Clinical Therapeutics/Volume ▮, Number ▮, 2015

Personal Protective Equipment: Protecting Health Care Providers in an Ebola Outbreak

William A. Fischer II, MD[1]; David J. Weber, MD[2]; and David A. Wohl, MD[2]

[1]Division of Pulmonary and Critical Care Medicine, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina; and [2]Division of Infectious Diseases, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina

ABSTRACT

Purpose: The recent Ebola epidemic that devastated West Africa has infected and killed more health care providers than any other outbreak in the history of this virus. An improved understanding of pathogen transmission and the institution of strategies to protect health care providers against infection are needed in infectious disease outbreaks. This review connects what is known about Ebola virus transmission with personal protective equipment (PPE) designed to arrest nosocomial transmission.

Methods: Articles pertaining to filovirus transmission and PPE in filovirus outbreaks were reviewed and findings are presented. In addition, studies that evaluated PPE and donning and doffing strategies are presented.

Findings: PPE is one step in a comprehensive infection prevention and control strategy that is required to protect health care providers. Given that the Ebola virus is primarily transmitted through direct contact of mucous membranes and cuts in the skin with infected patients and/or their bodily fluids, it is necessary to cover these potential portals of infection with PPE as part of a structured and instructed donning and doffing procedure.

Implications: Current recommendations about PPE and the donning and doffing processes are based on anecdotal experience. However, the use of non-human viruses can help provide evidence-based guidelines on both PPE and donning and doffing processes. (*Clin Ther*. 2015;▮:▮▮▮–▮▮▮) © 2015 Elsevier HS Journals, Inc. All rights reserved.

Key words: Ebola, infection prevention and control, outbreak, personal protective equipment, transmission.

INTRODUCTION

The recent Ebola epidemic that devastated West Africa evolved within months from a regional humanitarian crisis to a global public health emergency. As of May 27, 2015, 27,049 cases and 11,149 deaths from Ebola were reported by the World Health Organization (WHO), an underestimate that already eclipses the numbers of infections and deaths in all previous outbreaks combined.[1] With fewer than 0.1 physicians per 10,000 people in Liberia, Sierra Leone, and Guinea, the infection of 869 health care providers and the death of 507 in this epidemic alone has depleted an already precious resource.[2] Although the rate of confirmed cases has declined dramatically in West Africa, the loss of health care providers will continue to affect the people of this area for decades to come.

Despite major advances in the prevention and treatment of infectious diseases in general, there are currently no licensed vaccines, proven effective antiviral therapies, or proven postexposure prophylaxis strategies for Ebola virus disease (EVD). Personal protective equipment (PPE) plays a critical role in mitigating the risk of health care personnel (HCP) exposure to contaminated body fluids in the care of patients with communicable infectious diseases, including EVD. The importance of PPE was recognized during the outbreak of severe acute respiratory syndrome (SARS), in which HCP accounted for ~20% of persons who were infected with SARS.[3] Evidence of continued SARS transmission despite the use of droplet, contact, and airborne precautions drew attention to the possibility of nosocomial transmission during PPE removal or doffing.[4,5] In addition, recent studies suggest that viruses, including Ebola, have the

Accepted for publication July 10, 2015.
http://dx.doi.org/10.1016/j.clinthera.2015.07.007
0149-2918/$ - see front matter

potential to remain infectious on PPE for longer than it is typically worn, creating an opportunity for transmission during doffing. Historically, development of PPE strategies has been driven by the paradigm that infectious agents are transmitted by 1 of 3 routes: contact, droplet, or airborne. However, the consideration of self-inoculation in the removal of PPE is emerging as a major potential route of HCP infection.[6] To this end, we reviewed the major routes of Ebola virus transmission and the use of PPE to prevent HCP exposure and infection.

TRANSMISSION

Once the Ebola virus enters the human population, outbreaks are sustained through human-to-human transmission, which is facilitated by the presence of the virus in every body fluid, including blood, diarrhea, vomit, sweat, breast milk, vaginal secretions, and semen.[7,8] Ebola virus increases logarithmically in the blood during acute infection, and often the highest levels of viremia are achieved at the time of death.[9] In addition, patients in the later stages of disease have more severe symptoms, including diarrhea, vomiting, and bleeding complications, thus increasing the potential of spread via infectious body fluids. This coupled with limited health care infrastructure in the areas where most Ebola outbreaks occur contribute to the outbreak amplification that is often seen in health care settings.[10–12]

Epidemiologic studies suggest that the virus is spread primarily through direct contact with the patient and virus-laden body fluids, especially late in the clinical course of disease.[11,13,14] Of 173 household contacts of 27 infected patients, 28 (16%) developed EVD.[13] All 28 cases reported direct physical contact with the index patient (risk ratio = 3.6; 95% CI, 1.9–6.8).[13] Importantly, none of the 78 household members who reported no direct contact with the index patient developed EVD. In a separate study those family members who provided direct nursing care to the index patient had a 5.1-fold increased risk of infection, highlighting the importance of direct contact.[11] The risk of secondary transmission, in a separate study, increased with exposures that continued through the later states of illness (crude prevalence proportion ratio [PPR] = 6 [95% CI, 1.33–27.1] in the early stage of illness; crude PPR = 8.57 [95% CI, 1.95–37.66] when care was provided until the patients' death at the hospital; and crude PPR = 13.33 [95% CI, 3.2–55.59] when care was delivered until death at home).[14] Infection from direct contact likely results from the interaction between virus and mucosal membranes as animal models have demonstrated infection can occur through oral, nasal, and conjunctival routes.[15]

Given the high levels of virus in body fluids and on the skin of patients at the time of death, postmortem contact is also associated with an increased risk of infection (adjusted risk ratio = 2.1; 95% CI, 1.1–4.2).[13,16] The increased potential for transmission during contact with a dead body, as occurs during traditional burial practices, can be partly attributed to the durability of virus in body fluids even after death. In a nonhuman primate study of viral persistence after death, replication competent virus was detectable in oral, nasal, and blood samples from dead animals. Blood contained the highest concentrations of viable virus (2×10^5 median culture infectious dose/mL) and remained positive for the longest duration, 7 days postmortem.[17] Viral RNA was detectible from oral nasal and blood swabs for up to 3 weeks postmortem.[17] Together, these data highlight close contact with a dead body, as is custom during preparing a body for funeral, is a potential route of transmission.

Of 316 people infected in the Kikwit outbreak (in 1995) only 5 reported no physical contact with a confirmed patient, suggesting that alternative routes of transmission, including droplet or fomite-mediated transmission, may be possible but are unlikely events.[18] Theoretically, fomite transmission is possible, but the conditions, including the environmental surface and ambient temperature, affect the viability of the virus. In 1 study, filoviruses, including Ebola, were found to remain infectious in liquid media at room temperature for at least 46 days, but infectious virus could not be isolated when allowed to dry on a plastic or glass substrate at room temperature.[19] Reports from the current outbreak indicate that multiple environmental samples obtained from an Ebola treatment unit were positive for polymerase chain reaction.[10] However, when sampling occurred after routine cleaning in a separate study, all 31 environmental samples were negative, suggesting that routine sanitation, as part of environmental control, can decrease the potential of fomite transmission.[20]

Recently, the potential for airborne transmission has received considerable attention.[10,21] Although