COVID-19: Overview of Effective Surface Disinfection Technologies

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Disclosure: PDI

DISCLOSURES

2020-2021

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

Lecture Objectives

- Role of environment in disease transmission
- SARS-CoV-2 via environment
- Effective surface disinfection technologies
  - Surface disinfection
  - Ultraviolet light
  - Other room decontamination technologies
  - Continuous room decontamination technology

www.disinfectionandsterilization.org

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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

Acquisition of EIP on Hands of Healthcare Providers after Contact with Contaminated Environmental Sites and Transfer to Other Patients



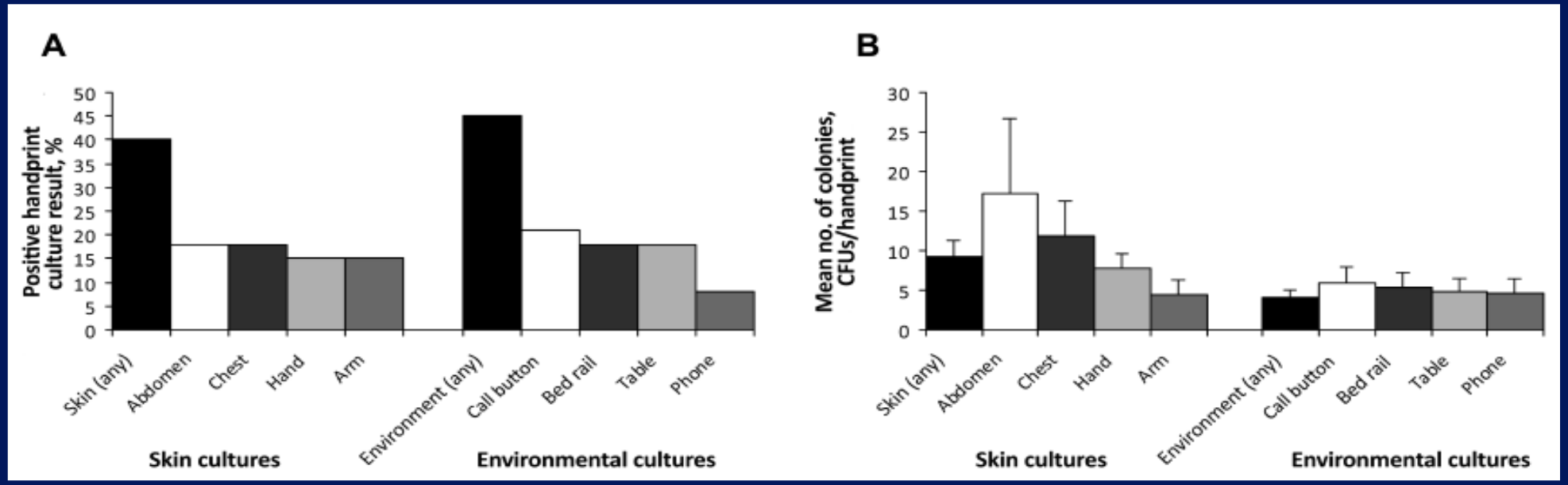


Acquisition of EIP on Hands of Patient after Contact with Contaminated Environmental Sites and Transfers EIP to Eyes/Nose/Mouth



FREQUENCY OF ACQUISITION OF MRSA ON GLOVED HANDS AFTER CONTACT WITH SKIN AND ENVIRONMENTAL SITES

No significant difference on contamination rates of gloved hands after contact with skin or environmental surfaces (40% vs 45%; p=0.59)



Stiefel U, et al. ICHE 2011;32:185-187

Lecture Objectives

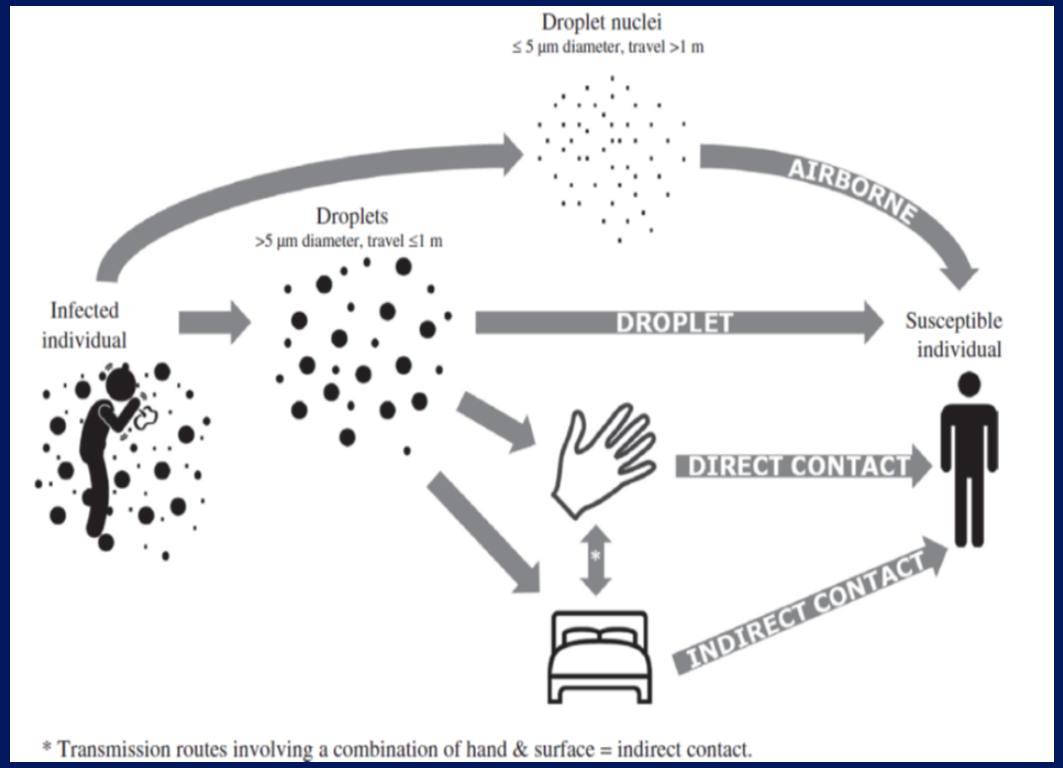
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Role of Healthcare Surface Environment in SARS-CoV-2 Transmission

Kanamori, Weber, Rutala, Clin Infect Dis, https://doi.org/10.1093/cid/ciaa1467, 28 September 2020

- Centers for Disease Control & Prevention says the virus spreads from person to person mainly through respiratory droplets from coughing, sneezing or talking in close proximity to each other, but the CDC has also said it may be possible for a person to get COVID-19 by touching a surface or object that has the virus on it and then touching their own mouth, nose or possibly their eyes. CDC clarified while it is still possible that a person can catch it from touching a contaminated surface, it's "not thought to be the main way the virus spreads."

Transmission of SARS-CoV-2



- Droplet (< 6 feet)
- Direct-person-to-person via respiratory aerosols
- Indirect (via the contaminated environment); not main route
- Asymptomatic (infection transmission demonstrated)
- Pre-symptomatic-highly likely

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- Survival on environmental surfaces
  - Hours to days (SARS-CoV-2)
  - Depends on experimental conditions such as viral titer (10^7 higher than real life) and volume of virus applied to surface, suspending medium, temperature, relative humidity and surface substrates
  - Human coronavirus 229E persist on surface materials at RT for at least 5 days
  - SARS-CoV-2 can be viable on surfaces for 3 days (plastic, stainless steel ~2-3 days, cardboard ~24h)
  - Suggest transmission of SARS-CoV-2 may occur

Human Coronavirus: Environmental Survival

Kampf G. J Hosp Infect 2020

Table I. Persistence of coronaviruses on different types of inanimate surfaces.

Type of surface	Virus	Strain / isolate	Inoculum (viral titer)	Temperature	Persistence	Reference
Steel	MERS-CoV	Isolate HCoV-EMC/2012	10^5	20°C 30°C	48 h 8 – 24 h	[21]
	TGEV	Unknown	10^6	4°C 20°C 40°C	≥ 28 d 3 – 28 d 4 – 96 h	[22]
	MHV	Unknown	10^6	4°C 20°C 40°C	≥ 28 d 4 – 28 d 4 – 96 h	[22]
	HCoV	Strain 229E	10^3	21°C	5 d	[23]
Aluminium	HCoV	Strains 229E and OC43	5×10^3	21°C	2 – 8 h	[24]
Metal	SARS-CoV	Strain P9	10^5	RT	5 d	[25]
Wood	SARS-CoV	Strain P9	10^5	RT	4 d	[25]
Paper	SARS-CoV	Strain P9	10^5	RT	4 – 5 d	[25]
	SARS-CoV	Strain GVU6109	10^6 10^5 10^4	RT	24 h 3 h < 5 min	[26]
Glass	SARS-CoV	Strain P9	10^5	RT	4 d	[25]
	HCoV	Strain 229E	10^3	21°C	5 d	[23]
Plastic	SARS-CoV	Strain HKU39849	10^5	22°-25°C	≤ 5 d	[27]
	MERS-CoV	Isolate HCoV-EMC/2012	10^5	20°C 30°C	48 h 8 – 24 h	[21]
	SARS-CoV	Strain P9	10^5	RT	4 d	[25]
	SARS-CoV	Strain FFM1	10^7	RT	6 – 9 d	[28]
	HCoV	Strain 229E	10^7	RT	2 – 6 d	[28]
PVC	HCoV	Strain 229E	10^3	21°C	5 d	[23]
Silicon rubber	HCoV	Strain 229E	10^3	21°C	5 d	[23]
Surgical glove (latex)	HCoV	Strains 229E and OC43	5×10^3	21°C	≤ 8 h	[24]
Disposable gown	SARS-CoV	Strain GVU6109	10^6 10^5	RT	2 d 24 h	[26]

Journal Proof

Role of Healthcare Surface Environment in SARS-CoV-2 Transmission

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Contamination of SARS-CoV-2 RNA by PCR on environmental surfaces and medical devices have been documented. Rate varies from 0-75% (median 12.1%).

