AIR TREATMENT SYSTEM

LED UV PANEL

SERIES - LINE VOLTAGE

by

mhtlighting

illuminating PoE technology

WELCOME

How MHTL-UV Works ?

MHTL-UV uses years of advanced research and development in ultraviolet light.

· Air is quietly drawn into a sealed UV-C air chamber with a series of fans and filters.

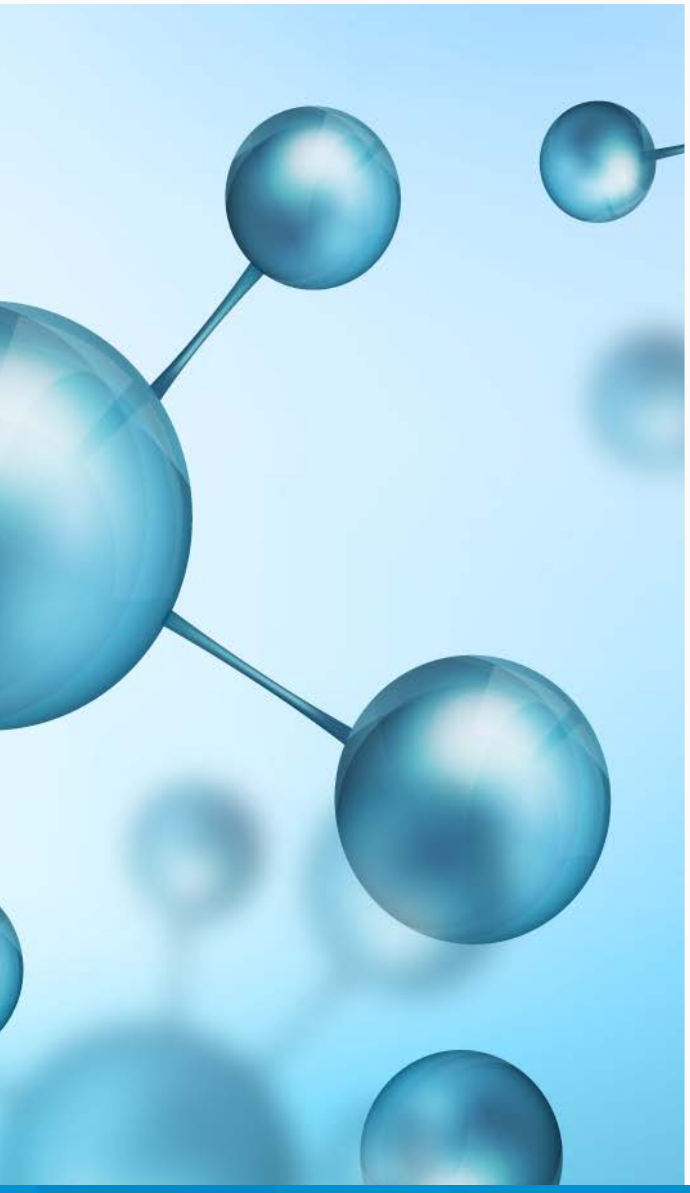
· Air is circulated through the UV-C air chamber where it is treated with an enclosed **high intensity UV-C light to de-activate bacteria, fungus and viruses** in the air. Treated air is then returned to the room creating a healthier environment.

· MHTL-UV air is unobtrusive, **works continuously**, and with the in-ceiling design, maintains the valuable floor space in patient and staff areas.

· MHTL-UV offers a **quiet operation** (< 35 db).

· Minimum of **two air circulation per hour providing 99.99% disinfecting solution**.

AUTOMATED CONTINUOUS UV-C AIR TREATMENT SYSTEM



Our engineered air system uses patented UV-C light air purification technology to reduce levels of viruses, bacteria and fungi by automatically and continuously treating the air to create healthier environments.

- **Simple** - MHTL-UV operates without interruption 24/7/365 and does not interfere with current staff workflow.
- **Seamless** - Designed with today's critical architectural and clinical considerations at the forefront, the system integrates a sealed UV-C air treatment chamber into existing or new construction in-ceiling lighting.
- **Effective** - Using the latest in advanced UV-C light purification technology, laboratory studies have shown effective removal of bacteria, fungus and viruses from the air.

Three kinds of antiseptic and antiviral mechanisms offer you 24hr all-weather protection against bacteria and virus with / without light

MHTL-UV - UV PANEL Series

GENERAL INFORMATION

Applications	Education / Hospitals / Labs / Hostpitality / Commercial
Warranty	Limited 5 Year Warranty*
Certifications	

PRODUCT DATA

Universal Input Voltage	120 - 277V
Mounting	Standard Grid Mount Ceiling Surface Mount Kit Suspended Cable Mount Kit
Rated Lifespan	> 10,000 Hours

ORDERING INFO: **Sample Code -** MHTL-UV-US-L

Series	Size	Mounting Options	Options
MHTL-UV			
MHTL-UV	US - 2x4 EU - 595mm x 1195mm	SM - Surface Mount Kit RM - Recessed Grid Mount AC - Suspended Cable Mount	(Blank) - No Light L - Led Light

* Aluminum body, IC board, light panel system, drivers & ballast: 5-year warranty · LV power supply and lamp holder: 2-year warranty · All other components: 1-year warranty

HOW UV-C AIR PURIFICATION WORKS

UV-C uses years of advanced research and development in ultraviolet light and IOT enabled technologies to create a truly modern and effective air treatment system:

- Using patented UV-C treatment technology, air is quietly drawn into a sealed UV-C air chamber with a series of fans and filters.
- Air is circulated through the UV-C air chamber where it is treated with an enclosed high intensity UV-C light to inactivate bacteria, fungus and viruses in the air.
- Treated air is then returned to the room creating a healthier environment.
- UV-C Clean Air is unobtrusive, works continuously, and with the in-ceiling design, maintains the valuable floor space in patient and staff areas.

COMMON APPLICATIONS

IDEAL FOR ALL PLACES OF GATHERING

HOSPITALS / LABS

Leading hospitals and Laboratory settings are combatting contaminated air with a proven, patented UV-C air purification system. Decrease the possibility of cross contamination in your labs.

EDUCATION

Create a safe environment for faculty and students in classroom settings.

COMMERCIAL

An outbreak of any kind is never conducive to productivity in the workplace. A sanitized work environment means employees feel safer at the office.

HOSPITALITY INDUSTRY

Crowded gathering places filled with strangers represent the largest opportunity for the spread of a virus or bacteria. Give patrons peace of mind by safeguarding these environments with an air sanitizing solution.

