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Major article

Impact of pulsed xenon ultraviolet light on hospital-acquired infection rates in a community hospital

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Background: The role of contaminated environments in the spread of hospital-associated infections has been well documented. This study reports the impact of a pulsed xenon ultraviolet no-touch disinfection system on infection rates in a community care facility.

Methods: This study was conducted in a community hospital in Southern Florida. Beginning November 2012, a pulsed xenon ultraviolet disinfection system was implemented as an adjunct to traditional cleaning methods on discharge of select rooms. The technology uses a xenon flashlamp to generate germicidal light that damages the DNA of organisms in the hospital environment. The device was implemented in the intensive care unit (ICU), with a goal of using the pulsed xenon ultraviolet system for disinfecting all discharges and transfers after standard cleaning and prior to occupation of the room by the next patient. For all non-ICU discharges and transfers, the pulsed xenon ultraviolet system was only used for *Clostridium difficile* rooms. Infection data were collected for methicillin-resistant *Staphylococcus aureus*, *C difficile*, and vancomycin-resistant *Enterococci* (VRE). The intervention period was compared with baseline using a 2-sample Wilcoxon rank-sum test.

Results: In non-ICU areas, a significant reduction was found for *C difficile*. There was a nonsignificant decrease in VRE and a significant increase in methicillin-resistant *S aureus*. In the ICU, all infections were reduced, but only VRE was significant. This may be because of the increased role that environment plays in the transmission of this pathogen. Overall, there were 36 fewer infections in the whole facility and 16 fewer infections in the ICU during the intervention period than would have been expected based on baseline data.

Conclusion: Implementation of pulsed xenon ultraviolet disinfection is associated with significant decreases in facility-wide and ICU infection rates. These outcomes suggest that enhanced environmental disinfection plays a role in the risk mitigation of hospital-acquired infections.

BACKGROUND

The Centers for Disease Control and Prevention estimated a national burden of 722,000 hospital-acquired infections (HAIs) occurring within acute care hospitals in 2011.[1] This estimation is house-wide, with over half of these infections occurring outside of the intensive care unit (ICU). Approximately 4% of all patients that are admitted will contract at least 1 HAI. Because >70% of gastrointestinal infections were caused by *Clostridium difficile*, the Centers for Disease Control and Prevention have recently changed their focus to understanding the factors that may contribute to HAIs beyond

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Conflicts of interest: As employees of Xenex Disinfection Services, LLC, C.R.D., S.S., and M.S. identify both financial and intellectual competing interests. P.G.V. and C.M.L. have not identified a competing interest regarding the study beyond working for the institution in which this study took place at (South Seminole Hospital, Orlando Health).

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actual operative procedures, with a particular emphasis given to understanding the role of contaminated surfaces within the patient room.[2,3]

Substantial evidence exists that air and surfaces within the patient room are regularly contaminated with multidrug-resistant organisms (MDROs).[4,5] Patients regularly shed organisms on skin squames that have the potential to disperse over a wide range.[6,7] Knelson et al[8] illustrated that both asymptomatic colonized patients and symptomatic patients were equally as likely to contribute to this environmental contamination with MDROs. Health care workers are just as likely to contaminate their gloved hands when touching inanimate surfaces as when touching the actual patient in a methicillin-resistant *Staphylococcus aureus* (MRSA)–, vancomycin-resistant *Enterococci* (VRE)–, or *Clostridium difficile*–positive patient room.[9-11] To make matters worse, the pathogens of common MDROs, particularly *C difficile* spores, have the potential to survive for months on dry surfaces if not adequately removed.[12]

Evidence supports what is known as prior room occupancy risk, or the increased risk of acquiring an infection after being admitted to a room with a previous MDRO-positive occupant rather than one who did not have an MDRO.[13] In fact, Shaughnessy et al[14] determined this prior room occupancy risk to be >2 times greater when the previous patient had *C difficile*. Because there is no physical contact between patients, the effects of this comparison can be isolated to that of environmental contamination.

