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.

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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.

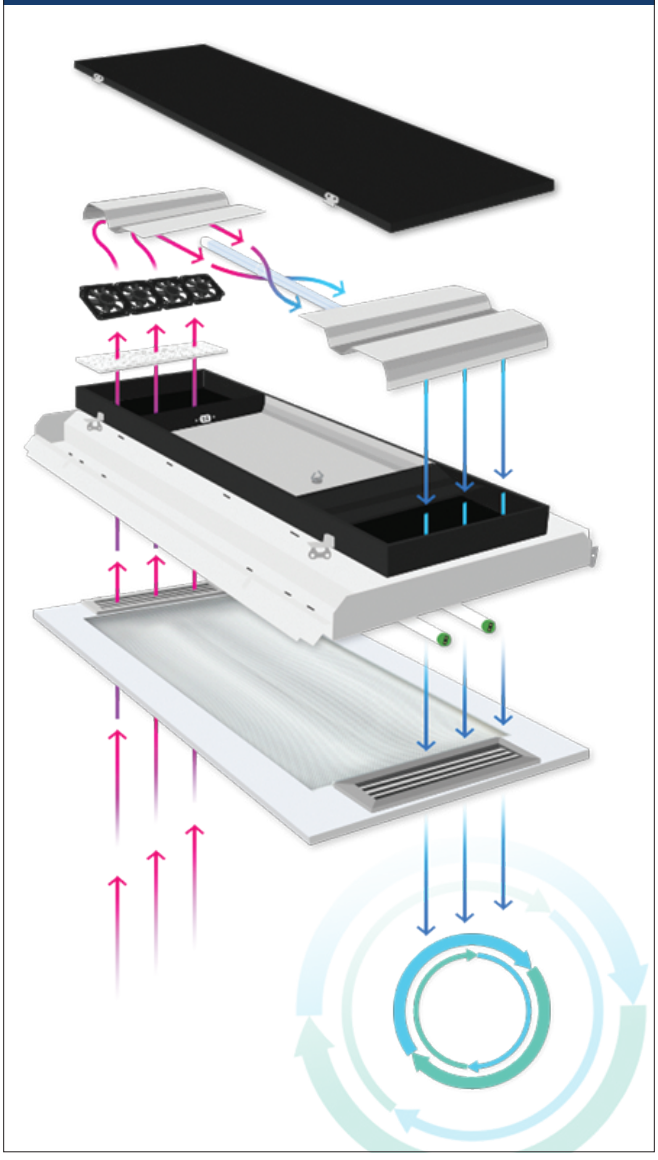
Facility staff had established housekeeping protocols for occupied patient rooms and terminal cleaning procedures upon patient discharge. They had no protocol to clean and treat the air. Because operations personnel did not have a program to validate ASHRAE air exchanges and percent air recirculation, 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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