Role of Healthcare Surface Environment in SARS-CoV-2 Transmission

Kanamori, Weber, Rutala, Clin Infect Dis, https://doi.org/10.1093/cid/ciaa1467, 28 September 2020

SARS-CoV-2 RNA				
Bed rail	Sink	BP monitor	Infusion pump	Keyboard
Bedside table	Floor	ECG monitor	Fluid stand	Phone
Chair	Toilet seat	Oxygen regulator	Hand sanitizer	Computer mouse
Doorknob	Toilet bowl	Oxygen mask	Trash can	Door
Light switches	Stethoscope	CT scanner	Self-service printer	Glass window
Call button	Pulse oximetry	Ventilator	Desktop	PPE storage area
Centrifuge	Biosafety cabinet	Infant bed	Air outlet	Ambu bag
TV remote	Bed sheet	Urinary catheters	TV	Beepers
Elevator buttons	Ventilator tubing	Glove boxes	Touch screen	All surfaces in nurse's station

Role of Healthcare Surface Environment in SARS-CoV-2 Transmission

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Detection of SARS-CoV-2 RNA does not represent the presence of viable virus. Further, even the detection of viable virus, does not mean an infectious dose of SARS-CoV-2 is present. Infectious dose for SARS-CoV-1 estimated to be 280 viral particles to cause disease in 50% of the population.

Do established infection prevention measures prevent spread of SARS-CoV-2 to the hospital environment beyond the patient room?

Jerry et al. J Hosp Infection 2020

Contamination rate: patient room-42% (11/26); nurse's station-3%; post terminal clean-4% (1/25)

Sites of swabs/air samples and results

Sample location	Grand total	Detected	Not detected
COVID-19 patient's room			
Bed rail	6	4	2
Bedside table	6	3	3
Call bell	4	1	3
Patient chair-arm	4	1	3
Remote for bed	2	2	0
Toilet door handle	4	0	4
Total	26	11	15
Nurses' station COVID-19 cohort ward			
Desk	10	0	10
Keyboard	10	0	10
Telephone	10	1	9
Total	30	1	29
Patient room post-terminal clean			
Bed rail	5	0	5
Bedside table	5	0	5
Call bell	5	1	4
Patient chair-arm	5	0	5
Toilet door handle	5	0	5
Total	25	1	24

Role of Healthcare Surface Environment in SARS-CoV-2 Transmission

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Raises concerns that contaminated surfaces leads to contamination of the gloves and hands of HCP and transfer

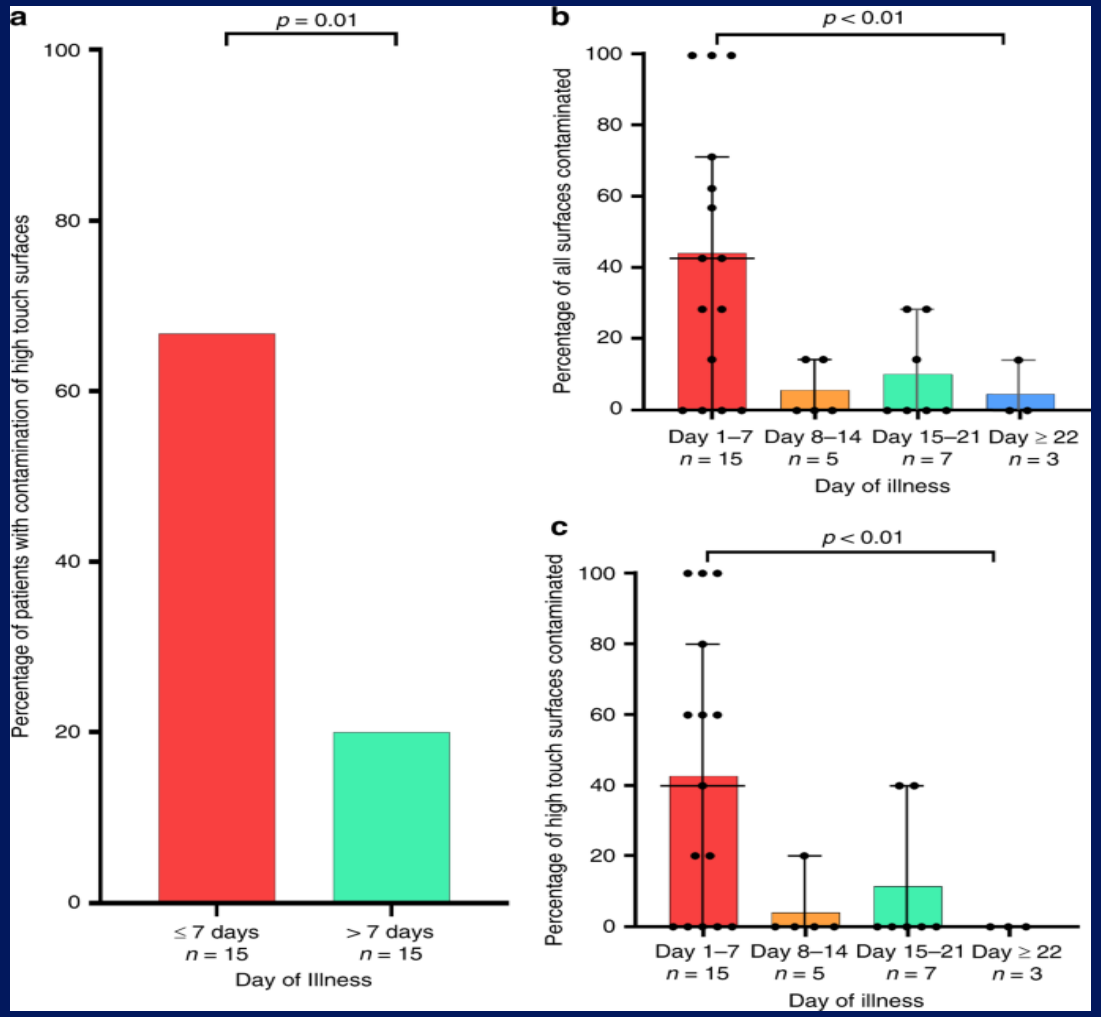
Role of Healthcare Surface Environment in SARS-CoV-2 Transmission

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- Contamination rate depends on the status of cleaning and disinfection in environmental sampling rather than symptomatic status of COVID-19 patients
- Environmental studies sampled before cleaning/disinfection reported infrequent to frequent contamination, while studies sampled after cleaning/disinfection revealed zero to infrequent contamination

Extent of environmental contamination correlated with day of illness timepoint

Chia el al. Nature Communications 2020



Role of Healthcare Surface Environment in SARS-CoV-2 Transmission

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Contamination of surfaces occurred more extensively within the first week of illness and decreased with increasing duration of illness and lower SARS-CoV-2 RNA levels, which supports studies describing the peak viral loads and active viral replication in the upper respiratory tract of COVID-19 patients during the first week

