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Major article

# Implementation and impact of ultraviolet environmental disinfection in an acute care setting

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*Key Words:*
Clostridium difficile
Multiple-drug-resistant organisms

***Background:*** Multiple-drug-resistant organisms (MDROs) and *Clostridium difficile* (CD) are significant problems in health care. Evidence suggests that these organisms are transmitted to patients by the contaminated environment.

***Methods:*** This is a retrospective study of the implementation of ultraviolet environmental disinfection (UVD) following discharge cleaning of contact precautions rooms and other high-risk areas at Westchester Medical Center, a 643-bed tertiary care academic medical center. Incidence rates of hospital-acquired MDROs plus CD before and during the UVD use were evaluated using rate ratios and piecewise regression.

***Results:*** The average time per UVD was 51 minutes, and machines were in use 30% of available time. UVD was used 11,389 times; 3,833 (34%) of uses were for contact precautions discharges. UVD was completed for 76% of contact precautions discharges. There was a significant 20% decrease in hospital-acquired MDRO plus CD rates during the 22-month UVD period compared with the 30-month pre-UVD period (2.14 cases/1,000 patient-days vs 2.67 cases per 1,000 patient-days, respectively; rate ratio, 0.80; 95% confidence interval: 0.73-0.88, $P < .001$).

***Conclusion:*** During the time period UVD was in use, there was a significant decrease in overall hospital-acquired MDRO plus CD in spite of missing 24% of opportunities to disinfect contact precautions rooms. This technology was feasible to use in our acute care setting and appeared to have a beneficial effect.



Multiple-drug-resistant organisms (MDROs) and *Clostridium difficile* (CD) are significant problems in health care. Evidence suggests that these organisms are transmitted to patients by the contaminated environment. Patients occupying a room that previously housed a patient with vancomycin-resistant *Enterococcus* (VRE),[1,2] methicillin-resistant *Staphylococcus aureus* (MRSA),[2] or CD infection[3] are at increased risk for acquisition of these organisms. Increased monitoring of cleaning procedures is associated with improved cleaning,[4] less environmental contamination,[2,5-8] and decreases in acquisition of VRE[9,10] and MRSA.[9]

Recently, supplemental methods for environmental disinfection, including ultraviolet light, have become available for use in patient care environments. Ultraviolet disinfection (UVD) technology uses either mercury bulb devices or pulsed xenon bulb devices. Rutala et al reported that mercury UVD reduced colony counts of MRSA and CD by more than 99% in test conditions and decreased both the number of positive cultures and the colony counts per positive culture when tested in rooms that had been occupied by patients with MRSA.[11] Boyce et al also reported significant reductions in aerobic bacterial colony counts from bedside rails, overbed tables, television remotes, bathroom grab bars, and patient bathroom toilet seats after using mercury UVD and significant reduction of CD spores with test plates located strategically in patient rooms.[12] In both studies, objects and surfaces in direct line of sight were more effectively decontaminated by UVD than areas in shadow. Although these studies have demonstrated significant reductions of bacteria in vitro and in clinical settings, there are limited studies on patient outcomes[13] or on the feasibility of use of mercury UVD in the health care environment.

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Pulsed xenon UVD became available after mercury UVD. Literature to support the efficacy of pulsed xenon UVD in decreasing vegetative bacteria[14,15] and bacterial spores[14] indicates it is comparable with mercury UVD. In the first peer-reviewed study on patient outcomes, pulsed xenon UV was associated with a 53% decrease in CD cases in a community hospital,[16] and preliminary data demonstrated an 80% to 90% decrease in CD room contamination and decreasing trends in CD infection and VRE colonization and infection among oncology patients.[14] The purpose of this study is to describe the implementation of a pulsed xenon UVD system for environmental disinfection in an acute care setting and to quantify the rates of hospital acquired MDROs plus CD before and during UVD.

