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Protecting Healthcare Personnel from Acquiring Ebola Virus Disease

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The ongoing outbreak of Ebola virus disease (EVD) in West Africa, the largest in history, has devastated the affected countries and raised public health concerns throughout the world. The Centers for Disease Control and Prevention (CDC) in conjunction with the World Health Organization (WHO) has reported that as of July 8, 2015, there have been 16,913 total cases (suspected, probable and confirmed) in West Africa (of which 11,965 were laboratory confirmed) and 6,446 deaths.¹ The CDC has estimated that there is potential underreporting by a factor of 2.5.² For the first time ever, an Ebola outbreak has crossed international boundaries, initially moving among neighboring countries from Guinea to Liberia and Sierra Leone, and then spreading to non-contiguous countries including Nigeria, Senegal, Mali, Spain, the United Kingdom, and the United States.¹ According to the WHO, as of July 5, 2015, a total of 875 confirmed healthcare personnel (HCP) infections had been reported from Guinea, Liberia, and Sierra Leone, with 509 deaths.³ As of March 12, 2015, 11 EVD-infected HCP had been transferred from West Africa to US hospitals.⁴ Secondary transmission from a patient with EVD to healthcare providers has also been reported in the United States and Spain.

EBOLA TRANSMISSION

Epidemiological studies have suggested that the Ebola virus spreads primarily through direct contact with a symptomatic person or their body fluids, especially in the latter stages of clinical disease.^{5,6} The elevated risk of transmission in the latter stages of EVD is likely due to a combination of increased viral titers in body fluids and increased body fluid discharges (ie, vomitus, stool, and blood). Post-mortem contact is also associated with a high risk of Ebola virus transmission.⁵ Concern has been raised regarding the possibility of aerosol transmission “either via large droplets or small particles in the vicinity of source patients.”⁷ Although animal studies suggest that droplet/airborne transmission may occur when the

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virus is experimentally aerosolized, epidemiologic studies of household contacts suggest that this rarely, if ever, occurs.^{5,6,8} However, there is concern that droplet or airborne transmission could occur in healthcare settings during aerosol-generating procedures such as intubation and induced sputum collection.

The fact that Ebola has been demonstrated to survive and remain infectious in liquid media at room temperature for at least 46 days raises concern about fomite transmission.⁹ Ebola inoculated onto glass carriers and maintained in the dark survived for hours to days (ie, 1- $\log_{10}$ decrease in 35.3 hours and 4- $\log_{10}$ decrease in 5.9 days).¹⁰ Some epidemiologic studies have suggested the possibility of transmission from contaminated environmental sources.⁶ Further, in the current outbreak, multiple environmental samples from an Ebola treatment unit were positive via polymerase chain reaction (PCR) testing.⁷ However, in a different study in which sampling was done following routine cleaning, all 31 environmental samples were negative by reverse-transcriptase PCR (RT-PCR), suggesting that routine environmental cleaning and disinfection can decrease the potential for fomite transmission.¹¹

PREVENTING EBOLA ACQUISITION BY HCP

As noted above, a substantial number of HCP in West Africa have acquired EVD. Nosocomial transmission of Ebola and infection of HCP has been repeatedly documented in past outbreaks.^{12–14} The cluster of Ebola cases in Dallas is illustrative of the 2 major risks for Ebola acquisition faced by US HCP.^{15,16} First, early recognition, triage, and isolation of all potential EVD cases are essential so adequate infection control measures can be applied and potential transmission of Ebola virus to HCP can be minimized. Second, the acquisition of EVD by 2 HCP who had substantial interaction with an Ebola patient while wearing protective equipment raised concern regarding the adequacy of protection afforded by personal protective equipment (PPE) or the training provided in its use.

