PANEL IV: BUILDING ENVIRONMENT AND USING EM/LIGHT – OVERVIEW & BEST PRACTICES AND USE OF EM/LIGHT TO DATE, GAPS IN RESEARCH

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EVIDENCE THAT ENVIRONMENTAL CONTAMINATION LEADS TO PATIENT ACQUISITION OF MDROs AND THAT IMPROVED TERMINAL CLEANING/DISINFECTION REDUCES HAIs

- Surfaces are contaminated-~25-50% multidrug-resistant organisms (MDROs)
- MDROs survive days to months
- Rooms not adequately cleaned (i.e., <50% cleaned)
- Rooms are frequently contaminated post-terminal disinfection
- Disinfection reduces contamination
- Contact with surfaces results in hand/glove contamination
- Improved terminal disinfection reduces HAIs
- Enhanced terminal disinfection (e.g., UV-C devices) reduces risk of MDR colonization/infection in subsequent patient admitted to the room
- Enhanced terminal disinfection of rooms with a colonized or infected patient may lead to hospital-wide decrease in HAIs

Weber D, Kanamori H, Rutala W. Curr Op Infect Dis 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

INCREASING BIOBURDEN ASSOCIATED WITH INCREASED HAIs: DECREASED BIOBURDEN ASSOCIATED WITH DECREASED 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

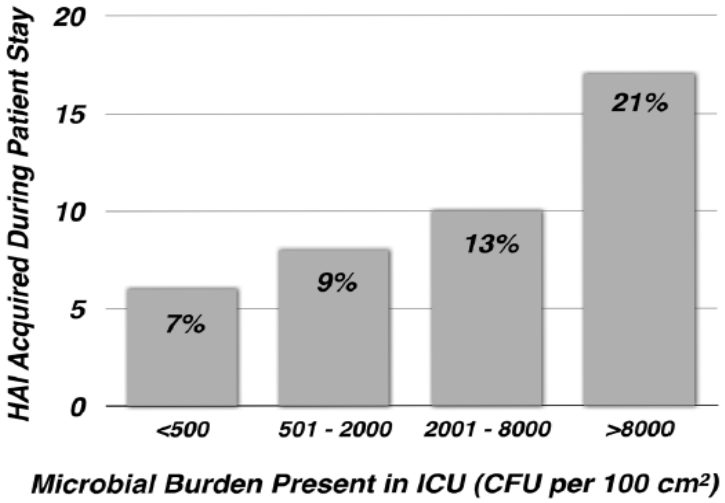


FIGURE 2. Quartile distribution of healthcare-acquired infections (HAIs) stratified by microbial burden measured in the intensive care unit (ICU) room during the patient's stay. There was a significant association between burden and HAI risk ($P = .038$), with 89% of HAIs occurring among patients cared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

Rutala WA, ….Weber DJ. ICHE 2018;39:1118-1121

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

FACTORS AFFECTING UV ROOM DISINFECTION DEVICE EFFECTIVENESS

- Intensity of UV delivered (i.e., energy)
- Wavelength of UV
- Distance (energy delivered falls off as a square of distance)
- Duration of exposure
- Orientation of the surface being disinfected to the UV light (UV energy delivered is line of sight)
  - For shadowed surfaces, UV reflectivity of walls
- Intrinsic susceptibility of microbes (e.g., spore formers such as *C. difficile* more difficult to inactivate than vegetative bacteria such as MRSA and VRE
- Study variables: 1) spreading the inoculum over a greater surface area enhances killing; 2) organic load (e.g., 10% fetal calf serum) significantly decreases killing; 3) test surface does not affect killing (e.g., Formica, glass, steel)
- UV device options: 1) Room disinfection units; 2) Portable handheld units; 3) Shielding around patient beds allowing use of a UV device in a multi-bed room

Adapted from, Cadnum JL, et al. ICHE 2016;37:555-560

VALIDATING UV DEVICES FOR ROOM DISINFECTION

- Progression of studies
  - Studies demonstrating microbial inactivation on artificially contaminated surfaces (assessing all UV variables)
  - Studies demonstrating microbial inactivation on contaminated surfaces in healthcare facilities
  - Studies demonstrating reduction in HAIs
- Types of epidemiologic studies: 1) Efficacy; 2) Effectiveness; 3) Efficiency
- Factors that should be measured (ideally) for efficacy/effectiveness studies: 1) Colonization of patients; 2) Infection in patients; 3) Confounders (hand hygiene compliance, cleaning compliance; 4) Cost; 4) Delays in admission to the room; 5) Transmission pathways of microbes (requires molecular techniques)
- Issues in study design: 1) Non-independence of outcomes; 2) Controlling for confounding; 3) HAIs are now low frequency events
- A key question: Are all UV room disinfection devices similar or do we need validation of each device