## METHODS

This is a retrospective study of the implementation of UVD and the rates of hospital-acquired MDROs plus CD before and during the UVD use. The period before UVD was 30 months (January 2009-June 2011), and the UVD period was 22 months (July 2011-April 2013). This study was conducted at Westchester Medical Center, a 643-bed tertiary care hospital, near New York City. The hospital offers full services to adult and pediatric patients including specialized services for trauma, burn, neurosurgery, cardiothoracic surgery, transplant, and oncology.

The Infection Prevention and Control Department works collaboratively with Environmental Services, which is an outsourced department, to assure that cleaning protocols are appropriate. Bleach-based (sodium hypochlorite 0.55%) disinfectants are used daily and at discharge for all rooms occupied by adults. Pediatric rooms are disinfected daily using a quaternary ammonium compound; a sodium hypochlorite 0.55% disinfectant is used daily for contact precautions rooms and for all discharge cleaning. Most adult patient rooms outside of the intensive care units are double occupancy; all pediatric rooms are single occupancy. Patients with MDROs or CD receive care in a private room, are placed in a semiprivate room with the other bed blocked from occupancy, or are cohorted with another patient who harbors the same organism.

Pulsed xenon UVD (Xenex Corporation, Austin, TX) began in May 2011. In preparation for UVD use at our institution, we performed an assessment of the number and timing of contact precautions discharges and found the mean rate of contact precautions discharges was 0.87 per hour during peak discharge times of 2 p.m. to 6 p.m.[17] These data guided the decision of how many machines would be needed. Two machines were leased with the primary goal of disinfecting contact precautions rooms upon patient discharge or transfer. Training of Environmental Services staff began in May, and UVD was in routine use in July of 2011. In addition to use for contact precautions discharges, UVD was used after end of day cleaning in the operating rooms, weekly in the dialysis unit, and for all burn unit discharges. UVD could be requested for rooms of long-stay patients or for discharges in units with high prevalence of MDRO or CD. In rooms with more than 1 occupant, UVD was deferred until the room was no longer occupied.

The UVD procedure was the following: The bed management system (Teletracking, Pittsburgh, PA) used text pagers to notify Environmental Services staff of room cleaning needs. This system displays contact isolation status. The Environmental Services supervisor received the text page and was responsible for delivery of the UVD machine to the room and for the UVD. Housekeepers were instructed to start cleaning in the bathroom for contact precautions rooms. After cleaning, the UVD machine was started in the bathroom with the door closed, while the housekeeper cleaned the patient room. To reduce the opportunity for user error, UVD was used exclusively at the longer setting appropriate to inactivate CD spores; this included 6 minutes in the bathroom and 6 minutes each at 2 positions within the patient room. The time required was determined by the room size and protocol for machine placement. This was based on the manufacturer's measurement of the UV dose on high-touch surfaces and measured log reductions of microbes after UVD. The time for cleaning and UVD was recorded into the bed management system. The location of UVD use was entered in a logbook until October 2012. After that date, the UVD machines were upgraded, and location data were entered directly into the machines.

The use of UVD was monitored on a weekly basis by the Infection Prevention and Control, Environmental Services, and Performance Management departments. The number and reasons for use based on logbook entries and the machine location input were compared with the contact precautions discharges from the bed management system. When UVD was not performed, reasons were categorized as roommate, no machine available, urgent need for room, or unknown reason. When the reason was unknown, Environmental Services further investigated the cause.

During both the pre-UVD and the UVD periods, there were several initiatives to optimize environmental disinfection. Before UVD use, from July 2008 to December 2009, the hospital participated in the Greater New York Hospital Association CD initiative.[18] This initiative required use of checklists for environmental cleaning and engaging the Environmental Services Department in assuring discharge cleaning was adequate. Mercury UVD (Lumalier, Memphis, TN) was used on a limited basis in the medical intensive care and burn units from January 2009 to June 2010. A new Environmental Services contractor began in January of 2011. Throughout this study, cleaning was monitored using supplemental methods; Adenosine triphosphate (3M Cleantrace; 3M, Minneapolis, MN) was used in 2010, and UV fluorescent tracking markers (Dazo; Ecolab, St. Paul, MN) were used in the 2011 to 2013 period. In September 2012, during the UVD period, a new discharge cleaning checklist was adopted for use by Environmental Services supervisors.

