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Brief report

Disinfecting personal protective equipment with pulsed xenon ultraviolet as a risk mitigation strategy for health care workers

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The doffing of personal protective equipment (PPE) after contamination with pathogens such as Ebola poses a risk to health care workers. Pulsed xenon ultraviolet (PX-UV) disinfection has been used to disinfect surfaces in hospital settings. This study examined the impact of PX-UV disinfection on an Ebola surrogate virus on glass carriers and PPE material to examine the potential benefits of using PX-UV to decontaminate PPE while worn, thereby reducing the pathogen load prior to doffing. Ultraviolet (UV) safety and coverage tests were also conducted. PX-UV exposure resulted in a significant reduction in viral load on glass carriers and PPE materials. Occupational Safety and Health Administration–defined UV exposure limits were not exceeded during PPE disinfection. Predoffing disinfection with PX-UV has potential as an additive measure to the doffing practice guidelines. The PX-UV disinfection should not be considered sterilization; all PPE should still be considered contaminated and doffed and disposed of according to established protocols.

Low levels of contamination with Ebola virus are sufficient to infect a human host.[1] Personal protective equipment (PPE) protects health care workers by providing a physical barrier when caring for infected patients. However, a risk is created during the doffing of PPE because any error in this detailed process could result in the contamination of the health care worker's hands or other part of their body.[2] Despite training and the use of an observer, 100% proficiency to successfully adhering to the Centers for Disease Control and Prevention's (CDC's) guidelines for PPE doffing cannot be expected at all times.[3,4] Fluorescent powder and other tracers are routinely used during training on the doffing process to demonstrate the presence of human error despite following these guidelines.[5] Furthermore, health care workers may be asked to don and doff PPE that they are unfamiliar with or have not received training on during emergency situations, increasing the likelihood of a doffing error.

This study examines the use of a pulsed xenon ultraviolet (PX-UV; Xenex Disinfection Services, San Antonio, TX) germicidal device as an additional process for disinfecting PPE prior to doffing as a risk mitigation strategy. The goal of this process is to reduce the probability of transmission in the event of a doffing error. PX-UV disinfection has been adopted by multiple hospitals for surface disinfection[6] and has demonstrated a reduction in the infection rates of *Clostridium difficile*, methicillin-resistant *Staphylococcus aureus*, and other multidrug-resistant organisms.[7-9] Ebola virus has

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Conflicts of interest: Ms. Simmons, Mr. Dale, Dr. Stibich, and Dr. Stachowiak are employees and shareholders of Xenex Disinfection Services. All work on this project was governed by the Cooperative Research and Development Agreement between the Central Texas Veterans Health Care System (CTVHCS) and Xenex Healthcare Services. Dr Jinadatha has served as principal investigator on other research projects conducted at CTVHCS, which were funded by Xenex Healthcare Services and governed by the Cooperative Research and Development Agreement between the 2 entities. Dr. Ganachari-Mallappa, Mr. Villamaria, Ms. Goulding, and Dr. Tanner have nothing to disclose.

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Table 1
Effectiveness of PX-UV disinfection on different surfaces inoculated with canine parvovirus

Inoculated surface	Distance (m)	Control (average log per carrier)	Log reduction (relative to respective time zero control)
Glass slide	2	5.98	>4.00
Face shield (PPE)	1	5.98	>4.00
Surgical gown (PPE)	1	5.98	>4.00

PPE, personal protective equipment; *PX-UV*, pulsed xenon ultraviolet.

a known sensitivity to germicidal ultraviolet (UV) light and is much more susceptible than hardy spores, such as *C difficile*.[10,11]

To determine the feasibility of PPE disinfection using PX-UV, the authors examined the following in a laboratory setting: (1) the effectiveness of PX-UV disinfection against an Ebola surrogate virus on a dry inanimate surface; (2) the effectiveness of PX-UV disinfection against PPE material inoculated with an Ebola surrogate virus; (3) the level of UV exposure for a person wearing PPE; and (4) the distribution of germicidal light coverage on PPE.

MATERIALS AND METHODS

The CDC and Environmental Protection Agency (EPA) recommend the use of hospital disinfectants with label claims for a nonenveloped virus (eg, norovirus, rotavirus, adenovirus, poliovirus) to disinfect environmental surfaces in rooms of patients with suspected or confirmed Ebola virus infection.[12] Canine parvovirus (ATCC VR-2016), a nonenveloped virus not infective to humans, was selected as the surrogate organism for this research because it meets the CDC's and EPA's recommendations and was safe to the researchers involved in this study. The virus was diluted to obtain a target density of 5-6 $\log_{10}$ per 0.02 ml and was then supplemented with heat-inactivated fetal bovine serum to a concentration of 5.0% to simulate typical amounts of protein loading. Glass carriers were inoculated with 0.02 ml volume in triplicate with triplicate controls and exposed to PX-UV for 5 minutes at 2 m.

