CONTINUOUS ROOM DECONTAMINATION TECHNOLOGIES

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Disclosures: Consultant to Germitec, PDI, Merck, Pfizer

CONTINUOUS ROOM DISINFECTION

- Surface disinfectants ("self-disinfecting" surfaces)
  - Heavy metals: Silver, copper, others
  - Persistent disinfectants
  - Others: Altered topography (micro-patterned), polycationic and light-activated antimicrobial surfaces, bacteriophage-modified surfaces
- Remote methods
  - High-intensity narrow-spectrum light
  - UV-A irradiation
  - Low dose continuous hydrogen peroxide

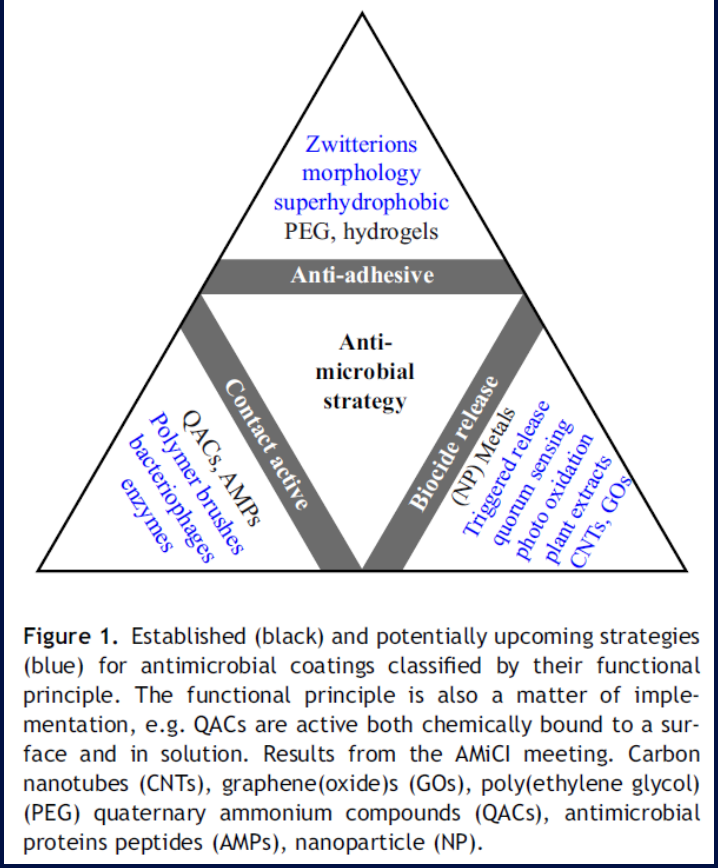


Figure 1. Established (black) and potentially upcoming strategies (blue) for antimicrobial coatings classified by their functional principle. The functional principle is also a matter of implementation, e.g. QACs are active both chemically bound to a surface and in solution. Results from the AMiCI meeting. Carbon nanotubes (CNTs), graphene(oxide)s (GOs), poly(ethylene glycol) (PEG) quaternary ammonium compounds (QACs), antimicrobial proteins peptides (AMPs), nanoparticle (NP).

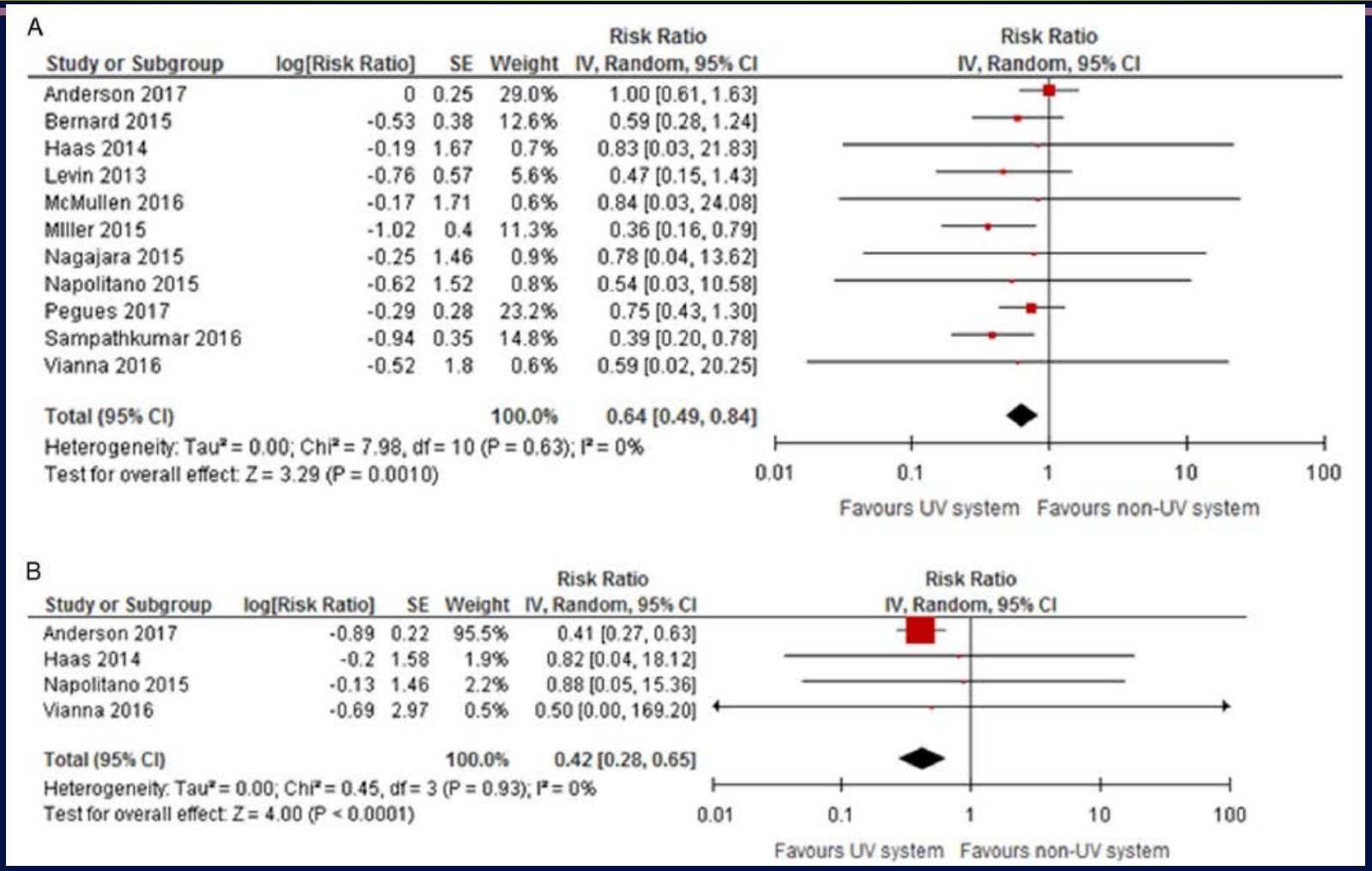
Weber DJ, et al. Curr Opin Infect Dis 2016;29:424-431

