# Are Nurses Protected? Observing the risk of skin contamination when donning and doffing personal protective equipment, using a Canadian protocol

by

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ABSTRACT

This study aimed to determine whether the Public Services Health and Safety Association's donning and doffing protocol for Ebola are effective in the prevention of skin and clothing contamination. Ten third-year nursing students performed a donning and doffing simulation, which included donning personal protective equipment (PPE), being sprayed with GloGerm, performing eight simulated movements, and doffing PPE. Fluorescent stains were observed using an ultraviolet scan and were documented by their location and size. Four participants (N=4) experienced at least one contamination event following the doffing of PPE. Contaminations were observed on: the left dorsal lower leg (41.3mm; 64.0mm); the right dorsal lower leg (77.9mm); the left plantar (9.5mm); the left index finger (2.8mm); the right middle finger (1.6mm); the left scapula (38.1mm); and the right buttock (57.2mm). Areas of difficulty in the protocol included donning and doffing: the gown, N95 respirator, and the outer footwear. Failures with the equipment, including breaches and punctures, also contributed to the documented contamination. Near-miss incidents were observed in nine of the twenty-four steps in the protocols and occurred a total of twenty times. Revisions to the protocols were completed and included additional information for the following protocol steps: hang hygiene, N95 respirator, gown, outer footwear, verification process.

*Keywords:* personal protective equipment; donning and doffing protocol; donning and doffing simulation; GloGerm contamination

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This experience has been rewarding and fulfilling. It has permitted me to expand my literacy and my understanding of personal protective equipment. I hope that I can use this knowledge to better myself in my educational career and in my future endeavors.

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| *Abbreviation* | *Explanation* |
|---|---|
| *HCWs* | Healthcare Workers |
| *PPE* | Personal Protective Equipment |
| *SARS* | Severe Acute Respiratory Syndrome |
| *EVD* | Ebola Virus Disease |
| *PSHSA* | Public Services Health and Safety Association |
| *MOHLTC* | Ministry of Health and Long Term Care |
| *RN* | Registered Nurse |
| *RPN* | Registered Practical Nurse |
| *WHO* | World Health Organization |
| *CDC* | Centre for Disease Control and Prevention |
| *AAMI* | Association for the Advancement of Medical Instrumentation |
| *LHIN* | Local Health Integration Network |
| *TO* | Trained Observer |
| *P* | Participant |
| *VSI* | Video Self-Instruction |
| *CPR* | Cardio-Pulmonary Resuscitation |

# Preface

Nurses can use personal protective equipment (PPE), as a control strategy to help mitigate hazards associated with exposure to contaminants in the workplace. Previous pandemics such as the Severe Acute Respiratory Syndrome (SARS) and Ebola Virus Disease (EVD) demonstrated deficiencies within the safety culture of hospitals (Campbell, 2006), which prompted the Public Services Health and Safety Association (PSHSA) of Ontario, Canada to create an acute-care donning and doffing protocol in collaboration with the Ontario Ministry of Health and Long Term Care (MOHLTC). The acute care donning and doffing checklists were created in 2014 as a result of Ontario's Ebola Readiness Program (Ontario Medical Association, 2014). All acute care institutions and Local Health Integration Networks (LHIN) were ordered to use these precautions and procedures to reduce the potential risks of EVD transmission, as part of the directive issued under Section 77.7 of the Health Protection and Promotion Act (Ontario Medical Association, 2014).

At the present time, no published scientific literature has been conducted on the effectiveness of the PSHSA donning and doffing protocols. These protocols are widely used across Ontario to ensure that self-contamination is reduced. Quantitative assessment of these protocols is required to effectively study their effectiveness in preventing disease transmission. Therefore the purpose of this research was to evaluate the effectiveness of the PSHSA acute care donning (Appendix A) and doffing (Appendix B) protocols in preventing skin and clothing contamination in nurses.

## Chapter 1: Review of the Literature

This study aims to explore the effectiveness of personal protective equipment (PPE) donning and doffing protocols in healthcare by measuring exposure transmission in a typical isolation procedure. Through the Severe Acute Respiratory Syndrome (SARS) outbreak, post-analysis revealed: a lack of preparation, communication, and knowledge as the key underpinnings contributing to the extent of the pandemic (Campbell, 2006). The development of new disease outbreaks such as Ebola (EVD) has heightened concerns regarding the safety of healthcare providers, including nurses (Hylton, 2011; McGolderick, 2015; Morales et al., 2014). Specifically, healthcare workers (HCWs) and researchers have voiced concerns with regard to the proper use of PPE and suitability of existing PPE protocols in healthcare (Beam, Gibbs, Boulter, Beckerdite, & Smith, 2011; Casanova, Alfano-Sobsey, Rutala, Webber, & Sobsey, 2008; Chiang et al., 2007; McGoldrick, 2015). With these concerns in mind, scientific literature regarding general information on the effectiveness of PPE, and key elements causing PPE breaches in healthcare settings were reviewed.

### Personal Protective Equipment

In healthcare, PPE is often used as a temporary hazard control mechanism for workers against danger or contamination (Canadian Centre for Occupational Health and Safety, 2015). It is the last line of defense and it is used when the danger cannot be removed or controlled sufficiently by other means (Health Canada, 2009). PPE refers to protective garments or other equipment designed to protect the wearer from injury or infection. In healthcare, for viral diseases in particular, the PPE includes the use of barrier garments including: gowns, hoods, aprons, gloves, foot coverings, N95 respirators, and face shields; all to cover and protect potential areas that could be exposed to viral contamination, including: mucous membranes,

airways, skin, and personal clothing from contact with infectious agents (Casanova et al., 2008; Siegel et al., 2007).

Ensuring that exposure to occupational hazards are controlled, is a key factor in protecting workers (CDC, 2016; Hylton, 2011; McGolderick, 2015; Morales et al., 2014). According to the hierarchy of controls, which assists in determining potential control solutions, PPE is at the lowest level and is referred to as the least effective in comparison with elimination or substitution of the hazards (CDC, 2016). However, in healthcare, the occupational risks stem from being contaminated with transmissible diseases through patient interaction. Patients cannot be eliminated or substituted, so unless human-patient interaction can be replaced, PPE-use remains as an accepted strategy (Hylton, 2011; McGolderick, 2015; Morales et al., 2014).

According to Ontario Regulation 67/93 from Section 13(3)(b) of the Occupational Health and Safety Act, "*a worker who is required by his or her employer or by this regulation to wear or use any personal protective clothing, equipment or device shall be instructed in its care and use before wearing or using it for the first time"*. By law, employers are obliged to ensure that tasks are being executed safely in order to protect their employees from any work-related hazard such as, but not limited to, exposure to infectious disease and contamination (Worker's Compensation Board of BC, 2015). It is the duty of the employer to certify that workers are educated and trained to work safely and are aware of the protocols and guidelines to be implemented in the case of emergencies.

With the emergence of new outbreaks, including EVD, the level of safety offered by PPE and their respective protocols has been widely investigated through scientific literature (Beam et al., 2011; Casanova et al., 2008; Chiang et al., 2007; Hylton, 2011; McGolderick, 2015). These studies reveal various discrepancies with regard to the use of PPE in healthcare by demonstrating

equipment strike-through, accidental self-contamination, and a lack of PPE training, which prompted the initiation of the current study.

