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Major Article

A trial of pulsed xenon ultraviolet disinfection to reduce *Clostridioides difficile* infection

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Background: An intervention was designed to test whether the addition of an ultraviolet (UV) disinfection step after terminal cleaning would be helpful in reducing *Clostridium difficile* infection (CDI) rates in a real-world situation.

Methods: This study was a quasi-experimental design using 3 units as intervention units for the intervention and 3 similar units as control units. Intervention units 2 hematology and bone marrow transplant units and one medical-surgical unit at a large teaching hospital in the Midwest. UV disinfection was added after patient discharge and terminal cleaning in the intervention units.

Results: At baseline, CDI rates in the intervention and control arms were similar. During the 6 months of UV disinfection, the CDI rate in the intervention units decreased to 11.2 per 10,000 patient days, compared with 28.7 per 10,000 patient days in the control units ($P = .03$). In addition, the intervention units also saw a reduction in vancomycin-resistant enterococci acquisition.

Conclusions: The addition of UV disinfection to the terminal cleaning resulted in a reduction in CDI that has been sustained over several months 2 years.

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The Mayo Clinic is a large tertiary care hospital in the upper Midwest with 2,059 licensed beds, an average of 50,000 admissions, and 330,000 patient days annually. The hospital-wide healthcare–associated *Clostridium difficile* infection (CDI) rate in 2014 was 9.23 per 10,000 patient days. The rate was up to 5 times higher in some units, including the hematology and bone marrow transplant (BMT) units. *C difficile* spores are resistant to routine cleaning agents,[1] and additional cleaning methods may help reduce environmental contamination and transmission of CDI in hospitals. Bleach cleaning had been implemented as a CDI reduction measure, but CDI rates remained high.

METHODS

As part of a quality improvement project aimed at reducing CDI rates, an intervention was designed to test whether the addition of an ultraviolet (UV) disinfection step after terminal cleaning would be helpful in reducing CDI rates in a real-world situation. Three units (2 hematology and BMT units and a medical-surgical unit) were designated as pilot units for the intervention, and 3 units with similar patient populations served as control units. Because of the high rates of CDI, all patient rooms on the hematology and BMT units were being cleaned with bleach daily and at terminal cleaning. PDI Sani-Cloth bleach wipes (PDI Healthcare, Orangeburg, NY) were used to wipe surfaces. After the wet contact time of 4 minutes, surfaces were rewiped with plain water. In the medical-surgical units, only the rooms of patients with known CDI were cleaned with bleach. The medical-surgical unit in the intervention arm had a few double rooms; all other units had only private rooms with private toilets. In the 3 units selected for the intervention, a UV disinfection step was added after patient discharge and terminal cleaning. Patient rooms received pulsed xenon UV (PX-UV) disinfection (Xenex Disinfection Services, San Antonio, TX) for a 6-month period between October 2014 and March 2015. The PX-UV device emits high-intensity broad-spectrum germicidal light of wavelength 200-300 nm at a pulsed frequency greater than 60 Hz. This UV disinfection was performed in 3 positions in 5-minute cycles after terminal cleaning and before the bed was made. Drawers and doors inside the room were left open,

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Table 1
Healthcare–associated CDI rates on control and intervention units

Unit	Before intervention January 2013 to September 2014				Intervention (6 months) October 2014 to March 2015			
	Healthcare–associated CDI	*Patient days*	*CDI per 10,000 patient days*	*P value*	*Healthcare–associated CDI*	*Patient days*	*CDI per 10,000 patient days*	*P value*
Intervention units	59	27,707	21.3	.17	10	8,958	11.2	.03
Control units	48	18,405	26.1		15	5,219	28.7	

CDI, Clostridium difficile infection.

telephone and blood pressure cuffs were hung, television remotes were placed on the tray table, pillows were positioned on window ledges, and curtains were three-quarters closed for the first cycle. The curtains were left partially open to allow for disinfection of the "grip" areas, which have been shown to be more highly contaminated.[2] On the second cycle, the television remote and pillows were flipped and placed in a different location. The third cycle was completed in the bathroom.

In addition to the healthcare–associated CDI rate, rates of hand hygiene, isolation compliance, and antimicrobial usage were followed on all the units. The primary endpoint was the rate of healthcare–associated CDIs. These CDIs were diagnosed by a polymerase chain reaction test, were classified as healthcare–associated infections, and were attributed to the unit if CDI was diagnosed >3 days after admission. Incidence rates were expressed as the number of healthcare–associated CDIs per 10,000 patient days. Data were analyzed using a negative binomial regression model in Stata 12 (StataCorp LLC, College Station, TX).

RESULTS

Approximately 85% of rooms in the UV pilot units were terminally disinfected with PX-UV during the intervention. The main reasons for not performing UV disinfection were unavailability of the machines (mechanical failures) or the need for quick room turnover. The baseline healthcare–associated CDI rates in the intervention and control arms were similar (Table 1). During the 6 months of PX-UV disinfection, the healthcare–associated CDI rate in the intervention units decreased to 11.2 per 10,000 patient days, compared with 28.7 per 10,000 patient days in the control units ($P = .03$).

The hematology and BMT units had an active surveillance program for vancomycin-resistant *Enterococcus* (VRE). Patients who were known to be colonized with VRE were flagged in the electronic medical record, and were placed on contact precautions at admission. All other patients were screened for VRE colonization at admission and twice weekly thereafter for the duration of their hospitalization. A rapid polymerase chain reaction test (Roche Diagnostics, Indianapolis, IN) that identified the presence of *vanA* and *vanB* genes, which code for VRE, was performed on rectal swabs. At baseline, the rate of VRE acquisition was lower in the intervention units than in the control units. The VRE acquisition rate was reduced further on the intervention units during the study period (Table 2).

