American Journal of Infection Control 43 (2015) 940-5

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major article

Clostridium difficile infections before and during use of ultraviolet disinfection

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Key Words:
Ultraviolet disinfection
Hospital acquired
Clostridium difficile

Background: We previously reported a significant decrease in hospital-acquired (HA) *Clostridium difficile* infection (CDI) coincident with the introduction of pulsed xenon ultraviolet light for room disinfection (UVD). The purpose of this study was to evaluate CDI cases in greater detail to understand the effect of UVD.

Methods: CDI rates (HA and community acquired [CA]), CDI patient length of stay, room occupancy, and number of days between a CDI case in a room and an HA CDI case in the same room were studied for the first year of UVD compared with the 1-year period pre-UVD.

Results: Compared with pre-UVD, during UVD, HA CDI was 22% less ($P = .06$). There was a 70% decrease for the adult intensive care units (ICUs) ($P < .001$), where the percentage of room discharges with UVD was greater ($P < .001$). During UVD, CA CDI increased by 18%, and length of stay of all CDI cases was lower because of the greater proportion of CA CDI. No significant difference was found in days to HA CDI in rooms with a prior CDI occupant.

Conclusion: These data suggest that UVD contributed to a reduction in ICU-acquired CDI where UVD was used for a larger proportion of discharges. Evaluation of UVD should include data for hospitalized CA CDI cases because these cases may impact the HA CDI rate.

Hospital-acquired *Clostridium difficile* infection (CDI) is a major cause of morbidity and mortality.[1] CDI is considered to be a preventable infection, and hospital-specific CDI rates are now available to the public in several states, including New York. Environmental cleaning, hand hygiene, contact precautions, and close attention to antibiotic prescription are all considered essential measures to limit the acquisition of *C difficile*.[2,3]

The recovery of *C difficile* from the environment of rooms housing patients with *C difficile* ranges from 29% for asymptomatic carriers to 49%-100% for patients with CDI.[4-13] Patients occupying rooms in which a prior occupant had CDI can be at significantly higher risk of acquiring CDI.[14] *C difficile* spores can survive on hard surfaces for up to 5 months.[15] Bleach can be used to kill the spore and is recommended to reduce the environmental reservoir of *C difficile*.[16,17] However, regardless of the product used, studies examining discharge cleaning practices have shown that cleaning is often suboptimal[18-24]; for example, in a multicenter study of 16 intensive care units (ICUs), on average only 57% of surfaces were cleaned effectively.[18]

In view of the importance of environmental contamination with *C difficile*, disinfection procedures that are not solely dependent on individual practice are being used. Machines that emit ultraviolet-C (UV-C) light can be used for room disinfection. UV-C light (200-320 nm) denatures DNA, halting the growth and reproduction of microorganisms. Ultraviolet light for room disinfection (UVD) machines cannot be used in occupied rooms. Two types of ultraviolet (UV) light machines are available for room disinfection: UV-C emitting devices, which provide continuous UV-C light from a mercury bulb in either a portable machine or a disinfecting wand, and pulsed xenon UV-C light. UVD has been shown to eradicate methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), *Acinetobacter*, and *C difficile* under the

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Conflicts of interest: None to report.

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http://dx.doi.org/10.1016/j.ajic.2015.05.003

artificial conditions of inoculating surfaces with bacteria, exposing the bacteria to UV light and then culturing the surface.[25-27] Studies have evaluated the impact of UVD in rooms that have housed patients by culturing surfaces before and after exposure to UVD. UVD was shown to significantly reduce positive *C difficile* and MRSA cultures from hospital rooms[28,29] and was associated with halting the transmission of CDI between 2 roommates in a long-term care facility,[30] whereas pulsed xenon UVD was associated with significant reductions in the microbial load of VRE in patient rooms.[31]

At our hospital, pulsed xenon UVD was added to standard cleaning of contact precautions rooms in May 2011. In a previously published study we observed a 17% reduction in hospital-acquired CDI coincident with the use of UVD for 22 months compared with a preintervention period of 30 months, which was statistically significant.[32] The purpose of this study was to evaluate CDI during the first year of UVD in greater detail than was provided by the prior report,[32] by including all CDI cases (hospital acquired and community acquired), evaluating length of stay and room occupancy, and assessing time from a CDI occupant in a room to a hospital-acquired CDI case occurring in the same room.