Other health care-associated infection reduction initiatives included public reporting of CD to the New York State Department of Health starting in January 2010 and a change from CD cytotoxin A+B enzyme immunoassay (Meridian Bioscience, Cincinnati, OH) to real-time polymerase chain reaction (Cepheid, Sunnyvale, CA) in July 2010. In addition, a randomized double-blind trial of chlorhexidine bathing was conducted on a single unit, and weekly intensive cleaning of occupied rooms in high-risk units occurred throughout both the pre-UVD and UVD periods.

### *Definitions*

MDRO cases were patients with organisms recovered from clinical cultures that include MRSA, VRE, or gram-negative bacteria susceptible to 2 or fewer classes of antibiotics. CD cases were defined as cases with a stool diagnostic test positive for CD. MDRO or CD cases were considered hospital acquired if there was no history of the organism and the onset of symptoms that led to recovery of the organism was present after 3 days of hospitalization and not incubating at admission or recovered within 48 hours after discharge. Incidence rates of MDROs and CD were defined as new hospital-acquired cases per 1,000 patient-days. Rate data were abstracted from Infection Prevention and Control databases without any links to individual patient information. This study was a quality improvement initiative that assessed summary data without individual patient identifiers.

### *Data analysis*

Descriptive statistics were used to report the number of UVD cycles completed, the reasons for use, the percent of contact

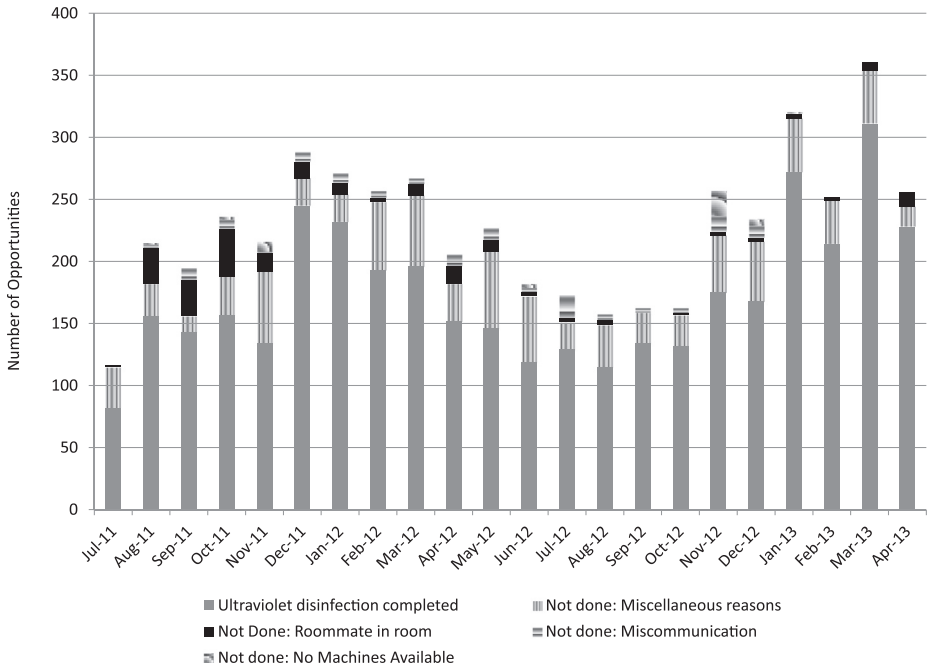


**Fig 1.** Ultraviolet disinfection use for contact precautions discharges and reasons for missed opportunities by month and year.

precautions discharge rooms that received UVD, the total time used, the average additional time needed for UVD, and the total utilization of the 2 UVD machines. Rate ratios with corresponding 95% confidence intervals and tests for trends in rates were estimated using Poisson regression. To assess the difference between the incidence rate before and during UVD use, piecewise regression was used.[19] The piecewise regression creates a combined model of the 2 time periods and compares the infection rates before and during UVD implementation. All data analyses were performed using Stata V.12.1 (StataCorp, College Station, TX).

