Scientific Background for UV Disinfection

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DISCLOSURES

2020-2021

- **Consultations**
  - PDI (Professional Disposable International)
- **Honoraria**
  - PDI

Lecture Objectives

- Role of environment in disease transmission
- New technologies for room decontamination
  - Ultraviolet light
  - Hydrogen peroxide and others
  - Continuous room decontamination technology

Uses of UVC

- Disinfection of surfaces
- Disinfection of air
- Disinfection of water (e.g., *Legionella*)



Environmental Contamination Leads to HAIs

Weber, Kanamori, Rutala. Curr Op Infect Dis .2016.29:424-431



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

Effective Surface Decontamination

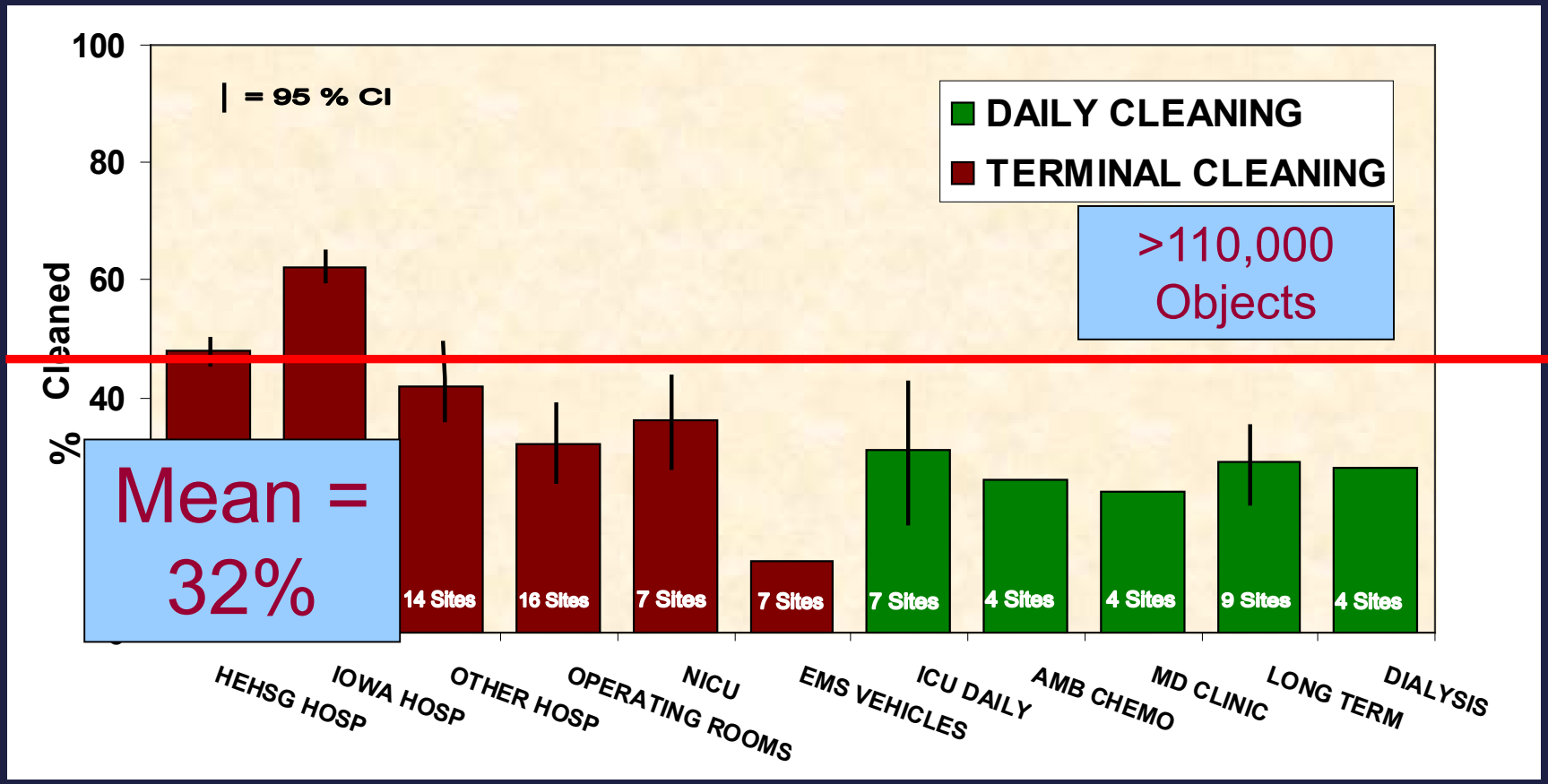
Product and Practice = Perfection

Clean/disinfect at least daily (one-step cleaning and disinfection)



