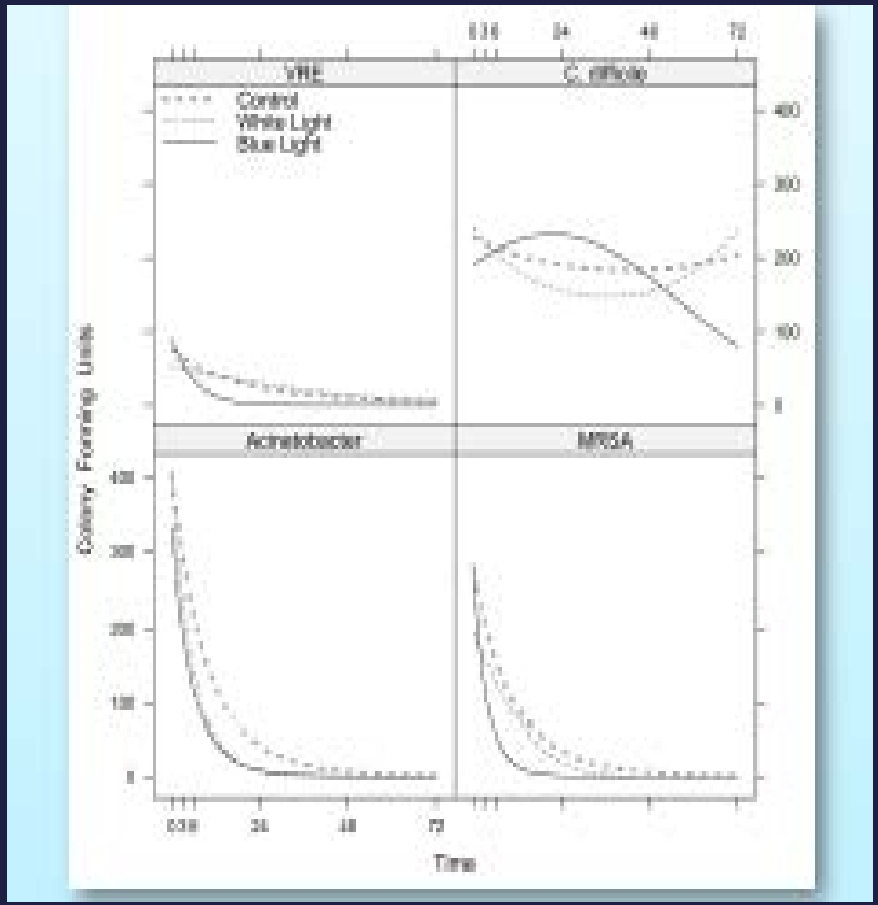
White light



Blue light-increase irradiance, increase kill

Inactivation of Health Pathogens by Continuous Visible Light Disinfection

Rutala et al. APIC 2017



- The treatment (i.e. both “blue” and “white” light) had significantly different rates over time for all four organisms
- Both light treatments were associated with more rapid decreases in observed bacterial counts over time with all four organism
- Overall, the model demonstrated improved inactivation of pathogens with the “blue” and “white” light

Time to Specified Percent Reduction of Epidemiologically-Important Pathogens with "Blue" and "White" Light

Rutala et al. APIC 2017

Pathogen	Treatment (light)	Time (least number of hours) to achieve sustained microbial reduction of listed percentage			
		25%	50%	75%	90%
MRSA	White	5	10	17	24
	Blue	2	3	6	10
VRE	White	13	29	51	NA
	Blue	2	5	9	15
MDR-*Acinetobacter*	White	2	5	9	14
	Blue	2	4	9	15
C. difficile	White	NA	NA	NA	NA
	Blue	56	68	NA	NA