## Case Examples of PPE Failure

Some of the major contributors to the severity of the spread of SARS and EVD were the lack of use, understanding, and/or availability of PPE, which have all been noted to be significant in the formation of a positive safety climate (Campbell, 2006). The lack of PPE awareness meaningfully contributed to infection rates and number of deaths during the span of these illnesses (Campbell, 2006; O'Neil, 2014). This raises questions with regards to the use of PPE and the guidelines employed during these pandemics to ensure safe work practices.

### Severe Acute Respiratory Syndrome (SARS)

SARS is a viral infection that manifests as an acute, respiratory illness, transmitted through close, person-to-person contact. (CDC, 2013). Symptoms of SARS include high fever, headache, overall feelings of discomfort, body aches, and dry cough (CDC, 2013). On May 17$^{th}$, 2004, following multiple SARS diagnoses, deaths, a code orange, and a travel advisory, the Minister of Health and Long Term Care deemed Toronto "SARS-free" (Campbell, 2006). According to Campbell (2006) the Greater Toronto Area (GTA) "*breathed a big sigh of relief, infection control and worker safety precautions were relaxed, hospitals held celebrations and the health system returned to the new normal*" (p. 6). Just a week later, another outbreak emerged at a nearby rehabilitation centre and at the North York General Hospital. It is now understood that the virus had never subsided, but rather, thrived undetected until relaxing safety protocols and PPE use allowed a renewed outbreak (Campbell, 2006). The use of precautions including the proper use of PPE had a major impact on containing the virus (Campbell, 2006). When precautions were introduced to the healthcare system, the number of cases diminished whereas relaxed protocols resulted in increased cases (Campbell, 2006). In the end, 375 people were

diagnosed with SARS in Toronto and 44 people died from the virus (Campbell, 2006). Of these, 72% were infected in a heath care setting and 42% were HCWs (Campbell, 2006). Most of these workers were nurses whose jobs brought them in close contact with infected patients (Campbell, 2006). This highlights the importance of PPE for the safety of workers and patients. In addition, the fact that so many HCWs were infected with SARS reinforced the concept that controls, including PPE guidelines and protocols, are needed to reduce the spread of infectious agents (Campbell, 2006).

The lack of PPE training is recognised as a significant contributor to SARS transmission (Campbell, 2006). Many HCWs confirmed that they had not been trained on donning and doffing procedures prior to the outbreak (Campbell, 2006). Below are direct quotes from HCWs who were working in hospitals in the GTA during the SARS outbreak:

> "I really did not receive any formal training on the use of the equipment. You were pretty well [told] there's equipment there; you figure out yourself how to put it on. And certainly the missing piece with me was that I didn't have any formal training in how to remove it properly" (Campbell, 2006, p.1074).
>
> "No [I did not receive formal training], there's a little pamphlet that came in the box of [the PPE] when you got the first ones that basically told you what to do" (Campbell, 2006, p.1074).
>
> "Training? I don't remember any training. We weren't given an official in-service until the middle of the second SARS" (Campbell, 2006, p.1075).

Given that SARS was predominantly spread through various hospitals, in Toronto, and that HCWs were a significant population of the infected individuals (42%); is an indication that poor training and PPE use contributed to the infection rates in this population (Campbell, 2006).

**Ebola Virus Disease (EVD)**

EVD, also known as Ebola Hemorrhagic Fever and Ebola, is a viral disease caused by ebola viruses and manifests itself similar to malaria or meningitis. Symptoms include: fever, headache, weakness, fatigue, and dry cough (CDC, 2015b) and it is transferred through direct contact with bodily fluids: blood, vomit, and diarrhea are the most contagious (National Institute for Public Health and the Environment, 2015). The average EVD fatality rate is 50% (WHO, 2016).

In 2014, EVD reached pandemic levels, which created an international public health emergency (Phillips, 2014). In a cohort study, vomitting or nausea were present in 50% of confirmed EVD patients (n=365) and diarrhea in 41% of cases (n=294). They were the most common presenting symptoms (Lado et al., 2015). Given that HCWs are often the principle people managing these fluids and half of all patients present with these symptoms, the need for PPE is clear.

Interestingly, compared to SARS, the EVD outbreak was better controlled in North America (WHO, 2015). To date, no cases have been confirmed in Canada, although exposure did occur in the United States of America (USA) where, in October of 2014, three American HCWs, who contracted EVD in Liberia, returned to the USA for treatment (WHO, 2015). Another American citizen was reported to have contracted EVD in Sierra Leone and later died in an Atlanta hospital (CDC, 2014a; Wilson, 2014).

In particular, HCWs are at high risk of exposure because they are likely managing the bodily fluids and they typically have the highest degree of contact with infected patients. Historically, HCWs have been infected while treating patients with suspected or confirmed EVD (WHO, 2015). According to the WHO, precautionary measures including: a combination of case management, surveillance and contact tracing, safe laboratory services, safe burials, and social

mobilisation were not sufficient to contain the disease during the EVD outbreaks (WHO, 2015; CDC, 2014b).

This was the case in Liberia, where a total of 810 cases of EVD were reported from June to August 14th, 2014 (CDC, 2014a). This event is of particular interest, with respect to this thesis, because ten clusters of EVD cases were discovered, among HCWs in facilities that were not EVD treatment units (CDC, 2014b). The Liberian Ministry of Health and Social Welfare and CDC examined these clusters by reviewing surveillance data, interviewing health officials, HCWs, and contact tracers; and visiting healthcare facilities (WHO, 2014). The investigation revealed that hospitals failed to recognize EVD symptoms in patients, which were likely why these HCWs were exposed to the virus. In addition, inconsistent recognition and triage of cases of EVD, overcrowding, limitations in layout of physical spaces, lack of training in the use of and adequate supply of PPE, and limited supervision were all observed as key underpinnings to the spread of the virus (WHO, 2014). The 2014 epidemic of EVD highlighted the hazards associated with insufficient safety practices (WHO, 2014). It showed that sustaining an effective public healthcare system is necessary to successfully combat such diseases (Shrivastava, 2015).

These cases demonstrate the risks associated with inadequate infection control practices and reinforces the importance of using PPE as the "last-line-of-defense" when all other safeguards fail. Critically, this should include educational aspects around why to use PPE, when to use PPE, and training on how to-effectively use PPE.

**The Outbreak Aftermaths**

Retrospective reviews of outbreaks have shown inconsistent use of PPE in HCWs who developed infection (Beam et al., 2011). As a result, these outbreaks have contributed to the development of significant changes in safety procedures, specifically in Ontario (Campbell, 2006; PSHSA, 2015; Wilson, 2014). These outbreaks stimulated stringent examination of

infection control procedures provincially and reinforced PPE use and training (Campbell, 2006; PSHSA, 2015; Wilson, 2014). Specifically, HCWs were provided with protocols and ongoing training for proper use, due to these outbreaks (Campbell, 2006; Wilson, 2014). HCWs were also educated on rigorous environmental cleaning practices for all patient care areas (Campbell, 2006; Wilson, 2014). The government acknowledged and addressed the need to strengthen public health services through planning and implementation (Wilson, 2014), and hospital accreditation standards were substantially modified in order to focus on infection prevention and control (Wilson, 2014).