Viable SARS-CoV-2 on Surfaces

Environmental Contamination in COVID-19 Rooms with Severe Pneumonia

Ahn et al. J Hospi Infect 2020;106:570

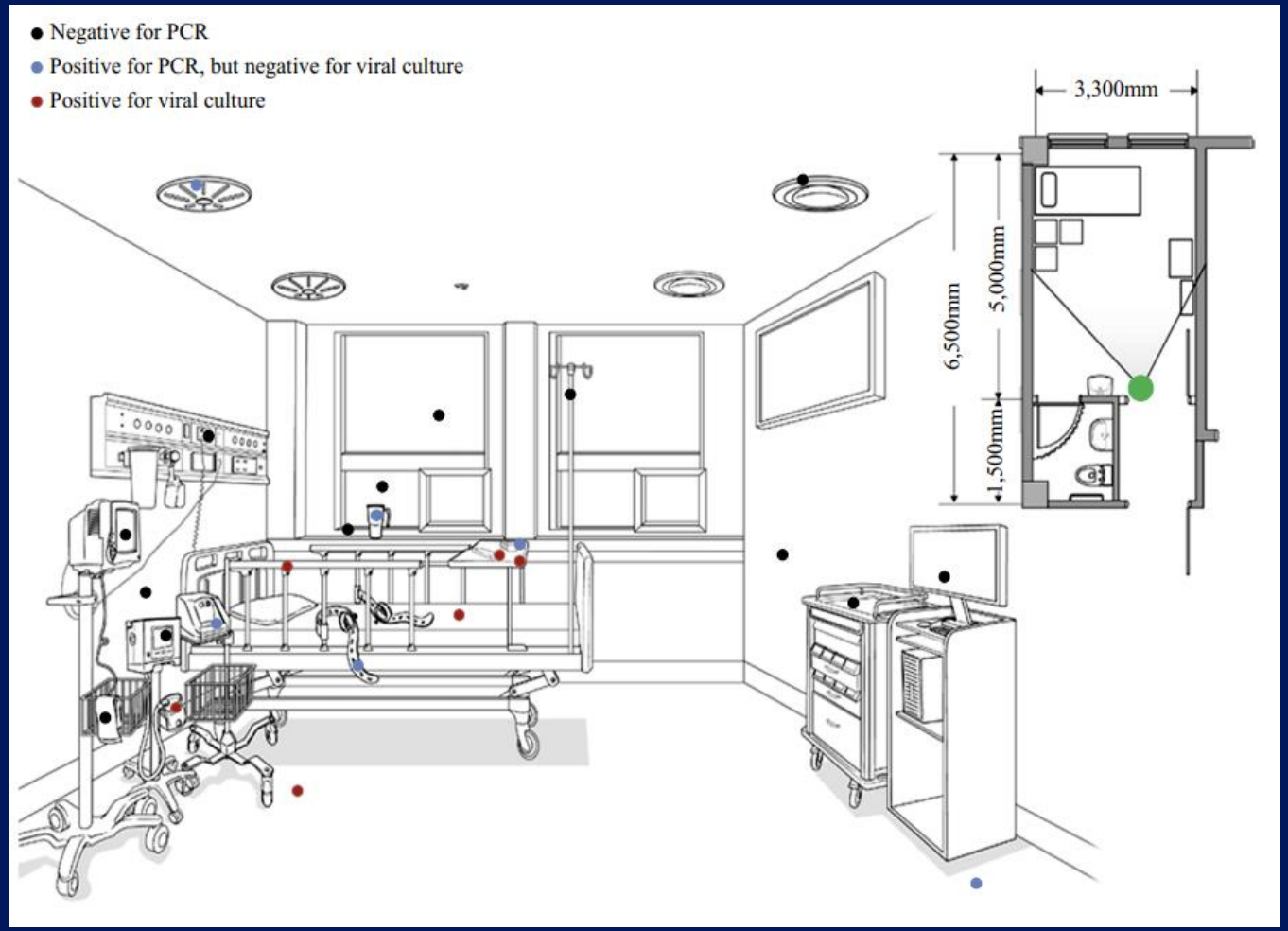
Pt 1 and 2-2/48-4% (closed suction to ventilator) pt 3-13/28-46% (high-flow oxygen therapy via nasal cannula, non-invasive ventilation). Found viable virus (7/28-25%) only on surfaces within droplet distance. All air samples negative.

Sample	Patient 1				Patient 2				Patient 3			
	PCR	C_T value		Culture	PCR	C_T value		Culture	PCR	C_T value		Culture
		E gene	RdRp			E gene	RdRp			E gene	RdRp	
Air	−			ND	−			ND	−			ND
Air outlet fan	−			ND	−			ND	+	33.93	34.99	−
Air inlet fan	−			ND	−			ND	−			ND
Nasal prong/endotracheal tube	+	30.95	31.36	+	+	32.33	33.02	−	+	31.78	34.28	+
Intravenous pole	−			ND	−			ND	−			ND
Computer	−			ND	−			ND	−			ND
Medication cart	−			ND	−			ND	−			ND
Window	−			ND	−			ND	U	U	U	−
Window frame	−			ND	−			ND	−	34.23	36.04	−
Blind curtain	−			ND	−			ND	−			ND
Wall 1	−			ND	−			ND	−			ND
Wall 2	−			ND	−			ND	−			ND
Floor near the patient[a]	−			ND	−			ND	+	30.38	33.07	+
Floor far from the patient[b]	−			ND	−			ND	+	31.97	34.28	−
Bed rails	−			ND	−			ND	+	30.22	30.13	+
Bedsheet	−			ND	−			ND	+	31.54	31.99	+
Pillows	−			ND	−			ND	ND			ND
Faucet handle	−			ND	−			ND	ND			ND
Door knob	−			ND	−			ND	−			ND
Call button	−			ND	−			ND	−			ND
Restraint	−			ND	−			ND	+	34.08	35.18	−
Blood pressure cuff	−			ND	−			ND	−			ND
Ambu mask/NIV mask	−			ND	−			ND	+	28.85	28.94	+
Ventilator	−			ND	−			ND	−			ND
Patient monitor	−			ND	−			ND	−			ND
Bedside table	ND			ND	ND			ND	U	33.09	U	+
High-flow oxygen generator	ND			ND	ND			ND	+	30.56	33.12	−
Telephone	ND			ND	ND			ND	+	31.39	33.42	−
Remote controller	ND			ND	ND			ND	+	29.48	29.66	+
Thermometer	ND			ND	ND			ND	+	31.56	32.13	−
Cup	ND			ND	ND			ND	+	32.32	33.55	−

Environmental Contamination in COVID-19 Rooms with Severe Pneumonia

Ahn et al. J Hospi Infect 2020;106:570

Found viable virus only on surface within droplet distance.



Role of Healthcare Surface Environment in SARS-CoV-2 Transmission

Kanamori, Weber, Rutala, Clin Infect Dis, , https://doi.org/10.1093/cid/ciaa1467, 28 September 2020

- Evidence suggests:
  - The healthcare environment contaminated with SARS-CoV-2 may play a role in transmission of SARS-CoV-2
  - Medical devices commonly used in daily practice also can be contaminated
  - Environmental surfaces in rooms occupied by patients with SARS-CoV-2 RNA and shared patient care items should be regularly and rigorously cleaned/disinfected by well-trained healthcare providers using appropriate disinfectant with an emerging viral pathogen claim.

Role of Healthcare Surface Environment in SARS-CoV-2 Transmission

Kanamori, Weber, Rutala, Clin Infect Dis, , https://doi.org/10.1093/cid/ciaa1467, 28 September 2020

SARS-CoV-2 RNA was not detected on environmental surfaces in clean, semi-contaminated, or contaminated areas of isolation wards after routine cleaning/disinfection, which suggests that the routine cleaning/disinfection with List N disinfectants and hand hygiene by HCP is effective

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- Describe at least two technologies or new research data that will eliminate the environment as a source of COVID-19
  - List N disinfectants (>450 disinfectants, 32 chemicals)
  - "No touch" room decontamination-given cleaning/disinfection often inadequate, supplemental use of no-touch should be considered when patients with coronavirus infection are discharged
    - 5 $\log_{10}$ reduction of MHV-59, mouse analog of MERs and SARs in 10m (Bedel et al. ICHE 2016)

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



Effective Surface Decontamination Reduces Microbial Contamination (all touchable surfaces not just high-touch)

Product and Practice = Perfection

Evidence That All Touchable Room Surfaces Are Equally Contaminated

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

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

	Mean CFUs/RODAC (95% CI)	
Surface (no. of samples)	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.

Role of Healthcare Surface Environment in SARS-CoV-2 Transmission

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Surface disinfection effective provided thorough cleaning/disinfection and effective product used as recommended

Effective Surface Decontamination

Product and Practice = Perfection

Recommendations for Cleaning and Disinfecting of Noncritical Surfaces and Medical Devices in COVID-19 Patient Care

Kanamori, Weber, Rutala, Clin Infect Dis, , https://doi.org/10.1093/cid/ciaa1467, 28 September 2020

- Use an EPA-registered disinfectant on the List N that has qualified under emerging viral pathogens program for use against SARS-CoV-2.
- All noncritical touchable surfaces and medical devices should be cleaned/disinfected at least once daily and when visibly soiled.
- Assess cleaning thoroughness with a validation method (e.g., fluorescent dye markers). Provide regular feedback to environmental services personnel on the thoroughness of cleaning.