PROVEN EFFECTIVE

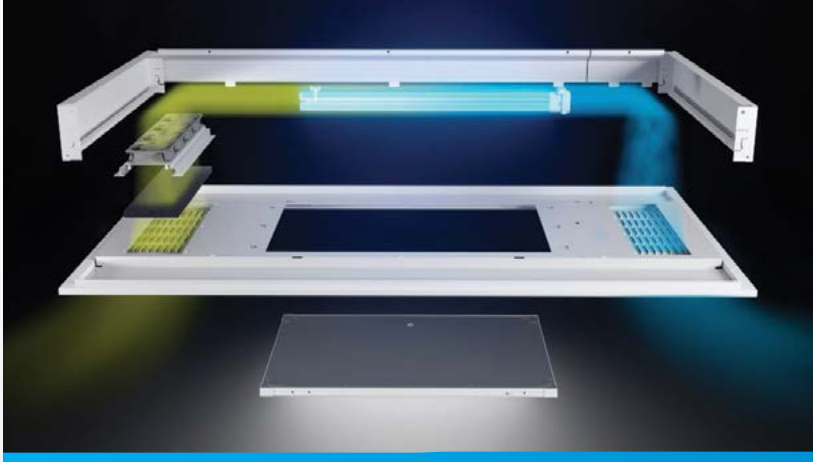
MHT Partners have conducted two separate third party laboratory tests against surrogate pathogens including Escherichia coli (gram-negative), Staphylococcus aureus (gram positive), Cladosporium cladosporioides (fungus spore formed) and MS2 Bacteriophage (MS2) (virus surrogate).

These tests conclusively support MHT Clean Air claims to treat bacteria, fungus and viruses in the air. The studies have proven the product's effectiveness at treating:

- **Gram-negative pathogens** which can cause pneumonias, bloodstream infections, wound and surgical site infections
- **Gram-positive pathogens** such as staphylococcus, streptococcus, enterococci and listeria
- **Fungal pathogen surrogates,** which could include pathogens such as aspergillus, yeasts and histoplasmosis

The UV Panel Air laboratory results showed elimination rates up to

99.99%



Research has shown that reducing contamination in the air also

REDUCES BACTERIA AND FUNGUS ON SURFACES.

Hospital air samples, on average, are

UP TO 8 TIMES MORE CONTAMINATED THAN SURFACES.[1]

1 Lee, Linda D, DrPH, MBA, LV-17-C042, Can using active air UV-C technology reduce the amount of bacteria and/or fungus in the air and improve indoor air quality? ASHRAE Conference (2017)

EFFICACY OF CEILING MOUNTED UV-C SYSTEMS

The CDC states that ultraviolet irradiation of air is an effective means of "reducing the transmission of airborne bacterial and viral infections in hospitals."1 Ultraviolet germicidal irradiation (UVGI) occurs when UV light at an effective wavelength of 254 nanometers, disrupts the nucleic acid in the DNA of a microorganism, preventing it from replicating.

The development of active UVGI air treatment systems that assume the footprint of a standard 600x1200mm ceiling panel or light fixture was developed in recent years. Similar to upper room air treatment and active air duct treatment, these systems can be safely used in occupied spaces dynamically where the pathogens are generated and freely circulated. Below are a few studies that show the effectiveness of this UV-C technology in healthcare.

PEER-REVIEW HOSPITAL

After installing UV-C ceiling mounted systems, airborne bacteria in patient rooms were reduced an average of **42%** in a hospital in Kentucky. 2 Common HAIs and catheter-associated urinary tract infections were reduced significantly as were overall infections by **60%**. There were no reported changes to the amount or type of cleaning done, infection control protocols, or reporting procedures. Other infections traditionally considered contact transmissible (central line–associated bloodstream infection and methicillin-resistant Staphylococcus aureus), also declined noticeably.

C. Diff reduced 88%
MRSA reduced 54%
VREs reduced 14%

CAUTIs reduced 55%
CLABSIs reduced 44%
Overall infections reduced 60%

Conclusions: Continuous shielded UV-C reduced airborne bacteria and may also lower the number of HAIs, including those caused by contact pathogens. Reduced infections result in lessened morbidity and lower costs.

UV VS. CORONAVIRUSES

There is currently great interest in emerging pathogens like coronaviruses. Approximately 100 sequences of the SARS-CoV-2 genome have been published and these suggest there are two types, Type I and Type II, of which the latter came from the Huanan market in China while the Type I strain came from an unknown location (Zhang 2020).

The effectiveness of UV on Coronaviruses was started by Hirano back in 1978. The table below summarizes the results of studies that have been performed on Coronaviruses under ultraviolet light exposure, with the specific species indicated in each case. The D90 value indicates the ultraviolet dose for 90% inactivation. Although there is a wide range of variation in the D90 values, this is typical of laboratory studies on ultraviolet susceptibility. The range of D90 values for coronaviruses is 7-241 J/m 2, the average which is 67 J/m 2, should adequately represent the ultravioletsusceptibility of the SARS-CoV-2 (COVID-19) virus.

MICROBE:	D90 Dose J/M^2	UV km^2/J	Base Paris kb	Source
Coronavirus	7	0.35120	30741	Walker 2007[a]
Berne virus (Coronviride)	7	0.32100	28480	Weiss 1986
Murine Coronavirus (MHV)	15	0.15351	31335	Hirano 1978
Canine Coronavirus (CCV)	29	0.08079	29278	Saknimit 1988[b]
Murine Coronavirus (MHV)	29	0.08079	31335	Saknimit 1988[b]
SARS Coronavirus coV-P9	40	0.05750	29829	Duan 2003[c]
Murine Coronavirus (MHV)	103	0.02240	31335	Lui 2003
SARS Coronavirus (Hanoi)	134	0.01720	29751	Kariwa 2004[d]
SARS Coronavirus (Urbani)	241	0.00955	29751	Darnell 2004
AVERAGE:	67	0.03433		
	[a] jingwen	[b] estimated	[c] mean estimate	[d] at 3 logs

PROOF OF EFFECTIVENESS

Tests conclusively support that MHT Air treats bacteria, fungus and viruses in the air including: Gram negative and gram-positive bacteria, fungal pathogens and viral surrogates. The MHT Air results showed laboratory elimination rates up to **99.99%.**