For PPE disinfection, a plastic face shield (T5 hood with face shield; Stryker, Kalamazoo, MI) and a fluid-resistant gown (MicroCool gown; Kimberly-Clark, Irving, TX) were used as hard and soft surface samples. Two and a half centimeters square segments were cut from the surgical gown and face shield and affixed onto glass carriers. As described previously, samples were inoculated in triplicate with triplicate controls with the same volume and concentration of viral solution. All samples were dried completely, allowing the solution to soak into the absorbent material of the gown. Exposure was for 5 minutes at a 1-m distance from the PX-UV system.

Samples were harvested into a neutralization medium (2% fetal bovine serum Eagle's minimal essential medium), serially diluted, and plated onto host cells (dog tumor cells, ATCC CRL-1542). Plates were incubated for 6 days, and a secondary hemagglutination assay was performed to confirm the presence or absence of virus.

To determine the potential UV exposure to a health care worker through PPE, a spectrometer (USB2000 + XR; OceanOptics, Dunedin, FL) was used to determine the amount of UV light that penetrates the PPE material when it is 1 m away from the UV source. PPE should be worn according to well-accepted published protocols, with full coverage of skin and eyes.[13] Final readings were compared with published standards of UV exposure limits recommended for safety purposes.[14]

UV photochromatic stickers were placed on specific areas of the PPE to assess light distribution: clavicle area, shoulders, arms, chest, back, hips, legs, and shoe covers. The stickers were qualitatively assessed for color change to indicate a sufficient dose of germicidal UV light. The photochromatic stickers were used to assess reflectors designed to shorten the exposure time by collecting and redirecting light being emitted from the opposite side of the disinfection system.

RESULTS

Glass carriers, face shield, and gown material at 5.98 log per carrier demonstrated a >4.00 log reduction relative to respective time zero controls. Negative cell culture controls demonstrated no cytopathic effects (Table 1).

The spectral readings for UV light passing though the face shield and gowns were less than established UV exposure limits. The addition of the reflector allowed for increased redirection of light toward the person and effectively reduced the exposure time for PPE disinfection by half.

DISCUSSION

These results indicate that UV disinfection can be used to reduce the contamination levels of nonenveloped viruses in a controlled experimental environment on PPE material. This preliminary safety and effectiveness data could lead to further research investigating applications that include real-world PPE contamination of nonenveloped viruses, especially Ebola. To our knowledge, this is the first study where PX-UV disinfection has been shown to be effective on nonenveloped virus-contaminated PPE material. The distribution of UV light throughout the PPE, especially when used in conjunction with the UV reflector, provided useful information and should be a consideration in future research. Photochromic stickers, if placed prior to UV exposure, may be a method of validation of UV dose for use in real-world settings.

Prior to conducting experiments where study personnel would be in the same room with a functioning device, UV exposure measurements were taken through the PPE material to assure that personnel were not at risk. The study personnel who wore the PPE and stood in front of the device reported no adverse symptoms related to noise of the device or the light from the PX-UV bulb. Heat stress could be a factor during this process; however, the individual exposed to the process did not report excessive discomfort. Additional studies should consider multiple raters of brightness, sound, and heat factors during the process of PX-UV disinfection.

Whether PX-UV is similarly effective in reducing Ebola virus load on PPE, the extent to which bodily fluids obstruct the PX-UV efficacy, and whether this process leads to a decrease in transmission are future areas of investigation. Of course, these questions may be unanswerable because of the extreme rarity of Ebola transmission in the health care setting in the United States and the justifiably limited access to the Ebola virus for research purposes. Because the CDC and EPA have recommend hospitals using nonenveloped virus claims to be adequate markers of effectiveness against Ebola, we believe this preliminary data could be used by facilities interested in exploring additional decontamination methods.

It is well-documented that doffing is a risky process with the potential for causing infection. Hence, adding UV disinfection to the doffing process has the potential to provide an additional layer of safety for health care workers based on the data provided here. However, proper PPE selection, donning practices prior to patient care, and proper doffing processes are paramount to patient safety and cannot be compromised. Training on and adherence to established practices is the first priority for safety.

The addition of PX-UV disinfection does not replace any of the existing steps associated with doffing PPE, and special care should be taken with degloving because fluids on gloves may inhibit PX-UV disinfection. After PX-UV exposure, all PPE should still be treated as though it is contaminated and doffed and disposed of

according to the most current CDC protocol. No disinfection system will be able to completely eliminate the risk associated with doffing contaminated PPE.

Furthermore, only PX-UV disinfection has been validated in this study. We did not test low-pressure mercury-based germicidal light disinfection technology. More research into the uses of the PX-UV addition into any Ebola containment protocol could provide additional insight into these preliminary findings.

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