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Seamless Suits: Reducing Personnel Contamination Through Improved Personal Protective Equipment Design

To the Editor—Healthcare personnel frequently use incorrect technique when putting on and removing isolation gowns and gloves.[1–3] Such lapses in technique increase the risk for contamination of the skin and clothing of personnel during personal protective equipment (PPE) removal.[1,3] Contamination of the hands and wrists may be particularly common due to exposed skin at the wrist or incorrect technique during glove removal.[1,3,4] In surgical settings, the gown–glove interface has also been described as the weakest point in the gown and glove barrier system.[5,6] In studies simulating removal of contaminated gloves, education to improve technique reduced but did not eliminate hand and wrist contamination.[1,4] Thus, improvements in PPE design to reduce the risk for contamination are needed.

We hypothesized that gowns and gloves designed to provide continuous coverage of the wrist and hand would reduce contamination during PPE removal. To test this hypothesis, we developed a seamless PPE prototype in which adhesive material on the outer sleeve of the gown at the wrist attaches to the inner cuff of the gloves, providing continuous coverage of the wrist and hand. This design prevents exposure of skin and requires that gloves be peeled off as the gown is removed. Here, we report the results of a pilot study to determine whether the seamless PPE design reduces hand and wrist self-contamination in comparison to standard gowns and gloves.

The Cleveland VA Medical Center's Institutional Review Board approved the study protocol. The prototype seamless PPE consisted of polyethylene contact isolation gowns (Safety Plus Polyethylene Gown, TIDI Products, Neenah, WI) and nitrile gloves (Denville Scientific, South Plainfield, NJ). Permanent contact bond adhesive (DAP Weldwood Contact Cement, DAP Products, Baltimore, MD) was applied circumferentially to the outer gown at the level of the wrist. Gloves were pressed to the gowns for 15 minutes and allowed to air dry for 24 hours.

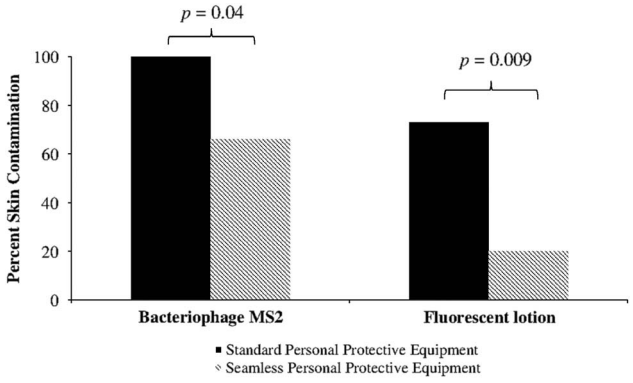

FIGURE 1. Hand and wrist skin contamination during removal of gloves contaminated with bacteriophage MS2 and fluorescent lotion.

Healthcare personnel were randomized to perform simulations of contaminated glove removal using either standard or prototype seamless PPE. To simulate contamination, bacteriophage MS2 15597-B1 (American Type Culture Collection, VA) a nonpathogenic, nonenveloped RNA virus and fluorescent lotion were used as previously described.[1] Gloved hands were inoculated with 0.5 mL phosphate-buffered saline (PBS) containing 10^{10} plaque-forming units of MS2 and 0.5 mL fluorescent lotion and the solutions were rubbed over the gloved hands until dry. Participants removed their gloves and gowns in their usual manner and hand and wrist skin contamination with the fluorescent lotion was assessed using a black light (Ultra Light UV1 by Grizzly Gear, SCS Direct, Trumball, CT). Participants then wiped both hands and wrists with a sterile, pre-moistened 4 × 4 gauze pad that was placed into a sterile container containing 10 mL PBS and mixed in a vortex mixer for 1 minute to elute the bacteriophage. Aliquots of each elutant were serially diluted and cultured to quantify virus particles.[1] The frequency of contamination between standard and seamless PPE was compared using the Fischer's exact test. Data were analyzed using R version 3.1.1.

A total of 30 simulations were performed. Contamination of skin with bacteriophage and fluorescent lotion was significantly lower with use of seamless PPE versus standard PPE (Figure 1). The mean plaque-forming units of MS2 cultured from hands was significantly lower with use of seamless PPE versus standard PPE (2.4 logs vs 4.3 logs, $P = .0002$). Tearing of the glove or gown was not observed in either PPE design.

