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Ultraviolet Germicidal Irradiation Capabilities to Decontaminate N95 Filtering Facepiece Respirators during the COVID-19 Pandemic

Executive Summary

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Ultraviolet Germicidal Irradiation Capabilities to Decontaminate N95 Filtering Facepiece Respirators during the COVID-19 Pandemic

Situation

In this review, we will evaluate the evidence to support use of Ultraviolet Germicidal Irradiation (UVGI) light capabilities to decontaminate N95 Filtering Facepiece Respirators (FFRs) for reuse by health care workers during the COVID-19 pandemic, and the evolving state of practice. This review will also include information on the rapidly evolving state of practice for the use of UVGI to decontaminate N95 FFRs and Personal Protective Equipment, as relevant, for reuse by health care workers.

This review will focus on UVGI to support decontamination and reuse of N95 FFRs, plus includes relevant information regarding the current and evolving state of practice for UVGI to support decontamination and reuse of N95 FFRs and other substances.

Problem Statement:
Given the enormous volume of N95 FFRs used by health care workers during the COVID-19 pandemic, does evidence exist that supports use of UVGI to decontaminate N95 FFRs for reuse by health care workers as compared to other technologies, while maintaining effective fit and function of the N95 mask?

Technology under Evaluation:
The primary focus under evaluation is UVGI to support decontamination and reuse of N95 FFRs by health care workers during the COVID-19 pandemic. Information is also included on the state of practice for the use of UVGI, plus the cost for ultraviolet technology, to support decision making and selection of a UVGI system for use by health care organizations.

Goal(s) of Assessment:

1. To review the literature for use of UVGI to decontaminate N95 FFRs for reuse by health care workers and as relevant, other competing technologies.
2. Provide information to support decision making, including cost, accessibility, and impact to operations for use of UVGI to decontaminate N95 FFRs based upon supply-demand mismatch of PPE during the COVID-19 pandemic.

Background

The COVID-19 pandemic has presented enormous challenges, including disruption to the global and health care Supply Chain. Frequent shortages of N95 FFRs and other vital equipment have been experienced by health care workers and organizations, creating further adversity for health care workers while facing the challenges of care delivery. In the face of N95 FFRs shortages, health care organizations have responded with innovative solutions, utilizing technology that both draws from the past and the present. Ultraviolet light, which has historically been utilized to

"clean" or disinfect items and equipment used in care delivery, has emerged as a technology that can support decontamination of N95 FFRs for reuse by health care workers.

Ultraviolet light disinfects by disrupting the molecular bonds that hold together microbial genetic material or proteins. The most commonly used lights have a wavelength of 254 nanometers (nm), which has a relatively short UV wavelength, or the "C" category. UVGI uses ultraviolet light to inactivate microorganisms, primarily by cross-linking thymidine nucleotides in DNA and uracil nucleotides in RNA, which blocks replication. UVGI systems are relatively quick and easy to use, and do not leave chemical residues or risk exposing workers to toxic chemicals. Continuous ultraviolet germicidal irradiation (UVGI) is well-established for the electromagnetic radiation wavelength range of 225 nm to 302 nm. Implementation of UVGI to disinfect air in the upper, unoccupied regions of rooms was motivated by the need to control the spread of tuberculosis and measles in public spaces (Wells et al., 1942; Perkins et al.,1947).

Additional mediums that UVGI has been applied to include the use of UVGI to ''scrub'' the air in health care facilities and laboratories for many decades. UVGI has been known to be efficacious to varying degrees in controlling the circulation of airborne infectious particles. Approximately 60% of all UVGI air disinfection systems are installed in health care facilities (Memarzadeh, 2010). In laboratory settings, UVGI has been successfully used to decontaminate N95 respirators exposed to the bacteriophage MS2 (an icosahedral, positive-sense single-stranded RNA virus) and the influenza virus (enveloped, negative-sense single-stranded RNA virus)(Lindsley et al., 2015; Bouvier et al., 2008).

Decontamination of N95 FFRs with UVGI is supported with limited studies (Lowe, 2020). Options for using this technology include having an UVGI source available in house or by acquisition, a dedicated decontamination room, a detailed systematic process for labeling, obtaining used masks, UV dosing and tracking dose occurrences with a protocol for returning decontaminated masks to the staff, as is currently being used by the University of Nebraska (Lowe, 2020). Due to the limited scientific evidence, controversy exists on the effectiveness of UVGI for multiple reuse due to the impact on polymers and particle penetration.

The current CDC guidance states that decontamination and subsequent reuse of FFRs should only be practiced as a crisis capacity strategy. At present, FFRs are considered one time use and there are no manufacturer authorized methods for FFR decontamination prior to reuse. However, the CDC considers UVGI an acceptable method for decontamination and reuse of N95s for any patient care activity *other than* aerosol generating procedures (AGPs) during a crisis strategy situation, such as COVID-19 surges. It is recommended to discard any N95 FFRs if integrity is compromised resulting from decontamination. Precautions listed for use after this method include visual inspection, user seal checks with clean non-sterile gloves with attention to the potential for degradation of materials (Lindsley et al, 2015).

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Assessment

A review of the published literature to determine the evidence to support UVGI to decontaminate N95 FFRs is presented in the following sections. The results have identified the following guidelines and position statements addressing UVGI to support the reuse of N95 FFRs.

Position Statements and Guidelines:

Name of Organization	Date Searched	Guidance Identified
Department of Defense COVID-19 Practice Management Guidelines	April 22, 2020	N/A
Centers for Disease Control and Prevention (CDC)		
Decontamination and Reuse of Filtering Facepiece Respirators	April 22,2020	Link provided
CDC Environmental Control for Tuberculosis: Basic Upper-Room Ultraviolet Germicidal Irradiation Guidelines for Healthcare Settings	April 22, 2020	Link provided.
World Health Organization (WHO)		
WHO COVID-19 Guidelines	April 22, 2020	N/A
Occupation Safety and Health Administration		
OSHA Enforcement Guidance for Respiratory Protection and the N95 Shortage Due to the Coronavirus Disease 2019 (COVID-19) Pandemic	April 22, 2020	N/A

Guidelines

1. Centers for Disease Control: **Decontamination and Reuse of Filtering Facepiece Respirators**

Decontamination and subsequent reuse of N95 FFRs should only be practiced as a crisis capacity strategy. At present, FFRs are considered one time use and there are no manufacturer authorized methods for FFR decontamination prior to reuse.