On October 20th, 2014, the acute care donning and doffing protocols were created as part of Ontario's Ebola Readiness Program by the Public Services Health and Safety Association (PSHSA) in collaboration with the Ministry of Health and Long Term Care (MOHLTC) (MOHLTC, 2016a). The PSHSA is funded by the Ontario Ministry of Labour and works with Ontario's Public Sector employers and workers, to provide training, consultation, and resources, with a goal of reducing workplace risks and preventing occupational illnesses (PSHSA, 2016). On October 30th 2014, the MOHLTC released a directive issued under Section 77.7 of the Health Protection and Promotion Act, R.S.O. 1990, c. H.7 ("HPPA"). This directive details the EVD precautions and procedures for acute care settings, including the use of PSHSA donning and doffing protocols (MOHLTC, 2016a; Ontario Medical Association, 2014). All acute care institutions and Local Health Integration Networks (LHIN) were ordered to use these precautions and procedures to reduce the potential risks of EVD (Ontario Medical Association, 2014). As a result, the PSHSA donning and doffing protocol was adopted by HCWs across Ontario.

## Chain of Infection

According to the principles of epidemiology in public health settings, transmission of infectious agents occurs when the infection leaves its host through a portal of exit, and is transmitted to the susceptible host via a portal of entry (CDC, 2012). The Chain of Infection is made up of six different links: pathogen (infectious agent), reservoir, portal of exit, means of transmission, portal of entry, and the new host. Each link has a unique role in the chain, and each can be interrupted, or broken, through various means, thereby preventing a new infection (CDC, 2012).

Illnesses are often transmitted by the host because they are unaware they are infected and take no special precaution against transmission (CDC, 2012). At other times, the host seeks medical attention, and illnesses are spread to the HCW in charge of their care by a mode of transmission (CDC, 2012) (see Figure 1).

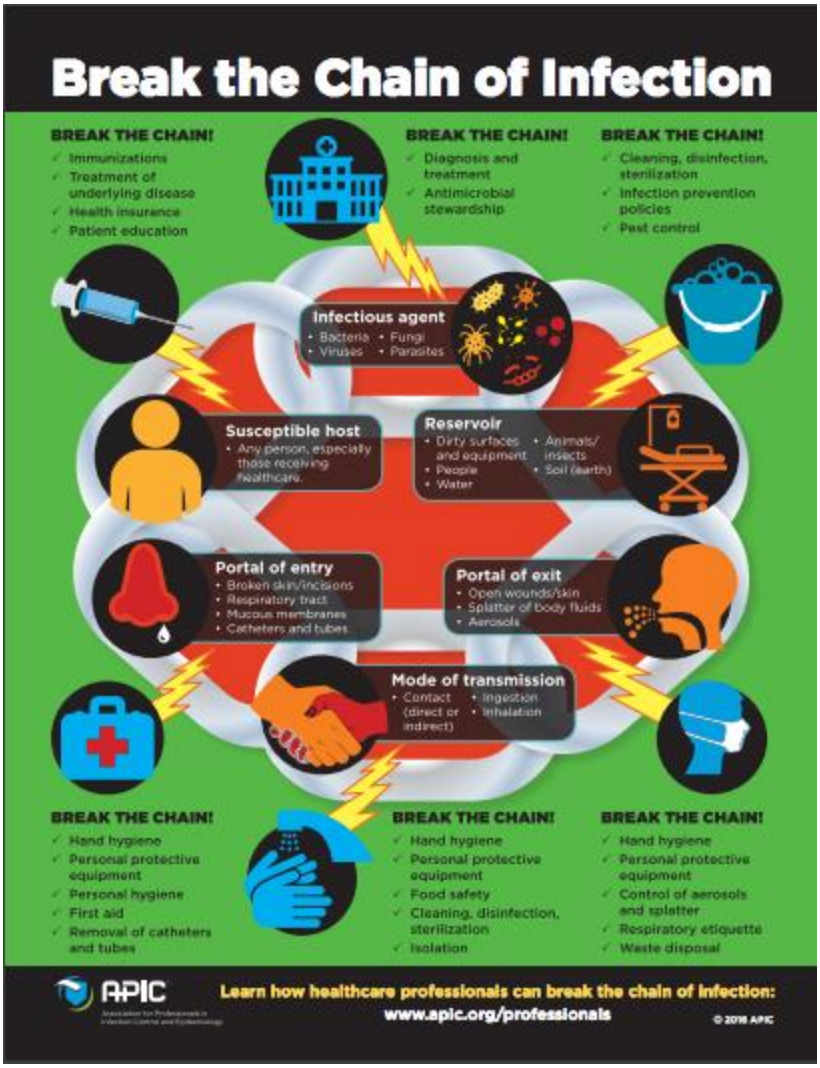


*Figure 1*: Outline of the Chain of Infection. Describes how the infection leaves to portal of exit and attains the susceptible host via a mode of transmission and portal of entry. Source: http://professionals.site.apic.org/files/2016/09/Break-the-chain-of-infection-thumbnail.png

## Modes of Transmission for Infection

An illness or disease such as EVD can be spread from the initial host to another susceptible host by means of various modes of transmission, which underlines the importance of selecting PPE based on the nature of the illness in question. Modes of transmission include contact and non-contact. Contact transmission includes: direct, indirect and droplet transmission; non-contact includes: airborne, vehicle-borne and vector borne. Contact transmission is

particularly relevant in the case of EVD. Each of these modes of transmission require specific selection of PPE along with routine precautions to prevent transmission. Routine precautions include: gloves, gown, face protection, and the use of administrative and environmental controls such as consistent laundry protocols, proper ventilation, training, and immunization (Canadian Centre for Occupational Health and Safety, 2017).

**Contact Transmission**

Direct transmission occurs through direct contact from person-to-person. This can include skin contact, kissing, or sexual intercourse (CDC, 2012). It also includes contact with blood or body fluids, including but not limited to: urine, saliva, sweat, feces, vomit, breast milk, or semen of a person who is infected. When at risk for direct transmission, a long-sleeved gown and gloves must be used along with routine precautions (Public Health Ontario, 2017).

Another form of contact transmission is through droplet spread. This refers to contact with relatively large, short-range sprays produced by sneezing, coughing, or even talking. This is considered direct transmission because aerosols and sprays can attain a susceptible host over a few feet before finally dropping to the ground. When at risk for droplet spread transmission, a mask and eye protection along with routine precautions must be used when the HCW is within two meters of the patient (Public Health Ontario, 2017).

Indirect transmission occurs when an infectious agent is deposited onto an object or surface (fomite) and survives long enough to transfer to another person who subsequently touches the object. Common precautions against this transmission includes sterilization of instruments, disinfecting surfaces and controlled removal of contaminated gowns etc. This is an important component of EBV control (CDC, 2012).

### Non-Contact Transmission

Airborne transmission transpires when infectious agents are suspended in the air or attach to air particles such as dust. When infectious agents are aerosolized they can be spread via ventilation systems or traveling by air currents, infecting a susceptible host at a distant site, usually via inhalation (CDC, 2012). To reduce transmission of airborne illnesses, the door to the patient's room must always be closed and an N95 respirator is required along with routine precautions (Public Health Ontario, 2017).