Our results demonstrate that a prototype PPE design that ensures wrist coverage and requires the wearer to remove gloves and gown simultaneously can reduce self-contamination of the hands and wrists. Other PPE designs have also been proposed to reduce contamination at the gown–glove interface. For example, Meyer and Beck[5] adapted the gown sleeve to the circumference of the wearer's forearm by creating darts or flaps that are folded over each other and sealed; after donning, the glove cuff is sealed to the gown underneath. Another method to prevent wrist skin exposure and facilitate doffing employs fingerless cloth gloves attached to the gown sleeve under the gloves.[7] When the user removes their gloves, the hand wear restrains the gown and reduces exposure to the outer contaminated surface of the glove.

Our study has some limitations. The number of assessments was small. We did not include training of personnel in the protocol. Thus, it is not known whether the modified PPE would provide a benefit in reducing contamination for personnel who have received training. Finally, the prototype design is more difficult to don than standard PPE because the gloves are attached to the gown. However, our ultimate goal is to modify the design to allow gloves and gowns to be donned separately followed by adherence of the glove and gown material after donning.

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Clinical Guideline Inconsistency Regarding the Prevention of Hepatitis B and C Virus Transmission

To the Editor—Every year, millions of people are infected with hepatitis B virus (HBV) and hepatitis C virus (HCV). HBV and HCV share common modes of transmission. The exact route of transmission is unknown in a third of patients with acute HBV infections; similarly, 30% of HCV patients do not have an identifiable risk factor. According to current HBV and HCV practice guidelines, including those from the United States Centers for Disease Control and Prevention,[1,2] and the American Association for the Study of Liver Diseases,[3,4] the sharing of toothbrushes is a risk factor for HBV and HCV transmission, but kissing is not. This seems to be a contradiction because it implies that indirect contact through the sharing of toothbrushes provides a more effective route of transmission than direct contact through kissing.

A toothbrush may induce gum bleeding, thereby facilitating oral infection. However, oral lesions and bleeding occur at any time and may be caused by traumas or multiple oral diseases (eg, ulcers, inflammation, cysts, oral tumors, jaw deformities, tooth impaction, etc.). These oral lesions and the associated bleeding may also facilitate HBV and HCV transmission during kissing.

A toothbrush is usually rinsed after use; therefore, it is relatively clean prior to its potential use by a second person. Further reduction in the number of available viral particles occurs when the potential second person rinse his/her mouth while tooth brushing. Thus, the amount of viral particles transferred should be at a trace level. In contrast, kissing directly transfers a greater amount of saliva between individuals. These facts do not support the current guidelines, which say that toothbrush sharing is a risk factor for HBV and HCV transmission but that kissing is not.

Investigations of infection routes have often focused on risk factors identified in practice guidelines, and patients also tend to associate their infections with risk factors they are aware of. These present blind spots in the study of risk factors. For example, sexual intercourse is considered a potential transmission route for HBV and HCV.[1–4] However, oral–oral kissing typically occurs simultaneously with sexual intercourse, confounding the analysis of whether the infection originated from genital sex, oral-genital sex, oral-oral kissing, or a combination of these. Few studies have attempted to control for oral-oral infection during sexual intercourse. The density of HBV ($10^{5–7}$ virions/mL) in saliva is actually similar to that in semen,[5,6] and the density of HCV (10^6 genome equivalents/mL) in saliva is nearly 10% of that in serum.[7] Furthermore, oral lesions are the most common form of lesions, and oral bleeding is the most common form of bleeding. Unfortunately, all these have been largely neglected.

Kissing directly transfers saliva and pathogens (if present) as does premastication. Reports have suggested that premastication may be associated with HBV transmission. For example, Huang reported that children fed by premastication had twice the prevalence of HBV infection.[8]

A study in Japan reported a case of acute HBV infection and suggested that this infection was caused by kissing.[9] The patient had a steady partner infected with HBV and the sexual relationship between them only included deep kissing, with no sexual intercourse, oral–genital sex, or anal–genital sex, because the patient knew his partner was also infected with HIV. After the diagnosis of acute HBV infection, direct sequencing of the full HBV DNA genome indicated identical sequences in the patient and his partner.

A valid hypothesis that describes the transmission routes of a pathogen should be able to explain various epidemiological aspects of the diseases. We recently proposed that oral wounds can be a route of transmission for HBV, and this hypothesis explains various observations regarding HBV epidemiology.[10]

Clinical practice guidelines play an important role in preventing the transmission of infectious diseases. Here, we present a striking inconsistency in the current HBV and HCV clinical practice guidelines regarding oral transmission. This inconsistency indicates that our understanding of HBV and HCV transmission is incomplete, especially with regard to the potential for oral transmission, and it suggests future directions for exploring potential risk factors.

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