Table A. Summary of Crisis Standards of Care Decontamination Recommendations

Method	Manufacturer or third-party guidance or procedures available	Recommendation for use after decontamination	Additional use considerations
Ultraviolet germicidal irradiation (UVGI)	Yes	Can be worn for any patient care activities	• Clean hands with soap and water or an alcohol-based hand sanitizer before and after touching or adjusting the FFR. • Avoid touching the inside of the FFR. • Use a pair of clean (non-sterile) gloves when donning and performing a user seal check. • Visually inspect the FFR to determine if its integrity has been compromised. • Check that components such as the straps, nose bridge, and nose foam material did not degrade, which can affect the quality of the fit, and seal. • If the integrity of any part of the FFR is compromised, or if a successful user seal check cannot be performed, discard the FFR and try another FFR. • Users should perform a user seal check immediately after they don each FFR and should not use an FFR on which they cannot perform a successful user seal check.
Vaporous hydrogen peroxide (VHP)			
Moist heat			
Ultraviolet germicidal irradiation (UVGI)	No	Can be worn for patient care activities except when performing or present for an aerosol generating procedure	
Vaporous hydrogen peroxide (VHP)			
Moist heat			

Table B. Summary of the Decontamination Method and Effect on FFR Performance

Method	Treatment level	FFR Filtration Performance	FFR Fit Performance	Other observations	References
Vaporous hydrogen peroxide (VHP)	Battelle report: Bioquell Clarus C HPV generator: The HPV cycle included a 10 min conditioning phase, 20 min gassing phase at 2 g/min, 150 min dwell phase at 0.5 g/min, and 300 min of aeration. Bergman et. al.: Room Bio-Decontamination Service (RBDS™, BIOQUELL UK Ltd, Andover, UK), which utilizes four portable modules: the Clarus® R HPV generator (utilizing 30% H2O2), the Clarus R20 aeration unit, an instrumentation module and a control computer. Room concentration = 8 g/m3, 15 min dwell, 125 min total cycle time.	Passed	FFR fit was shown to be unaffected for up to 20 VHP treatments cycles using a head form	Degradation of straps after 30 cycles (Battelle	
Ultraviolet Germicidal Irradiation (UVGI)	0.5–950 J/cm2	Passed	90–100% passing rate after 3 cycles depending on model		
Microwave generated steam	1100–1250 W microwave models (range: 40 sec to 2 min)	All models passed filtration evaluation for 1 or 20 treatment cycles as per test	95–100% passing rate after 3 and 20 cycles for all models tested		
Moist heat incubation	15 min–30 min (60°C, 80% RH)	6 of 6 models passed after 3 cycles of contamination	Passed		

2. Food and Drug Administration: Coronavirus Disease 2019 (COVID-19) Emergency Use Authorizations for Medical Devices

On February 4, 2020, the Secretary of the Department of Health and Human Services (HHS) determined, pursuant to section 564 of the Federal Food, Drug and Cosmetic (FD&C) Act, that there is a significant potential for a public health emergency that has a significant potential to affect national security or the health and security of United States citizens living abroad and that involves a novel (new) coronavirus (nCoV) first detected in Wuhan City, Hubei Province, China in 2019 (2019-nCoV). The virus is now named SARS-CoV-2, which causes the illness COVID-19.

Personal Protective Equipment Emergency Use Authorizations

On the basis of this determination, the Secretary declared that circumstances exist justifying the authorization of emergency use of personal respiratory protective devices during the COVID-19 outbreak, pursuant to section 564 of the FD&C Act, subject to the terms of any authorization issued under that section.

Date EUA Issued	PPE (Letter of Authorization)	Other Documents
04/20/2020	Sterilucent, Inc. Sterilization System	• Fact Sheet for Healthcare Personnel • Instructions for Healthcare Facilities • Instructions for Healthcare Personnel
04/18/2020	Face Masks (non-surgical)	• None
04/15/2020	Stryker STERIZONE VP4 N95 Respirator Decontamination Cycle	• Fact Sheet for Healthcare Personnel • Instructions for Healthcare Facilities • Instructions for Healthcare Personnel
04/11/2020	Advanced Sterilization Products (ASP) STERRAD Sterilization System	• Fact Sheet for Healthcare Personnel • Instructions for Healthcare Facilities • Instructions for Healthcare Personnel

Date EUA Issued	PPE (Letter of Authorization)	Other Documents
04/09/2020	STERIS Sterilization Systems for Decontamination of N95 Respirators	• Fact Sheet for Healthcare Providers • Instructions for Healthcare Facilities • Instructions for Healthcare Personnel
04/09/2020	Face Shields	• None
04/03/2020	Non-NIOSH-Approved Disposable Filtering Facepiece Respirators Manufactured in China	• Appendix A
03/29/2020	Battelle Decontamination System	• Fact Sheet for Healthcare Providers • Instructions for Healthcare Facilities • Instructions for Healthcare Personnel
03/28/2020	NIOSH-Approved Air Purifying Respirators for Use in Health Care Settings During Response to the COVID-19 Public Health Emergency	• EUA Clarification Letter on Respirators
03/28/2020	Imported, Non-NIOSH-Approved Disposable Filtering Facepiece Respirators	• Non-NIOSH Approved Respirator EUA FAQ

Product Specifications and Pricing

Based on the TractManager's consumable database, the pricing for UVGI systems that are both FDA approved through EUA and not, range from $15,000 to $100,000. Pricing can be dependent on several factors, including if a group or corporate agreement is in place. Consideration to the availability of different systems, given both aging and obsolescence issues, is important, as health care organizations will need immediate access to UVGI systems.

Table 1 below provides the most current information on pricing for Ultraviolet Room Disinfection Technology, which we provide as a reference to support procurement of UVGI systems.

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Table 1. Ultraviolet Room Disinfection Technology- Pricing

Product	Torch	Tru-D SmartUVC	Optimum-UV Enlight System	LightStrike
Manufacturer	ClorDiSys	Tru-D SmartUVC	UVDI, Inc.,	Xenex Disinfection Services
Product Features (From manufacturer website)	• 8 high-output UV-C 5 minutes at a distance of 10 feet. • 360 degree coverage angled for ceiling coverage to increase the dosage applied to the ceiling. • Up to 4 Torches can be daisy-chained together for larger areas or areas with complex shapes to get optimal coverage. • Optional: A UV intensity sensor is available to monitor both the intensity and dosage. • Torch Tower 68" H x 23" D x 23" W (1727mm H x 584mm D x 584mm W) 110-240 VAC, 6 Amps, 50/60 HZ 71 lbs (32 kg) • Lamps are rated 16,000 hours. • Lamp type: 4-pin, low pressure, UVC Germicidal, low ozone • Power cable: 15 feet, hospital grade • Produces an intensity of approximately	• Instrument-grade sensors calculate an accurately-timed cycle ensuring consistent, thorough disinfection. • Patented technology • Tru-D SmartUVC's 360 ° pathogen- • Tru-D is validated UV-C dose • Entire room disinfection • Single placement • Frees up staff • Shuts down automatically • Can notify staff via text or audio when cycle complete • Tru-D portal documents and tracks usage • Exportable data Brochure	• Combines powerful ultraviolet technology with smart data reporting. • 99.992% C. difficile Kill in 5 minutes at 8 feet and over 35 other HAI-causing pathogens • Intuitive Touch Screen Operating System • Smart Data System for Robust Data Collection • Verifies that a Specific UV-C Dose has been Received on a Target Surface • Cloud reporting and analytics • UV dose verify technology OR room Solutions brochure	• LightStrike Germ-Zapping Robots is delivers UV-B 200-315nm.and UV-C from 200-280 315nm. . • The LightStrike Germ-Zapping Robots deliver up to 4,300x more germicidal UV pathogen killing intensity than UV-C mercury vapor* and can disinfect an entire patient room in as little as 20 minutes • Cloud based reporting • Auto software update • Built in saftey feature senosr • Can create custom settings for room types, room numbers and postitions. OR Cleaning Solution 2 minute cycle at HOB for high touch surfaces Brochure