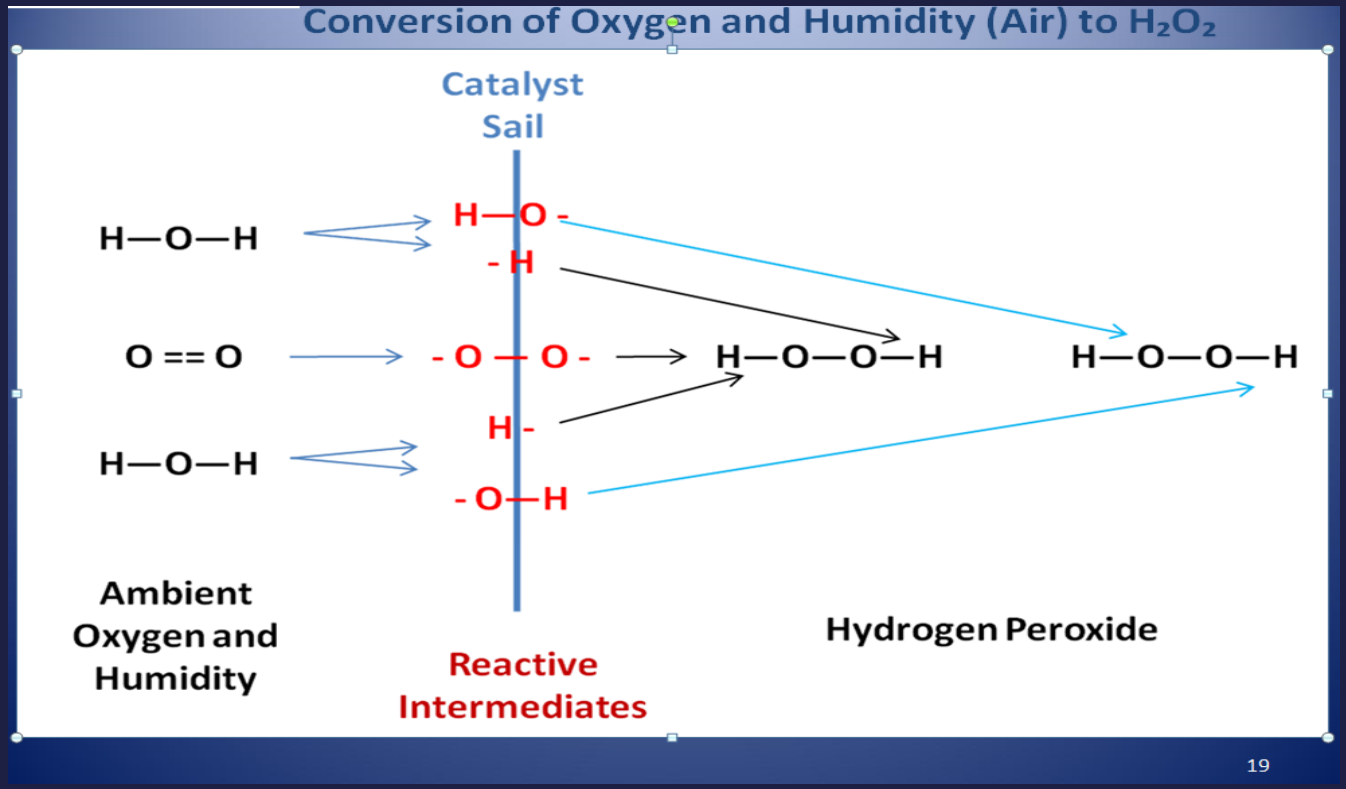
The earliest hour after which the model predicts a sustained reduction of CFUs by the stated percentage for epidemiologically-important pathogens with the "white" light and the "blue" light. "NA" indicates that a sustained reduction of the given was level was not achieved. Note that the largest reduction listed is 90% because the model cannot predict a 100% reduction except after infinite hours have passed.

Antimicrobial Activity of a Continuous Visible Light Disinfection System

- Advantages
  - Continuous decontamination can be accomplished 24/7 (lights must be on)
  - Patients and staff do not have to leave the room during decontamination
  - Biocidal activity against a range of HA pathogens
  - Room surfaces and equipment decontaminated
  - Residual free, and no known safety or health concerns
- Disadvantages
  - Has not been demonstrated to reduce HAIs in clinical trials
  - Kills in hours not minutes
  - Capital equipment costs are substantial
  - May cause patient dissatisfaction (e.g., lights on 24/7)

Dilute Hydrogen Peroxide Technology

UV activates the catalyst which creates H ion and hydroxyl radical and free electron, hydroxyl radicals removed from catalyst and combine to form HP; also H_2 and O_2 and electron make HP



Duct-Mounted and Stand-Alone Devices

Uses Harmless Black Light in the UVA Range to Powers its Catalyst

Duct-Mounted Device

Operation of DHP Technology:

1. Installation: DHP devices are installed in HVAC ducts by simply cutting a small hole in the side of the duct, inserting the device, and bolting the device in place to seal the insertion hole. The device is powered by connection to the nearest electrical source. Stand-Alone DHP devices are available for areas that do not have HVAC ducting and can be bolted to floor or walls.