Sources: Centers for Disease Control and Prevention. 2007 Guideline for Isolation Precautions: Preventing Transmission of Infectious Agents in Healthcare Settings. Available from: http://www.cdc.gov/hicpac/2007IP/2007isolationPrecautions.html. Accessed 26 August 2016 2. Tina Ethington, MSN, RN, CEN, NE-BC, Sherry Newsome, BSN, RN, MBA/MNA, Jerri Waugh, BSN, RN, MBA/MHA, Linda D. Lee, DrPH, MBA, Cleaning the air with ultraviolet germicidal irradiation lessened contact infections in a long-term acute care hospital, American Journal of Infection Control, December 2017 3. Douglas W.Kane, MD; Cynthia Finley RRT; Diane Brown RRT, Linda Lee PhD, UV-C Light and Infection Rate in a Long Term Care Ventilator Unit, May 23, 2016 4. Don Guimera, MSN, RN, CIC, CCRP, FAPIC, Jean Trzil, PharmD, Joy Joyner, RN, CIC, Nicholas D. Hysmith, MD, FAAP, Effectiveness of a shielded UV-C air disinfection system in an inpatient pharmacy of a tertiary care children's hospital, American Journal of Infection Control, August 2017 5. Linda D. Lee., DrPH, MBA, Surface and air: What impact does UV-C at the room level have on airborne and surface bacteria? Canadian Journal of Infection Control, Summer 2017 6. Lee. Report on the Performance of the UV Angel Air aWalker CM, Ko G Effect of ultraviolet germicidal irradiation on viral aerosols. Environ. Sci. Technol. 2007, 41, 15, 5460-5465 Weiss M, Horzinek MC. Resistance of Berne virus to physical and chemical treatment. Vet Microbiol. 1986;11(1-2):41-49. doi:10.1016/0378-1135(86)90005-2 Hirano N, Hino S, Fujiwara K Physico-chemical properties of mouse hepatitis virus (MHV-2) grown on DBT cell culture. Microbiol Immunol. 1978;22(7):377-90. bSaknimit M1, Inatsuki I, Sugiyama Y, Yagami K. Virucidal efficacy of physico-chemical treatments against coronaviruses and parvoviruses of laboratory animals. Jikken Dobutsu. 1988 Jul;37(3):341-5. cDuan SM, et. al, Stability of SARS coronavirus in human specimens and environment and its sensitivity to heating and UV irradiation. Biomed Environ Sci. 2003 Sep;16(3):246-55. Darnell ME, et al, Inactivation of the coronavirus that induces severe acute respiratory syndrome, SARS-CoV. J Virol Methods. 2004 Oct;121(1):85-91. dKariwa H1, Fujii N, Takashima I Inactivation of SARS coronavirus by means of povidone-iodine, physical conditions, and chemical reagents. Jpn J Vet Res. 2004 Nov;52(3):105-12.

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Major Article

Cleaning the air with ultraviolet germicidal irradiation lessened contact infections in a long-term acute care hospital

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Key Words:
UV-C
air disinfection
HAI
infection prevention
airborne bacteria

Background: This study was designed to determine whether removing bacteria from the air with ultraviolet germicidal irradiation (UV-C) at the room level would reduce infection rates.

Methods: We reviewed infection data for 12 months before and after UV-C installation in the special care unit (SCU) of a long-term acute care hospital. All patients admitted to the SCU during the study time frame were included. Microbiologic impactor air sampling was completed in August 2015. Shielded UV-C units were installed in 16 patient rooms, the hallway, and the biohazard room. Air sampling was repeated 81 days later.

Results: After UV-C installation, airborne bacteria (colony forming units [CFU] per cubic meter of air) in patient rooms were reduced an average of 42% (175 vs 102 CFU/m^3). Common health care–associated infections (HAIs) (*Clostridium difficile* [8 cases annually vs 1 case, $P = .01$] and catheter-associated urinary tract infection [20 cases annually vs 9 cases, $P = .012$]) were reduced significantly as were overall infections, in number of cases (average 8.8 per month vs 3.5, $P < .001$), and infection rate (average monthly rate 20.3 vs 8.6, $P = .001$), despite no reported changes to the amount or type of cleaning done, infection control protocols, or reporting procedures. Other infections, traditionally considered contact transmissible (central line–associated bloodstream infection and methicillin-resistant *Staphylococcus aureus*), also declined noticeably.

Conclusions: Continuous shielded UV-C reduced airborne bacteria and may also lower the number of HAIs, including those caused by contact pathogens. Reduced infections result in lessened morbidity and lower costs. Health care facilities might wish to consider continuous shielded UV-C at the room level as a possible addition to their infection prevention and control protocols.

BACKGROUND

Ultraviolet germicidal irradiation (UV-C) in various delivery methods has been clearly demonstrated to reduce bacteria. Seminal work published in 1877 showed that bacteria died when exposed to sunlight.[1] In 1924, Coblentz and Fulton published their work on the germicidal effects of ultraviolet radiation.[2] Sharp, in 1939, demonstrated the ultraviolet dosages needed to kill a variety of bacteria.[3] Through the years, investigations became more specific and the study of delivery methods expanded to include upper-room delivery and the development of a mobile emitter.

Kujundzuc et al used aerosolized active bacterial cells and fungal spores to seed a test room. Results showed UV-C lamps inactivated 75% of fungal spores and 97% of bacterial cells within 60 minutes.[4] In a guinea pig study, Escombe et al showed using upper-room UV-C lights prevented TB infections by 70% over the control group with no UV-C.[5]

However, trials in operational hospital settings that demonstrate the effectiveness of continuous (24/7) UV-C in clearing bacteria from the air have been lacking, as have investigations of whether cleaning the air could help reduce health care–associated infections (HAIs). This study was designed to see whether using continuous shielded UV-C at the room level to lower the bioburden in the air would have a positive effect on the rate and type of

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Conflicts of interest: L.D.L. is employed by American Green Technology.

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infections in patients in an intensive care unit of a long-term acute care hospital (LTAC).

HAIs present a problem of sizable proportions. The Centers for Disease Control and Prevention (CDC) reported that in 2011 (the most recent year for available data), 721,800 HAIs were recorded. An estimated 75,000 deaths occurred as a result of an HAI.[6] The CDC has made reduction of HAIs a priority.