	10.80 mJ/cm2 per minute (180 µw/cm2) at a 10 ft distance. • 3" diameter hospital grade wheels, of resilient monoprene Brochure			
FDA Safety Recalls	No safety recalls located.			
MAUDE FDA Manufacturer and User Facility Device Experience	No adverse events located for the products of interest using the Advanced search feature for April 20, 2010 to April 20, 2020			
(NOTE: According to the FDA: "…MAUDE data represents reports of adverse events involving medical devices. The data consists of voluntary reports since June 1993, user facility reports since 1991, distributor reports since 1993, and manufacturer reports since August 1996. MAUDE may not include reports made according to exemptions, variances, or alternative reporting requirements granted under 21 CFR 803.19…")				

Table 2: Specifications for Ultraviolet Room Disinfection Technology

Vendor	ClorDiSys	Spectra 254/1100 (No longer available)	Steris Pathogon (No longer available)	Tru-D SmartUVC	UVDI, Inc.	Xenex Disinfection Services
Capital Cost	$15,000	$40,000	$63,000	$98,500	$39,000	$100,000
Technology	Teflon coated UV-C bulbs	Mercury Continuous UV	Xenon Gas Lamp	Mercury – Vapor Lamp	Mercury – Vapor Lamp	Xenon – Pulse Gas Lamp or pod
Wireless Control	Yes	Yes	Yes	Yes	No	Yes
Cycle Time	5-6 minutes	5 – 15 minutes	4 – 25 minutes	15-35 minutes	30 minutes	8– 12 minutes
Set up	10 foot distance center of room	Placed in 1 to 4 different positions	Placed in the center of the room	Placed in the center of the room	Placed in 3 different positions	Placed in 2 to 3 different positions
Consumables (bulbs)	Bulbs	Included with warranty	Included in Service Contract	Included in Service Contract	Included in Service Contract	Included in Service Contract
Warranty		3 years	1 year	1 year	1 year	1 year
Service Costs	Lumacept coating-$150-209/gallon 16,000hr/bulb	$3,500/yr (years 4 and 5)	$5,780/yr	$8,500/yr	$5,200 /yr	$14,400/yr
Cost per Room	$1.00	$7.34	$15.96	$24.53	$8.07	$27.72

(No Labor (1,000 rooms per year) calc						
Cost per Room (Labor Included)	NR	$44.53	$57.72	$35.96	$43.07	
Lease terms and multiple unit discounts dependent. https://www.americanultraviolet.com/germicidal-healthcare-solutions/mobile-room-UVC.html https://www.uvccleaningsystems.com/lease-now.html						

Clinical Studies

A review of existing clinical studies that evaluate UVGI to support the reuse of N95 FFRs is provided in Table 4. A review of existing clinical studies for UVGI and N95 FFRs was conducted, which identified four studies that directly compared UVGI impact on N95 FFRs. We then expanded our search to identify studies that also considered alternative decontamination methods, resulting in the discovery of four additional studies that compared UVGI as one of several methods of decontamination and its impact on different types of Corona viruses. The information that follows is a summary of the literature reviewed to date to inform decision making for organizations considering methods to support reuse of N95 FFRs.

A systematic review by O'Hearn and colleagues (2020) on the efficacy and safety of UVGI for decontaminating N95 masks included a range of non-heterogenous studies on the properties of FFRs, and included an evaluation of germicidal properties, particle penetration, and air-flow resistance, with two studies on physical properties. From O'Hearn's analysis, the viricidal dosing that is recommended is no less than 20,000 J/m2 and ideally 40,000 J/m2, which is more than the CDC recommendation that ranges 5000-18,000 J/m2 for decontamination measures. The CDC levels may spare material degradation, although two studies demonstrated changes in face seal and tensile elasticity of straps after decontamination after UVGI application (Lindsley et al., 2015).

N95 FFR performance after decontamination was evaluated by several studies, relative to aerosol penetration and airflow. Seven of the studies reviewed also considered germicidal eradication, which demonstrated a reduction of viable viral pathogens. Options for using this technology include: 1) Using UVGI as an available source in house or by acquisition; 2) Establishing a dedicated decontamination room; 3) Implementing a detailed systematic process for labeling and obtaining used masks; and 4) Tracking UV dosing and dose occurrences with a protocol for returning decontaminated masks to the staff (Lowe, 2020).

Table 3. Summary of Systematic Reviews
Key: CI; confidence interval, FFR; filtering facepiece respirator; j/m² Joules per meter squared mfr; manufacturer, MD; mean difference, mm; milmeters, NIOSH; National Institute for

Occupational Safety and Health, UV-C, ultraviolet C; UV, ultraviolet; UVGI, ultraviolet germicidal irradiation, v; versus, w/; with

Citation Affiliation	Purpose of Review Included Studies Date of Last Search	Results	Key Findings / Strengths / Limitations
O'Hearn et al. (2020) Funding source: none	Systematic review to evaluate efficacy of UVGI on FFR decontamination. Search dates: 146-March 22, 2020 Included studies: - 13 studies -58 N95 masks -54 UVGI arms 7 studies -Viral/bacterial load 6 studies-physical appearance/odor 5 studies - aerosol penetration- 3 studies- air-filtration/flow/odor 2 studies-fit	Aerosol particle penetration: w/ I^2 heterogeneity p=0.84 95%CI -MD: 0.09 UVGI v Control = avg 1.19% (0.70-2.48%) v. 1.14% (0.57-2.63%) Airflow resistance: - w/ I^2 heterogeneity p =0.75 95%CI -MD: 0.03 UVGI v control = 9.79 v.9.85mm h^2o Germicidal reduction: -20,000 j/m^2->2 log reduction -40,000 j/m^2->3 log reduction Fit- pre- and post UVGI-multi-donning Physical Appearance – 5 -visual inspection -no significant change Odor- sniffing visual analog scale -no significant change	Authors pooled results findings suggest NIOSH standards met pre and post UVGI arms at 20,000 - j/m^2 for viral log reduction of > 2 and at 40,000 j/m^2 showed > 3 log reduction . No significant changes aerosol particle penetration, airflow resistance or appearance and odor. For Fit studies at 16,200–32,000 j/m^2 their results did not show compromise, but suggested further work in this area to with dosed at 40,000 j/m^2 Strengths: - Controlled studies or pre/post design (same lot # masks) -Extensive literature search and inclusion criteria by -Outcome evaluators blinded to study arms other than intervention Limitations -laboratory study settings -limited data -assumption of little difference between mfr mask types -calculated administered UV-C dose when time or intensity not reported.

