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Clostridioides Difficile Decontamination with Targeted Pulsed Ultraviolet Disinfection

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Abstract

Contaminated surfaces in hospitals play an important role in the transmission of several key nosocomial pathogens including *Clostridioides difficile* spores. Germicides are often inadequate and can leave environmental surfaces contaminated with nosocomial pathogens. Ultraviolet (UV) pulsated light decontamination systems are increasingly being used to supplement terminal disinfection. An *in-vitro* experiment was conducted to assess the efficacy of UV pulsed lighting with 360^{o} exposure in the eradication of *C. difficile* spores. *C. difficile* spore samples were placed 4 feet from the pulsed light source. Samples were exposed to UV for 1, 2.5, and 4 minutes at four different angles. The most effective result was observed when the exposure time was longer (4 minutes) and the angle was 0 degrees, which exhibited 98.99% eradication. Using continuous head rotation throughout each cycle, the unit delivers high efficacy light 360^{o} around the unit. The present study suggests that UV pulsed lighting devices may play an important role in reducing key nosocomial pathogens including *C. difficile*

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Background/Introduction

Hospital-acquired infections (HAIs) are those infections that patients develop while in the hospital that was neither present nor developing when patients were admitted (Ontario Health Assessment, 2018). Environmental contamination is one of the main causes leading to HAIs (Hunt et al, 2016). The risk of acquiring an HAI increases significantly when the prior room occupant has had an epidemiologically important HAI (Huang et al, 2006, Rutala, 2016). Although there is a remarkable improvement in health care services, HAIs continue to be a significant contributor to patient mortality in both the developing and developed world. The impact of HAIs extend beyond morbidity and mortality, which can result in prolonged hospitalization, impaired quality of life, loss of working power, and performance (Kurutkan et al, 2015).

*Clostridioides difficile (*formerly known as *Clostridium difficile*) infection is a major public health problem worldwide with significant morbidity and mortality as a result of the spread of spores (Vassallo, 2014). During the last decade, *C. difficile* has emerged as a major cause of healthcare-associated diarrhoea and is the primary cause of hospital-acquired colitis in patients receiving antibiotics. The pathogenicity of the organism is mainly due to the production of toxins (Singh et al., 2017). Transmission of this spore-forming bacterium is thought to occur primarily through the hands of healthcare providers or through contaminated environment (Barbut, 2015). The challenge in fighting *C. difficile* is two-fold; strains of the bacterium are increasingly hard to treat in patients, and the superbug spores can live on environmental surfaces for months, where they remain resistant to many disinfectant products (Keet, 2016). *C. difficile* infections can create a vicious cycle for healthcare facilities. Patients who are admitted to hospitals and are receiving antibiotic treatment can, in turn, become at risk for infection by other pathogens. *C. difficile* spores can persist in healthcare environments and readily infect those at-risk patients. Today, at least 80% of *C. difficile* infections remain healthcare-associated, placing the onus on hospitals to find the correct measures to bring these rates down (Pegues, 2017). Therefore, enhanced environmental cleaning/disinfection of the rooms housing *C. difficile*-infected patients is of utmost importance.

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When it comes to the fight against infectious diseases, many clinicians would agree that preventing the infections from happening in the first place is better than finding effective ways of treating them afterwards (Rosa, 2017). The standard method of reducing and preventing these infections is decontamination of patient rooms through manual cleaning and disinfection. Terminal room disinfection (disinfection of a room between occupying patients) can be enhanced by using a chemical disinfectant with sporicidal activity or by the use of supplemental disinfection technologies (Anderson et al, 2017). However, chemical germicides are sometimes inadequate and leave environmental surfaces contaminated with important nosocomial pathogens (Han el al, 2015). Thorough cleaning of these rooms is essential, but is often difficult to achieve on multiple surfaces and complex equipment. *C. difficile* endospores have been found to survive up to 5 months in a hospital environment (Kramer et al, 2006). *C. difficile* has also been shown to be resistant to some alcohol-based disinfectants, quaternary ammonium compounds, and even some detergents may even encourage sporulation of this organism (Ghantoji et al, 2015). In this study, an *in-vitro* experiment was conducted to assess the effectiveness of radiant angles of pulsed UV irradiation in the eradication of *C. difficile* spores from a distance of 4 feet.