To protect their patients, health care facilities are actively seeking ways to reduce pathogens that can result in HAIs. Airborne transmission of disease including influenza and tuberculosis has been well documented.[7-9]

In addition to the prevalence of HAIs, health care facilities must face the problem of antimicrobial resistance. The CDC reports that 1 in 4 catheter- and surgery-related HAIs in LTACs is caused by resistant bacteria identified as an urgent or serious threat. These pathogens include carbapenem-resistant *Enterobacteriaceae*, methicillin-resistant *Staphylococcus aureus* (MRSA), extended-spectrum β-lactamase–producing *Enterobacteriaceae*, vancomycin-resistant enterococci (VRE), multidrug-resistant *Pseudomonas*, and multidrug-resistant *Acinetobacter*.[10]

Beyond the cost in human life and health, HAIs create a huge economic impact. Marchetti and Rossiter, in 2013, estimated the cost of HAIs to U.S. society to be $96-$147 billion annually (in 2007 dollars).[11] Zimlichman et al, in a meta-analysis, reported the average attributable per patient costs of *Clostridium difficile* ranged from $9,118-$13,574 and MRSA costs was an average of $42,300 (in 2012 dollars).[12] Scott reported catheter-associated urinary tract infection (CAUTI) costs ranged from $862-$1,007 per incident. Cumulatively, the annual range for all occurrences of CAUTI was $0.39-$0.45 billion.[13]

HAIs also impact a facility's financial situation in a very direct way. The Deficit Reduction Act of 2005 required the listing of conditions that can cause payments by the Centers for Medicare and Medicaid Services to be reduced. Multiple HAIs are included on the list of conditions for 2017.[14,15] Reducing the number of these infections is a top priority for health care facilities, and this concern helped drive this study.

MATERIALS AND METHODS

The study was conducted in the special care unit (SCU) of a 123-bed LTAC in the east southcentral part of the United States. The analysis included comparing a baseline period during which air samples were obtained with a later period during which continuous UV-C room-level air cleaning occurred.

The SCU is this facility's intensive care unit. All patient rooms are negative pressure with single beds, and were occupied during the pre- and postinstallation time frames. All patients were on ventilators with gloves and gown contact precautions used throughout the study. Similar practices and patient acuity were reported for the preinstallation data review. Throughout the study, no additional cleaning or change in cleaning protocols or heating, ventilation, and air conditioning maintenance was reported in any room. Standard cleaning, maintenance, and infection control procedures were followed. Rooms were cleaned daily. Floors were mopped, trash was emptied, and bathrooms were cleaned. Terminal cleaning after patient discharge included cleaning all surfaces. Vaporized hydrogen peroxide was used, and the room was kept closed until a new patient was admitted.

Baseline sampling occurred August 11-12, 2015, when 130 samples from the SCU were collected onto trypticase soy agar plates (Hardy Diagnostics, Santa Maria, CA) for bacterial counts. Five to 9 samples were taken from each location (16 patient rooms, the hallway, and the biohazard room). The biohazard room is used for soiled linen, patient equipment, sharps containers, food trays, and so on. It is approximately 14 m^2 in size and is under negative pressure. Representative areas sampled included next to the patient bed, near the linen cart, at the nightstand, and near the window.

Samples were collected with SAS 180 samplers (BioScience International, Rockville, MD). All samples were run at 1,000 L (approximately 5.5 minutes), and air was collected onto 90-mm sampling plates. As plates were collected, they were packaged with frozen gel packs and shipped overnight to an independent laboratory (Antimicrobial Test Laboratories, Round Rock, TX; now named Microchem).

The sampler works by pulling 1,000 L of air through a 219-hole perforated cover. The air impacts the agar plates, which are coated with blood or other nutrients. The bacteria that impinges on the plates start to reproduce and form colonies. These colonies are counted (raw colony forming units [CFU]). The CFU counts are adjusted for the probability that >1 viable particle was pulled through a single sampling hole and merged with other particles on the plate to produce a single colony. This adjustment is the correction hole factor, standard in the industry.

After baseline sampling was completed, 24 UV-C units (VidaShield; American Green Technology, South Bend, IN) were installed. Sixteen units were installed in patient rooms (1 unit per room installed in the ceiling over the bed). Seven units were installed in the hallway (every other ceiling light was replaced with a UV-C unit), and 1 was in the biohazard room.

The facility had established housekeeping protocols for occupied patient rooms and also for terminal cleaning at patient discharge, but they had no protocol for cleaning the air. Because there was no program to validate American Society of Heating, Refrigerating and Air-Conditioning Engineers air exchanges and percent air recirculation, all air in the SCU was treated, not just that in patient rooms. Air moves freely among patient areas, doors are opened and closed, and hallways exchange air with other areas, including air from outside the building. UV-C units were installed in the biohazard room to reduce odors in the SCU and lessen the amount of circulating bacteria and fungus in the air.

Each unit contains a fully shielded chamber with a UV-C bulb housed atop a standard 2×4 ceiling light fixture. The shielded ultraviolet lamp produces 15 W of high output UV-C energy at a wavelength of 253.7 nm. Each unit has 4 small fans that pull air through a MERV 6 filter on the way to the irradiation chamber, and then the treated air is pushed back into the room. The intake and exhaust baffles are set at a 30° angle, which moves the air in a pattern that avoids repeatedly recirculating the same air and allows for maximum retention time to treat the air in the chamber. The UV-C units run continuously, 24/7, whether the room downlight is on or off. Once the units were installed, operational rooms were reopened for normal patient use.

On November 15 and 16, 2015, 81 and 82 days after installation of the UV-C units, respectively, air sampling was repeated. The study was originally planned for 6 months, and this was about midway through the study period. The study was later extended for 6 more months to collect additional data. Repeat sampling procedures mirrored those in the baseline sampling period.

Infection records for the SCU during the period of September 2014-August 2015 and September 2015-August 2016 were examined. The following were tracked: resistant organisms, possible ventilator-associated pneumonia, central line–associated bloodstream infection, CAUTI, and *C difficile*. The number of patient days with a central line and with a Foley catheter were also recorded.