METHODS

This study compares a pre-UVD period (May 1, 2010-April 30, 2011) with the UVD period (July 1, 2011-June 30, 2012) for total CDI rates, hospital-acquired CDI rates, length of stay, and room occupancy. The months of May and June in 2011 were excluded because UV disinfection was not used consistently until late June 2011. This study was conducted at Westchester Medical Center, a tertiary care hospital located in Valhalla, New York. The hospital has 180 ICU beds and is a referral center for highly immunocompromised patients. All ICUs and pediatric rooms are single occupancy. On the adult service, 13% of the non-ICU rooms are single occupancy.

The UVD procedures were standardized as follows. In each room, drawers, bed rails, phone, television remote, and blood pressure cuffs were placed in the path of UV light; the closets were also opened to be in the path of the UV light. Glass windows and door were covered with special curtains. In each room, doors were closed. In single-bed rooms, bathrooms were disinfected for 6 minutes. Then the machine was placed at the head and foot end of the bed for 12 minutes each. In semiprivate rooms, the bathrooms were cleaned first for 6 minutes. Then the UV machine was placed near the foot end of each bed for 6 minutes for a total of 12 minutes.

Contact precautions were required for all CDI cases until the patient had no diarrhea for a minimum of 3 consecutive days. Beginning in May 2011, UVD with pulsed xenon ultraviolet light (YANEX model; Xenex Healthcare Services, San Antonio, TX) was added after discharge cleaning for rooms housing contact precautions patients, as previously reported.[32] Changes occurring during this study that could impact infection rates are as follows: on January 1, 2011 (4 months before UVD was implemented), a new environmental services company began providing services for the hospital; and in the spring of 2011 (just before UVD started), the pediatric oncology service was expanded to include more highly immunosuppressed patients.

For all CDI cases the following data were collected: length of stay before CDI, during contact precautions, and after discontinuation of contact precautions; rooms occupied throughout the hospital stay; and rates of new hospital-acquired and nonhospital-acquired CDI. During the UVD period the number of UVDs performed for CDI discharge and any discharge and the reason(s) for no UVD were tabulated. To assess how long rooms with a prior CDI occupant remained without a hospital-acquired CDI case during the 2 periods, rooms housing any CDI patient were followed from the day of room discharge cleaning until one of the following end points occurred: a hospital-acquired CDI case, the study period ended, or 5 months (150 days) had elapsed postdischarge cleaning. Days without a hospital-acquired CDI case in the room were compared for the 2 periods.

Definitions

CDI was defined as a patient with diarrhea and a positive stool test for *C difficile*. Hospital-acquired CDI was defined as a CDI case diagnosed at least 72 hours after admission that was not incubating at the time of admission[16] and without a previously positive *C difficile* test during the prior 8 weeks. Community-acquired CDI was defined as all cases not acquired at Westchester Medical Center. Testing for CDI was performed using a polymerase chain reaction test for the toxin b gene (Cepheid GeneXpert System; Cepheid, Sunnyvale, CA). CDI cases were attributed to specific units by infection prevention and control staff based on the patient's location during the 48 hours prior to symptom onset. Incidence rates were the number of new CDI cases per 1,000 patient days. Days in a room were the number of days from the date of admission until the date of room discharge; for transfers within the hospital, the day of transfer was counted as a day in the new room. The number of UVD opportunities was the number of room discharges for patients on contact precautions for CDI.