Methods

Sample preparation: Experiments were all performed at ResInnova Labs. Ten microlitre aliquots of *C. difficile* spores were suspended in phosphate-buffered saline (PBS) and were spread on steel disc carrier with a diameter of 1.0 – 1.1 cm). The carriers were placed in a desiccator at room temperature, rather than air-drying, to accelerate the process and reduce the risk of contamination. The inoculum concentrations varied from experiment to experiment, with an average of 1 x10^6 CFU on each disc.

Simulation of the hospital & disinfection application: *C. difficile* spores were plated on steel disc carriers and was placed a distance of 4 ft height and 4 ft from the pulsed UV irradiating unit (Figure 1). Three exposures of 1 minute (short), 2.5 minutes (medium), and 4 minutes (long) and four different angles i.e., 0, 30, 45 and 60 degrees were studied. In the control, samples were not exposed to UV irradiation (Solaris Disinfection Inc. SL-001). To recover spores, steel carriers were submerged in 10 ml PBS with Triton X-100 (0.1%) and vortexed. Solutions were then plated on Brain Heart Infusion Agar (1x) supplemented with yeast extract (2%) and taurocholate (0.1%), and cultured at 37˚C for 24-48 ours in anaerobic conditions. Statistical tests were performed when the data was amenable to appropriate analysis.

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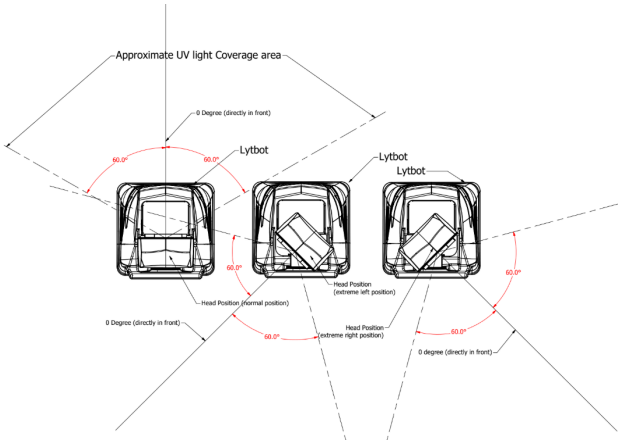


Figure 1: Experimental design. The degree of incidence relative to the UV-disinfection machine from which pulsated UV light is emitted is shown. The angles indicate the locations of the *C. difficile* samples relative to the same immediately in front of the equipment. During a disinfection cycle, the head containing the light source starts in position 1. The head then slowly rotates through position 2 and 3. In doing so, optimal energy output as tested at 0^{o} achieved throughout 360^{o} plane**.** Credit: Manjinder Dhillon, Solaris Disinfection Inc.

Results

Moderate reduction in contamination was observed in short and medium exposure with the angle of irradiation at 0, 30, and 45 degrees (Figure 1). The greatest relative reduction of *C. difficile* spores was observed when the exposure time was 4 min and the angle of irradiation was 0 degrees (98.9%) (Figure 2). A similar trend was also observed with a long exposure time at 30 degrees angle (98.2% reduction). However, logarithmic reduction was limited at an angle of 60 degrees with long exposure.

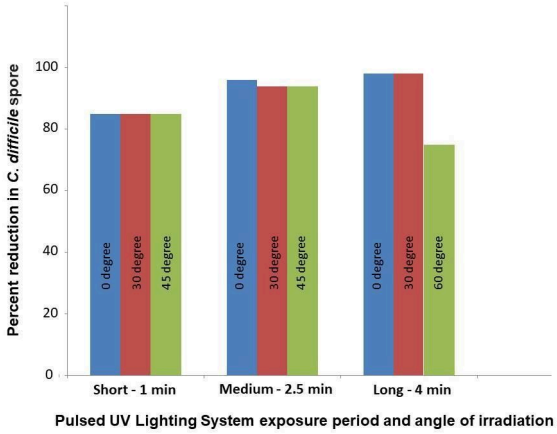


Figure 2: Reduction of *C. difficile* spore by pulsed UV lighting at different angles of irradiation.

Discussion

The objective of the investigation was to assess the radiant angles of effectiveness on the horizontal plane to evaluate the area of effective decontamination at a particular distance. Our study indicates that the decontamination rate is lower at angles greater than 0˚ (30˚, 45˚, 60˚). UV-C decay is inversely proportioned to the square of distance. Understanding the angle of incidence for effective decontamination is useful when quickly determining how to efficiently disinfect high touch areas, as we can develop a cleaning protocol from multiple angles to disinfect the surfaces.