Infection surveillance data were gathered according to the CDC's National Healthcare Safety Network surveillance definitions and criteria.[16]

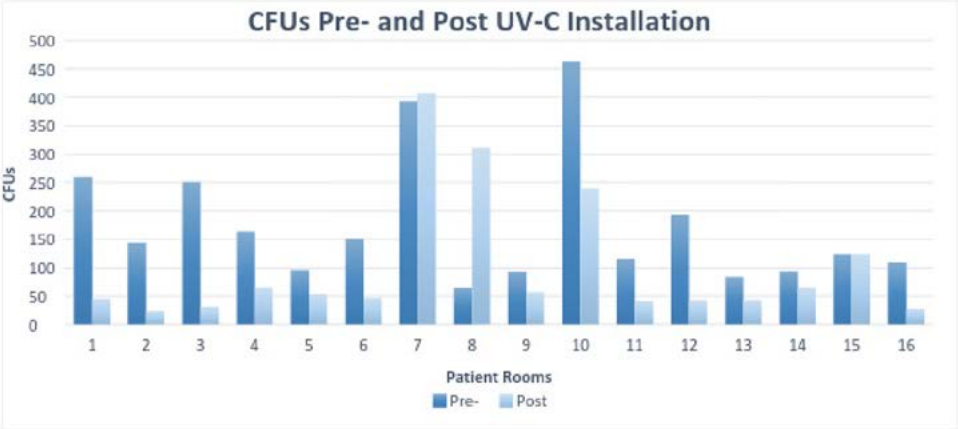

Fig 1. CFUs pre- and postultraviolet germicidal irradiation installation in patient rooms. *CFU*, colony forming units.

Table 1
Air results pre- and postinstallation

Location	Average baseline CFU/m^3 corrected	Average postinstallation CFU/m^3 corrected	% Corrected change	Difference (%)
Patient rooms	175	102	42 ↓	53
Biohazard room	258	172	33 ↓	40
Hallway	144	77	46 ↓	61

CFU, colony forming units.

RESULTS

XLSTAT software (Addinsoft, New York, NY) was used to compare pre- and postinstallation CFU (corrected) per meter cubed mean values from each area with a 2-tailed independent *t* test. The significance level α was set at 0.05; therefore, any *P* value ≤.05 was statistically significant. The mean CFU meter cubed count from patient rooms revealed an overall significant decrease in bacterial viable air particles by 42% ($P = .035$). Decreases in mean bacterial air particles in the biohazard room (33%) and the hallway (46%) were noted, but these values did not reach the level of statistical significance.

Results for patient rooms are shown in Figure 1.

Table 1 includes the average result for all patient rooms, plus the other areas included in the study.

Infection rates

The infection rate was calculated as number of infections per 1,000 patient days. Table 2 shows the number of infections as well as the infection rate for each month of the study.

DISCUSSION

Health care costs have spiraled upward for decades. HAIs have put patients at risk. We examined whether we could ameliorate both problems by asking whether reducing the pathogens in the air via continuous UV-C at the room level would result in fewer infections in patients.

There has been considerable investigation into the ability of UV-C to disrupt airborne pathogens, but much of that work was conducted in laboratories with seeded environments and selected contaminants, and not in an operational hospital setting. For example, Xu et al reported that ultraviolet germicidal irradiation reduced the room average concentration of culturable airborne bacteria between 46% and 98%, depending on the particular bacterium collected and the ventilation rate of the room.[17] Riley and Permutt conducted a study wherein a model room was aerosolized with *Serratia marcescens* and the effects of UV-C and ceiling fans were investigated. They concluded that moving the air with a large-bladed ceiling fan almost doubled the rate at which organisms were killed.[18] Tseng and Li reported on using UV-C against aerosolized viruses (4 different bacteriophages) in a laboratory test chamber. They concluded that airborne virus could be effectively inactivated with a UV-C dose recommended by the American Conference of Governmental Industrial Hygienists.[19] Miller et al found UV-C to be very effective at inactivating airborne bacteria in a full-scale test room environment.[20]

Anderson reported that in a cluster randomized, crossover trial at 9 U.S. hospitals, adding UV-C to standard cleaning protocols resulted in a significantly lower incidence of multidrug-resistant organisms (33.9 cases per 10,000 exposure days; relative risk, 0.70; 95% confidence interval, 0.50-0.98; $P = .036$).[21] Although this study was done in a live hospital setting, the UV-C delivery method was a mobile UV-C light emitter, which cannot be used in occupied space.

Our study was to explore the efficacy of implementing shielded UV-C at the patient room level where various pathogens are generated or brought into the patient environment by staff and visitors. The results showed a significant reduction in overall airborne bacteria. The success of this intervention is further bolstered by the reduction in overall infection rates for the 12 months of UV-C use versus the preceding 12-month period, without UV-C. Hospital infection control staff report no changes to cleaning protocols during that time. The maintenance staff also did not report any heating, ventilation, and air conditioning system changes during the study period.

We observed that although the infections reduced during our study are not those typically thought of as resulting from airborne transmission, they represent some of the expensive and aggressive HAIs. As Table 3 shows, not all HAI reduction achieved significant *P* value levels, but a clear trend is evident. Although fomites were not the focus of our study, the connections between airborne particles and resuspended particles are cogent to this work.

Roberts et al reported clear evidence of aerial dissemination of *C difficile* spores.[22] Kramer et al reported that most gram-positive bacteria, including MRSA and VRE, can survive on dry surfaces for months. Spores of *C difficile* can survive on surfaces for as long as 5 months.[23]

Table 2
Total infections and infection rate pre- and postinstallation of UV-C units

Pre–UV-C installation			Post–UV-C installation		
Date	No. of infections	Rate	Date	No. of infections	Rate
September 2014	5	11.26	September 2015	5	11.66
October 2014	8	18.78	October 2015	8	21.8
November 2014	10	22.99	November 2015	3	7.35
December 2014	15	41.32	December 2015	2	4.23
January 2015	14	29	January 2016	0	0
February 2015	7	16.39	February 2016	1	2.4
March 2015	10	20.79	March 2016	2	4.8
April 2015	5	11.29	April 2016	6	14.22
May 2015	6	13.48	May 2016	5	12.5
June 2015	9	19.82	June 2016	2	6.06
July 2015	7	16.47	July 2016	6	13.16
August 2015	10	22.57	August 2016	2	6.17
Total	106			42	
Average	8.833333	20.34667		3.5	8.695833

NOTE. The number of INFECTIONS have a *P* value of 0.00 and the infection RATE (per 1000 patient days) is 0.001. Student *t* test, 2-tailed *P* value infection rate .001.
UV-C, ultraviolet germicidal irradiation.

Martinez et al considered the environment as a risk factor for VRE, and concluded that among all other factors associated with VRE transmission, VRE acquisition may depend on room contamination, even subsequent to extensive cleaning.[24]

Hospodsky et al reported that direct human shedding may significantly impact the concentration of indoor air particles, especially in floor dust, which can then become resuspended in the air.[25] Nazaroff's keynote address at the Indoor Air 2014 meeting reviewed many similar studies that concluded fomites are a significant source of bioaerosols.[26]

Shiomori et al demonstrated that MRSA bacteria can recirculate through the air,[27] and that MRSA that has settled from the air onto surfaces can become airborne again when, for example, bedsheets are agitated by patient movement or bed making.[28]

Studies such as these help explain the sharp reduction in infections generally thought to be the result of person-to-person contact. Pathogens can persist for many months on surfaces, and have the potential to become airborne when disturbed. Our study suggests that cleaning the air may have a positive impact on contamination, which in turn can lead to lowered rates of infection.