COVID:19: Overview of Contamination of the Healthcare Environment and Effective Surface Disinfection Technologies

World Health Organization, May 2020

- World Health Organization
  - Cleaning/disinfecting practices and cleanliness should be routinely monitored
  - Number of cleaning staff should be planned to optimize cleaning practices
  - In general, WHO recommends cleaning/disinfection environmental surfaces in inpatient areas (plus screening/triage area) with suspected or confirmed COVID-19 patients at least twice daily

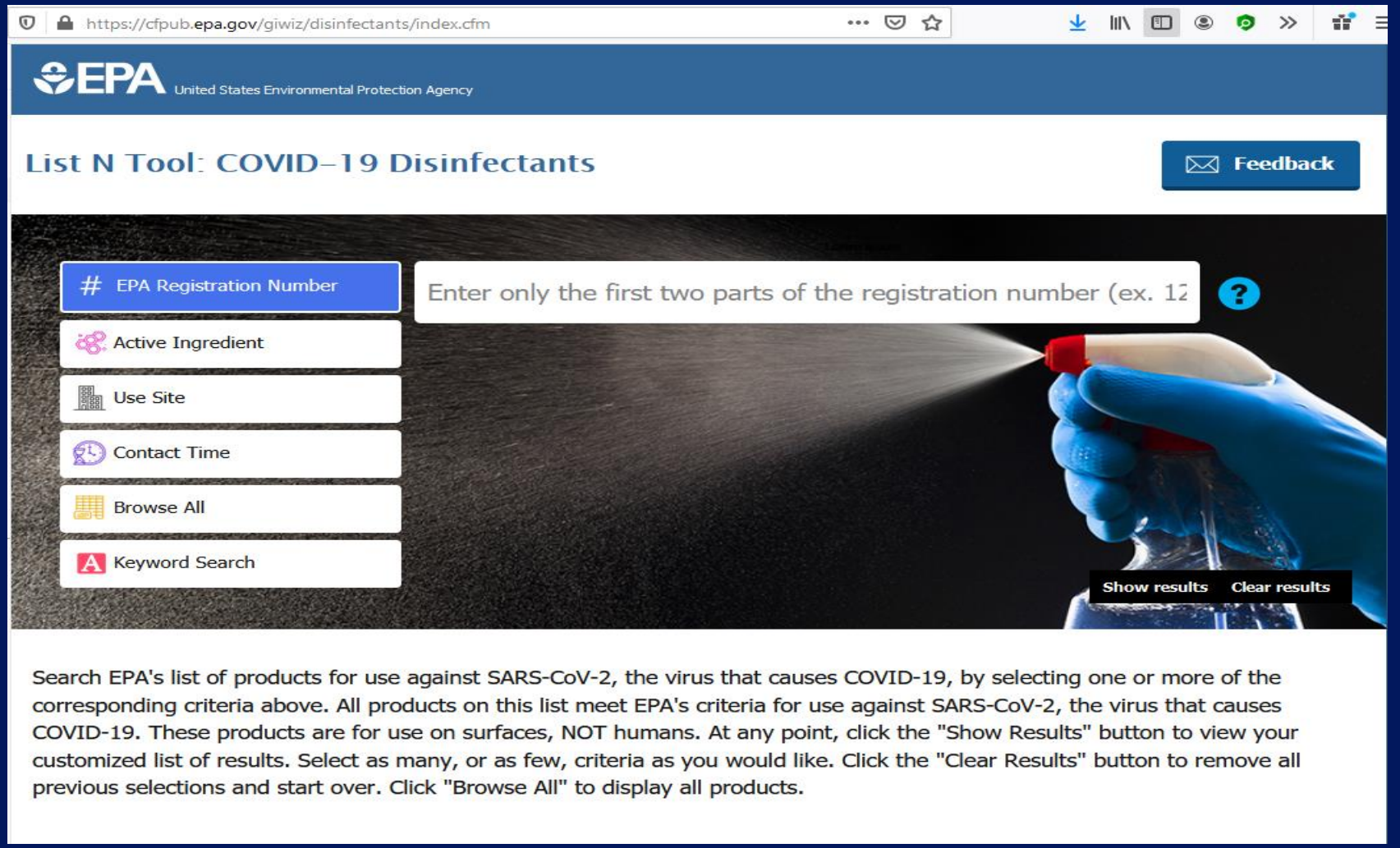
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- CDC recommends that an EPA-registered disinfectant on the EPA's List N that has qualified under the emerging pathogen program for use against SARS-CoV-2 be chosen for the COVID-19 patient care.
- List N has >450 entries and 32 different active ingredients

List N Tool: COVID-19 Disinfectants

https://cfpub.epa.gov/giwiz/disinfectants/index.cfm



Decreasing Order of Resistance of Microorganisms to Disinfectants/Sterilants

Rutala, Weber, CDC DS Guideline 2008. www.cdc.gov

Most Resistant

Prions

Spores (*C. difficile*)

Mycobacteria

Non-Enveloped Viruses (norovirus, adeno)

Fungi

Bacteria (MRSA, VRE, *Acinetobacter*)

Enveloped Viruses (SARS-CoV-2)

Most Susceptible

List N Tool: COVID-19 Disinfectants

32 Active Ingredients

- Ethyl alcohol
- Hydrogen peroxide
- Hypochlorite
- Isopropyl alcohol
- Peracetic acid
- Phenolic
- Quaternary ammonium

LOW-LEVEL DISINFECTION FOR NONCRITICAL EQUIPMENT AND SURFACES

Rutala, Weber. Infect Control Hosp Epidemiol. 2014;35:855-865; Rutala, Weber. AJIC 2019;47:A3-A9

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%
PA with HP, 4% HP, chlorine (*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)

Inactivation of Coronavirus

Kampf G. J Hosp Infect 2020

Table II. Inactivation of coronaviruses by different types of biocidal agents in suspension tests.

Biocidal agent	Concentration	Virus	Strain / isolate	Exposure time	Reduction of viral infectivity (log_{10})	Reference
Ethanol	95%	SARS-CoV	Isolate FFM-1	30 s	≥ 5.5	[29]
	85%	SARS-CoV	Isolate FFM-1	30 s	≥ 5.5	[29]
	80%	SARS-CoV	Isolate FFM-1	30 s	≥ 4.3	[29]
	80%	MERS-CoV	Strain EMC	30 s	> 4.0	[14]
	78%	SARS-CoV	Isolate FFM-1	30 s	≥ 5.0	[28]
	70%	MHV	Strains MHV-2 and MHV-N	10 min	> 3.9	[30]
	70%	CCV	Strain I-71	10 min	> 3.3	[30]
2-Propanol	100%	SARS-CoV	Isolate FFM-1	30 s	≥ 3.3	[28]
	75%	SARS-CoV	Isolate FFM-1	30 s	≥ 4.0	[14]
	75%	MERS-CoV	Strain EMC	30 s	≥ 4.0	[14]
	70%	SARS-CoV	Isolate FFM-1	30 s	≥ 3.3	[28]
	50%	MHV	Strains MHV-2 and MHV-N	10 min	> 3.7	[30]
	50%	CCV	Strain I-71	10 min	> 3.7	[30]
2-Propanol and 1-propanol	45% and 30%	SARS-CoV	Isolate FFM-1	30 s	≥ 4.3	[29]
		SARS-CoV	Isolate FFM-1	30 s	≥ 2.8	[28]
Benzalkonium chloride	0.2%	HCoV	ATCC VR-759 (strain OC43)	10 min	0.0	[31]
	0.05%	MHV	Strains MHV-2 and MHV-N	10 min	> 3.7	[30]
	0.05%	CCV	Strain I-71	10 min	> 3.7	[30]
	0.00175%	CCV	Strain S378	3 d	3.0	[32]
Didecyldimethyl ammonium chloride	0.0025%	CCV	Strain S378	3 d	> 4.0	[32]
Chlorhexidine digluconate	0.02%	MHV	Strains MHV-2 and MHV-N	10 min	0.7 – 0.8	[30]
	0.02%	CCV	Strain I-71	10 min	0.3	[30]
Sodium hypochlorite	0.21%	MHV	Strain MHV-1	30 s	≥ 4.0	[33]
	0.01%	MHV	Strains MHV-2 and MHV-N	10 min	2.3 – 2.8	[30]
	0.01%	CCV	Strain I-71	10 min	1.1	[30]
	0.001%	MHV	Strains MHV-2 and MHV-N	10 min	0.3 – 0.6	[30]
	0.001%	CCV	Strain I-71	10 min	0.9	[30]
Hydrogen peroxide	0.5%	HCoV	Strain 229E	1 min	> 4.0	[34]
Formaldehyde	1%	SARS-CoV	Isolate FFM-1	2 min	> 3.0	[28]

Journal Pre-proof

Recommendations for Cleaning and Disinfecting of Noncritical Surfaces and Medical Devices in COVID-19 Patient Care

Kanamori, Weber, Rutala, Clin Infect Dis, , https://doi.org/10.1093/cid/ciaa1467, 28 September 2020

- Comply with the manufacturer's treatment time/contact time/kill time for wipes and liquid disinfectants.
- Consider no-touch methods (e.g., UV devices) when available as an adjunct to chemical disinfection for terminal disinfection as data demonstrate reduction of microbial contamination and colonization/infection due to epidemiologically-important pathogens despite less scientific and clinical evidence on inactivation of SARS-CoV-2
- No recommendation for using a method of continuous room disinfection as there is insufficient evidence of effectiveness

Recommendations for Cleaning and Disinfecting of Noncritical Surfaces and Medical Devices in COVID-19 Patient Care

Kanamori, Weber, Rutala, Clin Infect Dis, In press

- Standardize cleaning/disinfection of environmental surfaces and medical devices in rooms occupied by COVID-19 patients.
- Follow CDC recommendation for letting room remain empty after discharge for the specified time period.
- Provide education and training for cleaning/disinfecting staff on proper donning and doffing of PPE as recommended by CDC.