Table 4: Summary of UVGI Clinical Studies Methods and Findings

Key: bdl; below detection limits, cov, coronavirus; dsDNA, double stranded dna; dsRNA, double stranded RNA; FFR, filtering facepiece respirator; hcw; healthcare worker, j/cm^2, joules per centimeter square, mfr; manufacturer, m; mean, mgs-microwave generated steam, mh; moist heat, niosh; national institute for occupational safety and health puvgi, pulsed ultraviolet germicidal irradiation; ssDNA, single stranded dna; ssRNA, single stranded rna; uv-c, ultraviolet c; uv, ultraviolet, uvdr; ultraviolet decontamination and reuse, UVGI, ultraviolet germicidal irradiation; WHO, world health organization.

Authors/Study Design	Study Population	Treatment	Results	Key Findings/ Strengths/Limitations
Nemeth et al. 2020 Field Study to determine healthcare workers perspective on UVDR methods of FFR in Influenza pandemic Structured guided interviews *Funding source*: NR	n=19 individual hcw interviews n=103 focus group interviews n=285 individual surveys	Interview/survey to evaluate on 1-10 scale: 1 low to 10 high = mean perception of safety -No FFR, -FFR extended period without decontamination -FFR with UVDR	No FFR: m=1.2 FFR extended period and no decontamination m=4.20 FFR w/ UVDR m= 7.72	In abstract conclusion perceptions reveal need for preparation and training for successful implementation of a UVDR program when needed to mitigate potential FFR shortages in a pandemic. *Conflicts of Interest*: None declared
Mills et al. 2018 Single Arm Study Controlled pre-post	No patient population studied. 12 samples each of 15 FFR N95 mask-various mfr	For each N95 FFR model, 12 intact FFRs were aseptically inoculated with 10 1-µL droplets of H1N1 influenza within a 2 cm2 area on 4 areas of each FFR, delivering 7 log10 TCID50 to each area. Each FFR was inoculated in the same 4 areas: the top, middle, and bottom of the facepiece's exterior (from the perspective of a donned FFR), and the strap.	Viral log reduction ≥3 for both soil agent and artificial skin contaminants to masks and straps after UVGI	Data suggest that FFR decontamination and reuse using UVGI can be effective. Implementation of a UVGI method will require careful consideration of FFR model, material type, and design. Strengths: • UVGI technology was used specifically *Limitations:* • Small, single site lab study • Staff proficiency w/ device not established at onset of study

		For each soiling agent, 3 contaminated FFRs were treated with 1 J/cm2 UVGI for approximately 1 minute, whereas 3 other contaminated FFRs remained untreated. Mean UV dose per FFR = 1.1 ± 0.1 J/cm2; mean temperature = 21°C ± 2°C; and the mean relative humidity = 48% ± 6% within the UV device. Outcomes: UVGI decontamination efficiency of influenza-contaminated FFRs was shown to be achieved by log reduction, rather than total absence of virus		*Conflicts of Interest:* None declared
Lindsley et al. 2017 Controlled pre-post experimental study on the effects of UVGI on the filtration performance and structural integrity of N95 respirator.	No patient population studied. Circular coupons and FFR mask straps from 4 models of N95 FFRs 3M 1860 3M 9210	UV-C 254 nm in a 91cm x31 x64 cm chamber 6 .2 cm below lamps Rotation of coupons for doses 0, 120, 240, 470, or 950 J/cm2 of UV-C on each side then tested for:	Airflow resistance- <6% change pre and post Particle penetration m= <5% pre-post (1.25% increase KC 46727)	The investigators summarized that UVGI could be used to disinfect FFRs with attention to the UVGI dose required to inactivate the pathogen. The impact of increasing doses of UV-C had an effect on all categories, though not always statically significant and varied between the masks tested. The strength of the strap at the decreased at progressive UV-C doses as did the bursting strength of the coupon layers. Particle penetration was within NIOSH limits.

	Gerson 1730 Kimberly-Clark 46727	Burst Strength – 12.7mm at 2.5 mm/sec Air flow rate 5 lpm Straps UVGI doses: 0, 590, 1180, or 2360 J/cm2 Materials testing machine stretch rate of 5mm/sec	Straps- breaking strength pre and post - 10%- 21% lowest dose and up to 51 % highest dose.	NOTE: respirators with a smaller safety margin between the actual penetration value and the 5% maximum allowed for an N95 respirator would need to be cautiously considered *Limitations:* -laboratory study -assumption that UVGI would be similar to their 4 models tested. -For air resistance testing unilateral airflow and a dry salt aerosol was used versus wearer exhaling humid air. *Conflict of interest:* None declared
Lore et al. 2012 Controlled Cohort study 3 FFR decontamination methods UVGI, Microwave-Generated Steam and Moist Heat Air-Force Research Laboratory Contract	No patient population studied. n=54 (9 control, 9 each model/per arm) 3M model -1860 3M model 1870	Inoculation with A/H5N1 and incubation environment and exposure duration were equal between controls and treated masks. UVGI- 18 k/jm $^{-2}$ Wavelength for 15 minutes MGS- 2 minutes at full power	Particle Penetration % pre/post-model # UVGI m= 1.08/0.99 1860 m= 0.39/0.37 1870 MGS	Deactivation of viable A/H5N1 applied to two 3M mask models at what the authors describe as “worst case scenario” viral load was noted with all three treatment methods with an absolute viral log reduction of > 4.0 logs tested by culture. More *inactive* viral genomic material remained with the MGS and MH methods. Post-decontamination filter performance for aerosol penetration was < 5 %. meeting NIOSH standards. *Strengths*:

		MH- 65 ± 5°C for 20minutes (after 3 hour prep) Non-treated respirators served as controls were exposed to virus. Followed by 1 % NaCl aerosol challenge and NIOSH certified filter testing of 300 nm particle size.	m=1.08/1.51 1860 m=0.39/0.99 1870 MH m=1.08=/1.04 1860 m=0.39/0.99 1870 Virus Concentrations Quantified with Spearman–Karber method expressed as log10 TCID50, Untreated Controls Model 1860 4.66 log10 Model 1870 4.70 log10 Virus Concentration post- treatment mean UVGI- Both masks m= > 4.0 log10 reduction	live virus, pre-post studies *Limitations*: laboratory setting v. human droplets minimal masks tested *Conflicts of interest:* None declared