Once the initial installation of the UV-C units is complete, only annual maintenance is required, which is changing the UV-C bulb and filter. As an engineering control, the cleaning effect of the unit is not dependent on any staff procedure or initiation.

Study limitations include the unpredictable conditions in a live setting. It is possible that staff became extremely vigilant about hand hygiene, for example, or made other behavioral changes to lessen the infection rate; however, none were reported by staff. Also, during September and October 2015, it was discovered that not all UV-C units were on dedicated circuits for the UV-C. In such cases, the UV-C cleaning would stop when the overhead light was switched off. This was corrected in October 2015.

Table 3
Specific organisms and infections pre- and postinstallation

Organism-infection	Preinstallation (cases)	Postinstallation (cases)	Student *t* test, 2-tailed *P* value
Clostridium difficile	8	1	.01
CAUTI	20	9	.012
MRSA	13	6	.107
CLABSI	16	9	.226
VRE	7	6	.764

CAUTI, catheter-associated urinary tract infection; *CLABSI*, central line–associated bloodstream infection; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *VRE*, vancomycin-resistant enterococci.

CONCLUSIONS

Although this study does not claim that the UV-C devices were directly and solely responsible for this dramatic reduction in infections, the decrease in airborne bacteria after installation is significant and a possible connection is postulated. Patient morbidity and financial costs and penalties may be lessened or avoided. More studies are needed to corroborate this finding.

Acknowledgments

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EMERGING TECHNOLOGIES

UV-C light and infection rate in a long term care ventilator unit

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ABSTRACT

Background: This six-month study examined the effect of continuous ultraviolet radiation (UV-C) at the room level on incidence of healthcare-associated infection (HAI). The study, conducted in a long-term care ventilator unit, counted each antibiotic start as an infection. The primary outcome measure was infection rate, calculated as infections/1000 patient days.

Methods: Eighty-six patients were admitted from September 2015 to February 2016. Study inclusion criteria were admission to the unit, full-time mechanical ventilation and age > 18 years. One wing of the ward had two shielded UV-C units installed per patient room (VidaShield™; American Green Technology, South Bend, IN). An adjacent wing without UV-C units was the control.

Results: The overall infection rate was significantly lower in rooms with UV-C units than in those without: 12.5±-2.12 vs. 17.5±-2.81 $p=0.022$.

Conclusion: Findings suggest that continuous exposure to UV-C treated air reduces HAI. Shielded UV-C units in patient rooms may be an effective non-staff intervention dependent method for reducing HAI.

KEY WORDS:
UV-C, HAI, air purification, infection control

INTRODUCTION

The morbidity, mortality, and financial cost of healthcare-associated infection (HAI) is well established. Hospitals are penalized financially for 30-day readmissions of patients with an HAI (1). Patients in skilled nursing facilities, especially ventilator units, are at continued risk for HAI, and these facilities will also soon be penalized for readmissions (2).

HAI management and prevention efforts are complicated by the emergence and persistence of multiple drug resistant organisms (MDROs). Some of the most common MRDOs include vancomycin-resistant enterococcus (VRE), methicillin resistant *Staphylococcus Aureus* (MRSA), and *Acinetobacter*. *Clostridium difficile* (*C. difficile*) is also a significant HAI.

In an effort to improve and extend standard infection control measures, many healthcare facilities are adding germicidal ultraviolet (UV-C) lights. It is clear that UV-C can reduce circulating pathogens. But how best to deliver the UV-C? Direct prolonged exposure to UV light is unacceptable because of the known deleterious biologic effects (3, 4). The mobile emitters (the so-called robots) have been limited to room exposure when patient rooms are vacated, which can be problematical in areas such as an ICU, or a long-term ventilator unit with double-bedded rooms, such as in our study, where empty patient rooms are uncommon.

Rooms treated with mobile UV-C emitters do show reduced bacterial surface colony counts, (5) but use of the emitter depends on initial cost, its availability, the allotted time between patients, the need for staff initiative, and an unoccupied space. Our study was designed to determine if the use of continuous, shielded UV-C lights that treat and recirculate patient room air could have an impact on infection rates. A long-term care ventilator unit was chosen because it is an environment with comparatively high infection rates, particularly MDRO and *C. difficile*.

Many of the common HAIs, such as *C. difficile* and MRSA, are considered contact transmissible. However, Best et al. reported that air and sample cultures were positive for *C. difficile* in 60% of hospital rooms where patients had symptomatic *C. difficile* infections. In other words, *C. difficile* can be suspended in air, and from there can settle onto surfaces (6). Surface bound bacteria may become intermittently airborne when surfaces are agitated. The frequent movement of bed sheets would be an example, as Shiomori et al. demonstrated (7). We wondered what impact cleaning the air with UV-C might have on HAIs, including those generally considered to be contact transmissible.

Acknowledgements: UV-C units were provided by American Green Technology, South Bend, IN. Manuscript preparation support was done by Diane Laux Communications, Chicago, IL. Dr. Kane was contracted by Eventa LLC to perform the study. Ms. Finley and Ms. Brown have no conflicts of interest to report.

METHODS

This study was completed at a long-term care ventilator unit in southern Tennessee from September 2015 through February 2016. Patient inclusion criteria were admission to the ward, receiving full-time mechanical ventilation and age greater than 18 years. Patients were assigned to rooms based on availability. Eighty-six patients were admitted during the study period: 40 to the UV-C wing and 46 to the control wing. Six months of retrospective infection rate data (January 2015 – June 2015) was examined to ensure consistency and understand any variability over time.

The physical layout of the ventilator unit comprised multiple wings. In one wing, all rooms had UV-C units installed. This included 18 patient rooms, 5 shared patient bathrooms, the hallway, and a respiratory therapy utility room. An adjacent wing of 17 patient rooms had no UV-C units, and served as the control. Thirty-three of the 35 rooms in the study were double occupancy, typical for this type of facility.