The basis for preventing the spread of infectious agents in healthcare facilities is the implementation of transmission-based precautions, which includes different room placement (ie, private room or airborne isolation room) and HCP use of PPE (gloves, gowns, mask, N95 respirator, and/or face shield) based on the mechanism of transmission of the infectious agent (ie, contact, droplet, airborne).¹⁷ Given the acquisition of Ebola by HCP in Dallas and the large number of HCP in West Africa, 2 key questions have arisen. First, what is the evidence that PPE protects HCP from acquiring a contact transmitted disease? Second, what steps can we take to minimize the risk to HCP of acquiring EVD while caring for an infected patient?

The gloves and gowns of HCP frequently become contaminated with pathogens while providing care to patients on contact precautions. Recently, Williams et al¹⁸ reported that HCP frequently contaminated their clothing despite wearing gloves and gowns for patient care. Casanova et al^{19,20} assessed the ability of standard PPE (ie, gloves, gowns, respirator, and goggles) to protect against contamination of skin and clothes by dotting the outside of the PPE with bacteriophage MS2, a nonenveloped, nonpathogenic RNA virus. PPE was removed using the CDC-recommended doffing procedure. Initial experiments revealed that

underlying clothing (scrub shirt, pants) and skin (dominant and nondominant hand) were contaminated >70% of the time.¹⁹ Further, the mean viral titer recovered was 1.8–2.4-log₁₀ (inoculating dose = 10₄ on several PPE sites). Despite double gloving, skin contamination (6%–23%) and clothing contamination (56%–94%) remained common.²⁰ The failure of standard PPE to protect HCP against skin and clothing contamination and the lack of validation of the level of protection afforded by PPE recommended for Ebola care have raised concerns.²¹

At the present time, it is recommended that HCP providing care to a patient with EVD use enhanced PPE.²² Although there is no consensus on each of the specific components of PPE among the major organizations providing care to EVD patients, all agree that it should uniformly protect the major portals of entry including mucous membranes and nonintact skin. CDC guidelines, which are directed toward the use of PPE in US hospitals, recommend double gloves, a single-use fluid-resistant gown or coverall, an impervious apron, and either a powered air-purifying respirator (PAPR) or an N95 respirator. If the latter is used, then it must be accompanied by a single-use surgical hood extending to the shoulders and a full face shield. Critical to maximizing PPE protection are detailed donning and doffing procedures, comprehensive training on proper donning and doffing, and use of a monitor to ensure proper donning and doffing.²²

As demonstrated by Casanova et al, the major risk to the HCP is that during the doffing procedure contamination of underlying clothes or skin may occur. This raises the question of whether additional methods may be used to further protect the HCP such as decontamination of the PPE prior to removal by either ultraviolet light (UV) or use of a germicide (eg, hypochlorite). In this issue, Tomas et al²³ report that a portable booth using UV-C radiation can be used to disinfect full-body PPE. They demonstrated that the delivered UV-C radiation resulted in 3-log₁₀ reduction in MS2 virus and methicillin-resistant *Staphylococcus aureus* (MRSA) within 3 minutes. Additionally, UV-C radiation has been demonstrated to inactivate the Ebola virus.²⁴ Although the UV-C booth may reduce the risk of skin/clothing contamination during the doffing procedure, it may be impractical for use in lesser-developed countries. Another strategy to mitigate the risk of skin/clothing contamination during doffing would be to decontaminate the outside of the PPE using a germicide applied by spray or wipe such as hypochlorite (diluted bleach).²⁵ However, although this procedure has often been used in the field, there is considerable debate about the use of sprays because of concern for aerosolizing laden body fluids that may contaminate the PPE.

To protect our HCP against acquisition of highly virulent pathogens such Ebola, we must assess all the potential risks for transmission (eg, inadequate detection of possible cases, inappropriate use of PPE) and implement strategies to minimize this risk (Table 1). The public health community needs to reduce the risks to our HCP by validating the currently recommended PPE, improving PPE as necessary, improve training of our HCP, and expand the number of facilities with healthcare units specifically designed to care for highly communicable diseases. We need to continue to develop innovative approaches such as that assessed by Dr. Tomas.