## RESULTS

UVD was performed 11,389 times from July 1, 2011, to April 30, 2013. Contact precautions discharges accounted for 3,833 (34%) uses, staff request for 3,695 (32%) uses, routine operating room and burn unit disinfection for 1,938 (17%) uses, and disinfection of bathrooms in occupied rooms accounted for 1,938 (17%) of uses.

Contact precautions rooms received UVD for 3,833 (76%) of discharges, with a range of 66% to 93% of discharges per month (Fig 1). The reasons for missed UVD upon discharge were miscellaneous 799 (67%) times, roommate was present 212 (18%) times, miscommunication with nursing 129 (11%) times, lack of availability of a machine 40 (3%) times, and because of urgent need for the room 9 (<1%) times.

UVD added an average of 51 minutes per discharge. This included approximately 31 minutes for arrival including setup of machine and setup of blackout curtains in areas that had open bays or glass windows and walls. UVD machines were in use for approximately 30% of the total time available. During the 22 months of UVD, changes were made to optimize utilization of the machines; these changes are summarized in Table 1.

The overall rates of hospital-acquired MDROs plus CD were stable for the 30 months before use of UVD ($P_{trend} = .89$) and for the 22 months during UVD ($P_{trend} = .28$) (Fig 2). However, the rate of hospital-acquired MDRO plus CD was significantly lower during the 22 months of UVD use compared with the 30-month period before UVD (2.14 cases per 1,000 patient-days vs 2.67 cases per 1,000 patient-days, respectively; rate ratio, 0.80; 95% confidence interval: 0.73-0.88, $P < .001$). The piecewise regression model showed a significant decrease in the infection rate during UVD use, $P < .001$. A subanalysis of the incidence rates of VRE, MRSA, CD, and resistant gram-negative bacteria demonstrated that each was significantly reduced during the UVD period (Table 2).

## DISCUSSION

In this study, several implementation considerations were defined and monitored to optimize use of UVD. First, there was a method for automatically deploying the machines to contact precautions discharge rooms. In our hospital, the bed management system sends a text page that has the contact precautions message included. Second, a crucial factor was assuring availability of personnel to run the machines. Labor cost and availability must be considered in the budget and implementation plan for UVD. Our machines were in use 30% of the total available time in large part because of labor constraints, and labor constraints may have contributed to missing 24% of contact precautions discharge UVD opportunities. Staff is not primarily budgeted to run UVD; rather, this task is added onto the existing role of the staff or supervisor and may divert staff from other essential functions. Finally, our team discussed each contact precautions room missed on a weekly basis. This allowed us to uncover system flaws such as not assigning delivery of the UVD machines to a specific role at shift change, miscommunication in which Nursing told Environmental Services staff that UVD was not necessary, and unintended consequences such as deploying UVD to contact precautions rooms housing respiratory virus patients rather than only to those with MDROs and CD. It appears that UVD is feasible in our institution because it was cancelled less than 1% of the time because of immediate need for the room for patient care. Review of missed opportunities weekly has allowed us to improve our processes, although the need to evaluate utilization and missed opportunities is ongoing.

During the period of UVD, there was a 20% decrease in overall hospital-acquired MDRO plus CD. This statistically significant decrease in MDROs plus CD occurred in spite of missing 24% of