Adhart C, et al. JHI 2018 (Epub ahead of print)

RATIONALE FOR DEVELOPING AND IMPLEMENTING CONTINUOUS ROOM DISINFECTION SYSTEMS

- Environmental surfaces in hospital rooms are frequently contaminated with MDROs (e.g., MRSA, VRE, *C. difficile*, *Acinetobacter*)
- Contact with contaminated surfaces leads to contamination of HCP hands and gloves which may lead to person-to-person transmission to other patients
- Failure to clean/disinfect shared equipment may indirectly lead to person-to-person transmission
- No touch methods for terminal disinfection have proven efficacy to reduce HAIs
- Daily cleaning/disinfection superior to periodic cleaning/disinfection for preventing contamination of HCP hands
- However, despite daily cleaning/disinfection, environmental surfaces rapidly recolonize with MDROs
- Continuous room disinfection may reduce the risk of transmission of MDROs between patients

EFFICACY OF UVC AT TERMINAL DISINFECTION TO REDUCE HAIs (A = *C. difficile*, B = VRE)

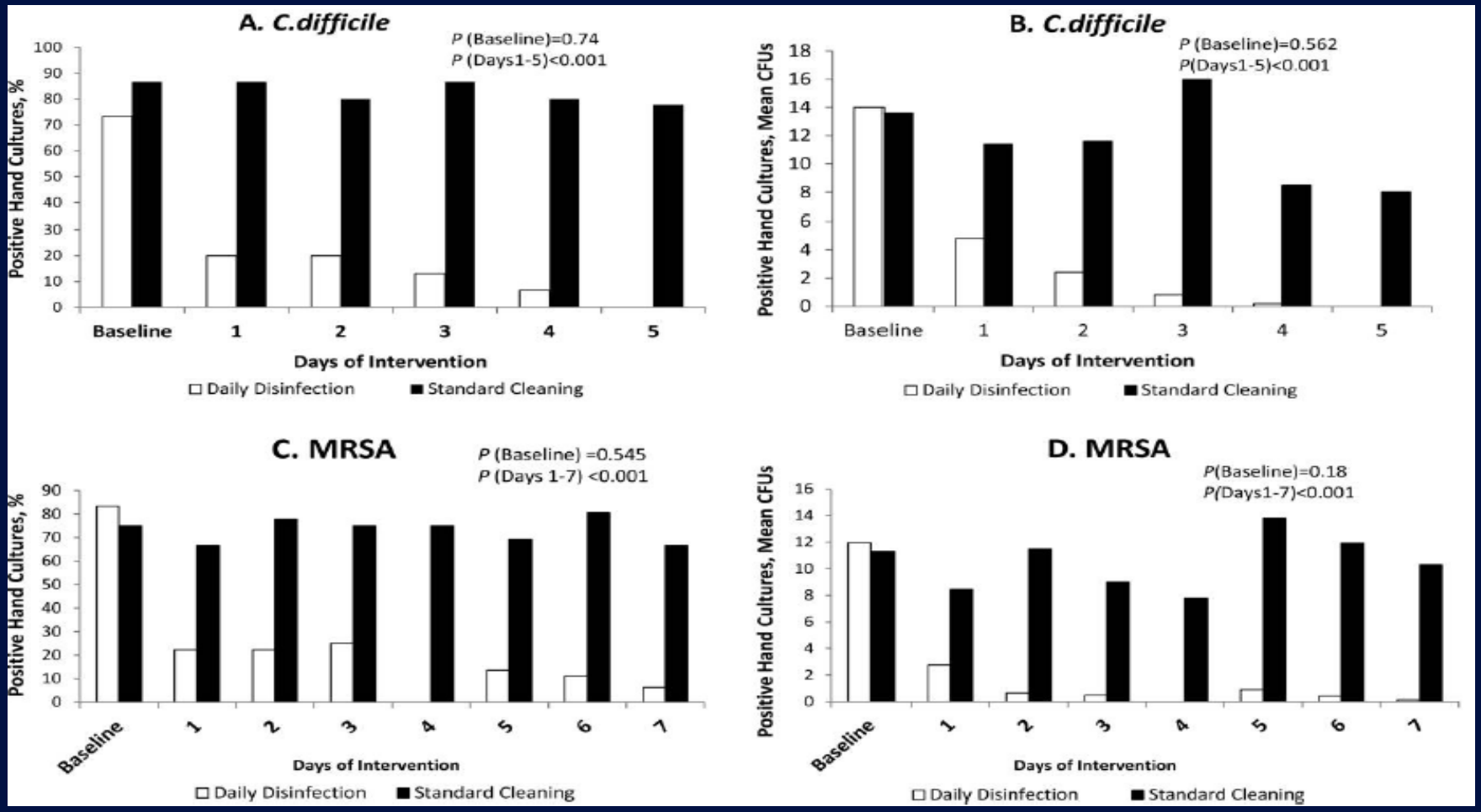


Marra AR, et al. ICHE 2018;39:20-31

ADVANTAGES OF CONTINUOUS ROOM DISINFECTION

- 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

EFFECT OF DAILY CLEANING VERSUS ONLY WHEN SOILED ON CONTAMINATION OF HCP HANDS



Kundrapu S, et al. ICHE 2012;33:1039-1042

EVALUATING "SELF DISINFECTING" OR CONTINUOUS DISINFECTION PROCESSES

- Demonstrating "self disinfecting" surfaces or continuous room disinfection systems are effective
  - Ability to inactivate within a reasonable time period artificially inoculated surfaces with relevant healthcare associated pathogens (i.e., MRSA, VRE, *C. difficile*, norovirus, MDR-GNRs)
  - Ability to inactivate actual hospital room surfaces
  - Demonstrate that inactivation is persistent and not affected by wiping or use of standard surface disinfectants
  - Prospective cluster randomized clinical trials demonstrating decrease in HAIs
- Required background information
  - Level and type of surface contamination in hospital rooms
  - Whether "high touch" surfaces are more contaminated
  - Degree of inactivation of microbes necessary to reduce HAIs