Environmental Services Fighting COVID-19

ES worked heroically to fight transmission-Lompoc Valley



Table B.1. Air changes/hour (ACH) and time required for airborne-contaminant removal by efficiency *

Air changes/hour (ACH) and time required for airborne-contaminant removal by efficiency *

ACH § ¶	Time (mins.) required for removal 99% efficiency	Time (mins.) required for removal 99.9% efficiency
2	138	207
4	69	104
6+	46	69
8	35	52
10+	28	41
12+	23	35
15+	18	28
20	14	21
50	6	8

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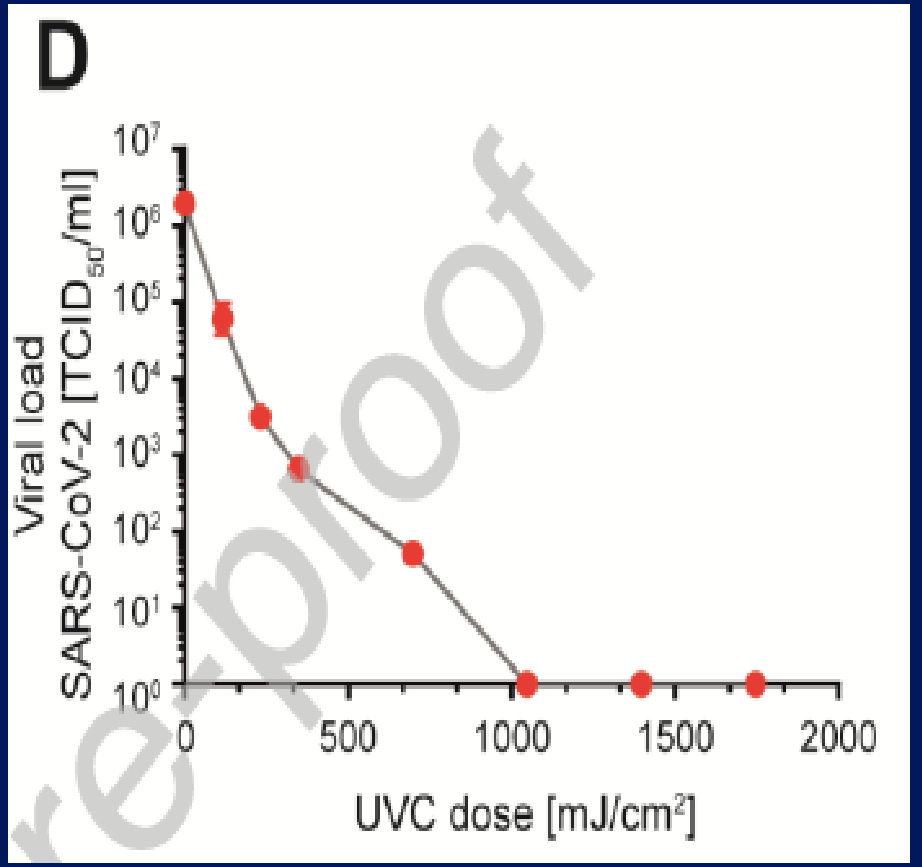
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Susceptibility of SARS-CoV-2 to UV Irradiation

Heilingloh CS et al. AJIC 2020

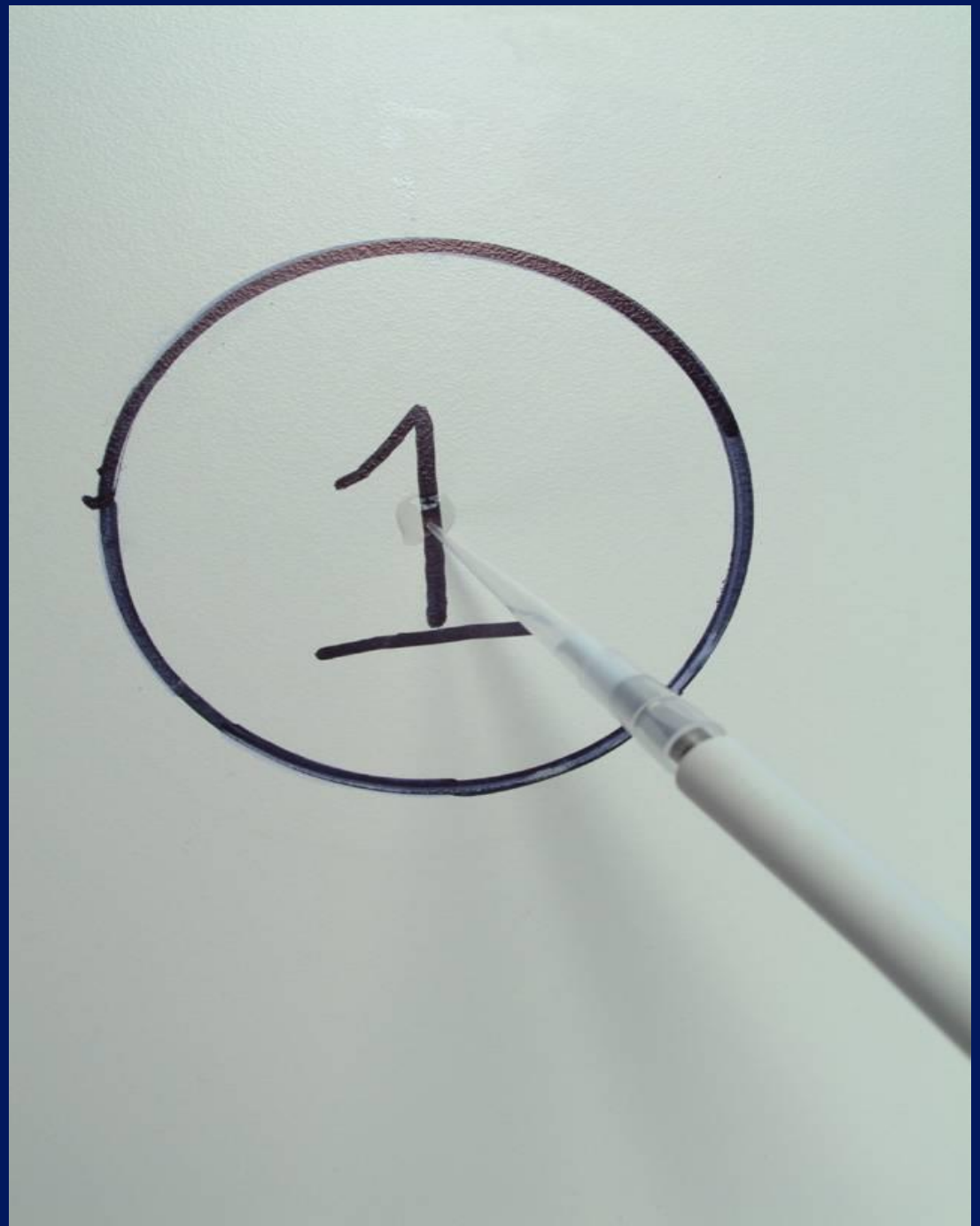
- Virus is highly susceptible to ultraviolet light
- High infectious titer of 5 x 10^6 was completely inactivated by UVC irradiation after 9 m of exposure
- UVC dose required for complete inactivation was 1048 mJ/cm^2
- UVC reliable disinfection method