Stand-Alone Device with On-Board Filter and Fan

Dilute Hydrogen Peroxide Technology

- A study conducted at the Pocono Medical Center (2015 APIC, Nashville)
  - 27 HVAC devices In place for six month study on the Cardiovascular Telemetry Ward – 40,000 square feet, 34 beds
  - 70% reduction in HAIs over 6 months (before-after)
- Each DHP device costs $2500 and may protect 1500-2000 ft^2. Consumable component replaced at 4-6 months ($100-150/year)
- Our study did not demonstrate that the unit produces a microbicidal level of hydrogen peroxide (methodology [test bacteria, Formica] similar to light disinfection method, used Draeger hydrogen peroxide tubes)

SURFACE DISINFECTANTS: PERSISTENCE

Surface disinfectant	Persistence
Phenolic	No
Quaternary ammonium compound	Yes (undisturbed)
Alcohol	No
Hypochlorite	No
Hydrogen peroxide	No

IN VITRO EFFECTIVENESS OF A SILVER COATING AGAINST BACTERIAL CHALLENGE

- Study design: In vitro study
- Study agent: Surfacine (~10 μg/cm^2 silver iodide)
- Methods: Surface coated with Surfacine and then challenged with VRE
- Results:
  - Antimicrobial activity retained despite repeated dry wiping or wiping with a QUAT

Table 3. Effect on vancomycin-resistant Enterococcus (VRE) survival of wiping Surfacine on a treated surface over an extended period

Surface	Intervention	Day 1	Day 6	Day 13
Formica	Control	50	95	120
	Treated	0 (100%)[a]	0 (100%)	0 (100%)
	Treated & wiped	0 (100%)	0 (100%)	0 (100%)

Rutala WA, Weber DJ. Emerg Infect Dis 2001;7:348

QUATS AS SURFACE DISINFECTANTS WITH PERSISTENT ACTIVITY

- Study of computer keyboards: Challenge with VRE or *P. aeruginosa*
- Keys wiped with alcohol or quats (CaviWipes, Clorox Disinfecting Wipes, or Sani-Cloth Plus)

Rutala WA, White MS, Gergen MF, Weber DJ. ICHE 2006;27:372-77.

TABLE 3. Sustained Efficacy of Disinfectants Applied to Keyboard Against Vancomycin-Resistant *Enterococcus* Species

	Efficacy of Disinfectant, by Time of Microbial Challenge and Duration of Disinfectant Exposure, %					
	Challenge at 6 Hours		Challenge at 24 Hours		Challenge at 48 Hours	
Disinfectant	10-min Exposure	60-min Exposure	10-min Exposure	60-min Exposure	10-min Exposure	60-min Exposure
Alcohol	3.05	5.67	12.58	3.31	10.89	5.59
CaviWipes	100.00	100.00	100.00	100.00	100.00	100.00
Clorox Disinfecting Wipes	100.00	100.00	100.00	100.00	100.00	100.00
Sani-Cloth Plus	100.00	100.00	100.00	100.00	100.00	100.00
Sterile water	0.00	0.28	9.69	0.00	0.00	9.09

TABLE 4. Sustained Efficacy of Disinfectants Applied to Keyboard Against *Pseudomonas aeruginosa*

	Efficacy of Disinfectant, by Time of Microbial Challenge and Duration of Disinfectant Exposure, %					
	Challenge at 6 Hours		Challenge at 24 Hours		Challenge at 48 Hours	
Disinfectant	10-min Exposure	60-min Exposure	10-min Exposure	60-min Exposure	10-min Exposure	60-min Exposure
Alcohol	0.00	0.00	10.28	0.00	1.07	0.00
CaviWipes	61.33	48.32	83.96	79.47	73.40	32.22
Clorox Disinfecting Wipes	69.99	59.43	69.45	74.70	79.81	55.62
Sani-Cloth Plus	68.91	70.54	91.75	90.41	86.71	85.86
Sterile water	16.58	27.76	34.75	40.85	16.51	17.74

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Major article

Long-term efficacy of a self-disinfecting coating in an intensive care unit

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Key Words:
Disinfection
Bacteria
Self-disinfecting surface
Efficacy

Background: Cleaning and disinfecting fomites can effectively remove/kill pathogens on surfaces, but studies have shown that more than one-half the time, surfaces are not adequately cleaned or are recontaminated within minutes. This study evaluated a product designed to create a long-lasting surface coating that provides continuous disinfecting action.