			MGS Both masks m= > 4.0 log10 reduction MH-Both masks m= > 4.0 log10 reduction	
Heimbuch et al. 2010 Applied Research Associates	No patient population studied. 6 commercially available FFRs 4 circular coupons cut from each mask	Inoculation of masks with H1N1 influenza Treatment arms: UVGI 254 nm-15 minutes MGS- 1250 watt microwave – 2 minutes MH- 30 minutes treatment (3 hours prep) Aerosol application of H1N1 Droplet application of H1N1	Post-decontamination *Viral Load Reduction* UVGI m=4.08-5 log reduction MGS m=5.67 to 5.94 log reduction MH m=4.91-5.50 log reduction Recovery of viable H1N1 virus *Aerosol application:*	All 3 methods effectively decontaminated the H1N1 virus when treated after aerosol spray, decreasing viral log by an average of 4.69. In the droplet nuclei tests sporadic viable virus was detected with the UVGI and MGS on a few of the masks and may pose a risk to the wearer so optimization of treatment was advised for these methods. Investigators also reported a MGS treatment of one mask caused a slight separation of the foam nose cushion. *Strengths*: live virus, pre-post studies *Limitations*: -laboratory setting v. human droplets -minimal masks tested

			UVGI= BDL MGS=BDL MH=BDL *Droplet application* UVGI 4 of 6 mask=BDL MGS= BDL 3 of 6 masks MH= BDL	*Conflicts of interest:* None declared
Tseng and Li 2007 Experimental laboratory study to determine the doses of UVGI needed for virus inactivation on surfaces. Clinical Registry Identifier: NR Funding source: None	No patient population was studied. Laboratory samples of 4 different bacteriophages w/ ssDNA, ssRNA, dsDNA, and dsRNA were tested in laboratory conditions.	UV: UV exposure was delivered by germicidal UV lamps with a radiation peak at 253.7 nm placed 30.5 cm above the samples. A range of doses were applied to identify those with desired levels of germicidal activity. Control: Samples were not exposed to UV or any other sanitizing intervention Both were tested under 55% and 85% RH	Laboratory Outcomes Required UV dose for 90% viral reduction: • ssRNA: 1.32 to 3.20mJ/cm2 • ssDNA: 2.50 – 4.47 mJ/cm2 • dsRNA: 3.80-5.60 mJ/cm2 • dsDNA: 7.70-8.13 mJ/cm2 For all, UV dose for 99% reduction in viral count was twice as high as for 90% reduction.	Results suggest dsRNA and dsDNA viruses are more resistant to UVGI than those of ssRNA and ssDNA viruses. Note: Coronavirus is an ssRNA virus Strengths: • Evaluated UVGI impact on viruses similar to the coronavirus (ssRNA) Limitations: • Used gelatin- based medium and may not be generalizable to all other kinds of surfaces that viruses may be found on. • Laboratory in vitro study • Does not study a UV robot Conflicts of Interest: NR

		Outcomes: Viral counts as determined Assessments: Single assessment, 24 hours after UV exposure	Higher UV doses were needed to achieve the same amount of viral reduction at higher RH. Complications N/A Operational Outcomes NR. Study authors note UVGI cannot completely penetrate shadowed areas/crevices	
Duan et al. 2003 Experimental laboratory study to test the impact of heat plus UV on viral infectivity of SARS CoV-P9. Clinical Registry Identifier: NR Funding source: NR, performed by Chinese Center for Disease Control and Prevention and Institute for Viral Disease Control and Prevention	No patient population was studied. Effects of UV on 96-well plates of 106 TCID 50 viruses in culture medium on viral activity was examined.	UV: >90 uw/cm2 at distance of 80 cm; exposed in 96-well plates. Irradiation was applied from 15 minutes to 150 minutes. No non-UV control was used Outcomes: Viral infectivity	Laboratory Outcome Infectivity declined after 15 minutes of UV exposure. 60 minutes of UV irradiation caused destruction of viral infectivity (undetectable viral levels achieved) Complications NA	Results suggest • SARS coronavirus is sensitive to UV irradiation; destroyed after 60 minutes of application. Strengths: • Tested the SARS coronavirus, similar to the virus of interest Limitations: • Laboratory in vitro study.

		Assessments: Viruses were collected from the plates and tested at unspecified 'various intervals.'	Operational Outcomes NA	
Lin W et al, 2018 Experimental laboratory study to test the effectiveness of PUVGI for inactivating an aerosolized surrogate of a human respiratory virus.	Φ6 bacteriophage (a surrogate used to study communicable enveloped human respiratory viral pathogens such as influenza virus) was aerosolized by a Collison device into an enclosed test defined.	Virus-laden airstreams were studied in a quiescent enclosed space.	Pulsed UV exposure of 10 to 30 s resulted in a two-log reduction in viable recovered virus from filter membranes and cyclone-based samplers. The small differences in Φ6 survival, after 10 to 30 s of exposure, emphasized the difficulty of complete eradication. Exposure to 10 s of PUVGI resulted in significant reduction of virus viability.	Study demonstrated the potency of PUVGI against a viral bioaerosol. Strengths: • Evaluated UVGI impact on viruses similar to the coronavirus (ssRNA) Limitations: • Used gelatin- based medium and may not be generalizable to all other kinds of surfaces that viruses may be found on.

State of Practice

Based on the literature reviewed, the state of practice (SOP)for the use of UVGI to decontaminate N95 FFRs for reuse is provided below in Table 6, as a summary of observations identified through the literature. We have also included state of practice for the UVGI application for other materials. Ongoing monitoring of the literature is recommended, given the evolving status for UVGI application.