Preproof

UVC Technology

- Safe
- Microbicidal
- Reduces HAIs
- Cost-effective


1


3325
Hill-Rom

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

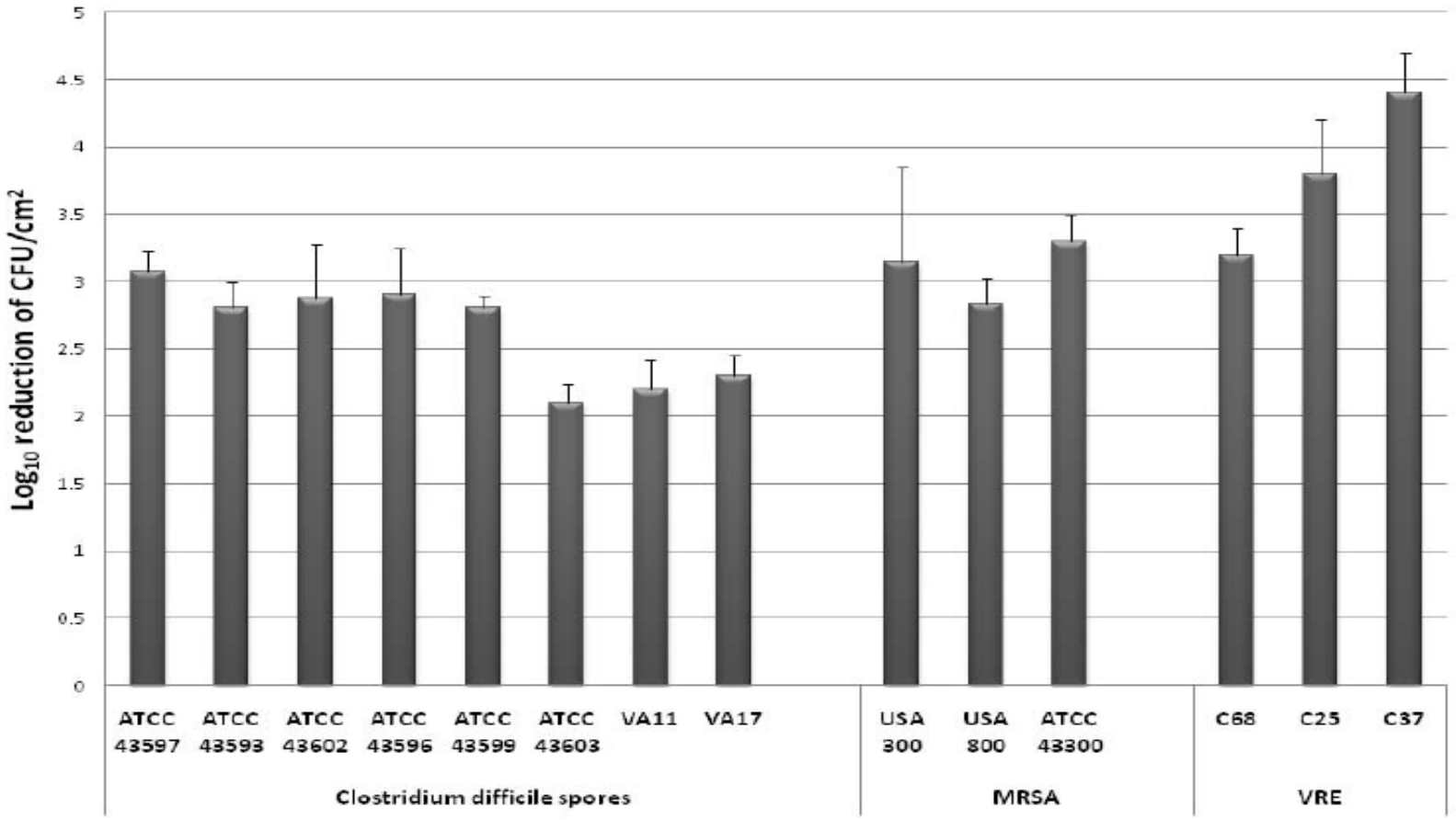


Figure 2 Mean reduction (log_{10} colony-forming units [CFU]/cm^2) in recovery of multiple strains of *Clostridium difficile*, methicillin-resistant *Staphylococcus aureus* (MRSA), and vancomycin-resistant *Enterococcus* (VRE) from laboratory bench top surfaces after the use of the Tru-D device. For 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.

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. diff*icile, 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

EFFECTIVENESS OF UV DEVICES ON REDUCING MDROs ON CARRIERS

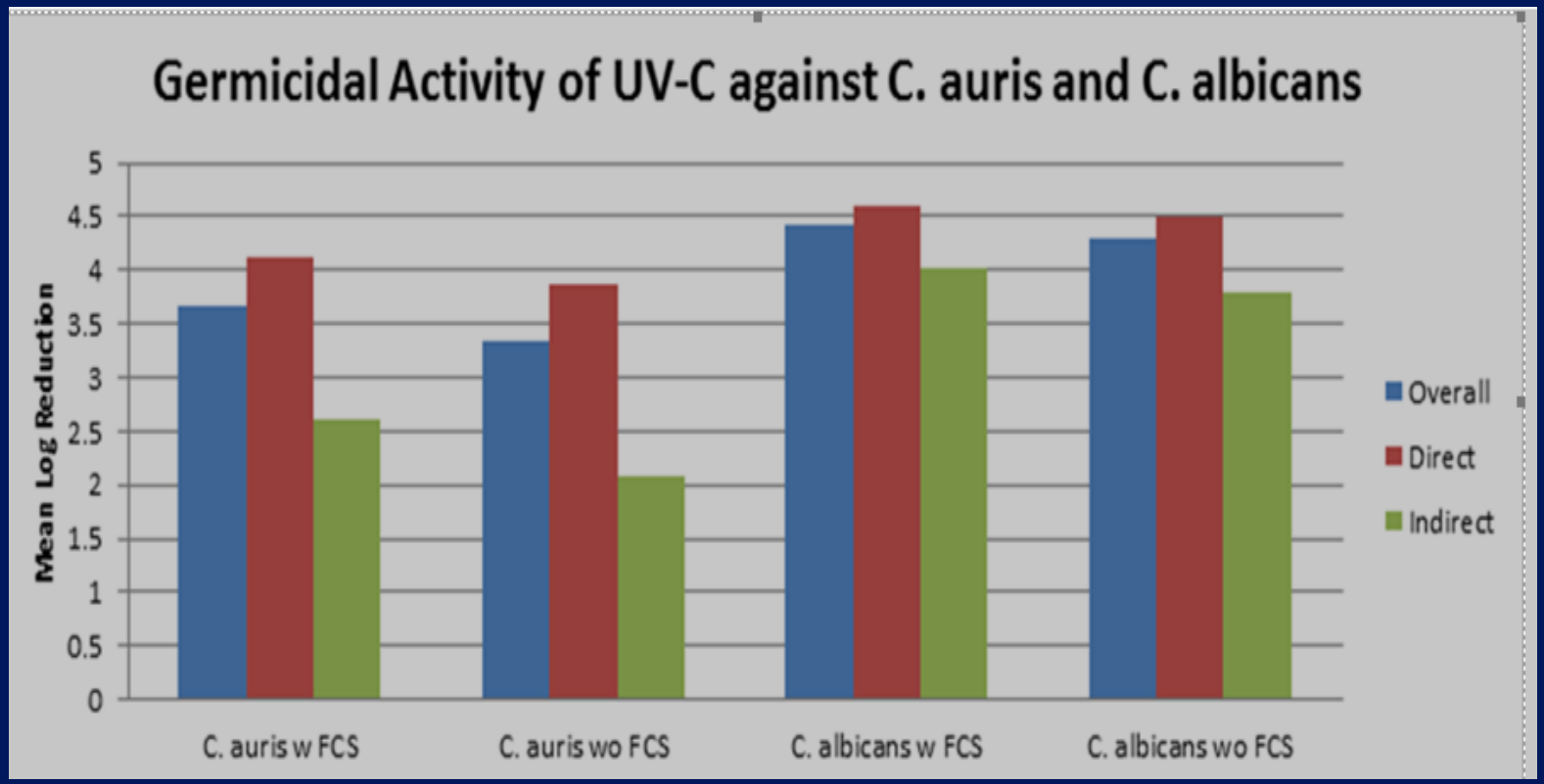
Author, year	UV system	MDROs	Time (min)	Energy ($\mu W/cm^2$)	Log_{10} reduction direct (indirect)
Rutala, 2010[27]	UV-C, Tru-D	MRSA, VRE, A	~15	12,000	4.31 (3.85), 3.90 (3.25), 4.21 (3.79)
Rutala, 2010[27]	UV-C, Tru-D	Cd	~50	36,000	4.04 (2.43)
Boyce, 2011[28]	UV-C, Tru-D	Cd	67.8 (1 stage)	22,000	1.7-2.9
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

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

Rutala WA et al. Infect Control Hosp Epidemiol. 2021 May 21;1-3. doi: 10.1017/ice.2021.214.



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

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

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.

"No Touch" Plus "Touch" Is Key

Rutala WA, Brewer A. Healthcare Facilities Today
https://www.healthcarefacilitiestoday.com/posts/Integrated-infection-prevention-is-essential-for-protecting-patients--23476

- Adding an automated technology to manual cleaning/disinfection as part of a comprehensive, layered process is essential for combating Contact Precaution pathogens on all surfaces
- If the UVC device reduced HAIs for approximately 20% of patients (patients of Contact Precautions) by 10-30% as demonstrated in a randomized trial, a 900-bed hospital with an infection rate of approximately 4 per 1,000 patient days would see approximately 18-55 fewer infections per year.
- If the hospital prevented 10% of infections per year (18 per year) for two years, the cost savings would be $309,000 (considers cost-UVC, ES staff, HAI).
- If 30% of infections were prevented per year (55 per year) for two years, the cost savings would be $2,085,000.
- An independent analysis found the cost savings of no-touch terminal room disinfection on *Clostridioides difficile* infection incidence to be $348,528 to $1,537,000 per fiscal year. Pegues et al. ICHE 2017;38:39-44.

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 "No Touch" (e.g., UV, HP)

Weber, Rutala et al. Am J Infect Control, 2016

- Since different "no touch" systems (e.g., UV) 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

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)

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)

CONCLUSIONS

- To combat the ongoing battle against infection and patient harm, HCF need to establish a comprehensive, layered set of procedures combining CD and “no touch” technology
- UV is effective in reducing the number of MDRO pathogens
- UV is effective in reducing the number of bacterial, viral and yeast 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).