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

CLINICAL TRIALS OF "NO TOUCH" METHODS FOR TERMINAL DISINFECTION

Year, author	Device/system	Study design	Setting	Selected results[a]
2016, Vianna *et al.* [44]	UV-PX	Before–after	Community hospital	Facility wide: ↓*C. difficile*, ↓all MDROs (MRSA, VRE, CDI)
2015, Horn and Otter [45]	HP vapor	Before–after	Hospital	↓CDI, ↓VRE, ↓ESBL GNB
2015, Anderson *et al.* [46]	UV-C	RCT	9 hospitals	↓All MDROs (MRSA, VRE, CDI)
2015, Pegues *et al.* [47]	UV-C	Before–after	Academic center	↓CDI
2015, Nagaraja *et al.* [48]	UV-PX	Before–after	Academic center	↓CDI
2015, Miller *et al.* [49]	UV-PX	Before–after	Nursing home	↓CDI
2014, Mitchell *et al.* [50]	Dry HP vapor	Before–after	Hospital	↓MRSA colonization and infection
2014, Haas *et al.* [51]	UV-PX	Before–after	Academic center	↓CDI, ↓MRSA, ↓VRE, ↓MDRO GNB, all MDROs
2013, Manian *et al.* [52]	HP vapor	Before–after	Community hospital	↓CDI
2013, Passaretti *et al.* [53]	HP vapor	Prospective cohort	Academic center	↓VRE, ↓all MDROs (MRSA, VRE, CDI)
2013, Levin *et al.* [54]	UV-PX	Before–after	Community hospital	↓CDI, ↓MRSA,
2011, Cooper *et al.* [55]	HP vapor	Before–after (2 cycles)	Hospitals	↓CDI (cases; incidence not significant)
2008, Boyce *et al.* [56]	HP vapor	Before–after	Community hospital	↓CDI

CDI, *Clostridium difficile* infection; ESBL, extended spectrum beta-lactamase producers; GNB, Gram negative bacteria; HP, hydrogen peroxide; MDRO, multidrug-resistant organism; MRSA, methicillin-resistant *Staphylococcus aureus*; UV-C, ultraviolet light – C; UV-PX, ultraviolet light – pulsed xenon; VRE, vancomycin-resistant *Enterococcus*.

[a]All listed results were statistically significant (see reference for more details).

Weber DJ,et al. Curr Opin Infect 2016;29:424-431

EVIDENCE THAT ALL TOUCHABLE ROOM SURFACES ARE EQUALLY CONTAMINATED

TABLE 1. Precleaning and Postcleaning Bacterial Load Measurements for High-, Medium-, and Low-Touch Surfaces

Surface (no. of samples)	Mean CFUs/RODAC (95% CI)	
	Precleaning	Postcleaning
High (n = 40)	71.9 (46.5–97.3)	9.6 (3.8–15.4)
Medium (n = 42)	44.2 (28.1–60.2)	9.3 (1.2–17.5)
Low (n = 37)	56.7 (34.2–79.2)	5.7 (2.01–9.4)

NOTE. CFU, colony-forming unit; CI, confidence interval.

Huslage K, Rutala W, Gergen M, Sickbert-Bennett S, Weber D
ICHE 2013;34:211-2

Number of culture sites and prevalence of contamination with nosocomial pathogens in intensive care units (N=523)

Ward	Culture sites[a]			
	HCWs' hands	Surfaces distant from patients	Surfaces close to patients	Prevalence of contamination
A	3/10 (30%)	0/22 (0%)	6/25 (24.0%)	9/57 (15.8%)
B	2/9 (22.2%)	4/19 (21.1%)	5/48 (10.4%)	11/76 (14.5%)
C	2/10 (20%)	2/26 (7.7%)	7/49 (14.3%)	11/85 (12.9%)
D	1/9 (11.1%)	2/24 (18.2%)	7/45 (15.6%)	10/78 (12.8%)
E	0/5 (0%)	4/22 (18.2%)	3/30 (10%)	7/57 (12.3%)
F	1/10 (10%)	0/11 (0%)	4/31 (12.9%)	5/52 (9.6%)
G	0/3 (0%)	2/14 (14.3%)	0/20 (0%)	2/37 (5.4%)
H	1/10 (10%)	0/16 (0%)	1/55 (1.8%)	2/81 (2.5%)
Total	10/66 (15.2%)	14/154 (9.1%)	33/303 (10.9%)	57/523 (10.9%)

HCW, healthcare worker.
[a] Number of contaminated samples/number of samples obtained.

Willi I, Mayre A, Kreidl P, et al.
JHI 2018;98:90-95

RELATIONSHIP BETWEEN MICROBIAL BURDEN AND HAIs

Table 1. Epidemiologically-important pathogens (EIP) by intervention and contamination in 92 patient rooms during the benefits of enhanced terminal room disinfection study.

Room type	Pathogen	Mean CFU/125 cm² (5 Rodacs) per room by treatment type				P-value		
		Quat (N=21 rooms)	Quat/UV (N=28 rooms)	Bleach (N=23 rooms)	Bleach/UV (N=20 rooms)	Quat vs Quat/UV	Quat vs Bleach	Quat vs Bleach/UV
Patient room only	MDR-*Acinetobacter*	8.76	0.18	0.39	0.25			
	C. difficile	0	0.07	0.04	0			
	MRSA	2.33	0.11	2.13	0.05			
	VRE	8.62	0.07	0.78	0.35			
	EIP[a]	19.71	0.43	3.35	0.65	0.013		
Bathroom only	MDR-*Acinetobacter*	0.19	0	0	0	0.018	0.032	0.045
	C. difficile	3.76	2.79	4.43	3.25			
	MRSA	6.19	0	2.26	0.80	0.044		
	VRE	30.95	0.14	1.65	1.55			
	EIP[a]	41.10	2.93	8.35	5.60	0.015		
Patient/Bathroom[b]	MDR-*Acinetobacter*	8.95	0.18	0.39	0.25	0.017	0.035	
	C. difficile	3.76	2.86	4.48	3.25			
	MRSA	8.52	0.11	4.39	0.85	0.032		
	VRE	39.57	0.21	2.43	1.90	0.034		
	EIP[a]	60.81	3.36	11.70	6.25	0.001		

Table 2. Relationship between microbial reduction of epidemiologically-important pathogens (EIP) and colonization/infection in a patient subsequently admitted to a room of a patient colonized/infected with an EIP by decontamination method.

	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

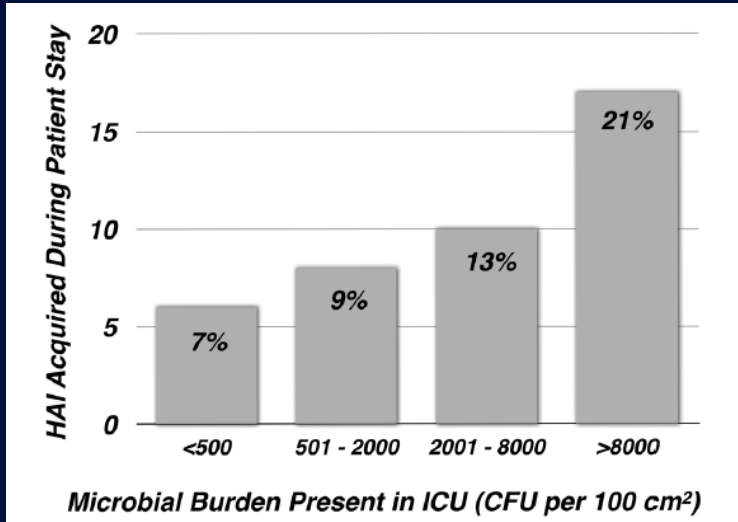


FIGURE 2. Quartile distribution of healthcare-acquired infections (HAIs) stratified by microbial burden measured in the intensive care unit (ICU) room during the patient's stay. There was a significant association between burden and HAI risk ($P = .038$), with 89% of HAIs occurring among patients cared for in a room with a burden of more than 500 colony-forming units (CFUs)/100 cm².