Thoroughness of Environmental Cleaning

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



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%)
- Exposure to contaminated rooms confers a 5-6 fold increase in odds of infection, hospitals must adopt proven methods for reducing environmental contamination (Cohen et al. ICHE. 2018;39:541-546)

Effective Surface Decontamination

Product and Practice = Perfection

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)

These interventions (effective surface disinfection, thoroughness indicators) not enough to achieve consistent and high rates of cleaning/disinfection

No Touch

(supplements but do not replace surface cleaning/disinfection)

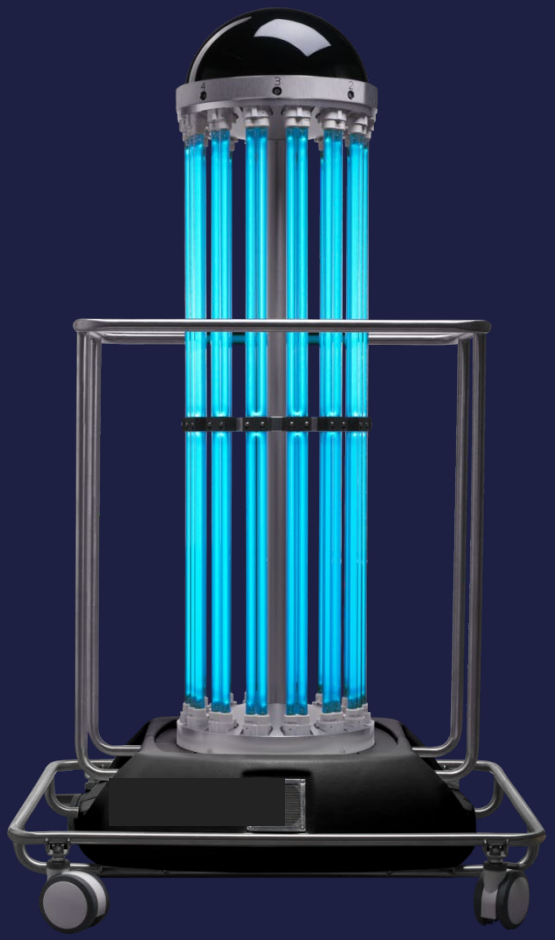
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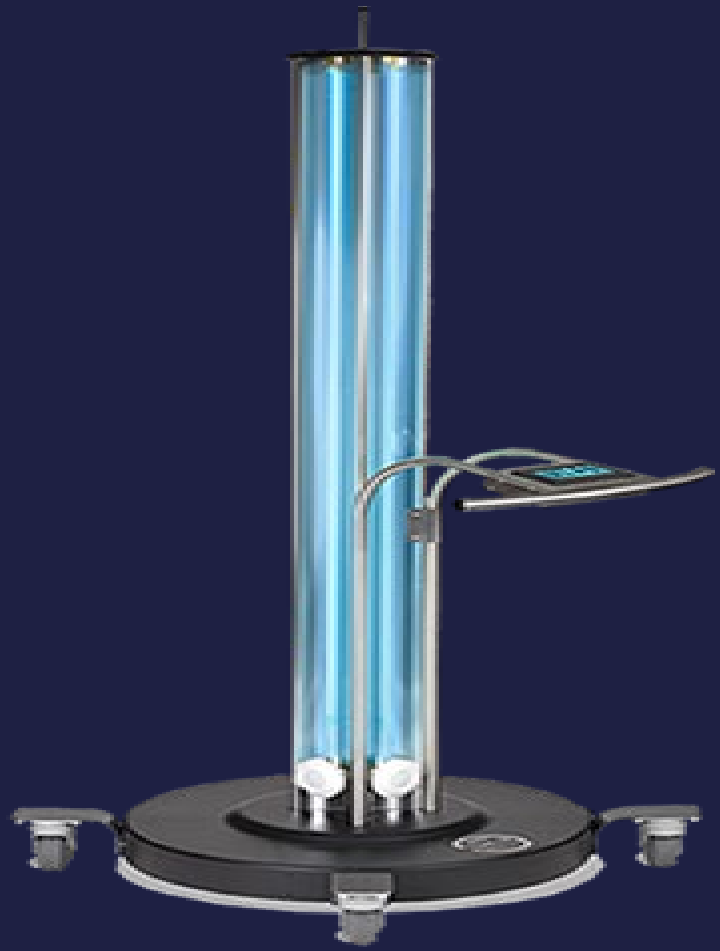
“NO TOUCH” APPROACHES TO ROOM DECONTAMINATION