Statistics

The sample size required for comparing the rates over the study time period was calculated based on an approach by Rosner.[33] This computation requires an estimate of the effect size and an estimate of the average person-time contribution per patient. Based on a known rate of hospital-acquired CDI of 1.1 per 1,000 patient days per year at the Westchester Medical Center and a median length of stay of 11 days per patient, approximately 200,000 patient days per arm would provide 80% power to detect a 25% reduction in the rate of hospital-acquired CDI at a significance level of 5%. All data were entered into a standardized database. Median and interquartile ranges of lengths of stay were compared using the Wilcoxon rank-sum test. Categorical variables were compared using the Fisher exact test, and continuous variables were compared using the Student *t* test. Rates of CDI were compared by calculating incidence rate ratios with 95% confidence intervals. To compare time to hospital-acquired CDI cases in rooms previously housing a CDI patient, the median number of infection-free days in rooms during the preintervention and UVD period was compared using the Kaplan-Meier product-moment estimator and the log-rank test. Analyses were conducted in Stata (version 12.1; StataCorp, College Station, TX).

The protocol was approved by the New York Medical College Committee for the Protection of Human Subjects.

RESULTS

There were 525 CDI cases (including both hospital-acquired and community-acquired cases) throughout the study: 251 cases occurred during the UVD period, and 274 cases occurred during the pre-UVD period. The total CDI rate (community acquired plus hospital acquired) was similar during the 2 periods (1.89 vs 1.96 CDI per 1,000 patient days; rate ratio [RR], 0.97; 95% confidence interval [CI], 0.81-1.15; $P = .72$). The rate of hospital-acquired CDI was 22% less during the UVD period, which was at borderline statistical significance (0.83 vs 1.06 CDI per 1,000 patient days; RR, 0.78; 95% CI, 0.61-1.009; $P = .06$) (Table 1, Fig 1). The rate of community-acquired CDI was 18% higher during the UVD period (1.06 vs 0.90 CDI per 1,000 patient days; RR, 1.18; 95% CI, 0.92-1.51; $P = .20$). The length of hospital stay for all CDI (hospital and community acquired) cases was significantly shorter during the UVD period

Table 1
Hospital-acquired *Clostridium difficile* cases and rates during the preintervention period and during the ultraviolet disinfection period

	Preintervention period (n = 148)			Ultraviolet disinfection (n = 110)			Rate ratio 95% CI *P* value
Hospital acquired CDI cases	No. of cases	Patient days	Rate per 1,000 patient days	No. of cases	Patient days	Rate per 1,000 patient days	
Total	148	139,677	1.06	110	132,574	0.83	0.78 0.61-1.009 .06
Unit specific							
Adult non- ICU	68	76,075	0.89	50	70,772	0.71	0.79 0.54-1.16 .24
Adult ICU	47	25,753	1.83	13	23,445	0.55	0.30 0.15-0.57 <.001
Adult oncology	16	13,871	1.15	27	14,720	1.83	1.59 0.83-3.16 .18
Pediatrics	17	23,978	0.71	20	23,637	0.87	1.19 0.59-2.42 .70

CDI, *Clostridium difficile* infection; *CI*, confidence interval; *ICU*, intensive care unit.

