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Commentary

Nebraska Biocontainment Unit patient discharge and environmental decontamination after Ebola care

Katelyn C. Jelden BS^a, Shawn G. Gibbs PhD^{a,b}, Philip W. Smith MD^{b,c},
Michelle M. Schwedhelm MSN^{b,d}, Peter C. Iwen PhD^e, Elizabeth L. Beam MSN^{b,f},
A. Kim Hayes RN^g, Nedra Marion MPA^g, Christopher J. Kratochvil MD^h,
Kathleen C. Boulter BA^b, Angela L. Hewlett MD^{b,c}, John J. Lowe PhD^{a,b,*}

^a Department of Environmental, Agricultural and Occupational Health, University of Nebraska Medical Center, Omaha, NE

^b Nebraska Biocontainment Unit, Nebraska Medicine, Omaha, NE

^c Department of Internal Medicine, University of Nebraska Medical Center, Omaha, NE

^d Trauma and Preparedness Services, Nebraska Medicine, Omaha, NE

^e Department of Pathology and Microbiology, University of Nebraska Medical Center, Omaha, NE

^f College of Nursing, University of Nebraska Medical Center, Omaha, NE

^g Division of Infection Control and Epidemiology, Nebraska Medicine, Omaha, NE

^h Office of the Vice Chancellor for Research, University of Nebraska Medical Center, Omaha, NE

The Nebraska Biocontainment Unit (NBU), which operates through collaboration of Nebraska Medicine, the University of Nebraska Medical Center, and the Nebraska Department of Health and Human Services, recently treated patients with Ebola virus disease (EVD) evacuated from West Africa to the United States. EVD is transmitted by contact with infected blood or bodily fluids with an infectious dose of <10 viruses and high virus concentrations in blood 10⁸ virus particles/mL.¹ Although negative for virus by molecular testing (quantitative polymerase chain reaction [qPCR] assay), discharged NBU patients successfully treated for EVD are at risk of touching EVD contaminated surfaces within the patient room and may serve as a disease vector to areas outside of isolation on discharge from the unit. Additionally, EVD patient remains are infectious and require safe and respectful infection control measures. To manage risks posed by EVD, the NBU uses infection control protocols that guide all steps of patient release, removal of patient remains, waste disposal, and systematic environmental decontamination that involves waste removal, surface cleaning, and multiple steps of disinfection.^{2,3}

We detail approaches of the NBU's patient dismissal, human remains removal process, and environmental decontamination experience, hoping to prepare medical facilities around the country for critical areas of environmental infection control in the care of patients with potential or confirmed EVD.

DISCHARGE PROCESS FOR A PATIENT SUCCESSFULLY TREATED FOR EVD

Patients undergoing treatment for EVD are followed closely using both molecular and serologic tests to determine viral loads and antibody responses to the disease at specific time points throughout hospitalization. This testing involves the utilization of a qPCR assay and Ebola virus-specific serologic assay, which are both performed at the Viral Special Pathogens Branch within the Division of High-Consequence Pathogens and Pathology at the National Center for Emerging and Zoonotic Infectious Diseases. Discharge of patients treated for EVD requires 2 consecutive blood samples drawn 24 hours apart that are confirmed as undetectable for Ebola virus RNA by qPCR testing. Samples submitted for Centers for Disease Control and Prevention testing require a courier willing to handle risk group 4 pathogens and must be packaged and transported as category A infectious substances as defined by the Department of Transportation.^{4,5}

Patient release procedures function to protect health care workers (HCWs) and eliminate the potential for discharged patients to transfer environmental contamination outside of the isolation unit. HCWs remain in personal protective equipment (PPE) after all procedures throughout the discharge processes.^{6,7} Prior to patient discharge, all surfaces within the NBU are disinfected by HCWs, and the corridor is cleared and mopped with hospital-grade disinfectant from the patient room to the NBU exit door.² A HCW in PPE (gown, booties, triple gloves, head covering, face shield, and mask) provides the patient a clean disposable gown within the patient care room, and the patient is relocated to a clean adjacent hospital room to shower for 10 minutes with chlorhexidine gluconate (CHG). While showering, the path the patient walked to enter the shower is mopped with hospital-grade

* Address correspondence to John J. Lowe, PhD, Department of Environmental, Agricultural and Occupational Health, University of Nebraska Medical Center, 984320 Nebraska Medical Center, Omaha, NE 68198-4388.

E-mail address: jjlowe@unmc.edu (J.J. Lowe).