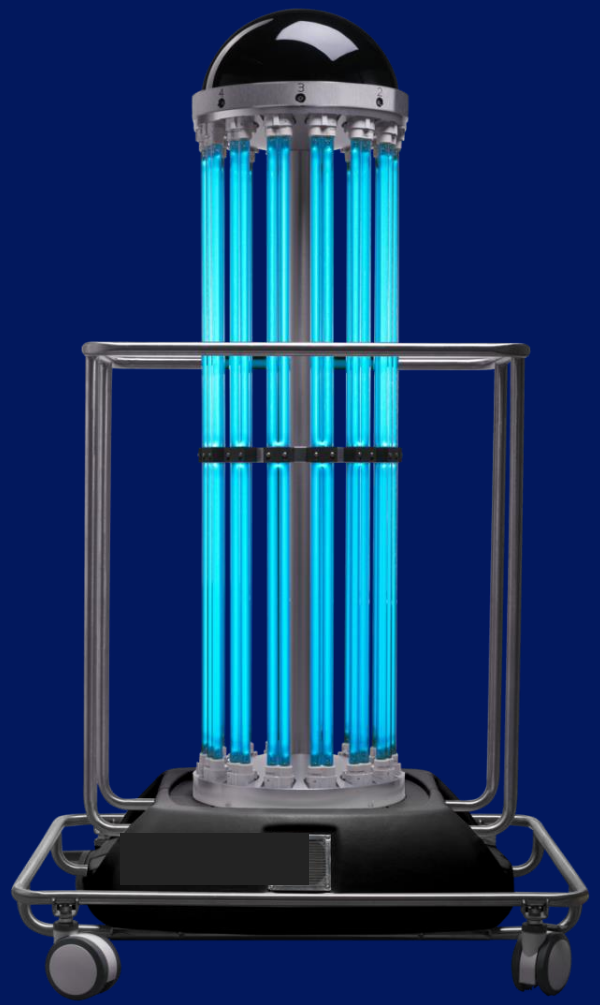
Lecture Objectives

- Role of environment in disease transmission
- SARS-CoV-2 via environment
- Effective surface disinfection technologies
  - Surface disinfection
  - Ultraviolet light
  - Other room decontamination technologies
  - Continuous room decontamination technology

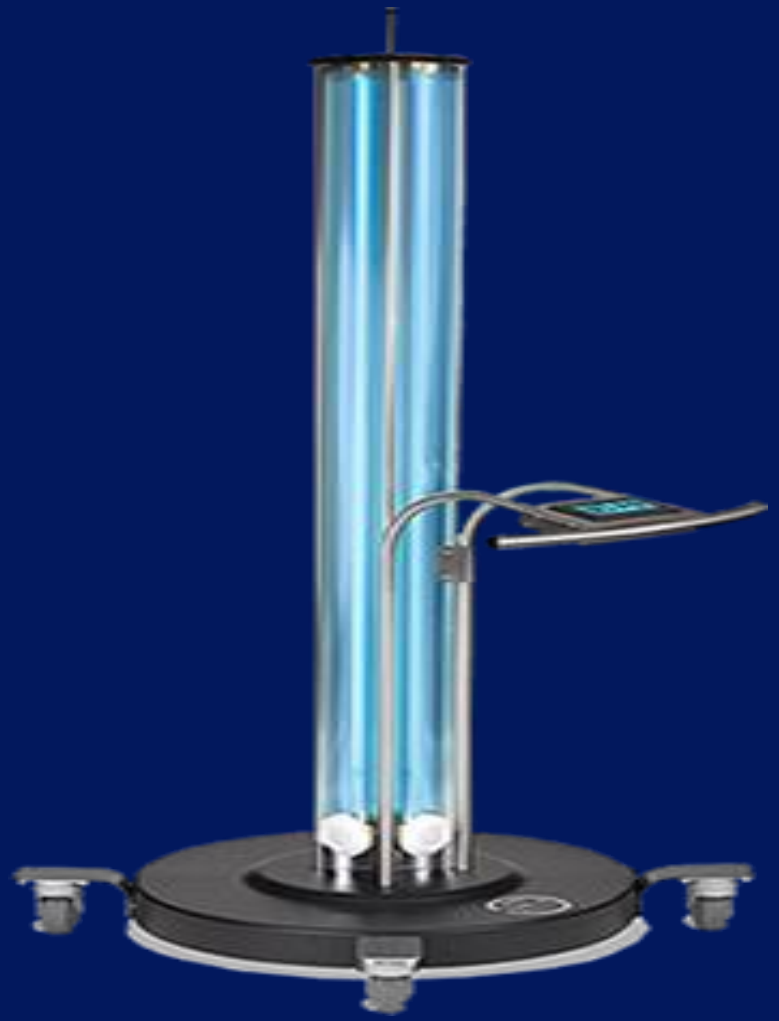
"NO TOUCH" APPROACHES TO ROOM DECONTAMINATION

(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.







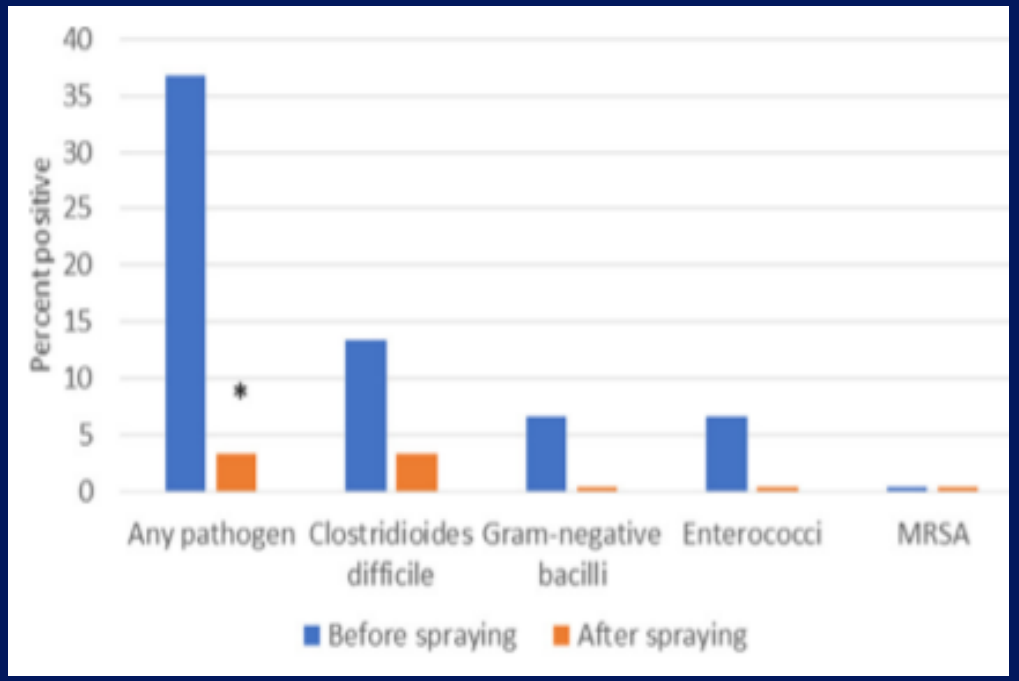
Efficacy of Disinfectant Spray in Reducing Pathogen Contamination

Cadnum et al. AJIC 2020

Picture of electrostatic sprayer
(0.25% sodium hypochlorite)



Efficacy of disinfectant spray
(waiting room chairs)



Lecture Objectives

- Role of environment in disease transmission
- SARS-CoV-2 via environment
- Effective surface disinfection technologies
  - Surface disinfection
  - Ultraviolet light
  - Other room decontamination technologies
  - Continuous room decontamination technology

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

No Touch

(supplements but does not replace surface cleaning/disinfection)

Environmental Contamination Leads to HAIs

- By contaminating hands/gloves via contact with the environment and transfer to patient or patient self inoculation
- Surfaces should be hygienically clean (not sterile)-free of pathogens in sufficient numbers to prevent human disease
- Two environmental surface concerns
  - Discharge/terminal-prevent infection to new patient in room
  - Daily room decontamination

Environmental Contamination Leads to HAIs

- By contaminating hands/gloves via contact with the environment and transfer to patient or patient self inoculation
- Surface should be hygienically clean (not sterile)-free of pathogens in sufficient numbers to prevent human disease
- Two environmental surface concerns
  - Discharge/terminal-new patient in room
  - Daily room decontamination (referred to “trash and dash”) and recontamination

Microbial Assessment of Recontamination with *Acinetobacter* in Patient Room Environment in Burn Units

Rutala et al. AJIC. 2020; 48 Suppl;S20

- Purpose: assess how much environmental sites (e.g., chair, bedrail, overbed table, stock cabinet, IV pump, etc.) become recontaminated with *Acinetobacter* over time after cleaning/disinfection.
- Results:
- At baseline all environmental sites sampled except overbed table were contaminated with *Acinetobacter*.
- No *Acinetobacter* were detected except bed rail just after cleaning/disinfection.
- First time to recontamination with *Acinetobacter* was 3 hours at chair, 2 hours at overbed table, 3 hours at stock cabinet, and 2 hours at IV pump. No recontamination was observed at the monitor.
- The level of *Acinetobacter* contamination on surfaces was occasionally high (e.g., when a stock cabinet was sampled at 5 hours, 75 of 96 CFU were *Acinetobacter*).
- The amount of recontamination with aerobes and *Acinetobacter* on some surfaces tended to increase over time.