Although interventions focusing on improved thoroughness and adherence and manual cleaning protocols has decreased this environmental burden,[15,16] there remains difficulty in sustaining improved cleaning compliance. Carling et al[17] demonstrated that only 47% of intended surfaces are actually contacted by a disinfectant on a routine cleaning basis. Additionally, confusion in cleaning roles between nursing and environmental surfaces can lead to inadequate disinfection of mobile medical devices used in multiple patient rooms.[18]

Pulsed xenon ultraviolet (PX-UV) disinfection is a non–user-dependent technology that can be an additional adjunct to cleaning regimens. Full-spectrum ultraviolet light has been found to improve environmental cleanliness to a significant degree, even eliminating MDROs, such as VRE, completely from selected high-touch surfaces.[19] Most importantly, hospitals that use PX-UV have actually significantly mitigated infection risks associated with environmentally mediated transmission routes, decreasing hospital-acquired *C difficile* and MRSA rates by 53% and 56%, respectively, facility-wide.[20,21]

Although PX-UV can be of particular relevance within the ICU, where patients have higher acuity and an increased utilization of indwelling medical devices, these studies also suggest that this technology could be extended to acute care, non-ICU inpatient settings where evidence based-literature is currently lacking.[22] In this article we describe the feasibility and impact of implementing a no-touch PX-UV disinfection system within the ICU and non-ICU setting of an acute care hospital in an attempt to identify significant changes in the rates of hospital-acquired MDROs (particularly *C difficile*).

METHODS

Facility and technology

South Seminole Hospital is a community hospital that is part of Orlando Health, with 126 medical-surgical beds located in Central Florida. The facility also houses an 80-bed psychiatric care unit. For the duration of the study, infection data were collected and calculated using the National Healthcare Safety Network criteria.

Beginning in November 2012, a PX-UV disinfection system was implemented as an adjunct to traditional cleaning methods on discharge of select rooms. The technology uses a xenon flashlamp to generate full-spectrum germicidal light that damages the DNA or RNA of pathogenic organisms. The full-spectrum, high-intensity characteristics of PX-UV light emission allow for rapid disinfection of patient care areas.[19]

ICU implementation

In the ICU, the goal was for all room discharges and transfers to be treated with no-touch disinfection after standard cleaning and prior to the next patient occupying the room. This methodology was selected because there is evidence showing that rooms can become contaminated with pathogenic organisms regardless of the infection or colonization status of the previous patient[23]; therefore, implementation of a no-touch disinfection program should not be limited to disinfection of rooms that previously housed only isolation patients. The impact of colonized or infected patients will extend beyond the room used for direct care because pathogenic organisms will be transmitted to other rooms by contaminated mobile medical equipment and on the hands of health care workers.[24]

Non-ICU implementation

For all non-ICU discharges and transfers, the no-touch disinfection system was only used for *C difficile* discharges. This methodology was selected because transmission of *C difficile* was the most prevalent hospital-associated infection, and it was not feasible to disinfect all discharges throughout the facility because of limitations on device availability and proximity of location.

Pulsed xenon disinfection

PX-UV disinfection systems are used after the room has undergone standard terminal cleaning practices including the use of bleach for *C difficile* isolation rooms. To maximize the distribution of light throughout a room, multiple positions are used when performing no-touch disinfection. Based on previous studies, the following protocol was used: in a standard patient room with an integrated private bathroom, the device is run for 1 cycle in the bathroom and 1 cycle on both sides of the bed, for a total of 3 cycles, each lasting 5 minutes. If the room does not have a separate bathroom, only 2 cycles are required.[19] An onboard data log allows the hospital service team to track which specific room is being disinfected at specific times and notifies the user when a disinfection cycle has been successfully completed.

Statistical analysis

Infection rates (incidence divided by patient days) for the PX-UV intervention were compared with infection rates before implementation. Because the data were not normally distributed, a 2-sample Wilcoxon rank-sum test indicated the significance of changes occurring (Stata Corp, College Station, TX).

RESULTS

PX-UV disinfection was implemented in >200 patient rooms per month from November 2012-August 2014 (>4,400 rooms total) and compared with January 2011-October 2012 (Table 1–3).

A significant 29% facility-wide decrease in all 3 MDROs (*C difficile*, MRSA, and VRE) was determined ($P = .01$), statistically driven by a 41% decrease in *C difficile* infection ($P = .01$). Although only moderately significant, the greatest decrease in facility-wide incident rates was seen with VRE, shifting from 34 to 15 infections within the PX-UV disinfection period ($P = .070$).