Vehicle borne transmission occurs when a single contaminated source spreads the infection. Vector Borne transmission occurs when the infection is spread by insects or animal vectors. Ebola viruses are common in certain animal species (e.g. bats, monkeys) and outbreaks are generally initiated by close interspecies interaction between humans and infected species (CDC, 2015d).

Infectious diseases can be spread through the various modes of transportation described above independently or simultaneously. The use of PPE is a key precaution to interrupt the chain of infection and prevent the spread of infection, mitigating the impact of infectious diseases. In settings and environments where the risk of infection is high, such as healthcare, the modes of transmission and the type of PPE required are especially important.

## PPE as a Defence Mechanism for EVD

### PPE Required for Contact Precautions

EVD is primarily spread from human-to-human through contact mode of transmission (CDC, 2015d; Office of the Provincial Health Officer, 2016). Contact transmission, as described above, includes: contact with broken skin; contact with mucous membranes; contact with blood or body fluids of someone with EVD; or through items contaminated with blood/body fluids containing EVD (Office of the Provincial Health Officer, 2016). EVD therefore requires a type C

level of precaution, which means that when caring for suspected EVD patient, contact precautions are required *in addition* to standard precautions (CDC, 2016a). Standard precautions require the use of gloves, a mask, a gown, an apron, and shoe covers. Contact precautions require the added use of a respirator, eye protection, gown, and gloves when the HCW is within two meters of the infected patient (Public Health Ontario, 2017).

For each item of PPE, it is important for HCWs to understand the purpose and proper functioning including how the item prevents against transmission of the infectious agent.

**Gowns and Aprons**

Gowns and aprons are used as a standard precaution to protect HCWs against exposure to contaminants (CDC, 2015c). Gowns protect the arms and several exposed body areas from blood, body fluids, and other infectious agents (Boyce, Mermel, Zervos, et al., 1995; Boyce, Potter-Bynoe, Chenevert, King, 1997; Hall, 2000). Aprons are a single-use, fluid-repellent item worn whenever the HCW is in close contact with patients, materials, or equipment that pose a risk of contamination with blood or body fluids (Loveday et al., 2014). They provide an added layer of protection, preventing seepage of fluid through to the gown. The use of isolation gowns is mandated by the OSHA Bloodborne Pathogens Standard (Siegel, 2007). As a result, a gown is required for donning and doffing when caring for suspected EVD. The apron reduces contamination to the gown by providing a means of rapidly removing a soiled outer layer during patient care (CDC, 2015c).

**Hood**

To mitigate risks of infection, HCWs caring for suspected or confirmed cases of EVD should have no skin exposed (Office of the Provincial Health Officer, 2016). Therefore the hood is used to protect the head, hair, face, and neck against contact contamination with infectious agents.

**Face Shield**

The importance of a face shield in the prevention of infectious diseases through respiratory droplets has only been studied for Respiratory Syncytial Virus (Office of the Provincial Health Officer, 2016). For Respiratory Syncytial Virus, research indicates that eye protection reduced occupational transmission (Agah, Cherry, Garakian & Chapin, 1987; Gala et al., 1986; Siegel et al., 2007). Given the abundant production of fluids during EVD, and the high mortality rate associated with the disease, it is believed that every precaution should be taken to prevent contact transmission of this virus – including protection to the eyes. Therefore, a face shield is considered an important component of PPE to reduce transmission of EVD (Public Health Ontario, 2017).

**Foot Protection**

Foot protection is crucial to reduce transmission of EVD via indirect contamination to other HCWs and patients, in non-contaminated environments. Disposable or washable footwear is another component of the donning and doffing process that reduces the contamination capacity of this highly contagious disease (CDC, 2015c). Additionally, single-use shoe covers can be worn over personal footwear to reduce the transmission of virus on the floor in the doffing area (CDC, 2015c). Using shoe covers over washable footwear can be compared to double gloving, (see below). It is also important to promote frequent disinfection of floors in the doffing area further ensure disruptions in transmission (CDC, 2015c).

**Gloves**

Gloves are recommended when a person is: in contact with blood, bodily fluids, or mucous membranes; having direct contact with patients who are contaminated; or using or touching visibly contaminated equipment or surfaces (Bhalla et al., 2004; Duckro, Blom, Lyle, Weinstein, Hayden, 2005; Siegel et al., 2007). Gloves act as a protective barrier for patients and

HCWs from exposure to infectious material (Duckro, Blom, Lyle, Weinstein, Hayden, 2005; Siegel et al., 2007). Current best-practice advocates for the use of double-gloves during invasive procedures (e.g., surgery) or when contact with blood or bodily fluids is anticipated (Office of the Provincial Health Officer, 2016), as is the case with EVD. Double-gloving has been proven to better protect HCW's hands from infectious contamination. Specifically Sadat-Ali et al. (2006) found that double-gloving decreases the risk of exposure to patient blood by as much as 87% when the outer glove was punctured.

**N95 Respirator**

An N95 respirator is the most common of the seven types of particulate filtering face piece respirators. This product filters at least 95% of airborne particles. Some N95 Respirators are also cleared by the Food and Drug Administration as a surgical mask – these are Surgical N95 Respirators. HCW should use surgical N95 respirator when exposed to small particles that can become or remain airborne, as is the case of EVD. Surgical N95 Respirators are effective barriers for coughing and sneezing. However, they do not eliminate air leakage around the edges (CCOHS).

**Administrative, Environmental, and Engineering Controls to Support Safe PPE Use**

While PPE is known as a safeguard for HCWs, it is not the only control in place to protect against disease transmission. In addition to PPE, administrative, environmental, and engineering controls exist, which should also be considered as important factors in mitigating EVD transmission.

According to the Canadian Centre for Occupational Health and Safety (2017), administrative controls refer to "controls that alter the way the work is done, including timing of work, policies and other rules, and work practices such as standards and operating procedures" (p.1). In healthcare, administrative controls can be applied in various ways, most notably by:

implementing PPE protocols; providing training for infection control; providing donning and doffing checklists; ensuring there is enough staff for the workload; encouraging self-monitoring of symptoms following treatment of EVD patients; ensuring records are kept up to date; developing an algorithm for patient screening (Office of the Provincial Health Officer, 2016).

Environmental and engineering controls include "designs or modifications to plants, equipment, ventilation systems, and processes that reduce the source of exposure" (Canadian Centre for Occupational Health and Safety, 2017, p.1). In establishments where contact with infectious diseases could occur, it is important to designate an isolation room with certain features such as: a private washroom; negative pressure and an antechamber; an intercom; and a large observational window (Office of the Provincial Health Officer, 2016). These rooms should have specified donning and doffing areas with clear distinctions (Office of the Provincial Health Officer, 2016).

In addition to the use of PPE, the use of administrative, environmental, and engineering controls is required to reduce the risks of EVD transmission to HCWs. Developing PPE protocols and checklists is a step in reducing exposure to hazards. Therefore, it is important to evaluate the protocols to ensure they are effective at protecting HCWs.