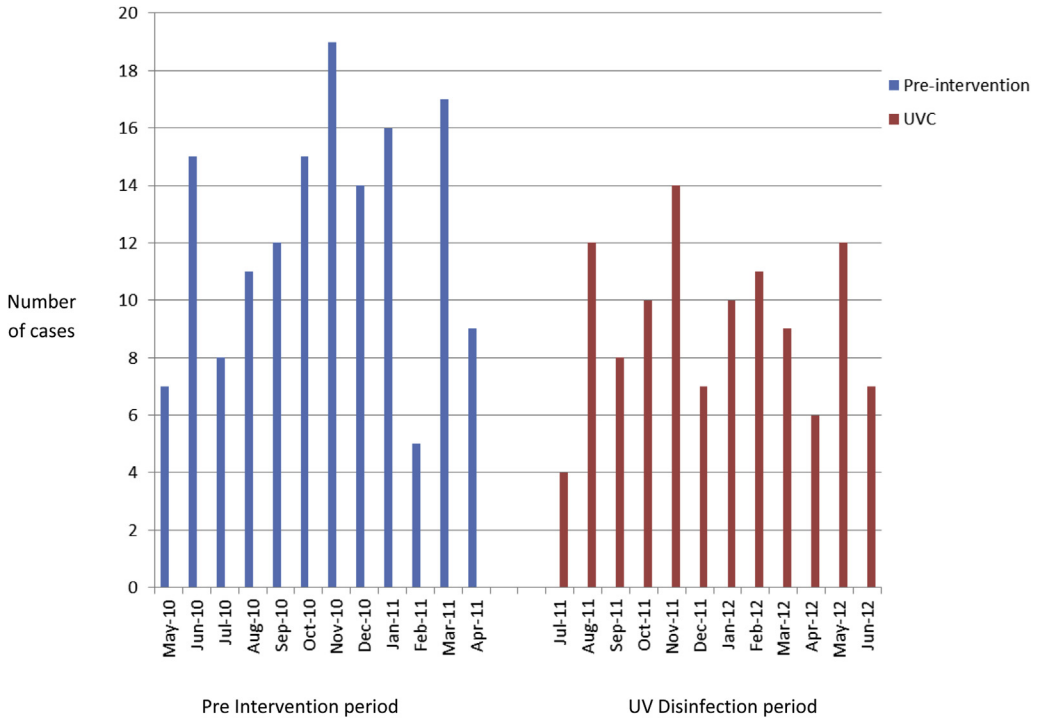

Fig 1. Cases of hospital-acquired *Clostridium difficile* infection before and during ultraviolet disinfection. In January 2011, a new environmental services company began service at the hospital. In August 2011 and May 2012, each month there were 5 cases of *C difficile* infection on the adult oncology unit resulting in audit of environmental services procedures on the unit. Abbreviation: *UVC*, ultraviolet-C.

(median, 11; interquartile range, 6-24 days vs median, 15; interquartile range, 8-34 days; $P < .01$), likely related to the greater proportion of community-acquired cases during the UVD period (141/251 [56%] vs 126/274 [46%]; $P = .02$). When length of stay was compared for the hospital-acquired cases and for the community-acquired cases separately, length of stay for each group was unchanged between the 2 periods (Table 2).

A subanalysis of hospital-acquired CDI by service demonstrated a 70% reduction in the adult ICU population ($P < .001$). The overall rate for all services excluding the adult ICUs remained the same (0.89 vs 0.89 CDI per 1,000 patient days; RR, 1.00; 95% CI, 0.75-1.34; $P = 1.0$). Although the adult non-ICU rates decreased overall, the rate for the adult oncology unit increased, as did the rate for the pediatric units (Table 1). The increase in pediatric cases occurred almost entirely on the pediatric oncology unit. The increase in adult oncology cases was associated with recognized clusters of CDI cases on that unit.

CDI patients had 454 room discharges from 232 rooms in the pre-UVD period, and during the UVD period CDI patients had 359 room discharges from 183 rooms. The median infection-free days in the room after CDI patient discharge during the UVD and pre-UVD periods were similar (63 days; 95% CI, 31-77 days vs 60 days; 95% CI, 31-69 days; $P = .79$). When this was evaluated for only the ICU rooms, time to hospital-acquired CDI cases was longer, but not significantly longer ($P = .43$) (Fig 2). During the UVD period, 287 (80%) of the 359 CDI room discharges had UVD performed. The 72 missed opportunities were because patients were not moved to a

Table 2
Length of stay for patients with CDI during the preintervention period and during the ultraviolet disinfection period

CDI patients	Length of stay	Preintervention period	UV disinfection period	*P* value
All CDI patients (n= 525)	Total days	15 (8-34)	11 (6-24)	.002
	Days before CDI	5 (1-13)	3 (1-10)	.039
	Days on contact precaution	7 (3-13)	6 (3-10)	.014
	Days post contact precaution	0 (0-3)	0 (0-0)	.045
Hospital-acquired CDI patients (n = 258)	Total days	25 (13-48.5)	21 (11-35)	.11
	Days before CDI	10 (6-19)	10 (7-17)	.75
	Days on contact precaution	8 (4-15)	7 (3-12)	.15
	Days post contact precaution	0 (0-9)	0 (0-1)	.10
Community-acquired CDI patients (n = 267)	Total days	8 (5-16)	7.0 (4-14)	.15
	Days before CDI	1 (0-3)	1 (0-2)	.65
	Days on contact precaution	6.5 (3-10)	5 (2-9)	.12
	Days post contact precaution	0 (0-0)	0 (0-0)	.47

NOTE. Values are median (interquartile range) or as otherwise indicated.
CDI, *Clostridium difficile* infection; *UV*, ultraviolet.