CLINICAL TRIALS OF "NO TOUCH" METHODS FOR TERMINAL DISINFECTION

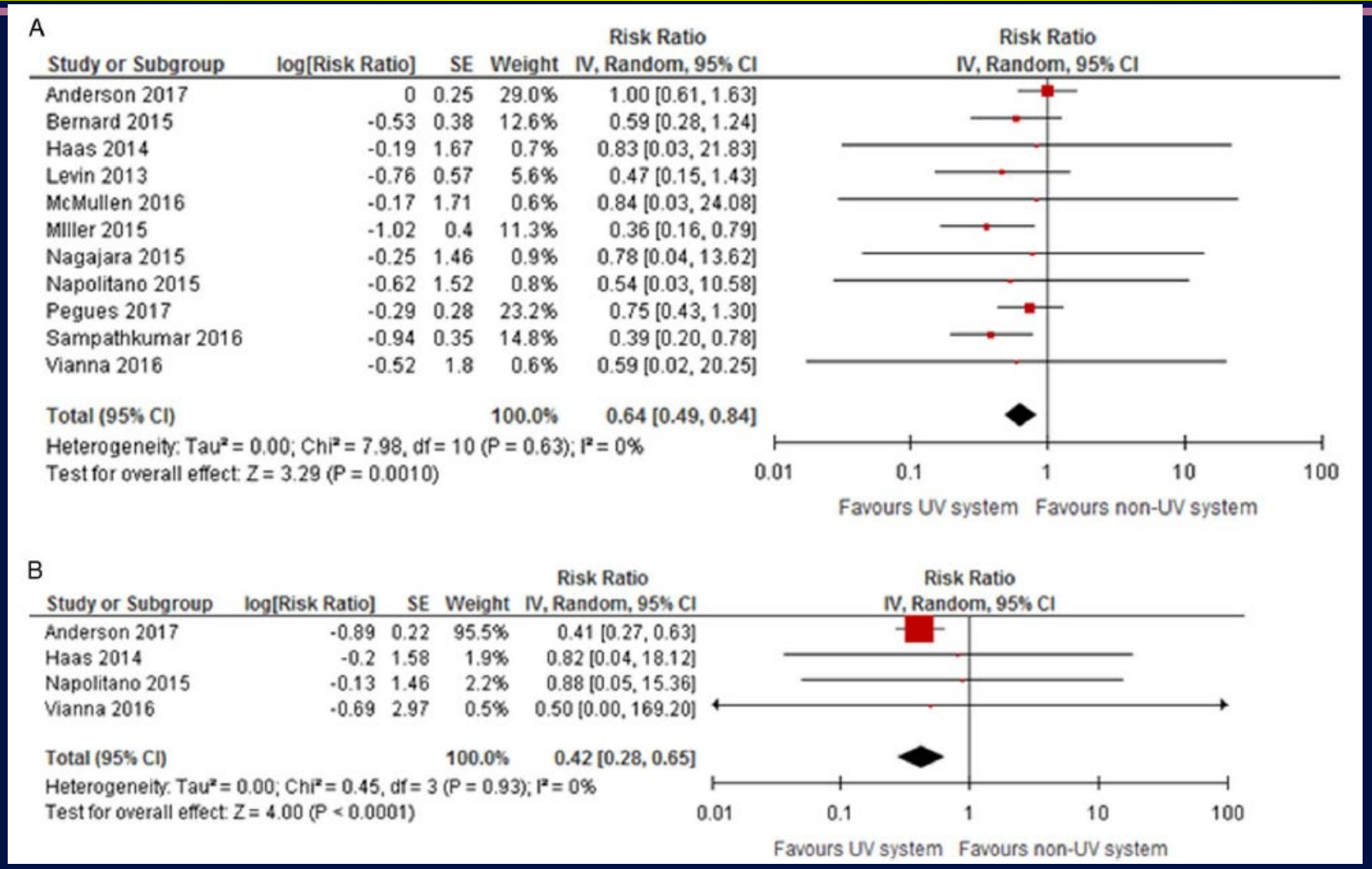
Year, author	Device/system	Study design	Setting	Selected results[a]
2016, Vianna *et al.* [44]	UV-PX	Before–after	Community hospital	Facility wide: ↓*C. difficile*, ↓all MDROs (MRSA, VRE, CDI)
2015, Horn and Otter [45]	HP vapor	Before–after	Hospital	↓CDI, ↓VRE, ↓ESBL GNB
2015, Anderson *et al.* [46]	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