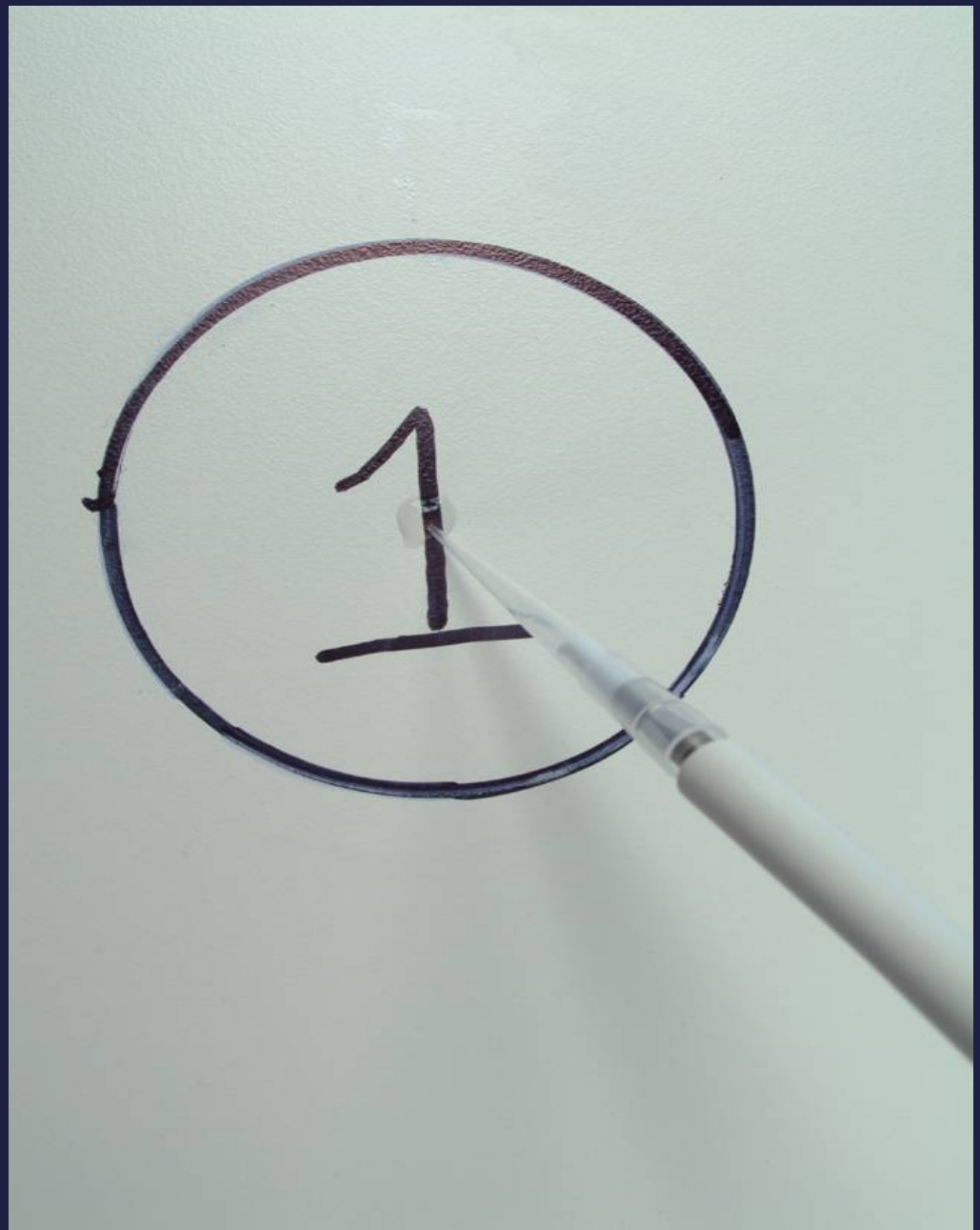
(UV/VHP~20 microbicidal studies, 12 HAI reduction studies; will not discuss technology with limited data)