## PPE Training and Education

Since EVD and other transmissible diseases have the ability to spread rapidly, implementation of infection control strategies are required to mitigate its effects (Ministry of Health and Long Term Care, 2016). Training and education are important components for prevention and understanding why PPE is important in disease control and how to properly use it to prevent disease spread are critical factors to be in place *prior* to disease encounter (Aziz, 2009; Carrico et al., 2007; McGovern, 2000). Healthcare facilities are therefore required to comply with applicable provisions of the *Occupational Health and Safety Act* (OHSA), R.S.O.

1990, c.0.1 and its Regulations (PIDAC, 2012). That is: the employer, in consultation with the joint health and safety committee or health and safety representative, if any, shall develop, establish and provide training and educational programs in health and safety measures and procedures for workers that are relevant to the workers' duties (PIDAC, 2012).

Therefore, HCWs are required to receive comprehensive training and demonstrate competency in performing infection control practices and procedures (MOHLTC, 2016a; MOHLTC, 2016b). This requirement reflects lessons learned from the recent experiences while caring for patients with EVD and highlights the significance of training, practice, competence, and observation of healthcare workers, particularly in accurate donning and doffing of PPE (CDC, 2015c). In light of Ontario's Ebola Readiness Program, the MOHLTC is requesting that specific PPE, education, and training requirements be met by all acute-care facilities (MOHLTC, 2016a; MOHLTC, 2016b). PPE requirements state PPE must be maintained and made available at the point-of-care at all times and HCWs must have access to sufficient types and quantities of PPE (MOHLTC, 2016a; MOHLTC, 2016b). With regards to training and education, HCWs are at a heightened risk of exposure and are required to have training at regular intervals and hands-on practice tests and drills. Furthermore, training needs to be focused on topics including symptoms of EVD, modes of transmission, use of precautions, organizational plans, selection, use, and limitations of PPE including donning and doffing, purpose and importance or PPE, use of trained observers, safe sharps disposal, proper use of engineering controls, human remains management, and hand hygiene (MOHLTC, 2016a).

In healthcare, comprehensive PPE programs demand commitment and active participation at the planning, development, and implementation levels (Canadian Centre for Occupational Health and Safety, 2011). Therefore, it is imperative for workers and their

supervisors to comply with ministry orders to achieve the necessary level of protection (Canadian Centre for Occupational Health and Safety, 2015).

Carrico et al. (2007) highlighted the importance of PPE training by conducting a pilot study to determine whether a standard classroom training method could increase the use of PPE among nurses. Twenty emergency department RNs participated and were randomly assigned to one-of-two groups: control and intervention. Both the intervention group and the control group completed standard classroom training, designed to provide text-based information about disease transmission. The intervention group received supplemental training using the visual demonstration of respiratory particle dispersion. The visual demonstration utilized a biostimulator; a patient whose cough projected fluorescent powder. Through this program, nurses were able to visualise the spread of disease, as contained within the micro-droplets produced during a cough or sneeze. This allowed them to see how the particulate could either be aerosolized for inhalation, or land on surfaces or skin for direct contamination. Prior to and subsequent to the training program, the participants were observed throughout their work shifts for a 2-month duration as they provided care to their patients. Overall, both groups showed a significant increase in pre-test to post-test PPE knowledge (mean change=0.12, SD=0.18; $t(20)=3.02$, $P=0.007$). The intervention group RNs also used PPE statistically more often than those in the control group.

The examined research demonstrates the importance of education and standard classroom training for the use of PPE. As calculated using a meta-analysis, HCWs who committed to PPE training were 5.7 times more likely to be compliant with PPE guidelines when compared to their colleagues without training (McGovern, 2000). These studies highlight the positive association between PPE education and understanding (Aziz, 2009; Carrico et al., 2007; McGovern, 2000).

## PPE Compliance

Several studies have evaluated compliance with PPE protocols (Chiang et al., 2008; Ganczac, & Szych, 2007; McGovern, 2000). Chiang et al. (2008) studied compliance with basic infection control measures during cardio pulmonary resuscitation; this includes the use of a mask, a gown, and gloves. They did so by capturing video segments of all CPR's and by extensively revising the video-recordings and time-motion analyses. Throughout the data collection, use of PPE was categorised as "adequate" or "inadequate". If a rescuer did not don appropriate PPE before starting resuscitation or approaching a patient, it was deemed inadequate. Contamination was also observed and was recorded when a participant made contact with a non-contaminated zone (i.e. chart) after touching a contaminated zone (i.e. patient or tool) without the use of proper hygiene techniques in-between. Overall, results demonstrated that 90%, 50%, 20%, and 75% of healthcare workers adequately utilized masks, eye protection, gowns, and gloves, respectively. Compliance with PPE use also varied significantly amongst health care professionals (doctors, nurses, and trainees), with doctors generally being the most compliant of the three groups. In addition, a total of 687 contamination events were recorded in 44 consecutive CPR sessions. Another common problematic component of PPE use was insufficient preparation for procedures (42%). Participants indicated that PPE for a specific task was not organised and assembled prior to the execution of the task, which often resulted in the contamination of clean zones.

In a study conducted by Ganczac and Szych (2007), factors associated with compliant and non-compliant behaviours were examined in 18 Polish hospitals. Surgical nurses (601) were asked to evaluate their perceived level of self-compliance with PPE. Results demonstrated that 63% of participants had a high degree of fear about contracting illnesses at work (n=378). Participants claimed to use glove 83% of the time, and protective eyewear 9% of the time.

Compliance with all equipment simultaneously was 4.8%. According to the study, operating room staff used PPE much more frequently than admitting area nurses. Training was identified as a significant factor in PPE compliance. The most commonly stated reasons for non-compliance was non-availability of PPE (37%), the notion that the source patient was not infected (33%), lack of time (19.2%), a conviction that PPE interfered with quality of care (32%), and a belief that the equipment provided was ineffective due to a lack of training (9.8%).

Michalsen, Delclos, and Felknor (1997) conducted a study to assess self-reported levels of compliance in Texan physicians (n=322). Physicians reported compliance to be high for glove use (94%) and disposal of sharps (92%), and low for wearing protective clothing (55%) and not recapping needles (56%). The following were judged as statistically significant for non-compliance: lack of knowledge (47%); lack of time (42%); forgetfulness (39%); and lack of means (28%). Compliant physicians were more likely to be characterized as those who had been trained in universal precautions since they perceived PPE to be an effective measure of safety (Michalsen, Delclos, & Felknor, 1997).

McGovern (2000) characterized levels of self-reported compliance with universal precautions among healthcare workers in Minnesota. In this cross-sectional study, a sample of 1135 healthcare workers were identified from hospital personnel records and sent a 210-item questionnaire designed by Gershon et al. (1995). The results demonstrated that 96.0% of respondents report wearing disposable gloves whenever a chance of exposure to blood or other body fluids existed, 62.2% reported wearing a disposable outer garment whenever a chance of soiling work clothes existed, 59.8% reported wearing protective eye shields whenever a possibility of splash or splatter to eyes existed, and 48.5% reported wearing a disposable face mask whenever a chance of splash or splatter to the mouth existed. Training, tenure, knowledge

of transmission, attitude, and safety climate were all noted to have a positive impact on compliant behaviours and were statistically significant in analyses. The significant association between the organization's safety climates to PPE compliance was consistent with the findings of Michalsen et al. (1997).