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



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

EFFECTIVENESS OF TARGETED ROOM DISINFECTION ON HOSPITAL-WIDE ACQUISITION AND INFECTION WITH TARGET PATHOGENS: A SECONDARY ANALYSIS OF THE BETR STUDY

- Goal: To assess the effectiveness of enhanced terminal disinfection on hospital-wide, hospital-acquired incidence of all target organisms
- Methods:
  - Pathogens of interest: MRSA, VRE, *C. difficile*, MDR-*Acinetobacter* (target organisms)
  - Outcome: Incidence of target organisms (patients with HAI due to target organism per 10,000 patient days)
- Findings
  - Enhanced terminal room disinfection with UV in a targeted subset of high-risk rooms led to a decrease in hospital-wide incidence of *C. difficile* and VRE. Enhanced disinfection overcomes limitations of standard disinfection strategies and is a potential strategy to reduce the risk of acquisition of multidrug-resistant organisms and *C. difficile*

Anderson SJ, Moehring RW, Weber DJ, et al. Lancet Infect Dis2018;389:845-53

	All patients in categories 1 and 2		Did not enter a seed room (category 1)	Entered a seed room (category 2)
Clostridium difficile				
Non-UV disinfection strategy groups	729/779 049; 9·36	RR .89	695/757 193; 9·18	34/21 856; 15·6
UV disinfection strategy groups	592/739 048; 8·01	P=0.031	583/730 619; 7·98	9/8429; 10·7
Individual disinfection strategy groups				
Reference	372/369 737; 10·1		353/358 875; 9·84	19/10 862; 17·5
UV	303/370 199; 8·18		296/365 100; 8·11	7/5099; 13·7
Bleach	357/409 312; 8·72		342/398 318; 8·59	15/10 994; 13·6
Bleach and UV	289/368 849; 7·83		287/365 519; 7·85	2/3330; 6·01
Meticillin-resistant *Staphylococcus aureus*				
Non-UV disinfection strategy groups	434/753 385; 5·76		365/690 566; 5·29	69/62 819; 11·0
UV disinfection strategy groups	394/716 204; 5·50		360/687 624; 5·24	34/28 580; 11·9
Individual disinfection strategy groups				
Reference	204/357 479; 5·71		171/327 342; 5·22	33/30 137; 11·0
UV	208/358 995; 5·79		191/344 721; 5·54	17/14 274; 11·9
Bleach	230/395 906; 5·81		194/363 224; 5·34	36/32 682; 11·0
Bleach and UV	186/357 209; 5·21		169/342 903; 4·93	17/14 306; 11·9
Vancomycin-resistant enterococci				
Non-UV disinfection strategy groups	304/777 649; 3·91		235/750 260; 3·13	69/27 389; 25·2
UV disinfection strategy groups	208/739 366; 2·81	RR .56	188/728 617; 2·58	20/10 749; 18·6
Individual disinfection strategy groups		P=0.048		
Reference	119/370 344; 3·21		96/358 867; 2·68	23/11 477; 20·0
UV	89/371 767; 2·39		79/367 108; 2·15	10/4659; 21·5
Bleach	185/407 305; 4·54		139/391 393; 3·55	46/15 912; 28·9
Bleach and UV	119/367 599; 3·24		109/361 509; 3·02	10/6090; 16·4

Data are number of patients per number of patient days; incidence per 10 000 patient days. UV=ultraviolet light. Bleach=bleach-containing disinfectant (10% hypochlorite).