**Table 1**
Timeline of ultraviolet disinfection use changes and rationale

| Month/year | Change | Rationale |
|---|---|---|
| 8/2011 | Environmental Services assigned the off-going supervisor to deliver the UVD machine to contact precautions rooms at change of shift. | To eliminate UVD misses at shift change. |
| 9/2011 | Contact precautions policy changed to require that patients who are eligible to have precautions stopped must be moved to a new room. Precautions are continued if they cannot be moved to a new room. | If precautions are discontinued and the patient remains in the room, the room will not be flagged for UVD at patient discharge. |
| 4/2012 | Discontinued use of UVD overnight in operating rooms. | A cleaning person was being diverted to run the UVD machine, resulting in a net loss of time dedicated to operating room cleaning. |
| 5/2012 | Routine use of UVD in bathrooms of occupied patient rooms added during non-peak discharge hours when staffing allowed. | Bathrooms are often highly contaminated, and it is feasible to use UVD in the bathroom with the door closed. |
| 1/2013 | Infection Prevention and Control is notified immediately if nursing told Environmental Services staff that UVD was not necessary. | Infection Prevention and Control can investigate communication breakdowns in real time and provide education to staff. |
| 4/2013 | Remove the isolation indicator that deploys UVD upon discharge from patients with respiratory viruses. | To maximize UVD availability for MDRO and CD room discharges. |

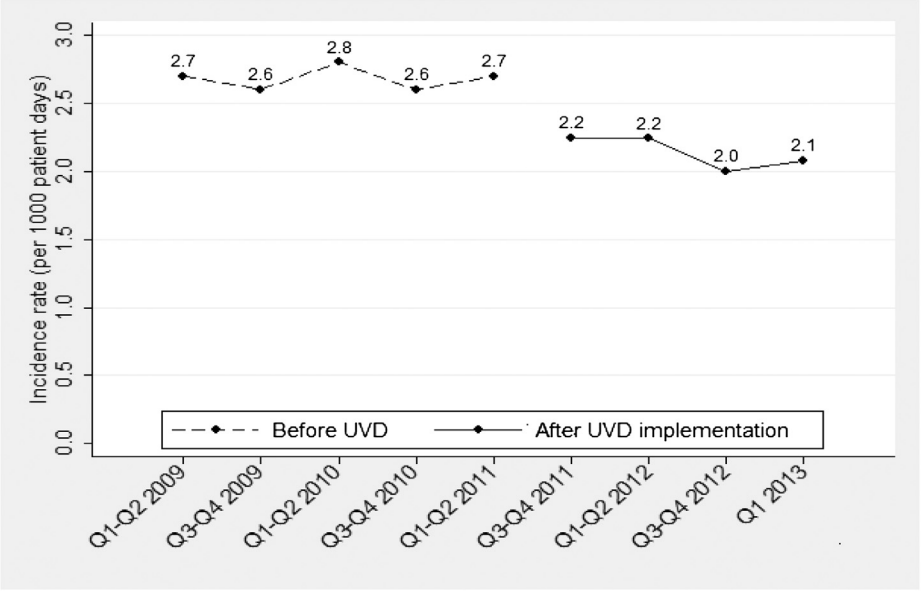


**Fig 2.** Incidence of hospital-acquired multiple drug resistant organisms plus *Clostridium difficile* from January 2009 until April 2013.

**Table 2**
Rates of hospital-acquired multiple-drug-resistant organisms and *Clostridium difficile* before and during ultraviolet disinfection

| Organism | Before ultraviolet disinfection, 1/2009-6/2011 | | During ultraviolet disinfection, 7/2011-4/2013 | | Rate ratio, (95% confidence interval), *P* value |
|---|---|---|---|---|---|
| | No. | Rate per 1,000 pt-days | No. | Rate per 1,000 pt-days | |
| Total | 1,320 | 2.67 | 749 | 2.14 | 0.80 (0.73-0.88) <.001 |
| Vancomycin-resistant *Enterococcus* | 443 | 0.90 | 257 | 0.73 | 0.82 (0.70-0.95) =.002 |
| *Clostridium difficile* | 390 | 0.79 | 228 | 0.65 | 0.83 (0.70-0.97) =.02 |
| Methicillin-resistant *Staphylococcus aureus* | 224 | 0.45 | 116 | 0.33 | 0.73 (0.58-0.92) =.007 |
| Multiple-drug-resistant gram-negative bacteria | 260 | 0.52 | 148 | 0.42 | 0.81 (0.66-0.98) =.04 |

*Pt*, patient.

opportunities for UVD of contact precautions rooms at discharge. Although there have been other studies of the effectiveness of UVD[8,11,12,15,20-22] for reducing vegetative bacteria and CD spores from environmental surfaces, this study is among only a small number of studies[14,16] evaluating rates of hospital-acquired pathogens in relation to the use of UVD.

