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Case Report

Ebola virus disease: The use of fluorescents as markers of contamination for personal protective equipment

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ABSTRACT

The recent Ebola virus disease (EVD) outbreak has created interest in personal protective equipment (PPE) content and usage. PPE testing has historically been done by individual component, rather than as a bundle for contact isolation. Fluorescent agents are commonly used in training for infection control techniques. The purpose of our study was to compare 2 PPE bundles and to evaluate the feasibility of fluorescent markers as an assessment tool for PPE effectiveness. Eight healthcare providers volunteered for this preliminary study. Participants were randomized to 1 of 2 PPE bundles that meet current (October 20, 2014) CDC recommendations. One PPE bundle utilized commercial EVD-recommended components. The other PPE bundle used components already available at local hospitals or retail stores. Participants were also randomized to standard or high volume exposures (HVE) to simulate fluid splash. Each participant was assisted in PPE donning and doffing by an experienced trainer. A training mannequin was contaminated with fluorescent agents to simulate bodily fluids. Participants were then given clinical tasks to care for the EVD "patient." De-gowned participants were examined under "black light" for fluorescence indicative of contamination. One participant in each PPE arm had evidence of contamination. One of the contamination events was suspected during the patient care exercise. The other contamination event was not suspected until black light examination. In spite of a large difference in cost of PPE, the two bundle arms performed similarly. Bundle testing using fluorescent markers could help identify optimal PPE systems.

Background

An unprecedented outbreak of Ebola virus disease (EVD) is occurring in West Africa. In addition to the morbidity and mortality effects on the population at large, there is a significant impact on healthcare providers in the region. Although many healthcare worker exposures may occur prior to EVD being suspected and appropriate isolation implemented, exposures can occur in spite of isolation procedures and PPE use. Although there is anecdotal evidence regarding the efficacy of PPE, a review of literature reveals few controlled studies of PPE ensembles relevant to EVD. Variations in current PPE recommendations from leading organizations highlight the lack of available data. Field studies of PPE in the setting of EVD are difficult because of ethical and safety concerns. It is thought a high level of training is required to safely don, use, and doff PPE. Introducing a new PPE ensemble into the field could increase exposure risk of participants who are already well-trained on a current PPE ensemble. There may be some hesitancy among participants to try an "unproven" PPE set. Finally, in a high disease prevalence area, with a relatively small number of "events," a very large study population would be required to account for the possibility of EVD acquisition from non-work exposures or activities (i.e. non-medical contacts within the community). The possibility that exposures can occur in spite of PPE utilization is evident from recent disease acquisition by two healthcare workers in the United States.

PPE testing is primarily performed according to industry regulatory standards. These regulatory standards are material standards so that testing of individual components (gloves, gown, etc.) result in a rating for the tested component. Some PPE ensemble testing has been performed, so called "Man-In-Suit-Testing (MIST)") but this has primarily focused on radiation,

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thermal or chemical exposures where exposure risk is dose-dependent, or in aerosol scenarios [1]. Zamora et al. compared two personal protective systems (ensembles) for biological exposures in 2006 and found significant differences in contamination rates [2]. In 2010 the Institute of Medicine released a report regarding certification of personal protective technologies, noting that additional testing of PPE ensembles should be performed [3]. Given the large number and variations of individual PPE components, it would not be feasible to test all potential combinations of PPE commercially available. Additionally, the recent surge in PPE purchasing in response to EVD has caused significant shortages of some PPE components and manufacturers with a history of field use. Some healthcare facilities have had to develop PPE protocols based on the best use of locally available components (Author, personal communication). Ideally, a PPE ensemble would be evaluated at the local level by the staff anticipated to wear the equipment. Doffing or removal of PPE after a patient encounter may be a particularly high risk activity [2]. Appropriate testing of PPE ensembles should include MIST type testing to confirm product efficacy in real world scenarios.

Phosphors, when exposed to ultraviolet light, fluoresce. "Black lights" are typically used to highlight the fluorescent material. Fluorescent agents have been used in training for hand-washing [4,5] and environmental decontamination [6], as well as PPE ensembles [2,7]. Non-toxic and mixed with an appropriate carrier, these agents can potentially mimic the natural contamination which occurs with an infectious agent spread by contact route. The purpose of our study was to compare two PPE ensembles used by volunteers with minimal prior training, and to evaluate the feasibility of fluorescent markers as an assessment tool for PPE effectiveness.

Methodology

Eight healthcare providers (six registered nurses and two physicians) volunteered for this preliminary study. All participants were given information about the purpose and intent of the study. The study protocol was approved by the Texas Tech University Health Science Center Institutional Review Board. Given the small number of participants, statistical analysis was not performed. The participants were randomized to one of two PPE ensembles that meet current (as of 10/20/14) CDC recommendations for PPE. One PPE ensemble (standard) utilized commercial components that meet current CDC recommendations. The other PPE ensemble (alternate) was composed of components already available at local hospitals or retail stores. The commercial PPE ensemble (Fig. 1) included a neck-to-ankle coverall with overlying water impermeable surgical gown, knee-length impermeable leggings, and Stryker® hood (Stryker, Kalamazoo, MI, USA). The alternate PPE (Fig. 2) ensemble included two plastic gowns (worn over the front and back of the torso), rain-suit pants, a rain-suit hood cut from a rain jacket, ankle length shoe covers, and a plastic "spark-shield" commonly used for metal working to cover the face. Both PPE ensembles utilized double gloving, with the outermost glove a forearm length surgical glove and N-95 masks. When complete, both PPE ensembles met the CDC recommendations for PPE and no skin was exposed in either group.

Fig. 1. Trainer assisting with doffing of standard PPE set.

Fig. 2. Trainer assisting with donning of alternate PPE set.

Subjects were then randomized to standard or high volume exposures (HVE) to simulate fluid splash. Subjects randomized to standard exposure came into contact with a training mannequin contaminated with fluorescent agents to simulate bodily fluids. Subjects randomized to HVE had standard exposure, but then also had an additional 100 ml of fluorescent agent splashed onto the front torso of their garment. The fluorescent agents used included fluorescent powder (GloGerm® GloGerm Co, Moab, UT, USA), liquid clothes detergent with bleach alternative (Tide® Proctor & Gamble Inc., Providence, RI, USA), and dissolvable fluorescent tablets (Bright Dyes Orange Dye® Kingscote Chemicals, Miamisburg, OH, USA). A base mixture of 500 ml of liquid detergent, 500 ml of water and three fluorescent tablets was used to create body fluids. The base mixture was combined with oatmeal, chocolate powder and crushed cereal to simulate different bodily fluids.

The testing area was divided into four areas, a PPE donning area (staging area), patient encounter room, PPE doffing area, and a separate dark room for black light photography. Each participant was assisted in PPE donning by an experienced trainer. After donning PPE, participants worked in pairs to perform a series of clinical tasks to care for the EVD "patient." Participants were asked to clean the contaminated mannequin, change the mannequin gown, place an automated BP cuff, and check and record the temperature. After completing the tasks, participants were assisted by the trainers in PPE removal. Finally, the de-gowned participants were examined under "black light" for fluorescence indicative of possible contamination. An LED black light panel, (Chauvet LED Shadow, model DMX-512 Led UV, Chauvet® Lighting, Sunrise, Florida) was used to illuminate. Photographs were taken with a Nikon® D90 Camera (Nikon Inc., Melville, New York).

Results

Most participants were nurses (6/8) and most were women (7/8). One participant in each PPE ensemble arm had evidence of