Methods: This study was performed in an intensive care unit (ICU) in a major hospital. Various sites within the ICU were cultured before treatment and then at 1, 2, 4, 8, and 15 weeks after application of an antimicrobial coating. Samples were cultured for total bacteria, as well as *Clostridium difficile*, methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant enterococcus, and carbapenemase-resistant Enterobacteriaceae.

Results: The average bacterial count on all treated surfaces was reduced by >99% (2 logs) for at least 8 weeks after treatment. Overall, average levels of bacteria never returned to those observed before treatment even after 15 weeks. Antibiotic-resistant bacteria were found on 25% of the sites tested before treatment, but were isolated at only 1 site during the 15 weeks after treatment.

Conclusions: The product assessed in this study was found to have persisted over 15 weeks in reducing the total number of bacteria and antibiotic resistant bacteria on surfaces within an ICU.

Long-Term Efficacy of a Self-Disinfecting Coating in an ICU

Tamimi, Carlino, Gerba. AJIC 2014. 42:1178-81

- Assess the effectiveness of a QUAT organosilane compound that binds to surfaces and produces residual disinfecting activity
- Coating applied with electrostatic spray applicator of all surfaces in the ICU
- During the course of the study, staff maintained normal daily cleaning schedule, which involved disinfecting with reusable cloths containing bleach and/or disposable QUAT wipes

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Tamimi, Carlino, Gerba. AJIC 2014. 42:1178-81

Bacterial numbers were 99.9% less at 4 weeks after the treatment, 99% after 8 weeks, and almost 99% after 15 weeks. Must reapply every 3-4 months to ensure effective reduction.

Table 2
Average (arithmetic mean) total bacterial numbers (cfu) isolated on 100 cm^2 from fomites and percent reduction after treatment

		Weeks after treatment				
Variable	Baseline*	1	2	4	8	15
Number of samples	95	81	64	64	64	45
Average number of bacteria	233,064	98	80	43	2,247	3,320
Range	10-7,000,000	10-2,500	10-840	10-2,500	10-44,000	10-57,000
% reduction	NA	99.96	99.97	99.98	99.04	98.58

NA, not applicable.
*Before treatment.

Continuous Room Decontamination

Rutala, Gergen, Kanamori, Sickbert-Bennett, Weber, 2015-2018

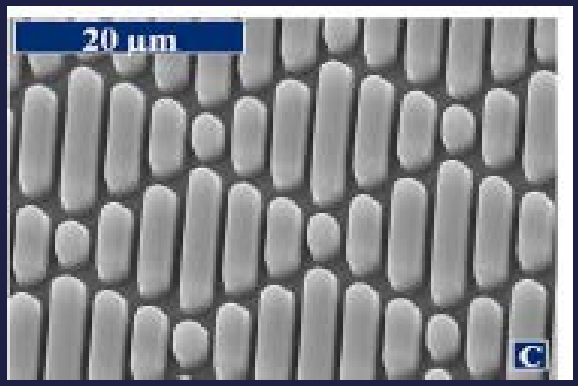
- Visible light disinfection system-effective
- Dilute hydrogen peroxide system-not effective (potential)
- Self-disinfecting surface coating-some data
- Others-copper-some data

RATIONALE FOR DEVELOPMENT OF SELF-DISINFECTING SURFACES

- Unlike improved environmental cleaning does not require an ongoing behavior change or education of personnel
- Self-sustaining once in place
- Allows continued disinfection (may eliminate the problem of recontamination), unlike no touch methods which can only be used for terminal disinfection
- Most hospital surfaces have a low bioburden of pathogens (i.e., <100 per cm^2)
- Once purchased might not have a maintenance cost