The first clinical study in which UVD appeared to have a beneficial effect for reducing CD was reported by Sitzlar et al. They reported using UVD in a double occupancy room in a long-term care facility; 2 men acquired CD separately, but each had 2 recurrences of CD symptoms that were temporally associated. After treatment and UVD of the room, neither had further recurrences.[13] This same group of investigators studied environmental contamination with CD spores after sequential interventions of feedback about cleaning, UVD, and supervised cleaning.[8] They found that UVD decreased CD spore contamination in rooms but that cleaning was less rigorous during the UVD period. Supervised cleaning included the use of a 3-person dedicated daily disinfection team for high-touch surfaces in CD rooms and implementation of a process requiring that terminally cleaned CD rooms be “cleared” for the next patient by environmental services supervisors and/or infection control staff. In the period of supervised cleaning, CD spore contamination was eliminated by the cleaning, with no incremental benefit of UVD. In contrast, recent reports using a before and after design have associated UVD use with significant reduction in CD infection[14,16] and VRE acquisition.[14] The benefit of UVD versus standard

cleaning and supervised "research" level cleaning is an area for further research.

In our study, overall decreases in MDRO plus CD were led by a decrease in VRE, which is our most common hospital-acquired MDRO. VRE has a large environmental reservoir; we and others[15,23,24] have reported recovery of VRE from at least 23% to 25% of rooms housing infected or colonized patients. The importance of the environment as a potential source for VRE acquisition was demonstrated in a multivariate analysis in which VRE acquisition was significantly more likely if the prior occupant had VRE or if an environmental culture had been positive in the room.[1,2] Hayden et al[10] and Datta et al[9] found decreased VRE acquisition following intensive monitoring of and feedback about housekeeping procedures. Although there were many other simultaneous infection control interventions occurring at our hospital during the period from 2009 until 2013 that could have contributed to the reduction in VRE acquisition, the rates experienced during UVD are the lowest incidence rates of VRE at our institution for the past 10 years[25] and were sustained for 22 months.

The incidence rates of MRSA, CD, and MDR gram-negative organisms were also significantly lower during the UVD period. Although many simultaneous infection control initiatives could have contributed to these reductions, none appeared temporally associated with any reduction. For example, we had participated in CD reduction initiatives that included use of bleach-based disinfectants and cleaning checklists without any change in CD rates. Rates decreased during UVD use despite the transition to a more sensitive diagnostic test (polymerase chain reaction), which increased overall CD test positivity from 10% to 13%.

The limitations of this study include the before and after implementation of UVD design, which has inherent weaknesses, and the fact that this report is from a single institution. We did not evaluate antibiotic utilization, which can clearly affect acquisition rates of MDRO and CD. There were many simultaneous interventions occurring to reduce acquisition of MDROs and CD. However, the MDRO plus CD rates were stable for 30 months before initiation of UVD and only decreased during the first 6 months of the UVD period. These decreases were then sustained throughout the UVD period. Although the possibility of a cumulative effect of the multiple infection control interventions that were occurring during the pre-UVD period and continuing into the UVD period cannot be eliminated, our data suggest UVD use had an impact on these reductions.

Further study is needed to optimize the use of UVD and to further assess the effect of UVD use on acquisition rates of MDROs and CD. In addition, a cost-benefit analysis of UVD use that includes labor costs is also needed. Use of UVD as an adjunct to routine discharge cleaning of contact precautions rooms was feasible and temporally associated with a significant decrease in hospital-acquired MDRO plus CD in our institution.

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