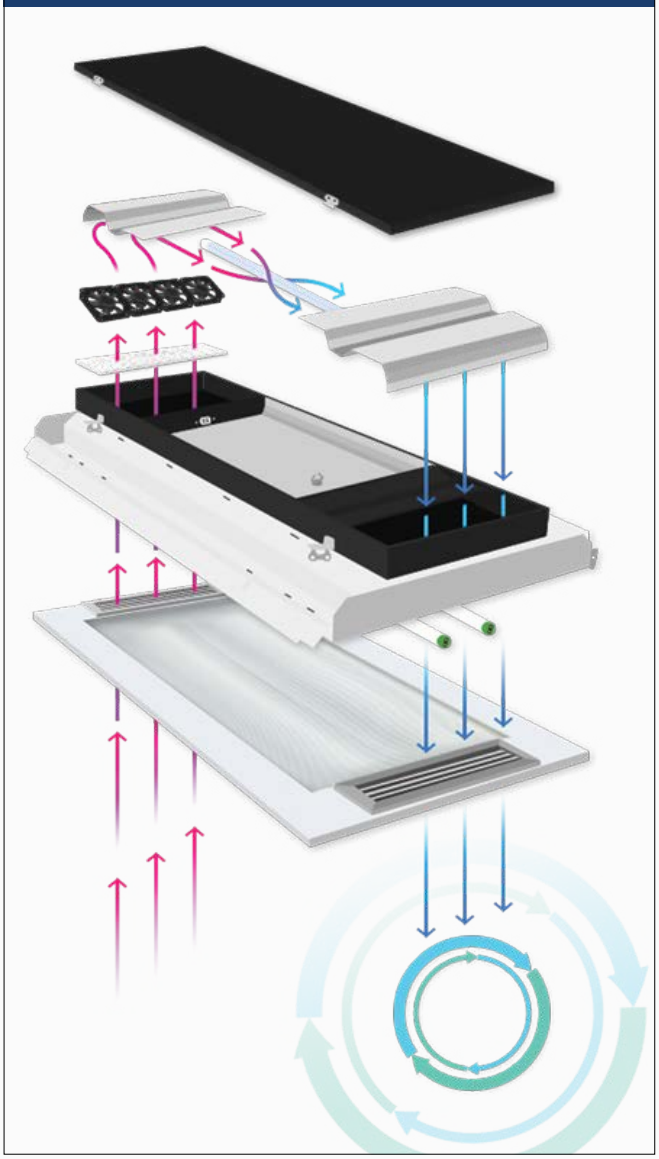
Facility staff had established housekeeping protocols for occupied patient rooms and terminal cleaning procedures upon patient discharge. They had no protocol to clean and treat the air. Because operations personnel did not have a program to validate ASHRAE air exchanges and percent air recirculation, all air in the patient unit was treated, and not just the patient rooms. Air moves freely among patient areas. Families and other visitors use patient bathrooms and leave the doors open afterwards. The hallways are consistently exchanging air with other areas, including air from outside the building. The UV-C units were installed in the biohazard room to reduce odors on the units and lessen circulating bacteria and fungus.

Two UV-C units (VidaShield™; American Green Technology, South Bend, IN) were installed in each room of one wing. The number of units was determined by room size and existing layout. One unit was installed over each patient bed. Each unit contained a fully shielded UV-C bulb. A 59 watt shielded UV lamp produced 15 watts of high output ultraviolet-C energy at a wavelength of 253.7 nanometers. Because the radiation chamber where the UV lamp is housed is enclosed and the air passes through the chamber, there is little to no distance from the lamp to the air that passes directly over the lamp. At its furthest point, the span is 6 inches. Each unit holds four small fans to create differential pressure that continuously draw air into the system at 50 cubic feet per minute. On the way to the irradiation chamber the air passes through a MERV 6 filter to remove dust and large particulates and then, once treated, the cleaned air is pushed back into the room. The intake and exhaust baffles are set at a 30 degree angle, which moves the air in a pattern that avoids repeatedly recirculating the same air (Figure 1).

The UV-C portion of the units run continuously, 24/7. There is no visible evidence of the units once they are installed, and attending physicians were not informed which wing had UV-C units installed. Clinical behaviour and decision-making were not changed in any way.

In general, an infection was counted when an antibiotic was ordered, based on patient symptoms and suspicion of a nosocomial infection. Infection site and culture results were recorded. Antibiotic orders changed within three days based on culture results or suspected lack of response were not counted as new infections. Infections within 48 hours of admission were excluded as were infections where treatment was initiated by the transferring acute care facility. Multiple infections noted at one time were counted as a single infection. Also, if a given infection required multiple antibiotics to treat it, only one infection was recorded. The type of organism was recorded.

FIGURE 1: UV-C unit



In our study, antibiotics were initiated in 99 suspected infection episodes. Of these 99, 24% were culture negative. Culture-negative infections are not uncommon. De Prost et al. reported a culture-negative sepsis rate of 40-60% for 1001 ICU admissions meeting a severe sepsis criteria (8). In a three-year study by Labelle et al., culture-negative pneumonia occurred in up to 34% of patients with healthcare-associated pneumonia (9). These studies indicate that infection can indeed be present despite negative cultures.

TABLE 1: Infection rate as number of infections per 1000 patient days

	UV-C Group				Control Group			
Month/ Year	Patient Days	Average Census	Infection (N)	Infection Rate	Patient Days	Average Census	Infection (N)	Infection Rate
Sept 15	540	18	9	16.7	510	17	13	25.5
Oct 15	660	22	11	16.7	589	19	11	18.7
Nov 15	600	20	10	16.7	551	19	14	25
Dec 15	480	16	6	12.5	372	12	5	13.7
Jan 16	527	17	3	5.7	580	20	8	13.8
Feb 16	620	20	4	6.5	620	20	5	8.1
TOTALS	3427	113	43	74.8	3222	107	56	104.8
AVERAGE	571.2	18.8	6.67	12.5	537	17.2	10	17.5

Infection rate is reported as the number of infections per 1000 patient days. Gender, age, liberation from mechanical ventilation, discharge disposition including site where deaths occurred, and readmission to an acute care facility are reported in percentage. MDRO and *C. difficile* infections are expressed as instances of infection for all patients in both groups.

A significance level of $p<0.05$ was used for all statistics. The paired t-test was applied for comparison of overall infection rates between groups. For MDRO comparisons, the Fisher's exact test was used to account for the small sample size. The Chi-square test was used for comparison of positive culture results between groups for all identified pathogens, discharge disposition, and weaning rates.

RESULTS

The overall infection rate was significantly less in patient rooms with shielded UV-C units where the rate was 12.5±-2.12 vs. the control group's rate of 17.5±-2.81 $p=0.022$, CI 1.075-8.925. The infection rate for each group was calculated as the number of infections per 1000 patient days in that wing.