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disinfectant. After the CHG shower, the patient dons a clean disposable gown with shoe covers and is led out of the room to the PPE doffing area of the NBU where the patient is met by a HCW in standard contact PPE (scrubs, isolation gown, surgical mask, single layer gloves, and shoe coverings). The patient is escorted to the NBU's exit corridor consisting of a final doffing area for shoe coverings, hospital gowns and scrubs, a hygiene shower, pass-through lockers, and dressing areas where the patient takes a second 10-minute CHG shower, dresses in clean street clothing, and exits the NBU.

REMOVAL OF REMAINS FOR A PATIENT WITH EVD

Procedures for removal of patient remains were developed to enable family observation, protect HCWs, and eliminate the potential for patient remains to transfer environmental contamination outside of the isolation unit. Visitation of patient remains is facilitated through a video link to allow family to identify patient remains and begin their closure process. Counseling services are available to family throughout the entire process. All necessary documentation is completed prior to removal of patient remains to comply with hospital and state and local health department regulations. The NBU has a pre-existing memorandum of understanding with a crematory and funeral director for cremation services after receipt of permission from family and the local health department.

Volunteer NBU HCWs handle remains to facilitate systematic isolation, disinfection, and movement within the NBU. Tegaderm (3M, St. Paul, MN) dressings are placed over areas of remains that may be at risk for leaking. Remains are carefully wrapped in bed sheets and moved into a biosafety level 4 containment bag (BioSeal Systems, San Diego, CA) within the patient care room. The bag is double heat sealed with the outer seal cut down the middle; therefore, any potential contamination is contained.⁸ The bag and bed are then disinfected with bleach. The patient bed is moved to the door of the patient care room with the head of the bed facing the hallway, and the headboard is removed.

Two HCWs in PPE (gown, booties, triple gloves, head covering, face shield and mask) receive the remains in the hallway onto a clean gurney with an 18-mil-thick leak-proof laminated vinyl bag with riveted handles. A patient sliding board is used to transfer the biosafety level 4 containment bag from the patient bed to inside the vinyl bag on the gurney. It is then placed in the patient care room for decontamination after transfer. HCWs in the hallway close the zipper on the vinyl bag, seal it, and disinfect the external vinyl bag and gurney. The HCWs change their outer layer of gloves and transport the remains to the NBU's donning area to 2 HCWs in contact PPE (scrubs, isolation gown, surgical mask, single layer gloves, and shoe coverings). The remains are transferred to a second clean gurney into a second 18-mil-thick leak-proof laminated vinyl bag with riveted handles and are positioned in the donning area. A clean patient sliding board is used to transfer double-packaged remains into the second vinyl bag on the second gurney. The vacant gurney and patient slide board are disinfected by the HCWs in the NBU's hallway. The HCWs in the donning area close the zipper on the second 18-mL vinyl bag, seal it, and disinfect the external vinyl bag and gurney. At this point, the remains are contained in the 3 isolation layers: (1) heat-sealed biosafety level 4 containment bag, (2) 18-mL-thick leak-proof laminated vinyl bag, and (3) a second 18-mL-thick leak-proof laminated vinyl bag.

Remains are moved from the donning area of the NBU into a secure hallway outside of the NBU. Once outside the NBU, no PPE is necessary because no contact with the bags containing the remains is necessary, and the gurney handles have been thoroughly disinfected with hospital-grade disinfectant. A modesty cover used by the funeral home for in-facility transport is placed, and remains are

moved to a funeral home vehicle with a security escort. A funeral director and a member of the NBU accompany patient remains until completion of cremation. A single car police escort with no lights and sirens facilitates the short transport to the funeral home. Local police and the state and local health departments are notified prior to the transport.

At the funeral home, the patient remains are transported on the gurney from the vehicle to the crematory. The NBU staff and funeral director, both wearing gloves, transfer the isolated patient remains into a cremation box. The box is closed and immediately placed into the crematory. NBU staff accompany until cremation is complete; cremated remains and certificates are returned to the family.

ENVIRONMENTAL DECONTAMINATION OF ISOLATION UNIT

After patient dismissal, PPE protocols used for cleaning the NBU are consistent with patient care PPE protocols.⁶ The patient room is cleared of linen and solid waste, and personnel in full PPE (gown, booties, triple gloves, head covering, face shield, and mask) continue processing waste and linen out of the NBU with a pass-through autoclave.³ Once all infectious waste is sterilized, the remaining HCWs left in the unit follow standard doffing procedures to exit. The NBU is sealed and left undisturbed for 48 hours to allow high air flows of 15-19 high-efficiency particulate absorption-filtered air exchanges per hour within the NBU to promote desiccation of the remaining virus.⁹

After 48 hours, NBU staff decontaminate the unit through manual disinfection and ultraviolet germicidal irradiation (UVGI). Unit HCWs and nonclinical supervisors perform decontamination instead of environmental service workers to avoid exposure of additional individuals, to ensure competency with PPE, and to maximize understanding of the risks and hazards. Infection control personnel observe and provide quality assurance throughout the terminal cleaning. Decontamination procedures were developed by the NBU's leadership team and were then evaluated and approved by hospital infection control personnel to provide a check and balance system to maximize safety. Infection control personnel intentionally do not participate in the decontamination but observe that all items on the cleaning checklist are decontaminated properly.