Rutala WW, …Weber D, et al. ICHE (In press)

Salgado CD, et al. ICHE 2013;34:479-86

HEAVY METALS

- Heavy metals comprise ~65 elements; most are either insoluble or rare: >30 potential ly able to interact with microbes: Ag, Gu, Bi, Bi, Co, Cu, Fe, Hg, Mn, Ni, Pb, Pt, Sb, Sn Ti, and Zn
- Silver
  - Highest level of antimicrobial activity of all heavy metals
  - Disrupts disulfide (S-S) and sulfhydryl (S-H) groups in proteins of cell wall
  - Both intrinsic and acquired resistance well described in bacteria
  - Used for coating IV catheters, topical antisepsis (silver nitrate, silver sulfadiazine)
- Copper
  - Essential trace element for most living organisms; >30 types of Cu-containing proteins
  - Increased levels toxic to most microbes because Cu generates reactive oxygen species and acts as a strong soft metal (leading to release of iron from Fe-S clusters)
  - Used to control of *Legionella* in water supplies (Cu-Ag ionization) and to control *Aspergillus* on building materials (copper-8-quinolate)
  - Both intrinsic and acquired resistance well described in bacteria

Weber D, Rutala W. AJIC 2013;41:S31-S35

IN VITRO EFFICACY OF A NOVEL SILVER COMPOUND FOR PERSISTENT SURFACE DISINFECTION

- Goal: Assess the in vitro efficacy of a silver compound (Surfacine) to provide persistent antimicrobial activity {Surfacine incorporates silver iodide in a surface immobilized coating; a modified polyhexamethylene biguanide}
- Design: Treated surfaces challenged with VRE (100 CFU/sq inch) at various time
- Comments: Surfacine could be applied by dipping, brushing or spraying. Adheres to all surfaces, is optically clear, and is not removed by wiping

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%)

[a]Percent reduction of VRE counts per Rodac plate ([treated/control] x 100) (11).

Rutala W, Weber D. Emerg Infect Dis 2001;7:348-353

EFFECTIVENESS OF COPPER-COATED SURFACES IN REDUCING ENVIRONMENTAL CONTAMINATION

- Goal: To assess the efficacy of copper-coating in reducing environmental contamination in an ICU with MDRO endemicity
- Design: Interventional, comparative crossover trial
- Methods:
  - Copper coated surfaces: beds (i.e,. with coated upper, lower, and side rails) and accessories (i.e., coated side table, IV pole stands, side-cart handles)
  - Phase 2a: coated items were placed next to non-coated ones (controls) in both compartments A and B; during Phase 2b, all copper-coated items were placed in compartment A, and all non-coated ones (controls) in compartment B.
- Results:
  - Copper coating reduced percent of contaminated surfaces, percent of MDRO contamination (GNR, enterococci), total bioburden, and GNR bioburden
  - Reductions more pronounced in Phase 2b

Souli M, et al. ICHE 2017;38:765-771

EFFECTIVENESS OF COPPER-COATED SURFACES IN REDUCING ENVIRONMENTAL CONTAMINATION

	Copper-Coated Surfaces (n = 311)	Standard (Noncopper) Surfaces (n = 374)	*P* Value[b]
Study Phase 2			
Colonized surfaces, no. (%)	173 (55.6)	271 (72.5)	**<.0001**
Surfaces with Gram-negative bacteria, no. (%)	43 (13.8)	85 (22.7)	**.003**
Surfaces with *Enterococcus* spp., no. (%)	4 (1.3)	17 (4.5)	**.014**
Surfaces with *A. baumannii*, no. (%)	28 (9)	51 (13.6)	.07
Surfaces with *K. pneumoniae*, no. (%)	1 (0.3)	5 (1.3)	.156
Surfaces with *S. aureus*, no. (%)	2 (0.6)	1 (0.3)	.466
Bacterial colonies, mean cfu/100 cm^2 (± SD)	2,858 (±8,662)	7,631 (±30,642)	**.008**
Colonies of Gram-negative bacteria, mean cfu/100 cm^2 (± SD)	261 (±1,380)	1,266 (±8,893)	**.049**
Study Phase 2a			
	Copper-Coated Surfaces (*n* = 130)	Standard (Noncopper) Surfaces (*n* = 217)	*P* Value[b]
Colonized surfaces, no. (%)	93 (71.5)	166 (76.5)	.311
Surfaces with Gram-negative bacteria, no. (%)	19 (14.6)	51 (23.5)	.053
Surfaces with *Enterococcus* spp., no. (%)	1 (0.8)	5 (2.3)	.417
Surfaces with *A. baumannii*, no. (%)	12 (9.2)	27 (12.4)	.386
Surfaces with *K. pneumoniae*, no. (%)	0	2 (0.9)	.272
Surfaces with *S. aureus*, no. (%)	0	0	…
Bacterial colonies, mean cfu/100 cm^2 (± SD)	3,225 (±8,961)	5,425 (±15,016)	.131
Colonies of Gram-negative bacteria, mean cfu/100 cm^2 (± SD)	257 (±1,315)	1,159 (±8,619)	.237
Study Phase 2b			
	Copper-Coated Surfaces (*n* = 181)	Standard (Noncopper) Surfaces (*n* = 157)	*P* Value[b]
Colonized surfaces, no. (%)	80 (44.2)	105 (66.4)	**<.001**
Surfaces with Gram-negative bacteria, no. (%)	24 (13.3)	34 (21.7)	**.044**
Surfaces with *Enterococcus* spp., no. (%)	3 (1.7)	12 (7.6)	**.014**
Surfaces with *A. baumannii*, no. (%)	16 (8.8)	24 (15.3)	.091
Surfaces with *K. pneumoniae*, no. (%)	1 (0.6)	3 (1.9)	.249
Surfaces with *S. aureus*, no. (%)	2 (1.1)	1 (0.95)	.186
Bacterial colonies, mean cfu/100 cm^2 (± SD)	2,594 (±8,455)	10,680 (±43,780)	**.015**
Colonies of Gram-negative bacteria, mean cfu/100 cm^2 (± SD)	263 (±1,427)	1,414 (±9,283)	.101