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Germicidal Ultraviolet (UV) irradiation has been shown to be effective in deactivating *C. difficile* endospores in laboratory and clinical settings, specifically, the UV-C frequency, which ranges from 200 to 280 nm (Ghantoji et al, 2015). Pulsed xenon UV (PX-UV) is a method of quickly producing germicidal UV that has been effective against *C. difficile* (Stibich et al, 2011). Hence, UV light decontamination systems are being used increasingly to supplement terminal disinfection of patient rooms (Ali et al, 2017). Novel 'no-touch' methods for room disinfection using PX-UV have recently been introduced in many hospitals. *In-vitro* studies suggest that UV-based methods can achieve ~2 $\log_{10}$ reduction in *C. difficile* spores placed on carriers (Barbut., 2015).

C. difficile-associated diarrhoea causes heavy financial burden on healthcare systems worldwide. As with all HAIs, prolonged hospital stays are the main cost driver. Previous cost studies only include hospital billing data and compare the length of stay of infected patients in contrast to non-infected patients (Hübner et al, 2015; Abdelsattar et al, 2015). Patients admitted to rooms previously occupied by patients harbouring a multidrug-resistant organism or *C. difficile* were 10–30% less likely to acquire the same organism if the room was terminally disinfected using an enhanced strategy, such as UV-C (Anderson et al, 2017). Hence, proper disinfection strategies should be adopted to contain this infection.

In a laboratory study, the effectiveness of PX-UV irradiation against *C. difficile* spores, methicillin-resistant *Staphylococcus aureus* (MRSA), and vancomycin-resistant *Enterococcus* (VRE) was evaluated. The PX-UV device reduced contamination of MRSA (1.85±0.49 log 10 (CFU)/cm+), *C. difficile* (0.55±0.34 log 10 (CFU)/cm2), and VRE (0.6±0.25 log 10 (CFU)/cm2) on glass carriers and on frequently touched surfaces in hospital rooms with a 10-minute UV exposure time from a distance of 4 ft (Nerandzic et al, 2015).

The Solaris Lytbot, which operates in the 254 nm range, is able to deliver high frequency bulb flash rate. Pulsed UV light involves the pulsing of a high power xenon lamp to produce broad spectrum light (100-1000 nm) with a large UV-C component (Kowaski, 2009). There are two deactivation mechanisms that take place. First, at 254 nm, UV-C causes the formation of thymine dimers which leads to incorrect DNA base pairing. Secondly, the deeper UV range of 100-220 nm produces cellular overheating because of the absorption of high energy photons, which ultimately leads to cellular rupture (Solaris Disinfection, 2018).

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The pulsed xenon ultraviolet (PX-UVD) light device has given rise to no-touch technologies to reduce colonization of surfaces and cross contamination. In a recent study, the use of a PX-UVD as adjunct to standard cleaning protocols was reported to be associated with a significant decrease in surface bio-burden (Dippenaar & Smith, 2018). However, it is important to note that the new no-touch methods for room disinfection are to supplement and not replace daily cleaning (Barbut, 2015). In a study that was carried out in forty isolation rooms at Queens Hospital (700 beds) in London, United Kingdom, the presence of aerobic bacteria after patient discharge was monitored after manual cleaning with a hypochlorous acid-troclosene sodium solution and after PX-UV disinfection. The results demonstrated that after the two stage disinfection, bacterial contamination decreased by 91% (Hosein, 2016). A multicentre, randomised controlled trial demonstrated that adding a UV-C device to quaternary ammonium disinfection decreased the risk of secondary infection by target organisms - from 51.3 cases per 10,000 exposure to 33.9 cases per 10,000 exposures (Anderson et al, 2017). Supplementation to the manual cleaning by pulsed UV light technology can enhance disinfection, which in turn, decreases risk of infectious pathogens including *C. difficile).*

Conclusion

Globally there has been a steady rise of *C. difficile* infection (Butler et al, 2016). In this study, we demonstrated that *C. difficile* spores can successfully eliminate up to 98% from the hospital environment by using a pulsed UV lighting device (Solaris Lytbot), for a duration of 4 minutes. The highest eradication occurs when the light is directly exposed to the contaminated area, which can be achieved in different areas of the room with 360^{o} exposure. Terminal disinfection using an enhanced strategy like PX-UV may play an important role in reducing nosocomial pathogens.

Notes

The research was independently conducted in ResInnova Labs using the innovative pulsed UV light technology system called Solaris Lytbot from Solaris Disinfection Inc.

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