Weber, Kanamori, Rutala. Curr Op Infect Dis 2016;29:424-431; Weber, Rutala et al. AJIC; 2016:44: e77-e84; Anderson et al. Lancet 2017;389:805-14; Anderson et al. Lancet Infect Dis 2018;June 2018.








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Effectiveness of UV Room Decontamination

Rutala WA, Gergen MF, Weber DJ. Infect Control Hosp Epidemiol 2010;31:1025-9

TABLE 1. UV-C Decontamination of Formica Surfaces in Patient Rooms Experimentally Contaminated with Methicillin-Resistant *Staphylococcus aureus* (MRSA), Vancomycin-Resistant *Enterococcus* (VRE), Multidrug-Resistant (MDR) *Acinetobacter baumannii*, and *Clostridium difficile* Spores

		UV-C line of sight						
		Total		Direct		Indirect		
Organism	Inoculum	No. of samples	Decontamination, $\log_{10}$ reduction, mean (95% CI)	No. of samples	Decontamination, $\log_{10}$ reduction, mean (95% CI)	No. of samples	Decontamination, $\log_{10}$ reduction, mean (95% CI)	*P*
MRSA	4.88 $\log_{10}$	50	3.94 (2.54–5.34)	10	4.31 (3.13–5.50)	40	3.85 (2.44–5.25)	.06
VRE	4.40 $\log_{10}$	47	3.46 (2.16–4.81)	15	3.90 (2.99–4.81)	32	3.25 (1.97–4.62)	.003
MDR *A. baumannii*	4.64 $\log_{10}$	47	3.88 (2.59–5.16)	10	4.21 (3.27–5.15)	37	3.79 (2.47–5.10)	.07
C. difficile spores	4.12 $\log_{10}$	45	2.79 (1.20–4.37)	10	4.04 (3.71–4.37)	35	2.43 (1.46–3.40)	<.001