SELECTED CLINICAL TRIALS ASSESSING EFFICACY OF COPPER TO REDUCE HAIs

Author, Year	Setting	Study Design	Microbes	Coated Surfaces	Outcomes (Cu vs Control)	Assessment of HH Compliance	Assessment of EVS Cleaning	Other HAI Preventive Initiatives
Von Dessauer, 2016	PICU, PIMCU	Quasi-experimental	All HAI	Bed rails, bed rail levers, IV poles, sink handles, nurses' work station	HAI (RR, 0.81; P = NS)	Yes	No	Not mentioned
Sifri, 2016	Acute-care units	Quasi-experimental (ie, before and after)	MDRO, *C. difficile*	Countertops (eg, sink), overbed table, bed rails plus Cu-impregnated linens	HAI (RR, 0.22; P = .023) *C. difficile* (RR, .017; P = .48) MDRO (RR, 0.32 P = NS)	Yes	No	Yes
Salgado, 2013	ICU	RCT	All HAI pathogens, MRSA, VRE	6 items: bed rails, overbed table, IV poles, arms visitor's chair, plus 2 of nurses' call button, computer mouse, bezel touchscreen monitor, computer palm rest	HAI (RR, 0.42; P = .013) MRSA or VRE colonization (RR, 0.36; P = .063)	No	No	Not mentioned

NOTE. Cu, copper; HH, hand hygiene; EVS, environmental service; HAI, healthcare-associated; RR, relative risk; PICU, pediatric intensive care unit; PIMCU, pediatric intermediate care unit; IV, intravenous; NS, not significant; MRSA, methicillin-resistant *Staphylococcus aureus*; VRE, vancomycin-resistant *Enterococcus* spp; RCT, randomized clinical trial.

Weber DJ, Rutala WA. ICHE 2017;38:772-776

EFFICACY OF COPPER-COATED SURFACES TO REDUCE HAIs

- Goal: Evaluation of copper-coated surfaces to reduce HAIs
- Design: Intention-to-treat trial in 3 ICUs
- Methods: Patients were randomly placed in available rooms with or without copper alloy surfaces, and the rates of incident HAI and/or colonization with MRSA or VRE in each type of room were compared.
  - Coated surfaces: bed rails, over-bed table, IV poles, visitor chair arms plus 2 of the following – nurse call button, computer mouse, bezel touch screen, computer hand rest
- Results: The rate of HAI and/or MRSA or VRE colonization in ICU rooms with copper alloy surfaces was significantly lower than that in standard ICU rooms (0.071 vs 0.123, p=0.020). For HAI only, the rate was reduced from 0.081 to 0.034 (P=0.013).
  - Copper coated rooms: BSI, 3; pneumonia, 10; UTI 4, other, 0 (total = 17)
  - Non-copper rooms: BSI, 11; pneumonia , 8; UTI, 5; other, 5 (total = 29)

Salgado D, et al. ICHE 2013;34:479-486

ADVANTAGES AND LIMITATIONS OF COPPER-COATED SURFACES FOR CONTINUOUS DISINFECTION

Potential Advantages

- Demonstrated *in vitro* microbicidal effectiveness including sporicidal activity
- Demonstrated ability to reduce the level and frequency of bacterial contamination on copper-coated surfaces in patient rooms
- Adverse reactions to contact with copper-coated surfaces very uncommon
- Provides continuous disinfection of copper-coated surfaces (ie, unlike ultraviolet devices and hydrogen peroxide systems, its use is not limited to terminal disinfection)

Potential Limitations and Deficiencies in the Scientific Literature

- Unclear how many and which surfaces must be coated
- Likelihood and frequency of development of reduced susceptibility to copper in healthcare-associated pathogens not well studied
- Only limited data that use of copper-coated surfaces will reduce healthcare-associated infections. Further, existing clinical trials have potential design flaws (ie, none assessed environmental cleaning effectiveness)
- Available in vitro studies and clinical trials have evaluated a variety of types of copper coatings (ie, no agreement best method to use)
- Cost of purchasing copper-coated surfaces not described in the scientific literature
- Durability of copper-coated surfaces in patient rooms poorly described
- Cost-effectiveness of using copper-coated surfaces to reduce healthcare-associated pathogens not available

Weber DJ, Rutala WA. ICHE 2017;38:772-776

ACTIVITY OF SELF-DISINFECTING SURFACES AGAINST *S. AUREUS*

- Goal: Assess activity of 5 different self-disinfecting surfaces against *S. aureus* under real-world conditions using dry inoculation method
- Surfaces studied: Micro-patterned (MP) – Antimicrobial = Zinc molybdenum (ZM), polyguanidin silica (PS), membrane-active polycations (maPK-i, maPK-a)
- Results (effective = $\geq$2-log$_{10}$ reductions): MP, maPK-I, maPK-a – activity ceased after disinfection with alcohol wipe (Bruhwasser C, et al. JHI 2017;97:196-199)

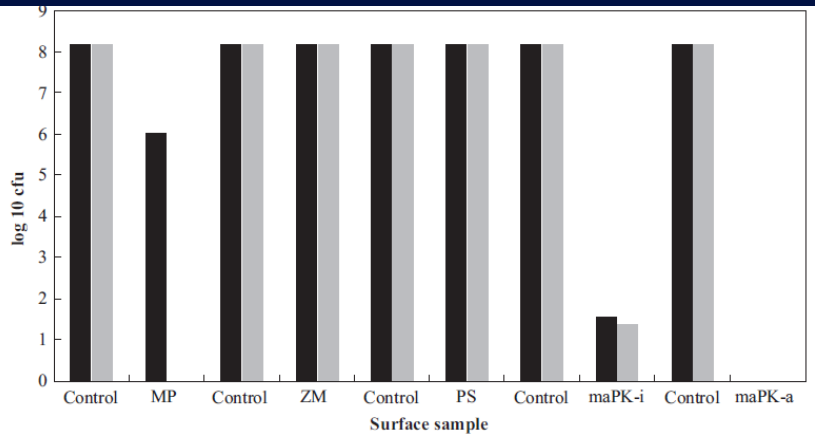


Figure 1. Log 10 of colony-forming units (cfu) of *Staphylococcus aureus* affected by self-disinfecting surfaces after 15 min (black bars) and 3 h (grey bars) of contact time. Micro-patterned (MP), membrane-active polycations incorporated (maPK-i) and membrane-active polycations acrylate (maPK-a) surfaces showed an antimicrobial effect on *Staphyococcus aureus* (activity defined as log10 reduction factor $\geq$2). PS, polyguanidin silica; ZM, zinc molybdenum.