SELF DISINFECTING SURFACES

Copper coated overbed table



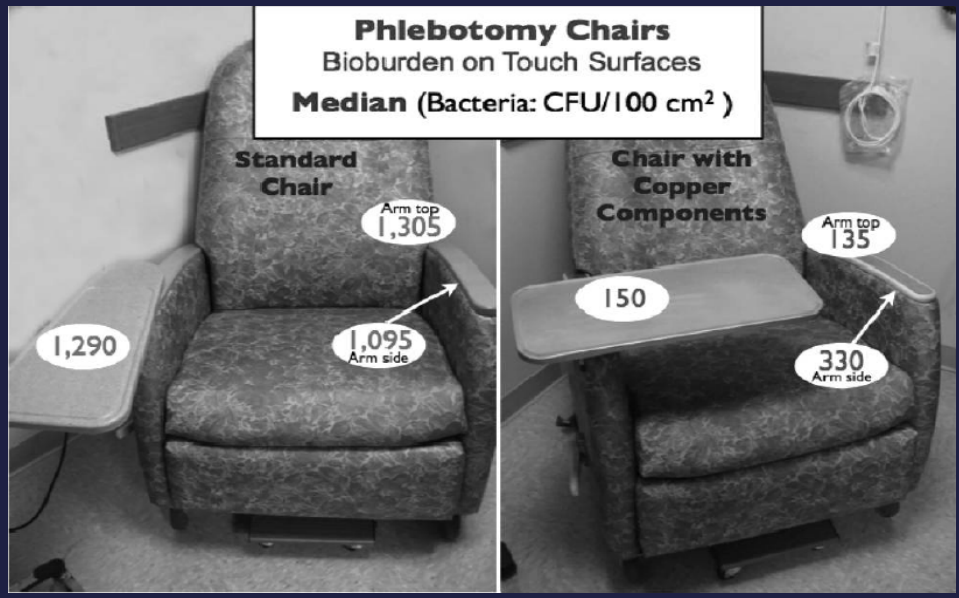
Sharklet Pattern

Antimicrobial effects of silver

Triclosan pen

EVALUATION OF PHLEBOTOMY CHAIR WITH COPPER COATED ARMS AND TRAYS

- Study design: Cross-over design
- Location: Outpatient ID clinic
- Methods:
  - Solid copper alloy (90% Cu) inlaid across arm tops and trays of phlebotomy chair (comparator = wood arms and plastic tabletop)
  - Cultures obtained 2x/week, mid-afternoon
- Results:
  - Median reduction in aerobic bacteria of 88% & 90%, trays & arms, respectively
  - Percent of surfaces with <2.5 CFU/cm^2: copper 62%, noncopper 10%



Rai S, et al. ICHE 2012;33:200-201

What's New: Strategies in Healthcare Environmental Infection Prevention

- Role of environment in disease transmission
- Products and practices for surface disinfection
  - New issues
    - Inactivation of emerging pathogens (e.g., CRE, *C. auris*)
- Technologies for terminal room decontamination (not including technologies with limited data)
  - Ultraviolet light
  - Vaporized hydrogen peroxide
- Continuous room decontamination technologies
  - Light disinfection
  - Low-concentration hydrogen peroxide
  - Self-disinfecting surfaces
  - Other
- Other Healthcare Environment Issues
  - Water-Heater-cooler units

Water and Healthcare
Multiple Uses

Clinical Infectious Diseases

INVITED ARTICLE

HEALTHCARE EPIDEMIOLOGY: Robert A. Weinstein, Section Editor

Healthcare Outbreaks Associated With a Water Reservoir and Infection Prevention Strategies

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

Keywords. waterborne outbreaks; healthcare-associated infections; water; outbreaks.

Healthcare-Associated Outbreaks with a Water Reservoir

Kanamori, Weber, Rutala, Clin Infect Dis 2016; 62:1424-1435.