EFFECTIVENESS OF UV ROOM DECONTAMINATION

Nerandzic et al. BMC Infect Dis 2010;8:197

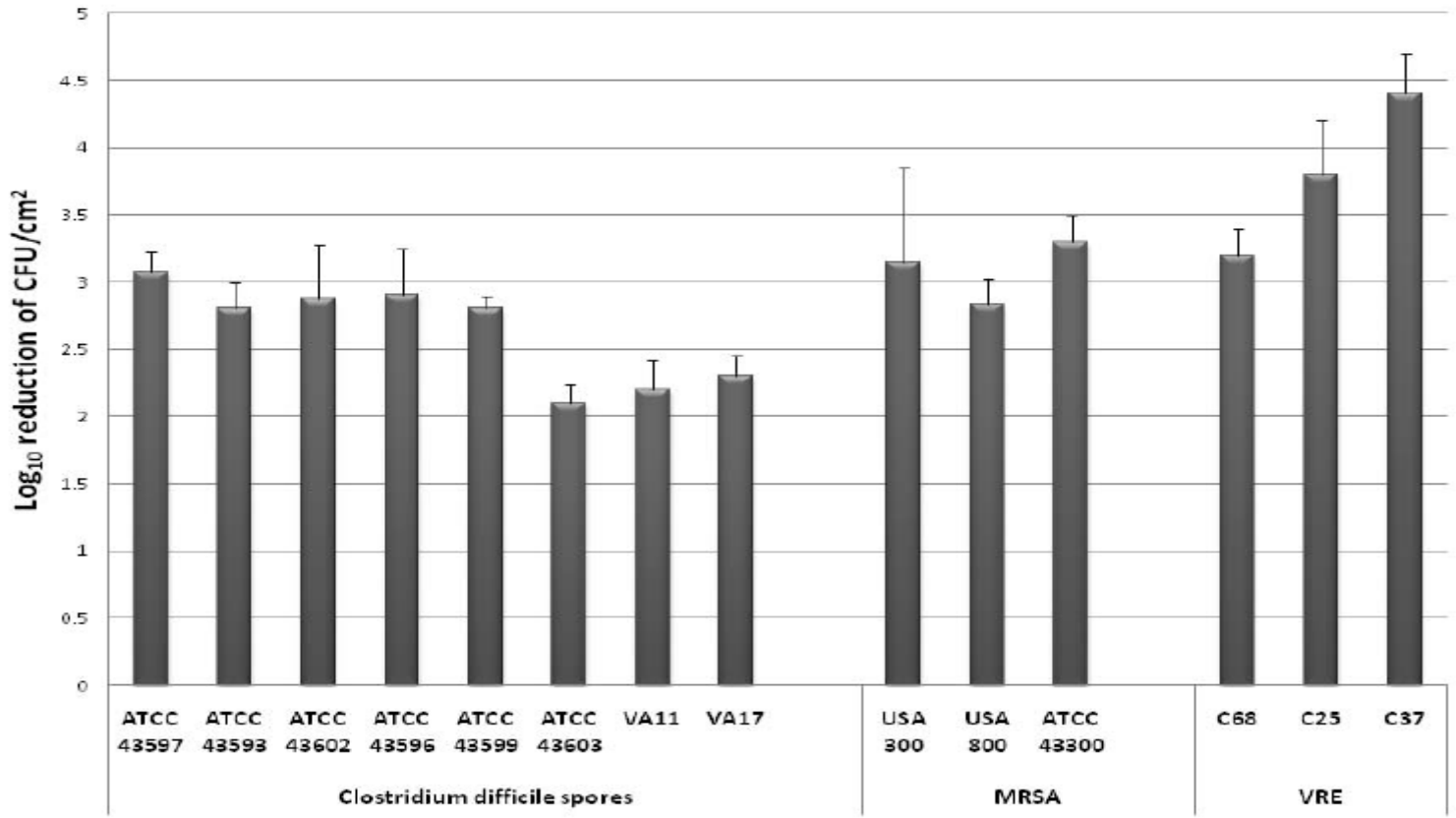
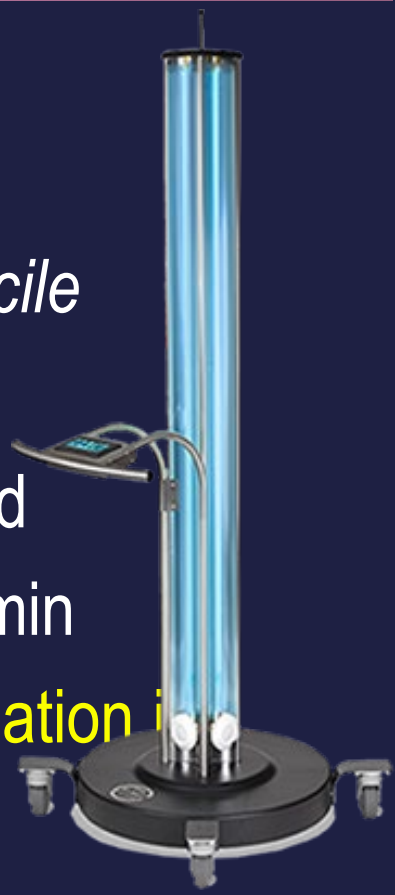