Effect of various self-disinfecting surfaces on *Staphylococcus aureus* ATCC 6538

Surface variation	PAE	RG	RG[a]
Control	–	–	–
MP	–	+	–
ZM	–	–	–
PS	+	–	–
maPK-i	–	+	–
maPK-a	–	+	+[b]

PAE, postantibiotic effect; RG, reduction of growth; MP, micro-patterned; ZM, zinc molybdenum; PS, polyguanidin silica; maPK-i, membrane-active polycations incorporated; maPK-a, membrane-active polycations acrylate; +, yes; –, no.

[a] Following surface disinfection.

[b] Remained stable for 19 disinfection cycles.

EFFICACY OF TITANIUM DIOXIDE (TiO_2) COATING TO REDUCE SURFACE CONTAMINATION

- Goal: Assess efficacy of TiO_2 coating (also contains Ag) of all surfaces to reduce microbial contamination in an ICU
- Methods: Pre- post-intervention prospective, single center study
- Results:
  - CFU difference pre- post- was (0.86-log_{10})
  - Week 4 difference = -0.47

  (95% CI, -0.24 to -0.70)
  - Discoloration noted
- Conclusion = TiO_2 had no effect on microbial colonization of ICU surfaces

Number of colony-forming units per room (mean) for three types of RODAC plates and mean ratios (with standard deviation) per room for the post-intervention period vs the pre-intervention period

RODAC plates	Pre-intervention period	Post-intervention period	Mean ratio/room
Staphylococcus aureus	116	65	0.71 (0.38)
Enterobacteriaceae	0	0	0.25 (0.50)
Non-selective	161	121	0.94 (0.64)
Total	276	187	0.86 (0.57)

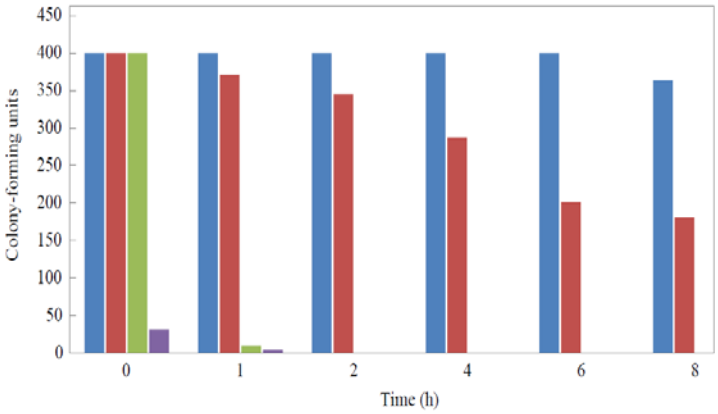


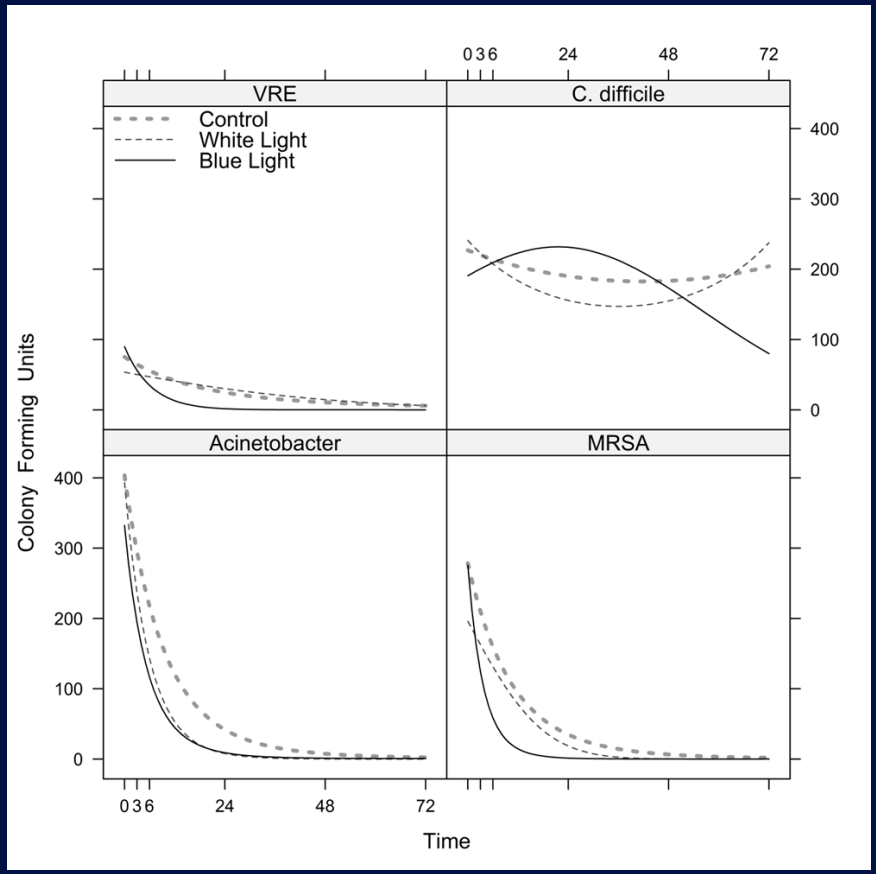
Figure 1. Number of colony-forming units (mean) for *Staphylococcus aureus* and *Escherichia coli* on plastic samples without (controls) or with MVX coating. Blue bars, control sample, *S. aureus*; red bars, MVX-coated sample, *S. aureus*; green bars, control sample, *E. coli*; purple bars, MVX-coated sample, *E. coli*.

ANTIMICROBIAL ACTIVITY OF A CONTINUOUS VISIBLE LIGHT DISINFECTION SYSTEM

- Goal: To evaluate the ability of high-intensity visible violet light with a peak output of 405nm to kill epidemiologically-important pathogens
- Methods (*in vitro* study): An overhead, visible light disinfection technology (Indigo-Clean, Kenall Manufacturing, Kenosha, WI, 53144) was evaluated in two different clinical configurations.
  - Phase 1 ("white" lights), two 2'x2' blended-white, ceiling-mounted fixtures were used to provide disinfection and ambient white illumination for use in normal clinical conditions in an occupied room (surface irradiance ~0.12-0.16 mW/cm^2).
  - Phase 2 ("blue" light), a higher-level of disinfection light was studied by adding a 2'x4' overhead "blue" light fixture to the two preexisting 2'x2' overhead, blended-white fixture (surface irradiance ~0.34-0.44 mW/cm^2).
  - Test organisms: MRSA, *C. difficile*, MDR-*Acinetobacter*, VRE
  - We fit a mixed effects negative binomial model to the data.
- Results: The treatment (i.e., both blue and white light) had significantly different rates of pathogen killing over time for all four organisms: *Acinetobacter* ($\chi 2=117.2$, df=4, $p<0.001$), MRSA ($\chi 2=80.5$, df=4, $p<0.001$), VRE ($\chi 2=150.4$, df=4, $p<0.001$), and *C. difficile* ($\chi 2=25.8$, df=4, $p<0.001$)