Table 5. State of Practice Observations related to UVGI use for Equipment and Substances

Type	Observation	SOP Implication	Source/Organization
N95 FFR	Requires consideration to maximum number of disinfection cycles, limited by FFR model and the UVGI dose required to inactivate the pathogen.	Step 1: After each use, health care workers put their masks in a paper bag. Step 2: The bag then goes to a room equipped with a UV light tower which is also used to decontaminate patient room air. The ultraviolet light disrupts the coronavirus's genetic material, deactivating it.	Lowe C et al. Nebraska Medicine, 2020
N95 FFR	Requires several phases to decontaminate. Requires consideration to maximum number of disinfection cycles, limited by FFR model and the UVGI dose required to inactivate the pathogen.	2 step process to disinfect: 1st step: Expose to UV-C light for 2 hours. 2nd step: Place in dry heat warming unit to disinfect.	Beaumont Health System, Michigan, 2020
Airstream	Requires pulsed UVGI exposure up to 10 s for reduction of virus viability on airstream.	Dose–response used for fast-decay regime of aerosolized Φ6 (Z = 0.24 m2/J) is similar to those reported for influenza A virus aerosols at similar relative humidity.	Lin W et al, 2017
Surfaces	Requires UVGI setting that is effective, but does not damage PPE.	Double UV dose is required to achieve 99% reduction across viral types. dsRNA and dsDNAviruses are more resistant to UVGI than those of ssRNA (ie COVID-19 disease virus type) and ssDNA viruses.	Tseng and Li, 2007

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Summary

This review examined the current literature relevant to the use of UVGI to support decontamination reuse of N95 FFRs. UVGI has the potential for additional applications in the healthcare setting for decontamination of surfaces, and supplemental information on this topic was also included. As identified in the Assessment section, the clinical studies reviewed identified several different methodologies and range requirements to utilize UVGI to be both safe and effective. The evidence to support decision making for organizations related to using UVGI provides compelling guidance for decontamination of N95 FFRs for reuse by health care workers.

Given the current supply challenge for N95 FFRs, UVGI is a potential method to enable reuse of these items. Prior to implementing UVGI technology, health care organizations will need to evaluate the current state of their operations to identify strategies that align their operational capacity and resource availability with the selection of an UVGI technology, to include staff, facility space and financial support. Based on these factors, health care organizations should evaluate whether insourcing or outsourcing decontamination services better aligns with their organization's operations. Additional considerations include: 1) the need to develop protocols for use of UVGI and criteria for reusing N95s, plus other Personal Protection Equipment targeted for reuse after decontamination; 2) number of times N95 can be reused, as the FDA EUA has set standard for reuse to be no greater than two times after decontamination; and 3) process for identifying each user's N95, per FDA EUA guidance (NOTE: CDC guidance does not address #2 or #3). Lastly, organizations will need to develop staff education materials to support use of UVGI technology.

Controversy does exist on the effectiveness of UVGI for multiple reuse, due to the lack of scientific evidence and the impact on polymers and particle penetration. The current CDC considerations for decontamination by UVGI and reuse report that the method is acceptable for any patient care activity other than aerosol generating procedures (AGPs) for a crisis strategy situation such as COVID-19 surges. The CDC summary of effectiveness and performance shared was 99.9% effective for all viruses including SARs-CoV, although COVID-19 (SARs CoV-2) was not specifically listed. The precautions listed for use after this method include visual inspection, user seal checks with clean non-sterile gloves with attention to the potential for degradation of materials (Lindsley et al, 2015).

Ongoing monitoring of future literature publications is recommended to inform decision making and update the state of practice for the use of UVGI to support the reuse of N95 FFRs for health care workers.

Abstracts

Stability of SARS coronavirus in human specimens and environment and its sensitivity to heating and UV irradiation

Duan S et al. Biomed Environ Sci. 2003 Sep;16(3):246-55.

OBJECTIVE: The causal agent for SARS is considered as a novel coronavirus that has never been described both in human and animals previously. The stability of SARS coronavirus in human specimens and in environments was studied.

METHODS: Using a SARS coronavirus strain CoV-P9, which was isolated from pharyngeal swab of a probable SARS case in Beijing, its stability in mimic human specimens and in mimic environment including surfaces of commonly used materials or in household conditions, as well as its resistance to temperature and UV irradiation were analyzed. A total of 10(6) TCID50 viruses were placed in each tested condition, and changes of the viral infectivity in samples after treatments were measured by evaluating cytopathic effect (CPE) in cell line Vero-E6 at 48 h after infection.

RESULTS: The results showed that SARS coronavirus in the testing condition could survive in serum, 1:20 diluted sputum and feces for at least 96 h, whereas it could remain alive in urine for at least 72 h with a low level of infectivity. The survival abilities on the surfaces of eight different materials and in water were quite comparable, revealing reduction of infectivity after 72 to 96 h exposure. Viruses stayed stable at 4 degrees C, at room temperature (20 degrees C) and at 37 degrees C for at least 2 h without remarkable change in the infectious ability in cells, but were converted to be non-infectious after 90-, 60- and 30-min exposure at 56 degrees C, at 67 degrees C and at 75 degrees C, respectively. Irradiation of UV for 60 min on the virus in culture medium resulted in the destruction of viral infectivity at an undetectable level.

CONCLUSION: The survival ability of SARS coronavirus in human specimens and in environments seems to be relatively strong. Heating and UV irradiation can efficiently eliminate the viral infectivity.

Effects of Ultraviolet Germicidal Irradiation (UVGI) on N95 Respirator Filtration Performance and Structural Integrity

Lindsley W et al. J Occup Environ Hyg. 2015;12(8):509-17. doi: 10.1080/15459624.2015.1018518.

The ability to disinfect and reuse disposable N95 filtering facepiece respirators (FFRs) may be needed during a pandemic of an infectious respiratory disease such as influenza. Ultraviolet germicidal irradiation (UVGI) is one possible method for respirator disinfection. However, UV radiation degrades polymers, which presents the possibility that UVGI exposure could degrade the ability of a disposable respirator to protect the worker. To study this, we exposed both sides of material coupons and respirator straps from four models of N95 FFRs to UVGI doses from 120-950 J/cm(2). We then tested the particle penetration, flow resistance, and bursting strengths of the individual respirator coupon layers, and the breaking strength of the respirator straps. We found that UVGI exposure led to a small increase in particle penetration (up to

1.25%) and had little effect on the flow resistance. UVGI exposure had a more pronounced effect on the strengths of the respirator materials. At the higher UVGI doses, the strength of the layers of respirator material was substantially reduced (in some cases, by >90%). The changes in the strengths of the respirator materials varied considerably among the different models of respirators. UVGI had less of an effect on the respirator straps; a dose of 2360 J/cm(2) reduced the breaking strength of the straps by 20-51%. Our results suggest that UVGI could be used to effectively disinfect disposable respirators for reuse, but the maximum number of disinfection cycles will be limited by the respirator model and the UVGI dose required to inactivate the pathogen.

Inactivation of viruses on surfaces by ultraviolet germicidal irradiation.

Tseng CC and LI CS. J Occup Environ Hyg. 2007 Jun;4(6):400-5. DOI: 10.1080/15459620701329012.