Figure 2 Mean reduction (log_{10}colony-forming units [CFU]/cm^2) in recovery of multiple strains of *Clostridium difficile*, methicillin-resistant *Staphylococcus aureus* (MRSA), and vancomycin-resistant *Enterococcus* (VRE) from laboratory bench top surfaces after the use of the Tru-D device. For each pathogen, the inoculum applied to the bench top was adjusted such that 10^3 to 10^5 CFU were recovered from the positive control specimens. The Tru-D device was operated at a reflected dose of 22,000 μWs/cm^2 for ~45 minutes.

Room Decontamination with UV

Rutala, Gergen, Tande, Weber. ICHE. 2014;35:1070-72

- Objective: Determine the effectiveness of a UVC device
- Method: Study carried out in standard hospital room using Formica sheets contaminated with MRSA, *C. difficile*
- Results: The effectiveness of UVC radiation in reducing MRSA was more than >99.9% within 5 min and the reduction of *C. difficile* spores was >99% within 10 min
- Conclusion: This UVC device allowed room decontamination i 5-10 minutes



EFFECTIVENESS OF UV-C DEVICE WITH SHORT EXPOSURE TIMES

- Design: Assessment of ability of UV-C (UVDI) to kill MRSA and *C. difficile* on contaminated Formica surfaces in patient room

TABLE 1. Ultraviolet-C Decontamination of Formica Surfaces in Patient Rooms That Were Experimentally Contaminated with Methicillin-Resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile* Spores with and without a Reflective Coating on Walls

	MRSA		*C. difficile*	
Variable	Without coating	With coating	Without coating	With coating
Cycle time, minutes	5	5	10	10
Direct surfaces	4.10 (3.88–4.32); 30	4.68 (4.61–4.76); 30	3.35 (3.14–3.55); 30	3.34 (3.10–3.59); 30
Indirect surfaces	2.74 (2.53–2.94); 20	4.21 (4.00–4.42); 20	1.80 (1.36–2.24); 20	2.61 (2.24–2.97); 20
Overall	3.56 (3.31–3.80); 50	4.50 (4.38–4.61); 50	2.78 (2.48–3.07); 50	3.05 (2.82–3.28); 50

NOTE. Data are mean $\log_{10}$ reduction in colony-forming units (95% confidence interval) and no. of samples, unless otherwise indicated. Patient room is 130 square feet (12.077 m^2) in area. Confidence intervals were calculated based on a Poisson distribution.

Rutala WA, Gergen MF, Tande DM, Weber DJ. ICHE 2014;35:1070-1072

Parameters Affecting Ultraviolet Light

Boyce JM, Donskey CJ. Understanding ultraviolet light surface decontamination in hospital rooms: A primer. Infect Control Hosp Epidemiol. 2019 Sep;40(9):1030-1035. doi: 10.1017/ice.2019.161. Epub 2019 Jun 18.