The addition of PX-UV added an average of 25 minutes to the room turnaround time. The UV devices were well accepted by environmental services staff, nursing and physician staff, patients, and families on the intervention units. As measured by direct observation by trained observers, hand hygiene rates and compliance with isolation precautions remained at >90% on both the intervention and control units. We acknowledge that these rates are subject to inherent limitations of Hawthorne effect and observer bias. No new antimicrobial stewardship initiatives were implemented during this time period.

Based on the results of this pilot, UV disinfection was expanded to additional units in January 2016. The 14 hospital units with the highest rates of CDI were chosen. About 60% of hospital-onset (HO) CDIs at our facility occurred on these units. We continued with the strategy of UV disinfection after terminal cleaning for all rooms on these units, rather than targeting rooms occupied by patients with known CDI. Our goal was to keep the utilization rate (proportion of rooms that received UV disinfection as part of terminal cleaning) at 80% or higher. The average UV utilization rate was 83% in 2016. The hospital-wide HO-CDI rate in 2015 was 6.4 per 10,000 patient days (180 cases, 284,605 patient days). In 2016, the HO-CDI rate decreased to 5 per 10,000 patient days (136 cases, 272,628 patient days) (Table 3). Fitting this data to a Poisson regression model shows that the drop in infection rates from 2015-2016 was statistically significant ($P = .034$). The standardized infection ratio decreased from 0.774 in 2015 to 0.571 in 2016 (using the 2015 national baseline for both time periods). This reduction in CDI has been sustained through 2018 (Table 3).

We also followed patient satisfaction with cleanliness of the environment (data from Press Ganey patient surveys [Press Ganey Associates, Inc., South Bend, IN]). The proportion of patients on the UV disinfection units who reported that their rooms and bathrooms were always clean increased from 70.5% in 2015 to 77.2% in 2016.

DISCUSSION

We report a reduction of both *C difficile* and VRE infections through the addition of UV disinfection to an environmental cleaning program that already included the use of daily bleach cleaning. Several prior studies have demonstrated reduction in environmental microbial contamination through the use of UV disinfection.[3-6] Some studies have shown a reduction in CDI rates in healthcare facilities,

Table 2
Healthcare–associated VRE (includes hematology and bone marrow transplant units only)

Unit	Before intervention January 2013 to September 2014				Intervention (6 months) October 2014 to March 2015			
	Healthcare–associated VRE	*Patient days*	*VRE per 10,000 patient days*	*P value*	*Healthcare–associated VRE*	*Patient days*	*VRE per 10,000 patient days*	*P value*
Intervention units	35	13,686	25.6	.002	4	4,085	12.3	.02
Control units	65	14,129	46.0		13	4,000	32.5	

VRE, vancomycin-resistant *Enterococcus*.

Table 3
Hospital-onset *Clostridium difficile* infection rates before (2015) and after (2016 and beyond) expansion of ultraviolet disinfection

Year	Patient days	Infections	Expected infections	SIR
2015	284,605	181	233.9	0.77
2016	272,628	136	238.3	0.57
2017	283,887	181	265	0.68
2018 YTD	144,528	85	195	0.55

SIR, standardized infection ratio; *YTD*, year to date.

but these have primarily relied on historical data as a comparator.[7-9] This is the first time there has been a direct head-to-head comparison between patient care units in the same facility using UV disinfection in addition to the use of bleach.

A recent large randomized study[10] showed that bleach and UV disinfection produced similar reductions in acquisition of multidrug-resistant organisms. One key difference in our strategy compared with that used in this study was that we were already using bleach in all patient rooms in units with the high rates of CDI. Second, we added UV disinfection to the terminal cleaning of all rooms on the patient care unit, not just the rooms of patients with known CDI.

Based on our initial results, we implemented UV disinfection in additional units with high CDI burden. We continued with the strategy of UV disinfection after terminal cleaning in all rooms on these units, rather than in only CDI rooms hospital-wide. This strategy had logistic benefits: (1) we needed to train a smaller number of environmental services staff on the use of the devices, and (2) the devices are housed on the nursing units; therefore, they are easier to access, and less time is spent transporting the devices around the hospital. This expansion of UV disinfection resulted in continued sustained reductions in CDI.

The UV devices have been received well by staff, patients, and patient families. Patients reported feeling safer knowing that the room they were occupying had received UV disinfection prior to their being admitted. The use of the UV device added an average of 25 minutes to the room processing time. Close coordination between nursing staff and environmental staff was needed to ensure that patients were not kept waiting for a room. Our facilities primarily have single-occupancy rooms, which made implementation easier. Hospitals with more than 1 patient in a room may have difficulty implementing a UV disinfection program.

In intensive care units with glass doors, the pulsed light involved in the UV disinfection process was an annoyance to staff and other patients. Blackout curtains were required in order to mitigate this. Hanging the curtains each time was both time and labor intensive. We now have vertical accordion-type blackout blinds that are easy to transport from room to room, and require minimal time and effort to set up.

The UV devices were expensive. Additional costs were incurred to increase staffing in environmental services, and to train staff to run the devices. However, high CDI rates can have a direct financial impact on institutional reimbursement through pay-for-performance programs, including value-based purchasing and hospital-acquired conditions, and may have an indirect effect through reduced patient satisfaction, higher hospital readmission rates, and Medicare spending efficiency.[11,12] Therefore, depending on baseline CDI rates and performance on other healthcare–associated infection metrics, UV disinfection has the potential to be a cost-saving measure.

CONCLUSIONS

The addition of UV disinfection to terminal cleaning has resulted in a reduction in CDI in our hospital that has been sustained over several months. During the pilot phase on units with a VRE surveillance program, we also saw a reduction in VRE acquisition.

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SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.1016/j.ajic.2018.09.018.

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