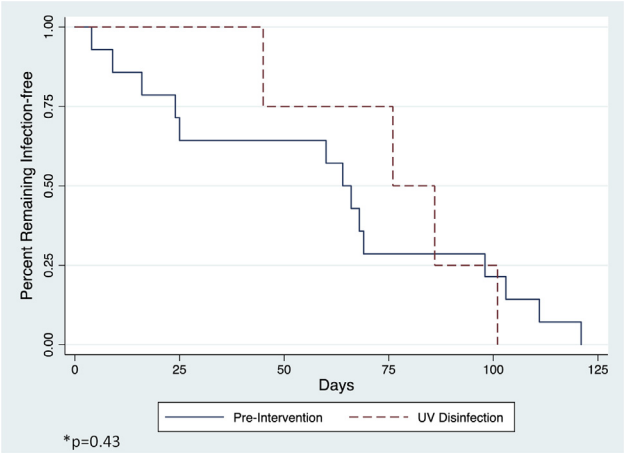

Fig 2. Days an intensive care room remained without a *Clostridium difficile* case after having housed a *C difficile* patient are shown for the 2 time periods and referred to as infection-free days. **P* = .43. *UV*, ultraviolet.

new room when contact precautions were discontinued (n = 19), a roommate could not be moved out of the room (n = 14), and notification failure of the need for UVD (n = 39). Of the 19 CDI cases not moved to a new room when contact precautions were discontinued, 5 were in the ICU and 14 were non-ICU. The percentage of room discharges with UVD performed for any reason (not limited to CDI patient discharge) was significantly greater in adult ICUs compared with adult non-ICUs (574 of 3,608 [15.9%] discharges vs 1,410 of 18,141 [7.8%] discharges; $P < .001$).

DISCUSSION

During the first year of UVD, the hospital-acquired CDI rate was 22% less than in the pre-UVD period. We were surprised to find that during this same time the community-acquired CDI rate increased by 18%, resulting in no overall decrease in total CDI cases. The increase in community-acquired cases documented during the UV disinfection period of this study may have been in part related to the use of more sensitive diagnostic tests for CDI that were becoming available in settings both in hospitals and outside of hospitals. Data from New York State Department of Health indicate that the percentage of hospitals using the more sensitive tests have increased from 10% to 70% over the last 3 years.[34]

We studied length of stay of all CDI patients because all cases may contribute to CDI transmission. Length of stay of all CDI patients was significantly shorter during the UVD period because of the greater proportion of community-acquired CDI cases. These cases had a median length of stay that was 2 weeks shorter than patients with hospital-acquired CDI (Table 2). The number of patient days with CDI as a proportion of all patient days on a unit is referred to as colonization pressure; colonization pressure has been shown to be an independent risk factor for acquiring CDI.[35] Although we did not measure CDI contact precautions days, it is likely that the increase in community-acquired CDI cases during the UVD period partially offset the reduction in colonization pressure because of fewer hospital-acquired cases. The reduction in hospital-acquired CDI might have been even greater if the community-acquired cases had not increased.