In many outbreaks caused by viruses, the transmission of the agents can occur through contaminated environmental surfaces. Because of the increasing incidence of viral infections, there is a need to evaluate novel engineering control methods for inactivation of viruses on surfaces. Ultraviolet germicidal irradiation (UVGI) is considered a promising method to inactivate viruses. This study evaluated UVGI effectiveness for viruses on the surface of gelatin-based medium in a UV exposure chamber. The effects of UV dose, viral nucleic acid type (single-stranded RNA, ssRNA; single-stranded DNA, ssDNA; double-stranded RNA, dsRNA; and double-stranded DNA, dsDNA), and relative humidity on the virus survival fraction were investigated. For 90% viral reduction, the UV dose was 1.32 to 3.20 mJ/cm2 for ssRNA, 2.50 to 4.47 mJ/cm2 for ssDNA, 3.80 to 5.36 mJ/cm2 for dsRNA, and 7.70 to 8.13 mJ/cm2 for dsDNA. For all four tested viruses, the UV dose for 99% viral reduction was 2 times higher than those for 90% viral reduction. Viruses on a surface with single-stranded nucleic acid (ssRNA and ssDNA) were more susceptible to UV inactivation than viruses with double-stranded nucleic acid (dsRNA and dsDNA). For the same viral reduction, the UV dose at 85% relative humidity (RH) was higher than that at 55% RH. In summary, results showed that UVGI was an effective method for inactivation of viruses on surfaces.

Pulsed ultraviolet light decontamination of virus-laden airstreams

Lin W et al. Aerosol Science and Technology. 2017 Jan;51(5); 554-563. Published online: 24 Jan 2017. https://doi.org/10.1080/02786826.2017.1280128.

Continuous ultraviolet germicidal irradiation (UVGI) has been extensively studied, but research on pulsed UVGI (PUVGI) is lacking and has primarily focused on disinfection of solid surfaces or liquids. This study addressed the gap in knowledge on the effectiveness of pulsed UVGI for

disinfecting virus-laden calm air, with relevance to indoor rooms. Φ6 bacteriophage (a surrogate used to study communicable enveloped human respiratory viral pathogens such as influenza virus) was aerosolized by a Collison device into an enclosed test chamber, wherein the bioaerosol was exposed to PUVGI. The spectral content and performance of a pulsed white light lamp with a substantial UVC component were defined. Pulsed UV exposure of 10 to 30 s resulted in a two-log reduction in viable recovered virus from filter membranes and cyclone-based samplers.

The small differences in Φ6 survival, after 10 to 30 s of exposure, emphasized the difficulty of complete eradication. However, exposure to 10 s of PUVGI resulted in significant reduction of virus viability. The dose–response displayed clear regimes of fast and slow exponential decay. Susceptibility factor for the fast-decay regime of aerosolized Φ6 (Z = 0.24 m2/J) was similar to those reported for influenza A virus aerosols at similar relative humidity. Our study demonstrated the potency of PUVGI against a viral bioaerosol. This has potential implications for the control of infectious bioaerosols in the healthcare setting.

Effectiveness of three decontamination treatments against influenza virus applied to filtering facepiece respirators.

Lore M et al. Ann Occup Hyg. 2012 Jan;56(1):92-101. doi: 10.1093/annhyg/mer054. Epub 2011 Aug 22.

Filtering facepiece respirators (FFRs) are recommended for use as precautions against airborne pathogenic microorganisms; however, during pandemics demand for FFRs may far exceed availability. Reuse of FFRs following decontamination has been proposed but few reported studies have addressed the feasibility. Concerns regarding biocidal efficacy, respirator performance post decontamination, decontamination cost, and user safety have impeded adoption of reuse measures. This study examined the effectiveness of three energetic decontamination methods [ultraviolet germicidal irradiation (UVGI), microwave-generated steam, and moist heat] on two National Institute for Occupational Safety and Health-certified N95 FFRs (3M models 1860s and 1870) contaminated with H5N1. An aerosol settling chamber was used to apply virus-laden droplets to FFRs in a method designed to simulate respiratory deposition of droplets onto surfaces.

When FFRs were examined post decontamination by viral culture, all three decontamination methods were effective, reducing virus load by > 4 log median tissue culture infective dose. Analysis of treated FFRs using a quantitative molecular amplification assay (quantitative real-time polymerase chain reaction) indicated that UVGI decontamination resulted in lower levels of detectable viral RNA than the other two methods. Filter performance was evaluated before and after decontamination

using a 1% NaCl aerosol. As all FFRs displayed <5% penetration by 300-nm particles, no profound reduction in filtration performance was caused in the FFRs tested by exposure to virus and subsequent decontamination by the methods used. These findings indicate that, when properly implemented, these methods effectively decontaminate H5N1 on the two FFR models tested and do not drastically affect their filtering function; however, other considerations may influence decisions to reuse FFRs.

A pandemic influenza preparedness study: use of energetic methods to decontaminate filtering facepiece respirators contaminated with H1N1 aerosols and droplets.

Heimbuch B et al. Comment in Am J Infect Control. 2011 Sep;39(7):615. DOI: 10.1016/j.ajic.2010.07.004

BACKGROUND: A major concern among health care experts is a projected shortage of N95 filtering facepiece respirators (FFRs) during an influenza pandemic. One option for mitigating an FFR shortage is to decontaminate and reuse the devices. Many parameters, including biocidal efficacy, filtration performance, pressure drop, fit, and residual toxicity, must be evaluated to verify the effectiveness of this strategy. The focus of this research effort was on evaluating the ability of microwave-generated steam, warm moist heat, and ultraviolet germicidal irradiation at 254 nm to decontaminate H1N1 influenza virus.

METHODS: Six commercially available FFR models were contaminated with H1N1 influenza virus as aerosols or droplets that are representative of human respiratory secretions. A subset of the FFRs was treated with the aforementioned decontamination technologies, whereas the remaining FFRs were used to evaluate the H1N1 challenge applied to the devices.

RESULTS: All 3 decontamination technologies provided >4-log reduction of viable H1N1 virus. In 93% of our experiments, the virus was reduced to levels below the limit of detection of the method used.

CONCLUSIONS: These data are encouraging and may contribute to the evolution of effective strategies for the decontamination and reuse of FFRs.

Ultraviolet (UV)-reflective paint with ultraviolet germicidal irradiation (UVGI) improves decontamination of nosocomial bacteria on hospital room surfaces.

Jelden K et al. J Occup Environ Hyg. 2017 Jun;14(6):456-460. doi: 10.1080/15459624.2017.1296231.

An ultraviolet germicidal irradiation (UVGI) generator (the TORCH, ClorDiSys Solutions, Inc.) was used to compare the disinfection of surface coupons (plastic from a bedrail, stainless steel, and chrome-plated light switch cover) in a hospital room with walls coated with ultraviolet (UV)-reflective paint (Lumacept) or standard paint. Each surface coupon was inoculated with methicillin-resistant Staphylococcus aureus (MRSA) or vancomycin-resistant Enterococcus faecalis (VRE), placed at 6 different sites within a hospital room coated with UV-reflective paint or standard paint, and treated by 10 min UVC exposure (UVC dose of 0-688 mJ/cm2 between sites with standard paint and 0-553 mJ/cm2 with UV-reflective paint) in 8 total trials. Aggregated MRSA concentrations on plastic bedrail surface coupons were reduced on average by 3.0 log10 (1.8 log10 Geometric Standard Deviation [GSD]) with standard paint and 4.3 log10 (1.3 log10 GSD) with UV-reflective paint ($p = 0.0005$) with no significant reduction differences between paints on stainless steel and chrome.