Rutala WA, Kanamori H, Gergen M, Sickbert-Bennett E, Sexton D, Anderson D, Laux J, Weber DJ. APIC 2017

ANTIMICROBIAL ACTIVITY OF A CONTINUOUS VISIBLE LIGHT DISINFECTION SYSTEM (Indigo-Clean)



The models predicted number of colony forming units of vancomycin-resistant *Enterococcus*-VRE (A), *C. difficile* (B), MDR-*Acinetobacter* (C), and methicillin-resistant S. aureus-MRSA (D) under the "blue", "white" and control lights (see Methods). The curves are drawn continuously over the temporal interval from 0 to 72 hours, however in the experiment, the actual time points when the CFUs were counted were at 0, 1, 3, 5, 6, 7, 24, 48, and 72 hours. Because the model treats time as continuous, we are able to get predicted values for any time point between 0 and 72.

Rutala WA, Kanamori H, Gergen M, Sickbert-Bennett E, Sexton D, Anderson D, Laux J, Weber DJ. APIC 2017

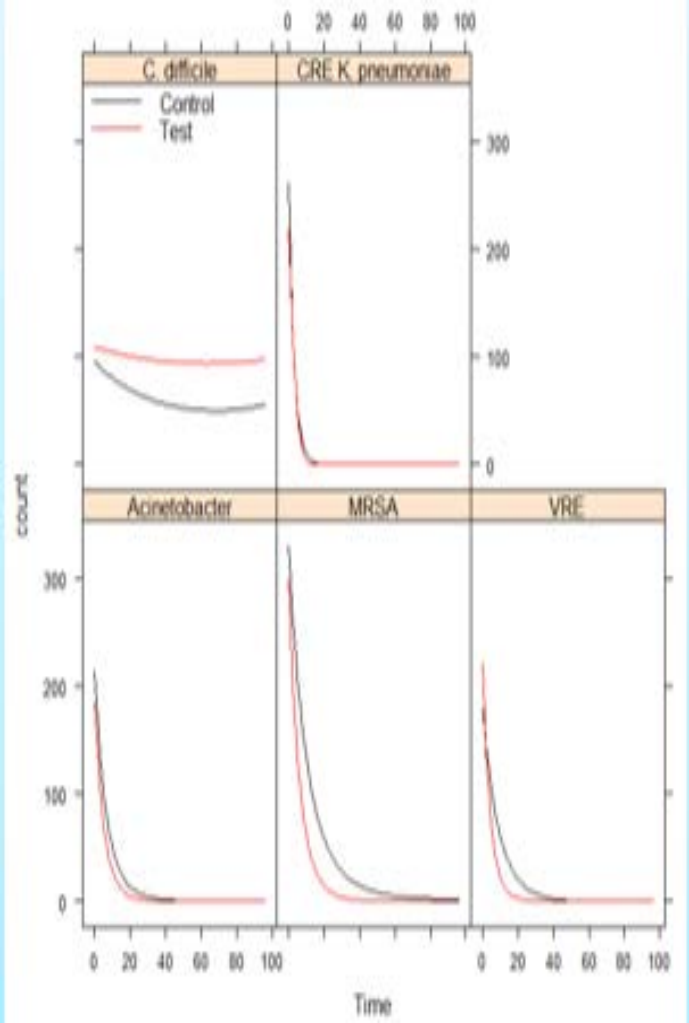
ANTIMICROBIAL ACTIVITY OF A CONTINUOUS VISIBLE LIGHT DISINFECTION SYSTEM

Time (least number of hours) to achieve sustained microbial reduction

Pathogen	Treatment (light)	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

Rutala WA, Kanamori H, Gergen M, Sickbert-Bennett E, Sexton D, Anderson D, Laux J, Weber DJ. APIC 2017

Inactivation of Health Pathogens by Continuous Visible Light Disinfection (Vital-Vio)



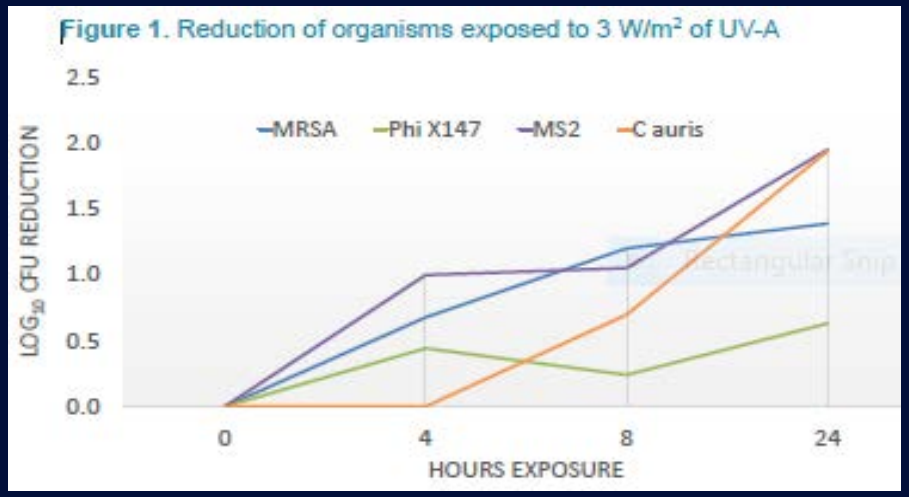
- Compared to control, the LED treatment led to a significant decline for MRSA ($p<0.001$), VRE ($p<0.001$), and MDR-*Acinetobacter* ($p<0.001$) but there is insufficient evidence that the treatment made a difference in the mean CFUs of CRE *K. pneumoniae* and *C. difficile*.
- This technology may have promise for decontamination of the healthcare environment.