Despite the implementation of guidelines and subsequent government regulatory action, several researchers have suggested compliance with PPE remains inadequate for infection control (Chiang et al., 2008; Ganczac, & Szych 2007, Michalsen, Delclos, & Felknor, 1997; McGovern, 2000). In comparing the studies above, commonalities were found with regards to compliance, as well as reasoning for compliant behaviours. If PPE is not used in a consistent manner the risk for self-contamination is greater (Chiang et al., 2008; Ganczac, & Szych, 2007; McGovern, 2000; Michalsen, Delclos, & Felknor, 1997). Although standard safety measures have been supported generously in recent years, compliance with PPE remains unsatisfactory among healthcare workers (McGovern, 2000). In addition, factors associated with PPE compliance include workers perception of a strong organizational safety climate and training on the use of PPE. That being said, non-compliance is often cited as a result of a lack of understanding of PPE protocols, a lack of training, and PPE availability (Ganczac, & Szych, 2007; McGovern, 2000; Michalsen, Delclos, & Felknor, 1997).

These findings reveal concerns that there is a lack of awareness regarding infection control measures, and suggest additional studies on current protocols are crucial. These non-compliant behaviours also suggest that detailed protocols are required to provide guidance for safe work practices. Ensuring that donning and doffing steps are properly outlined could reduce the risk of EVD transmission.

## PPE Donning and Doffing Protocols

In order to evaluate existing PPE protocols designed to reduce patient-to-healthcare worker contamination, several researchers have undertaken PPE donning and doffing studies (Beam et al., 2011; Casanova et al., 2008; Guo, Li, & Wong, 2014; Mitchell et al., 2013). Specifically, Casanova et al. (2008), evaluated a PPE doffing protocol designed by the Centre for Disease Control and Prevention, intended to minimize wearer contamination with pathogens (Appendix C). In this study, volunteers (n=10) donned gowns, gloves, respirators, and goggles. A bacteriophage MS2, which is a non-enveloped, nonpathogenic RNA virus was suspended in 0.01 mol/L phosphate-buffered saline and GloGerm, a synthetic fluid that fluoresces under UV light were together sprayed on the PPE equipment worn by participants on the following sites: the front shoulder of gown, back shoulder of gown, right side of N95 respirator, upper right front of goggles, and palm of dominant hand. Each site was contaminated with a total of $10^4$ PFU of MS2 in 5 drops of 5 μL each. Volunteers performed a blood pressure check and proceeded to doff the equipment following the CDC protocol (Appendix C). Results demonstrated that 90 and 70% of participants had been subject to self-contamination by transference of infectious agent to their right and left hand, respectively. Much of the contaminant was transferred on different areas of the workers clothing as well (80% on non-dominant glove; 100% on scrub shirt; 75% on scrub pant). None of the participants were noted to have contaminated their faces (Casanova et al., 2008).

Beam et al. (2011) evaluated HCWs techniques during the doffing process subsequent to a task. The participants (n =10) included registered nurses, respiratory therapists, and nursing assistants from various hospital units from the Nebraska Medical Centre. Each participant was assigned a patient care task based on their professional role. The participants were randomized to a group that had access to a CDC poster (Appendix D) on PPE donning and doffing or to a group

without access to any additional guidance. The participants all had access to an isolation cart with gowns, gloves, procedure masks, N95 respirators, and multiple styles of protective eyewear. Each participant was verbally given a patient scenario, and a patient chart. Typical isolation signage was posted on the door of each room. No other guidance on appropriate PPE was given. A powdered fluorescent marker, invisible to the eye, was spread in areas of the room where patient contamination commonly occurs, including the bedrails, bedside table, and the simulated patient's gown front and arms. The authors reported inconsistencies in the removal of PPE and found that no standard technique was used by the participants, and that 100% of the participants had at least one breach of standard airborne and contact isolation precautions. The most common breaches in PPE donning were, failing to conduct a seal check on the respirator, failing to tie the gown at both the neck and the waist, and donning the equipment in an incorrect sequence (Beam et al., 2011).

Furthermore, body contamination rates and environmental contamination levels during the doffing of three types of PPE (disposable water-resistant gowns, reusable cotton gowns, and disposable plastic aprons) were examined by Guo, Li, and Wong (2014). Fifty participants were recruited from a Hong Kong medical centre, which included nurses (n=20), support staff (n=15), doctors (n=10), and allied health workers (n=5). The average age of the participants was 33 years (standard deviation ± 5.7) and the average working experience was 11 years (standard deviation ± 5.1). This study evaluated two different protocols: the Individual Accustomed Removal Method (IARM) and the Gown Removal Method recommended by the CDC. Once the equipment were donned by the participants, using the assigned protocol, the researcher then sprayed 3.8g of the simulated germ lotion onto the upper body of the participant at a distance of 60 cm from the participant. In this study, the GloGerm powder was mixed with light olive oil

and water to resemble human aerosol as closely as possible (Guo, Li, and Wong, 2014). The participants were then asked to doff the PPE. The results indicated that the CDC-recommended gown removal method significantly reduced the overall environment contamination levels and reduced small stains in the front and left directions. However, the CDC gown removal method increased environmental contamination from the back direction and right direction. Using the IARM the hands were the least contaminated, whereas the shoes and environment obtained the highest contaminative hazards.

In summary, the review of literature surrounding doffing protocols for full-body wear revealed numerous discrepancies with regards to the use of PPE and PPE protocols. Previous research demonstrated that the gown removal sequence proposed by the CDC and the IARM protocol are insufficient to protect HCWs from contamination during PPE donning and doffing (Beam et al., 2011; Casanova et al., 2008; Guo, Li, & Wong, 2014). To prevent the spread of infectious diseases, a common, universal PPE protocol is required, which should be validated through research. Currently, there is no standard PPE protocol or technique used by HCWs when treating patients with an infectious disease, which can lead to confusion, non-compliance, and non-adherence. In addition, research has not validated the PSHSA protocol commonly used across Ontario.

## Summary

In nursing, caring for patients with communicable diseases places workers at risk for infection (Hylton, 2011; McGolderick, 2015; Morales et al., 2014). Although PPE is a last line of defense against disease transmission from patient to worker, it remains an important strategy to protect workers (Beam et al., 2011; Casanova et al., 2008; Chiang et al., 2007; Hylton, 2011; McGolderick, 2015). Best practices for PPE usage includes educational training and operational training, which incorporates proper sequencing for donning and doffing of PPE. The importance

of PPE usage was underscored in the SARS outbreak in 2004 (Campbell, 2006). One of the distressing features of the SARS virus was the contamination of pathogens during PPE removal, causing accidental self-contamination and then personal infection, and infection spread to other admitted patients and/or HCWs (Campbell, 2006). The SARS outbreak instigated renewed efforts by organisations and institutions to better prepare for the potential of another outbreak.