Average VRE concentrations were reduced by ≥4.9 log10 (<1.2 log10 GSD) on all surface types with UV-reflective paint and ≤4.1 log10 (<1.7 log10 GSD) with standard paint ($p < 0.05$). At 5 aggregated sites directly exposed to UVC light, MRSA concentrations on average were reduced by 5.2 log10 (1.4 log10 GSD) with standard paint and 5.1 log10 (1.2 log10 GSD) with UV-reflective paint ($p = 0.017$) and VRE by 4.4 log10 (1.4 log10 GSD) with standard paint and 5.3 log10 (1.1 log10 GSD) with UV-reflective paint ($p < 0.0001$). At one indirectly exposed site on the opposite side of the hospital bed from the UVGI generator, MRSA concentrations on average were reduced by 1.3 log10 (1.7 log10 GSD) with standard paint and 4.7 log10 (1.3 log10 GSD) with UV-reflective paint ($p < 0.0001$) and VRE by 1.2 log10 (1.5 log10 GSD) with standard paint and 4.6 log10 (1.1 log10 GSD) with UV-reflective paint ($p < 0.0001$). Coating hospital room walls with UV-reflective paint enhanced UVGI disinfection of nosocomial bacteria on various surfaces compared to standard paint, particularly at a surface placement site indirectly exposed to UVC light.

Ultraviolet germicidal irradiation of influenza-contaminated N95 filtering facepiece respirators

Mills D et al. American Journal of Infection Control 46 (2018):49-55.

Background: Safe and effective decontamination and reuse of N95 filtering facepiece respirators (FFRs) has the potential to significantly extend FFR holdings, mitigating a potential shortage due to an influenza pandemic or other pandemic events. Ultraviolet germicidal irradiation (UVGI) has been shown to be effective for decontaminating influenza-contaminated FFRs. This study aims to build on past research by evaluating the UVGI decontamination efficiency of influenza-contaminated FFRs in the presence of soiling agents using an optimized UVGI dose.

Methods: Twelve samples each of 15 N95 FFR models were contaminated with H1N1 influenza (facepiece and strap), then covered with a soiling agent—artificial saliva or artificial skin oil. For each soiling agent, 3 contaminated FFRs were treated with 1 J/cm2 UVGI for approximately 1

minute, whereas 3 other contaminated FFRs remained untreated. All contaminated surfaces were cut out and virus extracted. Viable influenza was quantified using a median tissue culture infectious dose assay.

Results: Significant reductions (≥3 log) in influenza viability for both soiling conditions were observed on facepieces from 12 of 15 FFR models and straps from 7 of 15 FFR models. Conclusions: These data suggest that FFR decontamination and reuse using UVGI can be effective. Implementation of a UVGI method will require careful consideration of FFR model, material type, and design.

Preparing for an Influenza Pandemic: Hospital Acceptance Study of Filtering Facepiece Respirator Decontamination Using Ultraviolet Germicidal Irradiation.

Nemeth C et al. Patient Saf. 2020 Mar 12. doi: 10.1097/PTS.0000000000000600. [Epub ahead of print]

OBJECTIVES: Predictions estimate supplies of filtering facepiece respirators (FFRs) would be limited in the event of a severe influenza pandemic. Ultraviolet decontamination and reuse (UVDR) is a potential approach to mitigate an FFR shortage. A field study sought to understand healthcare workers' perspectives and potential logistics issues related to implementation of UVDR methods for FFRs in hospitals.

METHODS: Data were collected at three hospitals using a structured guide to conduct 19 individual interviews, 103 focus group interviews, and 285 individual surveys. Data were then evaluated using thematic analysis to reveal key themes.

RESULTS: Data revealed noteworthy variation in FFR use across the sample, along with preferences and requirements for the use of UVDR, unit design, and FFR reuse. Based on a scale of 1 (low) to 10 (high), the mean perception of safety in a high mortality pandemic wearing no FFR was 1.25 of 10, wearing an FFR for an extended period without decontamination was 4.20 of 10, and using UVDR was 7.72 of 10.

CONCLUSIONS: In addition to technical design and development, preparation and training will be essential to successful implementation of a UVDR program. Ultraviolet decontamination and reuse program design and implementation must account for actual clinical practice, compliance with regulations, and practical financial considerations to be successfully adopted so that it can mitigate potential FFR shortages in a pandemic.

Comparison of two whole-room ultraviolet irradiation systems for enhanced disinfection of contaminated hospital patient rooms.

Ali S et al. J Hosp Infect. 2017 Oct;97(2):180-184. doi: 10.1016/j.jhin.2017.08.011. Epub 2017 Aug 16.

BACKGROUND: Ultraviolet (UV) light decontamination systems are being used increasingly to supplement terminal disinfection of patient rooms. However, efficacy may not be consistent in the presence of soil, especially against Clostridium difficile spores.

AIM: To demonstrate in-use efficacy of two whole-room UV decontamination systems against three hospital pathogens with and without soil.

METHODS: For each system, six patient rooms were decontaminated with UV irradiation (enhanced disinfection) following manual terminal cleaning. Total aerobic colony counts of surface contamination were determined by spot-sampling 15 environmental sites before and after terminal disinfection and after UV irradiation. Efficacy against biological indicator coupons (stainless-steel discs) was performed for each system using test bacteria (106 cfu EMRSA-15 variant A, carbapenemase-producing Klebsiella pneumoniae) or spores (105 cfu C. difficile 027), incorporating low soiling [0.03% bovine serum albumin (BSA)], heavy soiling (10% BSA) or synthetic faeces (C. difficile only) placed at five locations in the room.

FINDINGS: UV disinfection eliminated contamination after terminal cleaning in 8/14 (57%) and 11/14 (79%) sites. Both systems demonstrated 4-5 log10 reductions in meticillin-resistant Staphylococcus aureus and K. pneumoniae at low soiling. Lower and more variable log10 reductions were achieved when heavy soiling was present. Between 0.1 and 4.8 log10 reductions in C. difficile spores were achieved with low but not heavy soil challenge.

CONCLUSION: Terminal disinfection should be performed on all surfaces prior to UV decontamination. In-house validation studies should be considered to ensure optimal positioning in each room layout and sufficient cycle duration to eliminate target pathogens.

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