Table 2. Variables Affecting Ultraviolet C (UV-C)Doses Required to Reduce Microorganism Counts

Variable	Comment
Inoculum preparation	May be quite variable for *Clostridium difficile*
Inoculum size,no. of colony-forming units	Size: 10^4–10^5, 10^5, 10^6, 10^5–10^7
Inoculum dispersal onto carrier	Area over which inoculum is spread (drop vs spread over carrier surface)
UV exposure conditions	Inoculum in liquid suspension, suspended in air, placed on agar plate, dried on solid carrier
Carrier material and size	Material: stainless steel, laminate, glass, plastic, aluminum Size (diameter in mm):10, 20, 40 Size (area in cm^2): 25, 35
Presence and type of organic load	5% or 10% fetal calf serum; 0.03%, 0.3% or 10% bovine serum albumin; ASTM E2197
Pathogen strain studied	Various strains of *Escherichia coli*, *C. difficile*, methicillin-resistant *Staphylococcus aureus* (MRSA), and vancomycin-resistant *Enterococcus* (VRE)
Spore formation by microorganism	*C. difficile*, *Bacillus subtilis*
Relative humidity and temperature	Decreased UV sensitivity with higher humidity and lower temperature
Method for recovery of viable microorganisms after exposure to UV-C	Carrier submerged in liquid; swab; RODAC plate

Parameters: distance, direct vs indirect line-of-sight, energy, wavelength, duration, orientation of object (facing UV or at an angle), reflective paint (walls)

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

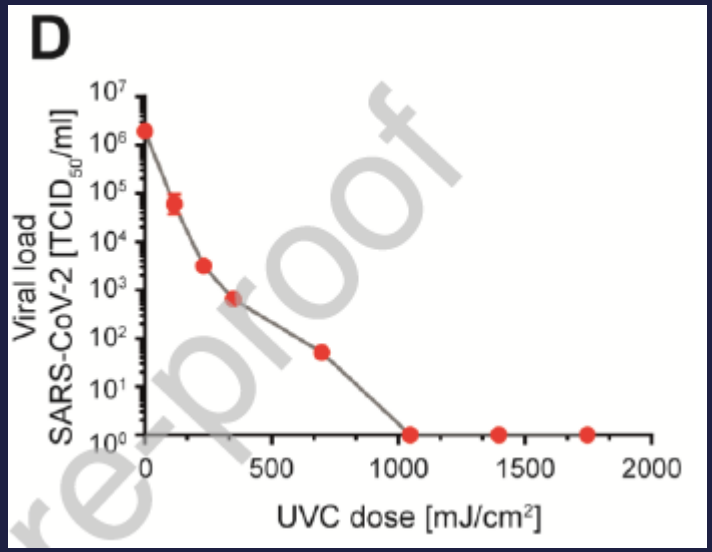
A, *Acinetobacter* spp; *As*, *Aspergillus*; *Cd*, *Clostridium difficile*; *MDRO*, multidrug-resistant organism; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *NS*, not stated; *OR*, operating room; *PX*, pulsed xenon; *UV*, ultraviolet light; *VRE*, vancomycin-resistant enterococci.