Table 3: Post-hoc analysis of patients who did not enter a room disinfected with UV

"NO TOUCH" ROOM DECONTAMINATION: ADVANTAGES AND DISADVANTAGES OF UV DEVICES AND HP SYSTEMS

Advantages

- Reliable biocidal activity against a wide range of pathogens (UV, HP)
- Surfaces and equipment decontaminated (UV, HP)
- Demonstrated effectiveness to reduce HAIs in before-after studies (UV, HP) and randomized clinical trial (UV)
- Residual free and does not give rise to health and safety concerns (UV, HP)

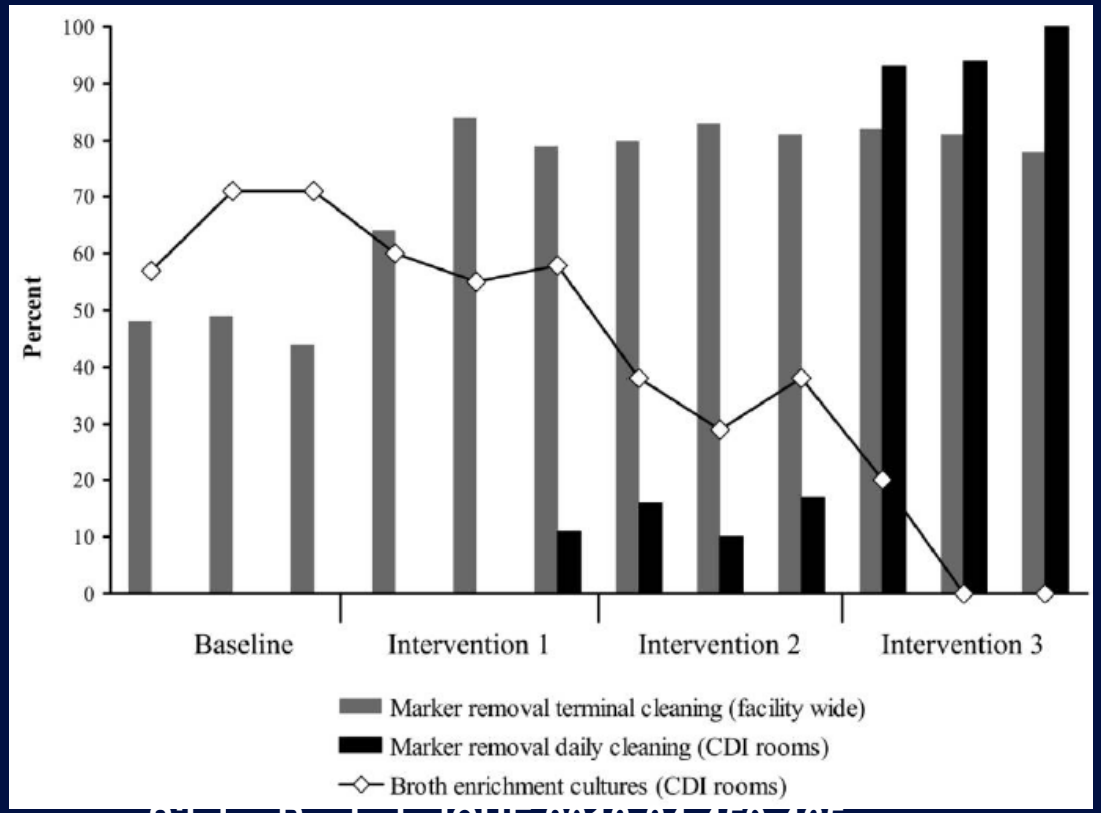
Differences and disadvantages

- Can only be done for terminal disinfection (UV, HP)
- All patients and staff must be removed from room (UV, HP)
- Time: UV=5-15 min (vegetative bacteria), 10-45 min (*C. difficile*); HP=1.5-2.5 hr
- UV requires direct or indirect line of sights unlike HP
- HP requires the HVAC system be sealed off unlike UV
- Substantial capital equipment costs (UV, HP)
- Does not remove dust and stains which are important to patients/visitors (UV, HP)

Weber DJ and Rutala WA. (unpublished)

VALUE OF SEQUENTIAL INTERVENTIONS TO IMPROVE DISINFECTION OF *C. difficile* ROOMS

- Design: Prospective intervention
- Interventions
  - 1. Fluorescent markers used to provide monitoring and feedback on cleaning
  - 2. UV irradiation used for terminal disinfection of CDI rooms
  - 3. Enhanced disinfection of CDI rooms including dedicated daily disinfection team
- Results
  - Cleaning improvement: 47%→87%
  - Reduction CDI positive cultures: 67% (baseline)→57% (1) →35% (2)→7% (3)