Table 1
Comparison of infection rates [(incidence/patient days) × 1,000] for common MDROs before and after implementation of PX-UV: comparison of non-ICU rates pre and post PX-UV disinfection

Facility	Organism	Pre rate	Post rate	% Change	*P* value	Pre incidence	Post incidence	Pre patient days	Post patient days
SSH	*Clostridium difficile*	0.75	0.45	–40	.04	71	38	94,777	84,161
SSH	MRSA	0.24	0.37	52	.05	23	31	94,777	84,161
SSH	VRE	0.26	0.17	–37	.27	25	14	94,777	84,161
SSH	All 3	1.26	0.99	–21	.16	119	83	94,777	84,161

NOTE. A significant difference exists when $P < .05$.
Abbreviations: *ICU*, intensive care unit; *MDRO*, multidrug-resistant organisms; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *pre*, January 2011-October 2012; *post*, November 2012-August 2014; *PX-UV*, pulsed xenon ultraviolet; *SSH*, South Seminole Hospital; *VRE*, vancomycin-resistant *Enterococci*.

Table 2
Comparison of infection rates [(incidence/patient days) × 1,000] for common MDROs before and after implementation of PX-UV: comparison of ICU rates pre and post PX-UV disinfection

Facility	Organism	Pre rate	Post rate	% Change	*P* value	Pre incidence	Post incidence	Pre patient days	Post patient days
SSH	*Clostridium difficile*	2.40	1.31	–45	.25	11	5	4,579	3,805
SSH	MRSA	2.40	1.05	–56	.22	11	4	4,579	3,805
SSH	VRE	1.97	0.26	–87	.01	9	1	4,579	3,805
SSH	All 3	6.77	2.63	–61	.01	31	10	4,579	3,805

NOTE. A significant difference exists when $P < .05$.
Abbreviations: *ICU*, intensive care unit; *MDRO*, multidrug-resistant organisms; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *pre*, January 2011-October 2012; *post*, November 2012-August 2014; *PX-UV*, pulsed xenon ultraviolet; *SSH*, South Seminole Hospital; *VRE*, vancomycin-resistant *Enterococci*.

Table 3
Comparison of infection rates [(incidence/patient days) × 1,000] for common MDROs before and after implementation of PX-UV: comparison of facility rates pre and post PX-UV disinfection

Facility	Organism	Pre rate	Post rate	% Change	*P* value	Pre incidence	Post incidence	Pre patient days	Post patient days
SSH	*Clostridium difficile*	0.83	0.49	–41	.01	82	43	99,356	87,966
SSH	MRSA	0.34	0.41	20	.23	34	36	99,356	87,966
SSH	VRE	0.34	0.17	–50	.07	34	15	99,356	87,966
SSH	All 3	1.51	1.07	–29	.01	150	94	99,356	87,966

NOTE. A significant difference exists when $P < .05$.
Abbreviations: *ICU*, intensive care unit; *MDRO*, multidrug-resistant organisms; *MRSA*, methicillin-resistant *Staphylococcus aureus*; *pre*, January 2011-October 2012; *post*, November 2012-August 2014; *PX-UV*, pulsed xenon ultraviolet; *SSH*, South Seminole Hospital; *VRE*, vancomycin-resistant *Enterococci*.

In the ICU alone, all 3 infection types similarly experienced significant reductions ($P = .01$) together. However, changes in VRE incidence was only statistically significant alone ($P = .01$). Nonetheless, *C difficile*, MRSA, and VRE rates decreased by 45%, 56%, and 87%, respectively.

On all other non-ICU floors combined, only a 40% change in *C difficile* infections alone was relevant ($P = .04$). MRSA infection rates actually increased 52% ($P = .05$) in this setting, unlike the 56% decrease observed within the ICU alone ($P = .22$). In addition, VRE acquisition rates actually decreased 37%, despite the focus of only *C difficile* terminal cleans being disinfected with full-spectrum ultraviolet light in the non-ICU setting.

DISCUSSION

Implementation of PX-UV disinfection resulted in a 29% and 61% decrease in facility-wide and ICU-wide infections, respectively, for all 3 pathogens together. These findings are encouraging given the history of environmental implicated infections and exceptional environmental reservoirs associated with these organisms.[25] The difference in infection rates for the ICU compared with the non-ICU areas demonstrates the increased risk of infection in the ICU and the leverage that ICU-based interventions can have on the facility-wide rates. Furthermore, there seems to be a direct correlation between the focused use of PX-UV on all *C difficile* discharges facility-wide and a decrease in postincidence infection rates. Only *C difficile* infections were significantly reduced facility-wide, and only *C difficile* contact precaution rooms received enhanced disinfection in the non-ICU setting.