Table 1. Characteristics of Waterborne Outbreaks and Infections in Healthcare Settings, 1997 January–2015 June

Reservoir	Organism(s)	Transmission	Patient Population	Type of Infection	Molecular Typing	Study Type	First Author, Year
Bathing and tub immersion (bathing tub drain)	*Pseudomonas aeruginosa*	Tub immersion water contaminated from drain when whirlpool bathtub filled	Patients with hematological malignancies (leukemia)	Bloodstream infection, pneumonia, UTI	PFGE	Outbreak – strong causation	Berrouane, 2000 [6]
Bathing and tub immersion (showering)	*Mycobacterium mucogenicum*	Water contamination of CVCs during bathing or showering	BMT and oncology patients	Bacteremia	RAPD	Outbreak – strong causation	Kline, 2004 [7]
Bathing and tub immersion	*Legionella pneumophila*	24 h bath water contaminated	An elderly patient with dementia admitted to a nursing home	Pneumonia	PFGE	Case report (single) – strong causation	Mineshita, 2005 [8]
Bathing and tub immersion (bathing mattress)	*Alcaligenes xylosoxidans*	Bathing procedures and hydrotherapy in burn unit	Burn patients	Cholecystitis, meningitis	PFGE	Case report (single) – strong causation	Fujioka, 2008 [9]
Decorative water fountain	*Legionella pneumophila*	Exposure to contaminated water from decorative fountain	Allogeneic stem cell transplant patients	Pneumonia	PFGE	Outbreak – strong causation	Palmore, 2009 [10]
Deionized water from the hospital pharmacy	*Exophiala jeanselmei*	Contaminated deionized water solution that was used to prepare antiseptic solutions	Hematological malignancies	Fungemia	RAPD	Outbreak – strong causation	Nucci, 2002 [11]
Dialysis water supply	*Burkholderia cepacia*	Inadequate cleaning and a leak in the reverse osmosis tubing connection	Hemodialysis patients	Bacteremia	RAPD	Outbreak – strong causation	Souza, 2004 [12]

HEALTHCARE-ASSOCIATED NTM OUTBREAKS ASSOCIATED WITH WATER

- Species
  - *M. chimaera*
  - *M. abscessus*
  - *M. chelonae*
  - *M. fortuitum*
  - *M. genavense*
  - *M. mucogenicum*
  - *M. neoaurum*
  - *M. phocaicum*
  - *M. simiae*
- Sources
  - Heater-cooler units
  - Potable (tap) water
  - Showers
  - Bathing and tub immersion
  - Electronic faucets
  - Sinks
  - Showers
  - Hospital water systems
  - Ice and ice machines
  - Municipal water systems

Kanamori H, Weber DJ, Rutala WA. Clin Infect Dis 2016;62:1423-35

HEATER-COOLER UNITS

- Current manufacturers
  - LivaNova (Sorin)
  - Maquet
  - Cardioquip
  - Terumo
  - Cincinnati-Sub-Zero

OVERVIEW OF *M. CHIMAERA* OUTBREAK

- July 2015: Invasive *M. chimaera* reported in 6 patients who underwent cardiac surgery with implants, 2008-2012, at one hospital in Zurich, Switzerland
- Investigations revealed *M. chimaera* in the water tanks of heater-cooler units (HCU); air sampling also positive for *M. chimaera* when the units were running
- Additional cases confirmed in several European countries and in US
- Studies suggest NTM from the HCU aerosolized from contaminated water in the device into the air
- Risk of disease not entirely clear
  - 0.39 cases per 10,000 person-years (5 year risk){Chand M, et al. CID 2017;64:335-42}
  - If hospital has had 1 case, patient risk between 0.1% and 1% {CDC}
  - Risk higher if prosthetic material implanted
- Impact of outbreak: >250,000 cardiac bypass procedures done each year in US using HCU (CDC 2016).

SOURCE OF *M. CHIMAERA* OUTBREAK

- Point-source contamination of 3T HCU suggested by 2 studies
  - Europe: *M. chimaera* isolates from 5 patients, 3T HCU from 3 different countries and from new 3T HCU and environment at manufacturer facility – identical by sequencing (typing unpublished – preliminary)
  - US: *M. chimaera* isolates from 11 patients and 5 3T HCU from PA and Iowa were the same by whole genome sequencing
- Manufacturing facility added disinfection and active drying procedures to production line in Sept 2014 due to *M. chimaera* contamination

Contamination during production of heater-cooler units by *Mycobacterium chimaera* potential cause for invasive cardiovascular infections: results of an outbreak investigation in Germany, April 2015 to February 2016

Mycobacterium chimaera Contamination of Heater-Cooler Devices Used in Cardiac Surgery — United States

Haller S, et al. Euro Surveill 2016;21(17), April 28 Perkins KM, et al. MMWR 2016;65:1117