Finally, HCP at all US hospitals need to remember that more than 1 million travelers arrive in the United States each week.²⁶ As demonstrated by the recent case of Lassa fever in New Jersey,²⁷ the outbreak of MERS-CoV in Korea,²⁸ and the Ebola cases resulting from travelers from West Africa,²⁹ we are all only a plane ride away from potentially highly communicable and virulent infectious diseases.

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TABLE 1

Protecting Healthcare Personnel from Acquisition of Ebola: Defining the Problems and Possible Solutions

Issue	Possible Solutions
1. Unrecognized EVD in a patient presenting to a clinic or emergency department	<ul style="list-style-type: none"> • Screening arriving travelers from Ebola epidemic country by the TSA • Active screening of returned travelers by health departments • Signage at all medical facility entrances • Screening at initial triage or clinic sign-in of all patients • Scripting by phone for all patient notifications and appointments • Management plan for how to handle a traveler with epidemiologic risk for Ebola and symptoms
2. Nonvalidated protection from PPE and current doffing method	<ul style="list-style-type: none"> • Use of PPE that should prevent any patient body fluid contact with mucous membranes or nonintact skin of HCP • Assess PPE protection and doffing procedure using MS2 • Assess enhanced protection by spraying front of PPE with 1:10 diluted hypochlorite prior to doffing • Assess enhanced protection using a UV-C booth for PPE decontamination
3. PPE shortages	<ul style="list-style-type: none"> • Develop national or regional repositories
4. Proper training in PPE donning and doffing	<ul style="list-style-type: none"> • Use of PPE monitors during donning and doffing • Three-tiered approach <ol style="list-style-type: none"> 1. Basic PPE donning and doffing (plus cleaning/disinfection of environmental spills and management of PPE breach) 2. Simulation laboratory training, specialty specific (eg, nursing, physicians) 3. Team training in Ebola care unit
5. Maintain PPE proficiency	<ul style="list-style-type: none"> • Periodic retraining
6. General safety of Ebola care team	<ul style="list-style-type: none"> • Assess health status of prospective Ebola care team members • Exclude from Ebola care team HCP who cannot safely wear PPE, including an N95 respirator • Exclude from the Ebola care team HCP who are trainees, immunocompromised, pregnant, or have nonintact skin • Obtain the temperature of Ebola care team members after they doff PPE following providing care—if hyperthermic, provide treatment • Provide shower facilities for Ebola care team members to use immediately after providing care to a patient with EVD • Develop methods for safe disposal of patient's liquid and solid wastes (eg, lid on toilet)
7. Prevent HCP fatigue	<ul style="list-style-type: none"> • Short shifts • Buddy system • Enforced rest periods • Provide adequate numbers of Ebola care team to prevent fatigue
8. Define high- and low-risk zones in an Ebola care unit	<ul style="list-style-type: none"> • Develop proper unidirectional flow throughout the unit • Develop areas for donning and doffing

Issue	Possible Solutions
	<ul style="list-style-type: none"> Develop an area for point of care lab testing
9. Environmental survival of Ebola virus	<ul style="list-style-type: none"> Assess environmental survival on variety of hospital surfaces Routinely disinfect the environment surrounding a patient with EVD Provide terminal disinfection of a room housing an EVD patient with vaporized hydrogen peroxide Disinfect or safely discard all possibly contaminated medical devices or equipment
10. Disinfectant susceptibility	<ul style="list-style-type: none"> Assess susceptibility to standard hospital disinfectants Until such testing is published, use a disinfectant with a disinfectant claim against nonenveloped viruses or spores
11. Management of PPE breaches	<ul style="list-style-type: none"> Develop and training HCP in management of breaches including contamination of intact skin, non-intact skin, mucous membranes, and percutaneous injury In the case of high-risk exposure, provide experimental vaccine, and/or convalescent serum

NOTE. TSA, Transportation Security Administration; ED, emergency department; EVD, Ebola viral disease; HCP, healthcare personnel; PPE, personal protective equipment.