Retrospective analysis of infection rates for six months prior to the study shows the infection rate during the study was not significantly different from the rate before the study ($p=0.57$). This data is shown in Table 2.

The type of infection-causing organisms were tracked, and results for four common HAIs (*Acinetobacter*, MRSA, VRE, and *C. difficile*) showed that the UV-C group had fewer MRDOs and *C. difficile* infections than did the control group, but levels did not reach statistical significance because the difference between the UV-C wing and the control wing was too small relative to total sample size. If the proportions remained constant, the results for MRSA would become significant ($p>.05$) when the sample size reached 207. This data set, at a sample size of 81, is underpowered.

Although it was not possible to truly randomize the groups (because beds were assigned based on availability), the two groups were similar in age and gender. In the UV-C group, the average age was 61, with 57% males and 43% females. The control group was moderately younger, with an average age of 53, and a gender division of 60% males and 40% females.

Weaning rates from mechanical ventilation were similar for both groups, with 16 in the UV-C group and 17 in the control group. Discharge dispositions, as shown in Table 3, demonstrate that significantly more patients in the UV-C wing were discharged home ($p=0.01$).

DISCUSSION

HAIs present a significant challenge for healthcare facilities because they result in increased morbidity, mortality, and cost. The Centers for Disease Control and Prevention report that on any given day, about 1 in 25 patients has an HAI. A 2014 study showed approximately 75,000 patients die annually resultant to an HAI. (10) Marchetti, in 2013, estimated HAIs cost $96-$147 billion annually (11). It is an enormous problem.

The presence of these dangerous microorganisms has generated increased isolation efforts, glove and gown diligence, terminal cleaning of rooms, and other infection prevention and control policies.

Using gloves, gown, mask and handwashing can reduce pathogen transmission, but compliance is often poor. McGuckin et al. reported that with education and feedback, hand hygiene compliance for ICUs rose from 26% to 37%, and for non-ICUs from 36% to 51% (12). Essentially, healthcare workers are cleaning their hands as they ought half the time or less. Gershon et al. used a confidential questionnaire of more than 1700 hospital-based healthcare workers regarding compliance with universal precautions. They reported overall compliance rates below 30% (13).

The reality is that facilities often do not benefit from this inexpensive and effective infection control method. This suggests that potential benefits of an infection prevention or control method may not be obtained unless the method is independent of worker initiation.

Healthcare facilities have begun to show interest in adapting the germicidal effects of UV-C as an adjunct to existing strategies. UV-C works against microorganisms by damaging the

TABLE 2: Infection rate as number of infections per 1000 patient days, baseline vs. control		
Month	**Pre-study Infection Rate**	**Study Infection Rate (Control Group)**
1	13.1	25.5
2	19.0	18.7
3	17.2	25.0
4	13.3	13.7
5	20.8	13.8
6	9.7	8.1
TOTALS	93.1	104.8
AVERAGE	15.5	17.5

cells so they cannot reproduce. Many studies have shown the effectiveness of UV-C against pathogens, including mitigating TB transmission in a homeless shelter (14), using it specifically against *C. difficile,* VRE, and *Acinetobacter* (15) and also against influenza (16). The germicidal capabilities of UV-C are clear.

Healthcare facilities have adopted UV-C in a variety of ways. One way is with an automated UV-C emitter. Anderson et al. demonstrated that colony counts for VRE, *Acinetobacter* spp. and *C. difficile* are significantly reduced by this technology (15). In a retrospective study, Haas et al. reported using UV-C produced a 20% reduction in the rate of MRDO and *C. difficile* infections in a 643 bed tertiary care academic medical center (17).

The emitter, however, can't be used in occupied space because unshielded UV-C can damage skin and eyes (3). Nardell et al. showed the safety of upper room UV-C (4). The units in our study are more completely shielded than the ones Nardell discussed; people are safe in spaces where and when the units are operating.

UV-C is not a substitute for universal precautions or room cleaning. Memarzadeh et al. considered UV-C in various forms to be effective, but best used as part of a larger plan of disinfection (18). If emitters used during terminal cleaning truly result in the 20-34% reductions in HAIs reported by Anderson et al. (15) and Napolitano et al. (19) it would be of value to know if combining using the emitter with continuous UV-C at the room level would yield an even greater impact.

Maintenance on the UV-C units is minimal: replacing the MERV-6 filter quarterly and the UV-C bulb annually. This is typically done by regular facility maintenance staff without special tools or training.

The UV-C light units were in patient rooms, hallway, bathrooms, and the respiratory therapy workroom and operated 24 hours/day. We cannot verify to what degree each of these contributed to the results.

The reduced comparative infection rate in our study included all sites. Most common infections were urinary tract and respiratory. The likelihood that the shielded UV-C light units had a positive effect on infection rate in our study for organisms not generally thought to cause infection via airborne transmission suggests the possibility that cleaning the air can help reduce surface contamination.

Patients were admitted to rooms based on availability but this is not formal randomization. Study limitations include this lack of true randomization, inclusion based on need for continued mechanical ventilation without consideration for comorbidities, and lack of a standardized method for diagnosing and verifying infection. Further study with larger randomized controlled trials is needed. The study might have benefitted from a longer timeframe, which would have provided a greater patient population and thus more data points. Also, for the retrospective data collection (six months before study launch), it was not possible to determine infection rates in the rooms later selected to UV-C light installation. However, all ventilator rooms were

TABLE 3: Patient discharge disposition			
Discharge Disposition	**UV-C Group N (%)**	**Control Group N (%)**	***p* value**
Home	19 (45)	9 (19.6)	0.01
Death in the vent unit	5 (12)	2 (4.4)	0.24
Death in the hospital	1 (2.3)	1 (2.2)	1.00
Transfer off vent unit	2 (5)	2 (4.4)	1.00
Hospital readmission	4 (9.5)	1 (2.2)	0.18
Hospice	2 (4.8)	0 (0)	0.21

considered equal in terms of the admissions process, patient acuity, and staffing.

The study occurred in a long-term care ventilator facility where all care behaviours and methods proceeded unaltered by the study in order to observe the effects of continuous UV-C on HAI in a real life setting. In units like ours, where rooms are rarely vacant and using an emitter presents some challenges, our results suggest that shielded upper room UV-C in use 24/7 reduces the rate of HAIs including those caused by common MDROs and *C. difficile*. Healthcare facilities may want to consider adding this non-staff dependent infection control method to their infection prevention and control protocols.

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