WHY NTM

- Can grow in stagnate and low organic carbon conditions
- Relatively resistant to disinfectants (thick waxy hydrophobic outer membrane)
- Likes to adhere to surfaces and form biofilm (limits chance for eradication with disinfection)
- Disinfectant kills off other competitors
- Relative heat resistant
- In HCU: air bubbles become concentrated with hydrophobic NTM organisms, rupture at surface, expel NTM, then carried by airflow towards patient

Falkinham, III. Int J Environ Res Public Health 2015;12:4533
Falkinham, III. Appl Environ Microbiol 2003;69:5685
Taylor et al. Appl Environ Microbiol 2000;66:1702
Vaerewijck. Microbiol Rev 2005;29:911
Schultze-Robbecke et al. Appl Environ Microbiol 1992;58:1869
Falkinham, III. NTM and heater-coolers. FDA Devices Panel. June 2, 2016

CDC GUIDANCE

- Patients who have had open heart surgery should seek medical care if they are experiencing symptoms associated with infections, such as night sweats, muscle aches, weight loss, fatigue, or unexplained fever.
- Available information suggests that patients who had valves or prosthetic products implanted are at higher risk of these infections.
- Hospitals should consider notifying patients in writing if they were exposed to the Stöckert 3T devices during open-chest cardiac surgery at their institution since January 1, 2012. Hospitals that did not use the Stöckert 3T device during this entire time period should adjust the patient notification timeframe accordingly.
- A possible exception (to notification) pertains to hospitals that have taken additional steps (e.g., moved the Stöckert 3T device out of the operating room) to eliminate patient exposure to the exhaust from these devices. These hospitals may consider not notifying patients who had surgery after these interventions if they are confident that the risk was abated.
- Notify patients even if cultures have been negative (testing neither reliable nor timely)

https://www.cdc.gov/HAI/outbreaks

LIVANOVA (SORIN): IFU

- Use filtered tap water (0.2 micron)
- Water change in tank/reservoir(s)
  - Weekly
  - Disinfectant added (3% H_2O_2)
- Disinfection
  - Every 2 weeks
  - Disinfectant run through the system (bleach)
- No manufacturer's recommendations regarding
  - Manual cleaning, detergent or enzyme treatment to disrupt biofilm
  - Disinfection of other internal parts

UNC HOSPITALS' PREVENTION PLANS

- Notification letter regarding potential risks to be sent to all patients on whom a HCU was used (~600)
- Notification of UNC physicians
  - ID Conference
  - Cardiology Grand Rounds (UNC and Rex)
- Physical changes to use of HCU
  - HCU exhaust pointed away from patient (has always been done)
  - Use of HEPA filter at site of exhaust (now implemented)
  - Consideration to channeling exhaust outside of OR
- Use filtered water (changed daily)
- Disinfection of water channels per manufacturer