The importance of this preparation was highlighted during the EVD pandemic in 2014. Given the virulent and deadly nature of EVD in particular, renewed efforts were made by organizations to ensure precautionary measures were taken by HCWs handling patients with infectious diseases. Specifically, the CDC created a training program for HCWs who provide care to patients with Ebola (Appendix E), which demonstrated how to apply and remove all components of the required equipment for managing these patients (CDC, 2015). PPE donning and doffing protocols were also established by other organizations including PSHSA (Appendix A; Appendix B), and WHO (Appendix F) in preparation for disease advancement (Campbell, 2006; CDC, 2014c; CDC, 2014d; PSHSA, 2014; WHO 2008). As described above, researchers have studied some donning and doffing protocols, namely the CDC and WHO protocols. However, the PSHSA protocol employs a different sequence for donning and doffing and has yet to be evaluated. Therefore, research is required to evaluate the effectiveness of the PSHSA protocol for the prevention of self-contamination.

## Purpose of the Study

The purpose of this research was to evaluate the effectiveness of the PSHSA acute care donning (Appendix A) and doffing (Appendix B) protocols in preventing skin and clothing contamination in nurses.

## Research Questions

Previous research was successful in determining contamination patterns for international protocols (Beam et al., 2011; Casanova et al., 2008; Guo, Li, & Wong, 2014; Mitchell et al., 2013). The PSHSA acute care donning and doffing protocols for EVD have yet to be evaluated; therefore, this study will address the following questions:

1) Are the PSHSA Acute Care Donning and Doffing Protocols for EVD effective in preventing contamination for HCWs in a simulated environment?
2) If the protocols are found to be ineffective, what changes can be suggested to improve the protocols?

# Chapter 2: Methods

The following methodology was primarily derived from previous scientific literature conducted to study American and International PPE protocols (Casanova et al., 2008; Beam et al., 2011; Guo et al., 2014). Laurentian University's Research Ethics Board approved the experimental methodology used in this study.

## Participants

Ten, female, third year university nursing students were recruited, through a convenience sample to participate in this study (Appendix I) (Gershon et al., 1995; McGovern et al., 2000). Participants provided informed consent (Appendix J).

## Study Design

This preliminary study used a cross-sectional design to simulate an isolation procedure. Results were obtained by measuring contamination post-doffing. First, participants were asked to visit the laboratory one for approximately one hour where they completed the following: consent form, a demographic questionnaire (Appendix K), and participation in a training session. The demographic questionnaire asked each participant to disclose their gender, age, year of study, prior training, prior experience with PPE, and type of PPE used. The training session is outlined below. For the simulation, PPE was applied and removed by participants, as per the PSHSA acute care donning and doffing protocols (Appendix A; Appendix B). Contamination was simulated using a GloGerm aerosol and simulated nursing movements were performed to mimic the spread of contamination. Upon completion of the simulation, participants answered an exit questionnaire.

## Instrumentation

### Personal Protective Equipment

The PSHSA acute care donning and doffing protocols are designed to be used when caring for a suspected or confirmed case of EVD in their care environment (PSHSA, 2014). In accordance with the protocol, the PPE used in this study included: a gown (brand: Kimberly-Clark; item #:KMB36150), gloves (brand: NitriClear; item #:51491, 51492, 51493), gloves with extended cuffs (brand: Cobalt; item #:51271, 51272, 51274), a face shield (brand: Medline; item #: NONFS300), a N95 respirator (brand: 3M ; item #:MMM1860), boot covers (brand: Kimberly-Clark; item #: KMB36811), foot coverings (brand: Condor; item #: CDR2RUZ3) a hood cover (brand: Dupont; item #: DUCIC668BWH001000B), and an apron (brand: Condor; item #: CDRDAP4A2842) (PSHSA, 2015).

For the selection of PPE to be used for this protocol, the PSHSA (2012) referred to the Provincial Infectious Diseases Advisory Committee (PIDAC) guidelines (Appendix L; Appendix M) (PIDAC, 2012). Each piece of equipment is disposable and regarded for once-only use. Each piece used for the simulation was scanned by the researcher to ensure the equipment was free of holes, punctures, or tears prior to and after the donning simulation.

### GloGerm

Two tablespoons of GloGerm powder was added to 300mls of water to resemble an aerosol contaminant (Guo, Li, & Wong, 2014). In order to simulate a situation where a high degree of bodily fluids are transferred to a HCW during an isolation procedure, the GloGerm was sprayed onto the participants at a distance of 30 cm (from the spray nozzle to the participant), on the following locations: the chest, sternum, right and left palm, top of left and right hand, frontal quads, frontal lower leg, buttock, and plantar areas. A body map indicating the locations is included in Appendix N. Similar studies (Casanova et al., 2009; Guo et al. 2014) sprayed

GloGerm contamination on fewer locations, however, the current study sprayed contamination on multiple body sites. Spraying multiple sites simulated an environment where a high-degree of bodily fluid contamination occurs, which allowed the research team to gather insight on the effectiveness of each step of the protocols.

**Ultraviolet Light**

An ultraviolet (UV) lamp (model: BioRad1660500) was used to detect the GloGerm transfer on the body of the participants, the PPE, and the surrounding environment. The florescent strain simulated strains on contamination in this study. The UV lamp was tested and checked prior to commencing the study and was used for the entire duration of the study to avoid contradictory results during the examination.

**Video Recorder**

Video recording has previously been used to evaluate infection control behaviors (Beam et al., 2011; Chiang et al., 2008; Hassan et al., 2009). This allows the research team to play back the donning, simulated movements, and doffing sequencing conducted by each participant for a careful examination of events. Therefore in this study, each donning and doffing simulation was recorded using a digital video recorder. The playback was used to identify potential and actual contamination events that could or did occur during the donning and doffing protocol steps and or sequences.

**PPE Checklist**

Each participant had access to the PSHSA acute care donning (Appendix A) and doffing (Appendix B) protocols along with a trained observer who read each step aloud. The 12-step donning checklist included: hand hygiene, gown application, N95 respirator application, face shield/hood cover application, footwear application, and glove application and the 12-step doffing checklist demonstrated how to remove the equipment mentioned above. Both checklists

were designed to ensure that PPE application and removal steps are performed as outlined in the PSHSA guidelines, which provide directives to prevent self-contamination when treating patients with an infectious disease such as EVD.

## Resources

### Trained Observer

During patient care for a suspected or confirmed case of EVD, a trained observer (TO) must be present in order to supervise each step of every PPE donning/doffing procedures (CDC, 2015b; CDC, 2015c). In this study a TO was present during each donning and doffing simulation and they were responsible for aiding the participant in following the PPE donning sequence, assisting the participant with gown application, observing PPE for breaches, and looking for potential environmental contamination. If a breach was observed, the TO was instructed to provide corrective instruction to the participant.

### Training Session

Each participant and TO took part in a 1-hour training session, facilitated by the researcher, to review how to don and doff PPE prior to participating in the donning and doffing simulation. In the training session, the participants viewed a PowerPoint presentation containing segments from the CDC PPE donning and doffing training video (CDC, 2014e); however, the order to PPE donning in the CDC training video was modified to align with the PSHSA donning checklist PPE sequence. The MOHLTC refers to the CDC in their emergency management plan (MOHLTC, 2016a). The training video demonstrated how to properly put on and remove each piece of PPE required according to the PSHSA donning checklist. The training video was also viewed and verified by the co-creator of the PSHSA acute care donning and doffing protocols for accuracy prior to the participants attending the training session. Each donning and doffing step was explained in this video and a visual demonstration showed participants how to safely don,

adjust, use, and doff the PPE required in the PSHSA donning and doffing checklist. The training video also outlined the environmental zones of contamination. The zones of contamination help identify the level of contamination (low, medium, high) in a particular area. A green zone indicates a clean zone, where contamination is unlikely, a yellow zone indicates a treatment zone where contamination is possible, and a red zone is an area of significant contamination (Occupational Safety and Health Administration, 2015).