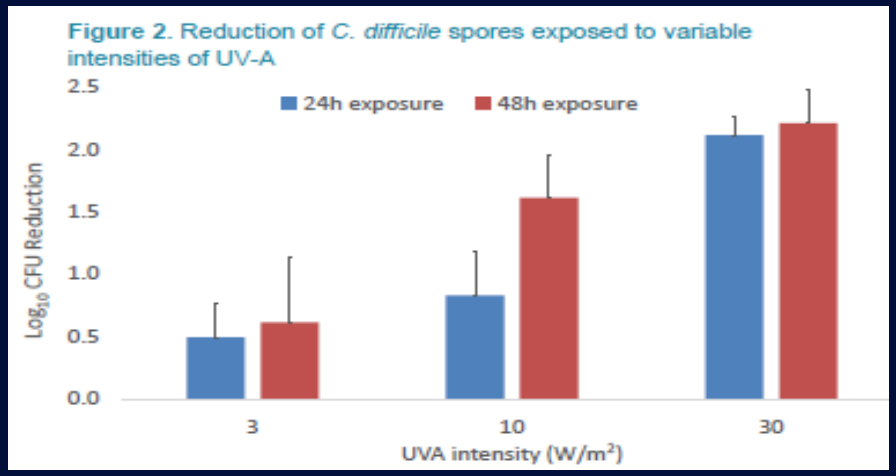
Rutala, Kanamori, Gergen et al. ID Week 2017

ANTIMICROBIAL ACTIVITY OF A CONTINUOUS VISIBLE LIGHT DISINFECTION SYSTEM

- Advantages
  - 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-small log reduction (is it enough?)
  - Capital equipment costs are substantial

Efficacy of UV-A Light System





- UV-A (315-400nm) proposed as a safe method to provide continuous disinfection of surfaces while patients and staff are in the room
- At 3W/m^2 of UV-A light was effective in reducing MRSA, *E. coli* and MS2
- At higher intensities (10, 30 W/m2), UV-A also effective against *C. difficile* spores

Livingston, et al, SHEA Poster 2018

Application of Dilute Hydrogen Peroxide Technology for Continuous Room Decontamination

- HPH units were installed in ceilings of a model room and the hallway in front of the room. We tested 3 test organisms: MRSA, VRE, and MDR-*Acinetobacter*
- An estimated 100-500 CFU for each test organisms was inoculated and spread on each Formica sheet then exposed to the DHP gas released into the room air
- Triplicate samples were collected at times 0, 1, 3, 5, 6, 7, 24, and 48 hours
- Following incubation, the CFU of the test organisms on each Rodac plate were counted
- Two separate experimental trials were performed for all time points.
- Statistical significance between intervention and control groups at each time point was determined by the Wilcoxon test

Application of Dilute Hydrogen Peroxide Technology for Continuous Room Decontamination

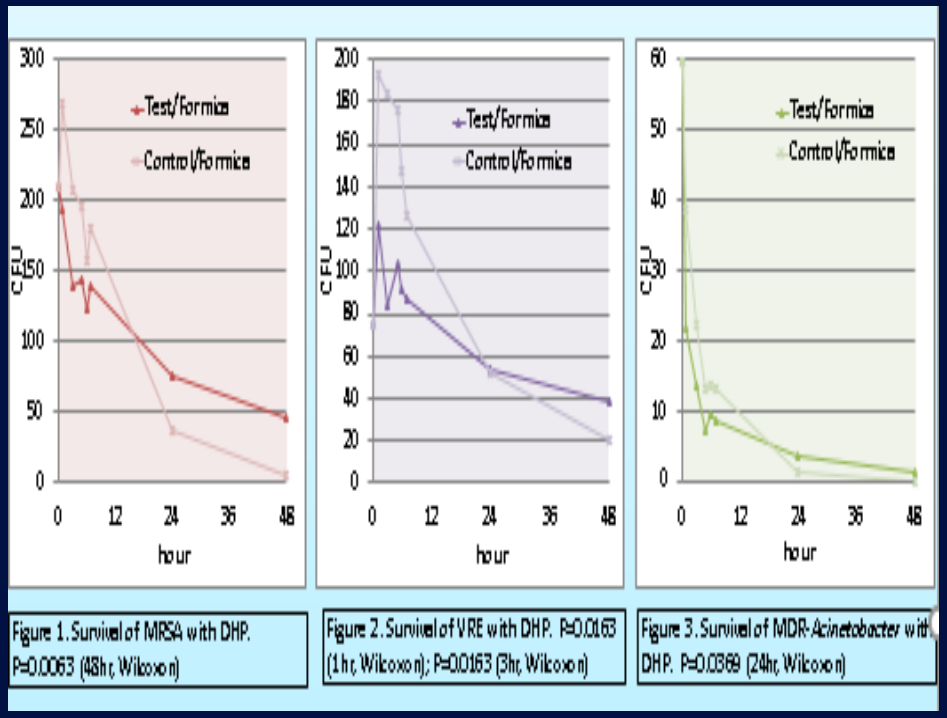


Figure 1. Survival of MRSA with DHP. P=0.0063 (48hr, Wilcoxon)

Figure 2. Survival of VRE with DHP. P=0.0163 (1hr, Wilcoxon); P=0.0163 (3hr, Wilcoxon)

Figure 3. Survival of MDR-*Acinetobacter* with DHP. P=0.0369 (24hr, Wilcoxon)

- There were no statistical differences in survival between the DHP intervention and control groups except for very few time points
- Our preliminary study using DHP demonstrated inconsistent microbiocidal activity against MDRO on room surfaces, likely because we were unable to generate sufficient germicidal level under our test conditions

Rutala W, Kanamori H, Gergen M, Weber D. IDweek 2017

SURFACE DISINFECTANTS: PERSISTENCE

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

Rutala W, White M, Gergen M, Weber D. ICHE 2006;27:372-77

EFFICACY OF A PERSISTENT CHEMICAL DISINFECTANT

- Goal: Assess the persistent antimicrobial activity of a novel disinfectant
- Methods: Surfaces were inoculated , treated with the novel disinfectant, allowed to dry, and then abraded using a standardized abrasion machine under multiple alternating wet and dry wipe conditions (N=12) interspersed with 6 re-inoculations. After 24 hours, the surface was re-inoculated a final time and ability of the disinfectant to kill >99.9% of 9 test microbes within 5min was measured on 3 test surfaces (glass, Formica, and stainless steel).
- The novel persistent disinfectant proved successful decontamination against a variety of pathogens

Test Pathogen	Mean Log_{10} Reduction, 95% CI n=4
*S.aureus**	4.4 (3.9, 5.0)
S.aureus (formica)	4.1 (3.8, 4.4)
S.aureus (stainless steel)	5.5 (5.2, 5.9)
VRE	≥4.5
E.coli	4.8 (4.6, 5.0)
Enterobacter sp.	4.1 (3.5, 4.6)
Candida auris	≥5.0
K pneumoniae	1.5 (1.4, 1.6)
CRE *E.coli*	3.0 (2.6, 3.4)
CRE *Enterobacter*	2.0 (1.6, 2.4)
CRE *K pneumoniae*	2.1 (1.8, 2.4)

Rutala W, Gergen M, Sickbert-Bennett E, Anderson D, Weber D. Unpublished.

CONCLUSIONS

- Continuous room disinfection strategies (e.g., self-disinfecting surfaces, remote room units) show great promise
- Likely >2-$\log_{10}$ inactivation will be sufficient to reduce the risk of contamination of HCP hands, surfaces, and equipment
- Multiple strategies are under study – no clear superior device/method at this time
- No device/method has convincingly demonstrated reduction of HAIs

THANK YOU!!