Portable HEPA Filter

Rutala et al. ICHE. 1995; 16:391-398

EFFECTIVENESS OF HEPA UNITS

Rutala et al. ICHE. 1995; 16:391-398

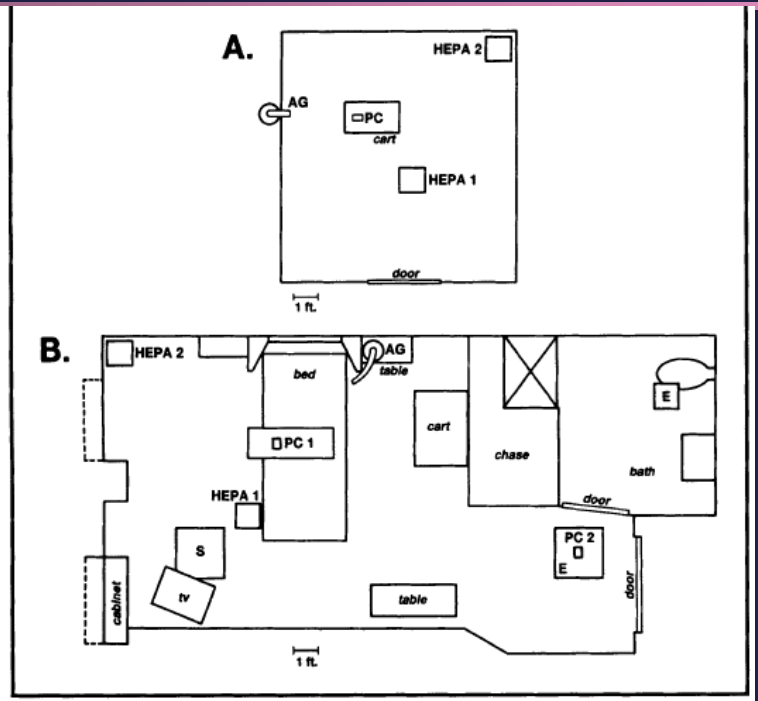
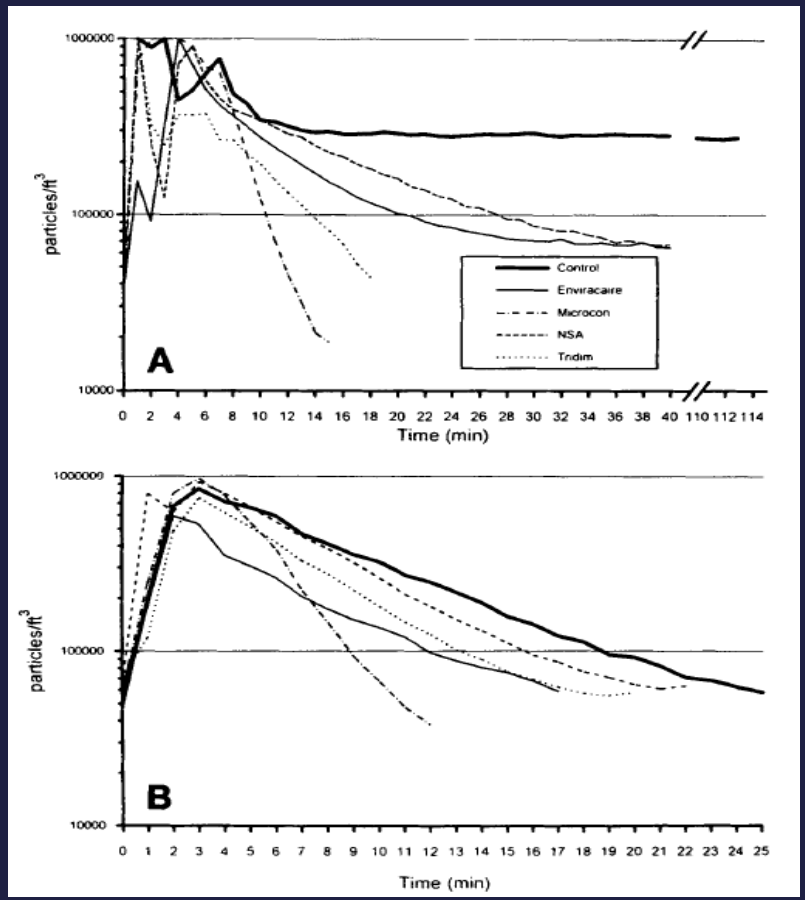


FIGURE 1. (A) Diagram of aerosol chamber demonstrating placements of aerosol generator, filtration unit, and particle counter. Abbreviations: AG, aerosol generator; PC, particle counter; HEPA 1, filtration unit, position 1; HEPA 2, filtration unit, position 2.

(B) Diagram of hospital room demonstrating placements of aerosol generator, filtration unit, and particle counter. Abbreviations: AG, aerosol generator; PC 1, particle counter, position 1; PC 2, particle counter, position 2; HEPA 1, filtration unit, position 1; HEPA 2, filtration unit, position 2; S, supply vent; E, exhaust vents.



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Challenge

Prevent All Infectious Disease Transmission Associated with Surface Environment in 5 years (2021)

Strategies to Prevent Infections Associated with the Environment

- Implement evidence-based practices for surface disinfection
  - Ensure use of safe and effective (against emerging pathogens such as *C. auris* and CRE) low-level disinfectants
  - Ensure thoroughness of cleaning
- Use “no touch” room decontamination technology proven to reduce microbial contamination on surfaces and reduction of HAIs at terminal/discharge cleaning
- Investigate new continuous room decontamination technology that continuously reduces microbial contamination
- Water reservoirs of HA pathogens may present unacceptable risk to high-risk patients

THANK YOU!

www.disinfectionandsterilization.org