In a previously published study from our hospital, Haas et al reported a significant 17% reduction in hospital-acquired CDI coincident with UVD use over a period of time that was approximately twice as long as this study.[32] Although our study was not powered to detect statistically significant decreases in the 20%-25% range for CDI, the 22% reduction observed in the first year of UVD represents a clinically significant decrease. The 22% reduction (95% CI, 0.61-1.01) in hospital-acquired CDI was essentially caused by a highly significant 70% reduction (95% CI, 0.15-0.57) in the adult ICUs and a 20% reduction in the larger population of adult non-ICUs. The significant reduction in the adult ICUs may have been caused by the greater use of UVD in this location. The adult ICU rooms have significantly more UVDs performed per discharge because all ICU rooms are single bed and once UVD was available, the ICU staff began to request UVD regularly regardless of whether or not the discharged patient had been on contact precautions. Double-occupancy rooms outside of the ICU complicated UVD use, with roommates precluding use of UVD for approximately 20% of CDI discharges. Recent data suggest that only approximately one-third of hospital-acquired cases are caused by nosocomial transmission of similar strains and that many hospital-acquired cases may be caused by acquisition of a *C difficile* strain from other sources, such as asymptomatic carriers or their environments.[36] This suggests that to interrupt transmission of *C difficile* there may need to be widespread use of UVD on a unit.

A prior room occupant with CDI has been shown to increase the risk of hospital-acquired CDI.[14] In this study, during the UVD period we did not find a statistically significant increase in time to hospital-acquired CDI in rooms that previously housed CDI patients, even in the adult ICU rooms. The reasons for this may include the small sample size of adult ICU rooms, the total number of occupants and terminal cleanings between a CDI discharge and a hospital-acquired CDI case in the same room was not studied, and acquisition of *C difficile* may be dependent on the overall colonization pressure within a unit rather than the risk from the room alone.

The principal limitation of this study is the preintervention, intervention design, which cannot exclude confounding variables that affect CDI acquisition. The change to a new environmental services company 6 months before UVD started may have impacted CDI rates; however, both companies monitored cleaning similarly, and the decision to implement UVD was based on CDI rates not decreasing during the first 3 months of use of the new environmental services company. We did not perform a randomized controlled study because our study was done soon after UVD was introduced and we needed to minimize errors in

use at the onset and to be sure that the procedures were accurately in place.

UV light disinfection can be performed using pulsed xenon UV light (used in this study) or continuous mercury bulb UV disinfection. Mercury bulbs emit a continuous low pressure light at a single range of 254 nm, and the effect of this UV light is cumulative requiring a longer cycle time of approximately 45 minutes for spore reduction. Pulse xenon UV disinfection emits a broad range of UV light from 200-280 nm in a high-intensity pulsatile manner, and the recommended average cycle time is approximately 18 minutes. Pulsed xenon devices also are somewhat safer because mercury-based devices can release toxic gases if they break accidentally.[37] We choose to use the pulse xenon device because of the shorter cycle time. A recent study comparing the 2 devices in vitro, by inoculating organisms onto glass slides, found that mercury UV-C resulted in a significantly greater reduction of MRSA, VRE, and *C difficile* spores. However, in the same study, pulsed UV significantly reduced colony counts of MRSA, VRE, and *C difficile* spores in actual hospital rooms in which frequently touched surfaces were cultured before and after UVD.[38] Although the reduction may be less than that attained by continuous mercury UV-C, it may be sufficient given the low inoculum of bacteria on environmental surfaces.[38] The study also demonstrated that the effectiveness of pulsed UV light is reduced when distance between the UV light and surfaces is 1.22 m. In our study we standardized positioning of the pulsed UV light, but some surfaces in the room would have been >1.22 m away. A randomized comparison of the continuous mercury UV-C versus pulsed UV-C light in a hospital setting is needed to further understand the differences between these devices.

Overall, these data suggest that UVD contributes to a reduction in ICU-acquired CDI and may be an important adjunct to standard cleaning practices. The reduction in CDIs is likely related to the greater use of UVD in the ICU, where rooms have single beds and patient movement is tightly controlled. After 1 year of UVD, hospital-acquired CDI rates were 22% lower despite an 18% increase in the rate of community-acquired CDI, suggesting UVD had an overall beneficial effect on the reduction of hospital-acquired CDI. These data also demonstrate the importance of monitoring community-acquired CDI and total CDI contact precautions days along with interventions that may affect hospital-acquired rates. A controlled trial of UVD use is needed to further clarify the effect of UVD on *C difficile* transmission.

Acknowledgments

We thank the infection prevention and control staff, the environmental services staff, and the nursing staff.

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