Floors are mopped twice with hospital-grade disinfectant, starting from the NBU's entrance and ending with areas likely to be most contaminated in the patient room. Disposable items from the patient room are autoclaved and discarded into the existing NBU's waste stream. Medical equipment is manually disinfected according to manufacturer recommendations by HCWs cleaning in tandem to wipe all surfaces while being observed by infection control personnel.

Four UVGI generators (Torch, ClorDiSys Solutions, Lebanon, NJ) are used as a final disinfection step after all surfaces have been bleach wiped. Each unit emits 254 nm ultraviolet C spectrum light from low-pressure, mercury-arc lamps. All 4 units are used in tandem to ensure an exposure level >17 mJ/cm², which has been previously found to inactivate Ebola virus.¹⁰ All surfaces in the unit, including the equipment in the unit, are exposed to a minimum of 100 mJ/cm². This is accomplished by using multiple UVGI units simultaneously surrounding equipment or within rooms and by strategically placing the UVGI monitor in areas to ensure readings are lower than actual exposure of many surfaces. Large medical equipment is exposed by arranging 4 UVGI units around each individual machine, with a UVGI monitor under the equipment. Areas with a higher likelihood of contamination, such as the patient room and bathroom, are treated for longer exposures, with the patient room receiving an exposure >800 mJ/cm² and the bathroom

receiving an exposure $>1,000$ mJ/cm². After UVGI treatment, the NBU is again sealed for 48 hours to allow for additional desiccation.

After the second 48-hour period, the NBU is deemed safe for entry without PPE. Risk communication is performed by the NBU's leadership for groups that enter the now decontaminated unit to ensure a thorough understanding of the cleaning process and removal of infection risk. Biomedical services retrieve the decontaminated medical equipment. Environmental services personnel enter the area to perform an aesthetic cleaning to remove chemical residues throughout the unit. Environmental services staff don standard hospital cleaning PPE during this process.

DISCUSSION

Hospital dismissal of a patient who recovered from EVD, removal of the remains of a patient who has died from EVD, and decontamination of the isolation unit introduce contaminant exposure risks that must be identified and addressed through infection control procedures. We critically emphasize appropriate PPE use, including donning and doffing procedures, throughout dismissal and decontamination with the same rigorous enforcement used throughout patient care. First, the recovered patient may still serve as a disease vector by transferring external contamination and should be thoroughly cleaned before dismissal from the isolation unit. Second, patient remains are a known transmission route; therefore, they must be treated safely while maintaining respect and dignity for the patient. Finally, the entire isolation unit must be meticulously decontaminated using procedures for appropriate treatment and removal of all waste, disinfection of nondisposable medical equipment, desiccation of virus potentially present in the environment, manual disinfection, and a terminal disinfection treatment of the entire isolation unit. We acknowledge the known limitations that UVGI only disinfects areas where the light can penetrate, which is why we used multiple generators to reduce shadows.

Decontamination procedures were thoroughly considered for their Ebola virus disinfection efficacy. It is no coincidence that our decontamination process takes almost a week from the time the patient exits the NBU until people can enter the NBU again without PPE because under ideal conditions this virus has been found to survive for up to 6 days on dry surfaces.⁹ Physical cleaning of all surfaces is essential prior to UVGI, gas, or vapor disinfection because the presence of organic bioburden (eg, dried blood) has been shown to reduce the effectiveness of these methods.¹⁰ In experimentation, 3%-4% of Ebola virus survived ultraviolet treatment in the presence of other organic materials.¹⁰

Sagripanti et al,⁹ in a study to evaluate Ebola virus contamination in an isolation ward, found virus in fluids and only on environmental surfaces visibly bloodstained. They concluded that the likelihood of exposure from nonvisibly contaminated surfaces was low. We agree with these findings and fully acknowledge that our

cleaning procedures likely go well beyond what is required to return the patient care area back to a safe environment. However, given public concern and interest, the morbidity and mortality of EVD, and the misinformation regarding the spread of the Ebola virus, our additional cleaning measures represent a cost-effective way to ensure safety and address public perception.

We offer our procedures and recommendations for decontaminating patients who have recovered from EVD, for removal of the remains of a patient who has died from EVD, and for decontamination of isolation units that have been used to house a patient with EVD. These methods may also be useful in preparing other medical facilities in environmental infection control practices in the event another highly infectious pathogen is encountered.

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