Continuous Room Decontamination Technologies for Disinfection of the Healthcare Environment

Weber, Rutala et al. AJIC. 2019;47:A72; Rutala et al. ICHE 2019

- Visible light disinfection through LEDs
- Dry/dilute hydrogen peroxide
- Self-disinfecting surfaces (e.g., copper)
- Far UV 222 nm
- Bipolar ionization
- Multijet cold air plasma
- Continuously active disinfectant (CAD) or persistent disinfectant that provides continuous disinfection action
  - Allows continued disinfection and may eliminate the problem of recontamination
  - Patients, staff and visitors can remain in the room

Efficacy of a Continuously Active Disinfectant Against Healthcare Pathogens

Rutala WA et al. ICHE 2019;40:1284; Redmond et al. ICHE 2021, https://doi.org/10.1017/ice.2021.66

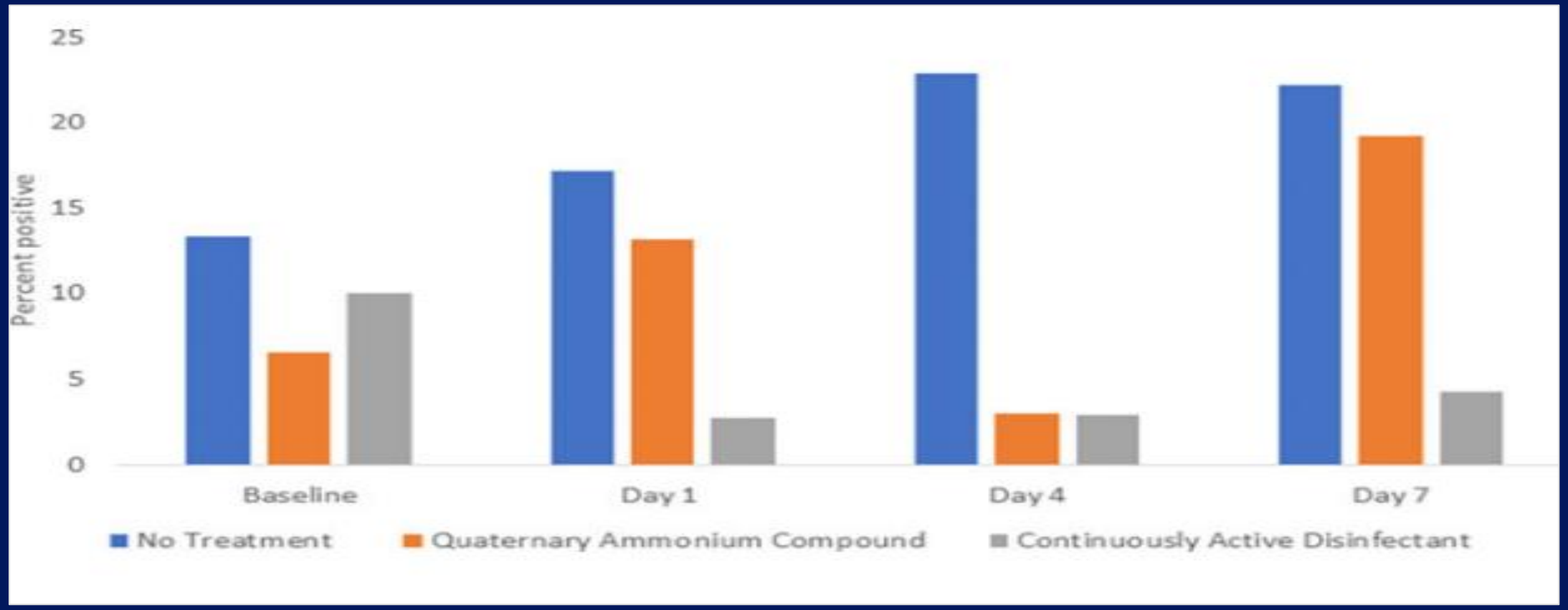
4-5 log_{10} reduction in 5min over 24hr for most pathogens; ~99% reduction with *Klebsiella* and CRE *Enterobacter*. Redmond et al. found 5 log_{10} reduction for CRE *Enterobacter, K. pneumoniae*, MRSA, VRE, and *C. auris*

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)

Efficacy of Continuously Active Disinfectant for Portable Medical Equipment

Redmond et al. ICHE 2021, https://doi.org/10.1017/ice.2021.66

- Comparison of *S. aureus* and enterococci recovered from PME at baseline, 1, 4, 7days
- The percentage of sites positive for *S. aureus* and/or enterococci was significantly reduced on days 1-7 in the continuously active group (3 of 93, 3%) versus both the no treatment group (20 of 97, 21%) and the Quat group (11 of 97, 11%)



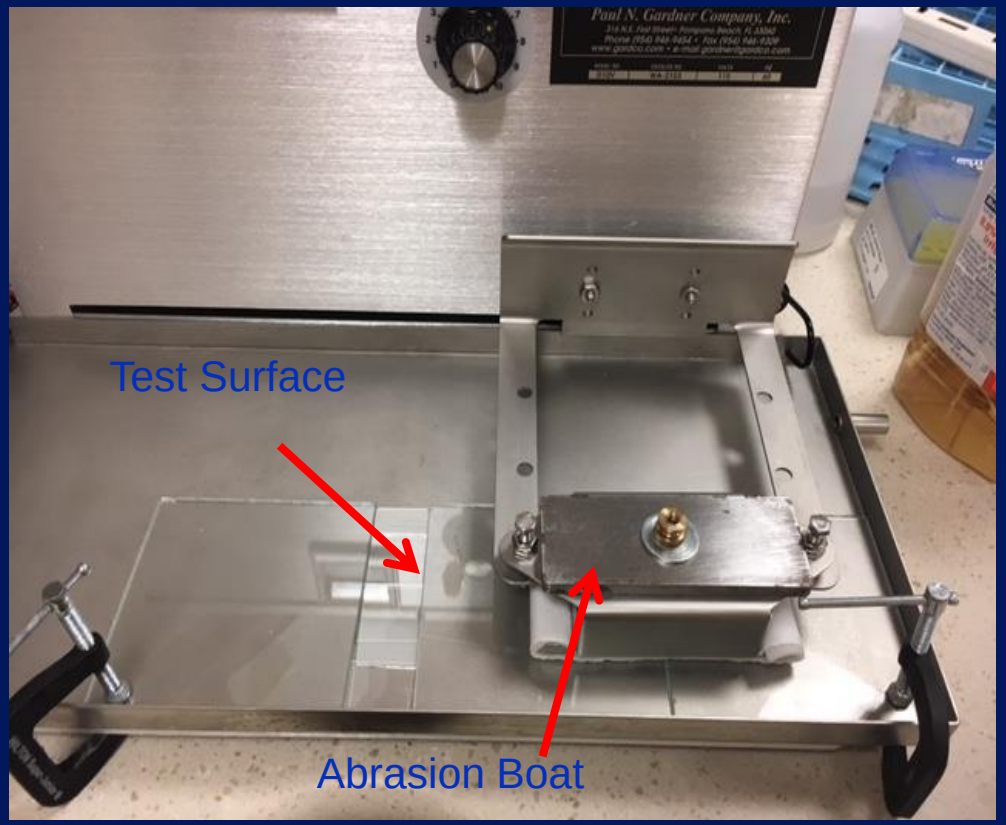
Will the continuously active disinfectant kill viruses like coronaviruses?

Evaluation of a Continuously Active Disinfectant

"EPA Protocol for Residual Self-Sanitizing Activity of Dried Chemical Residuals on Hard, Non-Porous Surfaces"

Rutala et al. Unpublished Results, 2021; Rutala et al. ICHE 2019

- Test surface inoculated (10^5), treated with test disinfectant, allowed to dry.
- Surface will undergo "wears" (abraded under alternating wet and dry conditions [24 passes, 12 cycles]) and 6 re-inoculations ($10^{\geq 3.75}$, 30min dry) over 48hr
- At the end of the study and at least 48 hours later, the ability of the test surface to kill microbes (99.9%) within 1 min is measured using the last inoculation (10^6)



Efficacy of a Continuously Active Disinfectant Against a Human Coronavirus, 229E, Evaluated after 48 hours

Rutala WA et al. Unpublished data, September 2020

A novel disinfectant studied using an EPA protocol (wears/re-inoculations) demonstrated excellent continuous antiviral activity (i.e., >4.5-log_{10} reduction) in 1 minute after 48 hours for a human coronavirus, 229E

Carrier Treatment with Wears and Re-inoculations	Contact Time	Mean Viral Recovery Titer per Carrier (log_{10})	Log_{10} Reduction
Control (sterile water, n=3)	1 minute	6.00 ± 0.25	N.A.
Test disinfectant (n=3)	1 minute	≤ 1.50 ± 0.00	>4.50

Efficacy of a Continuously Active Disinfectant

Summary

A continuously active disinfectant may reduce or eliminate the problem of recontamination and the role of contaminated environmental surfaces and equipment in transmission of healthcare pathogens including SARS-CoV-2.

Lecture Objectives

- Role of environment in disease transmission
- SARS-CoV-2 via environment
- Effective surface disinfection technologies
  - Surface disinfection
  - Ultraviolet light
  - Other room decontamination technologies (e.g., HP, ES)
  - Continuous room decontamination technology

COVID:19: Overview of Effective Surface Disinfection Technologies
Summary

- Follow CDC recommendations for cleaning/disinfection
- Provide education/training for cleaning/disinfection staff on proper PPE
- Use EPA-registered disinfectant on List N
- All noncritical touchable surfaces and medical devices cleaning/disinfection daily
- Assess cleaning/disinfection thoroughness with a validation method
- Comply with manufacturer's contact time for disinfectants
- Use "no touch" methods as adjunct to cleaning/disinfection for terminal disinfection
- Consistent with scientific literature, consider use of continuously active disinfectants

THANK YOU!
www.disinfectionandsterilization.org

THANK YOU!

www.disinfectionandsterilization.org