Sitzlar B, et al. ICHE 2013;34:459-465

EFFECTIVENESS OF COPPER-COATED SURFACES IN REDUCING ENVIRONMENTAL CONTAMINATION

Goal: To assess ability of CU to reduce surface colonization

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

	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

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

FUTURE RESEARCH NEEDS:
ROOM DISINFECTION USING UV, DEMONSTRATING EFFECTIVENESS

- IDSA Guideline on *C. difficile* ():
  - "There are limited data at this time to recommend use of automated, terminal disinfection using a sporicidal method for CDI prevention (no recommendation)"
  - Study limitations: "before–after study designs, inappropriate statistical methods to analyze the data, other concurrent interventions, high baseline incidence of CDI prior to implementation, reduction of CDI back to baseline prior to no-touch technology implementation, and reductions driven by results from single units without apparent impact on other units"
- Issues to be addressed in a future RCT to demonstrate effectiveness of UV for room disinfection
  - Need to use the hospital (best choice) or at least hospital unit (i.e., ICU) as the unit for randomization/analysis
  - Need to control for frequency of hand hygiene, chemical disinfection, other interventions
  - Ideally, assess for colonization not just infection; ideally use molecular methods to demonstrate transmission
  - Result of design: Best design = Cluster randomized study : High cost ($millions), need for informed consent, prolonged study time
- Cost effective analysis demonstrating benefit of UV room disinfection

FUTURE RESEARCH NEEDS: UV DEVICES FOR SURFACE DISINFECTION

- Room disinfection devices
  - Demonstrate overall hospital reduction in HAIs by using UV devices for patients on contact precautions (e.g., CRE)
  - Assess effectiveness of room disinfection units when used for terminal disinfection of all patients (not just those on contact isolation)
  - Assess effectiveness in other hospital settings: Operating room, play rooms, common areas, ambulances, etc.
  - Assess effectiveness in other settings: Nursing homes, day care centers, veterinary hospitals, etc.
- Other potential uses of UV (demonstrating effectiveness: 1) kills inoculated surfaces; 2) kills microbes on actual hospital surfaces; 3) reduces HAIs in hospital unit (ideally a RCT); 4) reduces overall hospital HAIs
  - Assess effectiveness for disinfecting shared medical equipment, personal devices (e.g., stethoscopes, computers, cell phones, etc.)
  - Assess effectiveness for use of handheld UV devices
  - Assess effectiveness for use of barriers allowing UV devices to be used in multi-bed rooms
- UV for disinfection of other sources/reservoirs for HAIs: Water (sink traps, facets), air (OR), food

OTHER IMPORTANT SURFACES: UV MAY HAVE A ROLE IN DISINFECTION

Curtains frequently contaminated with MDROs. Possible solutions: disposable curtains, antimicrobial curtains, routine disinfection of grab area. Rutala WA, et al. ICHE 2014;42:426

Shared patient items may transmit MDROs. Possible solution: Assess cleaning (fluorescent dye, ATP) with feedback. Donskey C. AJIC 2019;47S:A90

Floors contaminated with MDROs. May serve as source for contaminating socks and shoes leading to dissemination. Possible solutions: EVS education, use disinfectant on floors. Donskey C. AJIC 2019;47S:A90

Fabric covered chairs may be contaminated with MDROs leading to transmission among patients. Possible solution: Use only non-porous furniture in hospital to facilitate cleaning & disinfection. Noskins GA, et al. AJIC 2000;28:311.

TECHNOLOGIES TO IMPROVE DISINFECTION OF ENVIRONMENTAL SURFACES: COMPETITION FOR UV DEVICES

- Terminal disinfection: “No touch” systems and devices
  - UV light devices: UV-C or pulsed xenon
  - Hydrogen peroxide systems: Vapor or aerosol
  - Portable devices: UV, steam, chemical disinfectant (e.g., hydrogen peroxide, hypochlorite)
- Daily and terminal disinfection: New surface disinfectants
  - Surface disinfectants with persistence*
  - Improved hydrogen peroxide*
  - Electrochemically activated saline solution
- Continuous disinfection: “self disinfecting” surfaces or room disinfection systems
  - Heavy metal surface coatings: Silver, copper
  - Germicide impregnated surfaces (e.g., light activated germicides)
  - Low dose continuous hydrogen peroxide systems
  - “Blue” lights (i.e., visible lights near UV spectrum)

* Already commercially available

THANK YOU!!