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

Susceptibility of SARS-CoV-2 to UV Irradiation

Heilingloh CS et al. AJIC 2020

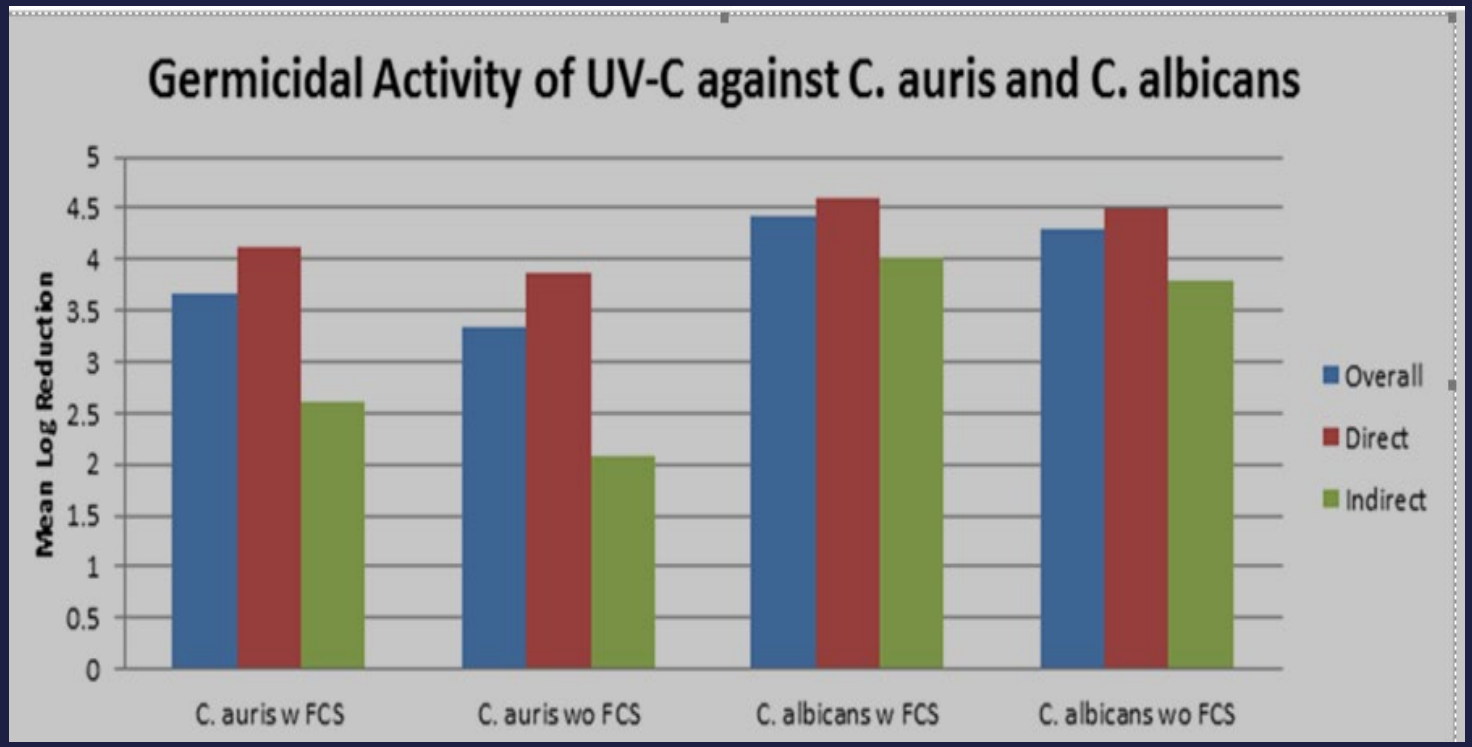
- Virus is highly susceptible to ultraviolet light
- High infectious titer of 5 x 10^6 was completely inactivated by UVC irradiation after 9 m of exposure
- UVC dose required for complete inactivation was 1048 mJ/cm^2
- UVC reliable disinfection method



reproof

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).

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

Anderson et al. Lancet 2017;289:805; Rutala et al. ICHE 2019

	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.

Germicidal Activity of UVC (254nm)

- Photohydration: the water molecules are pushed into the DNA and prevent the transcription
- Photosplitting: strands of DNA are split apart
- Photodimerization: the DNA bases fuse inappropriately
- Photocrosslinking: the cell walls are damaged and this causes cell lysis (breaking down of the membrane and death of the cell)

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)
  - Demonstrated effectiveness to reduce HAIs in before-after studies and randomized clinical trial
  - 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)
- 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)

This technology (“no touch”-e.g., 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

- 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

CONCLUSIONS

- UV is effective in reducing the number of MDRO pathogens
- UV is effective in reducing the number of MDRO pathogens contaminating surfaces in patient rooms (decrease in number of positive sites and level of contamination)
- Before-after studies have strongly suggested that UV can reduce HAIs
- RCT has demonstrated that UV for terminal disinfection of rooms occupied by patients colonized/infected with an MDRO is superior to standard room disinfection for preventing MDRO colonization/infection in subsequent patients admitted to the room
- "No touch" (e.g., UV) should be used for terminal room disinfection (e.g., after discharge of patients on Contact Precautions).

THANK YOU!

www.disinfectionandsterilization.org