A novel aspect of this study is that it examines 2 different deployment strategies for ultraviolet disinfection: using ultraviolet disinfection for every terminal discharge on a unit and for *C difficile* isolation rooms only. The different magnitude of rate reduction associated with these 2 deployment strategies indicates best practices for ultraviolet disinfection. This is an advantage over studies that examine the disinfection efficacy only because those studies do not give information about where ultraviolet disinfection should be deployed to impact infection rates.

Diagnostics remained consistent over the time period as the facility adopted polymerase chain reaction technology for *C difficile* diagnosis in January 2011. Additionally, a ventialator associated pneumonia prevention bundle was initiated in the ICUs in 2007. An antimicrobial stewardship program was initiated in January 2012 (11 months before the ultraviolet device was introduced) and resulted in reductions in the use of ciprofloxacin and moxifloxacin (by 73% and 81%, respectively); however, this change was not linked to a reduction of the nosocomial *C difficile* rate prior to the introduction of the ultraviolet device. These programs were active and monitored throughout the intervention period.

It is encouraging to identify a consistent downward trend in infections of each organism type alone within the ICU, where usage goals were centered on ultraviolet exposure after every discharge. This change was not as significant in the non-ICU setting, where only *C difficile* contact precaution rooms were exposed to the ultraviolet disinfection cycles. This observation supports the consistent feasibility of PX-UV in an area of higher acuity and patient flow.

South Seminole Hospital experienced 39 fewer *C difficile* and 19 fewer VRE infections within the 22-month facility-wide PX-UV intervention window. In addition, >280 and 110 patient bed days were generated for each infection, respectively. Assuming a similar trend in infection rates without the intervention in place, this could have potentially resulted in net savings of >$730,000. *C difficile* and VRE cases are nonreimbursable, costing a facility an additional average $14,000 per case.[26,27]

These outcomes suggest that enhanced environmental disinfection plays a significant role in the risk mitigation of HAIs. Using prior room occupancy risk as a proxy measure, previous literature has suggested prior risk for MRSA, *C difficile*, and VRE to be 40%,[28,29] 135%,[14] and 280%,[30] respectively, on the new admission of a patient; however, these rate estimates may not apply to all settings, such as community hospitals. The ICU at South Seminole Hospital had no recorded infections for any organism between May and December 2013, and alone only 1 VRE incident has been recorded on addition of the PX-UV intervention, with zero infections occurring between November 2012 and July 2014. It has been suggested that enhanced environmental cleaning could have a larger impact on VRE because the environment could play a larger role in transmission.[31] However, slight variation between absolute changes in infection rates between organisms is most likely attributed to a combination of a small patient day population and the fact that HAIs are a rare event statistic in this analysis.

Although insignificant, VRE incidence rates decreased by approximately 40% in non-ICU areas. This is surprising, given PX-UV was not deployed in VRE contact precaution situations and MRSA infections were actually trending upward of >50% within the intervention. It is possible that the ICU is the primary transmission point of VRE at South Seminole Hospital, causing all other step-down areas of patient care within the facility to be effected by the drastic reduction of VRE rates within the ICU. However, these trends might be irrelevant, given these exceedingly insignificant statistical conclusions.

Limitations of this study include using historical comparison data rather than an experimental design, effecting potential statistically significant conclusions within the area of the ICU. Because of the nature of the study design, confounders, such as hand hygiene compliance, manual environmental cleaning quality, antimicrobial stewardship, and colonization pressure, were not controlled and could have influenced the outcome. In general, a small patient population provides less sensitivity in detecting significant changes. For ICU patient days to match the absolute effect size of the rest of the hospital, our intervention period would have required an exceptional length of time.

CONCLUSIONS

Significant infection reduction trends in cases where all 3 organisms are paired together suggest a significant overall impact of PX-UV on patient outcomes and a significant net return on investment. As more evidence unfolds within the literature, the environmental significance to nosocomial infection acquisition and potential for no-touch disinfection can be better justified and compared.

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