Twenty-two days elapsed between the training session and the donning and doffing simulations.

## Data Collection

### Zones of Contamination

The room used for this study was separated into 3 distinct zones of contamination: red, yellow and green (Figure 2). These zones indicated the level of risk, based on the contamination suspected to be present (Occupational Health and Safety Administration, 2005). The red zone is an area contaminated with pathogens, the yellow zone is in adjacent to the contamination zone (red) and the green zone is an area beyond the dispersal range of the contamination (Occupational Health and Safety Administration, 2005). The green zone was scanned using the UV light and disinfected prior to each donning and doffing simulation. The chairs in each zone were also cleaned using an alcohol based disinfectant wipe.

In this study, the PPE used was stored in and donned in the green zone. The GloGerm application and simulation exercises took place in the red zone. Highly soiled PPE were doffed in the red zone including: boot covers, apron, and outer gloves. The remaining PPE was removed in the yellow zone including: face shield, hood cover, gown, foot covering, inner gloves, N95 respirator.

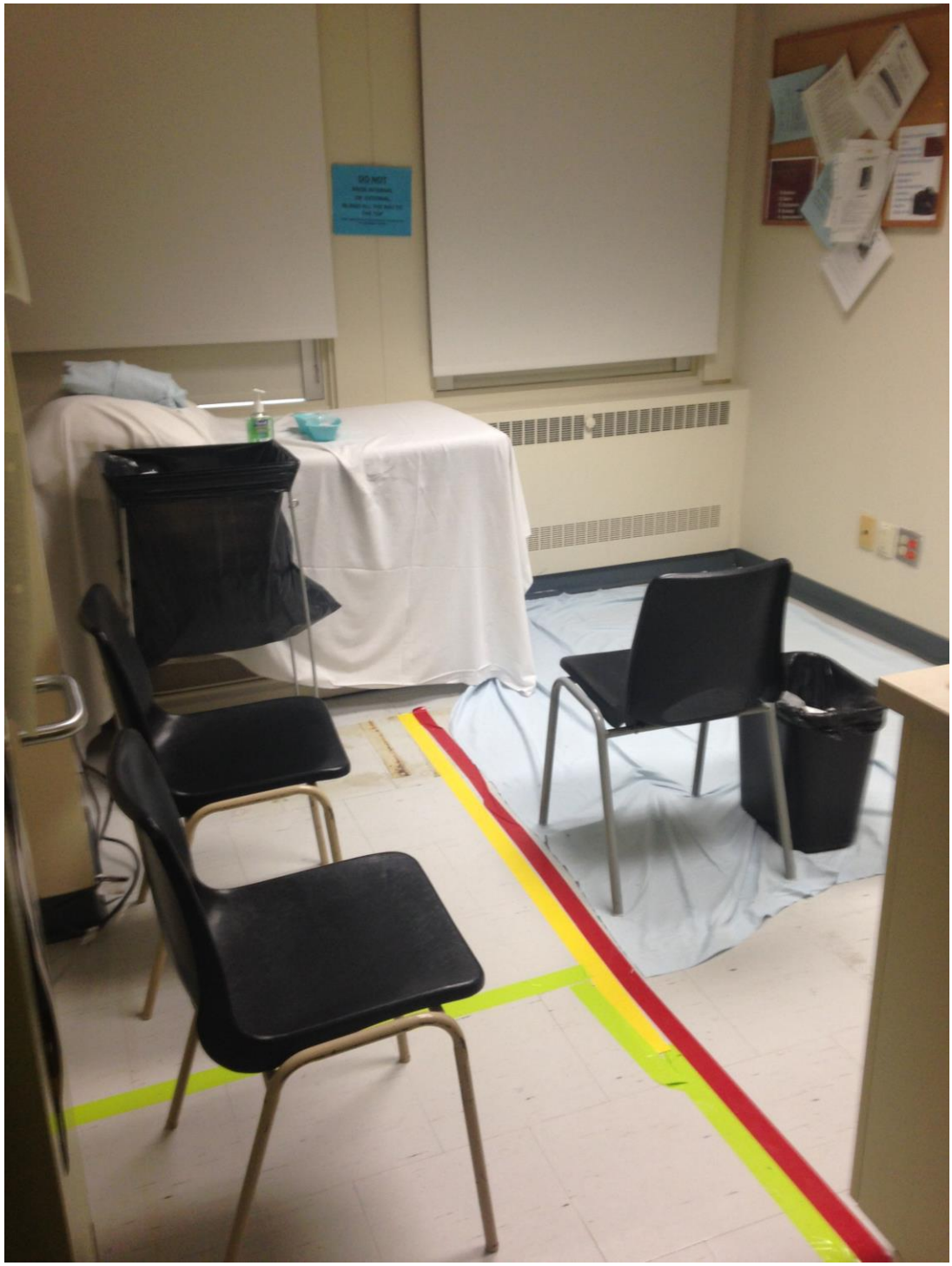

*Figure 2*: Examination room and contamination zone separation. Donning occurred in the green zone, where contamination was unlikely. Participants then entered the red zone, where they were sprayed with GloGerm, produced the simulated movements, and began the doffing process. The first three steps of the doffing protocol occurred in the red zone and the remaining equipment was doffed in the yellow zone. Once they were free of contamination and PPE was removed, participants re-entered the green zone for the UV scan.

**Procedure**

An examination room with video capability in the University nursing department was used for the donning and doffing simulations. Prior to each simulation, the clean zone (green zone) was screened using a UV light to ensure that no fluorescence was present. Fluorescent molecules including lint, residual GloGerm, dust, and dirt, were cleaned using an alcohol-based disinfectant wipe. The participants were also screened using the UV light in order to ensure that their clothing and skin were clear of fluorescence. This was done to ensure that other fluorescent materials on their clothing or skin were not confused with GloGerm during the post-doffing screening process. Participants were asked to bring two pairs of scrubs to the simulation, and when too much lint was present on the clothing, they were asked to change into a different pair.

Screening occurred using a UV light screening protocol (Appendix O) produced by the National Criminal Justice Information System (2015). Scanning started at the top of one shoulder and swept down one side of the front of the torso, down the leg to the ankle, then back up the front of this opposite leg and torso, ending with the opposite shoulder (National Criminal Justice Information System, 2015). The side of the arms, legs, and inner legs were then scanned, followed by a scan of the hands, wrists, and feet (National Criminal Justice Information System, 2015). Any fluorescence observed during the pre-scan was noted by location and size and removed using an alcohol based disinfectant wipe. Size was measured in millimetres using a circle stencil template. Once the scan was complete, donning began.

Each participant was asked to read the donning (Appendix A) and doffing (Appendix B) checklists. They had access to them throughout the donning and doffing process. The TO had the checklist in hand and ensured that each step of the protocol was followed accordingly by reading them aloud. Once the equipment was donned (Figure 3), the PPE was examined by the TO, to ensure that no breach was present, which is part of the verification step of the protocol (last step).

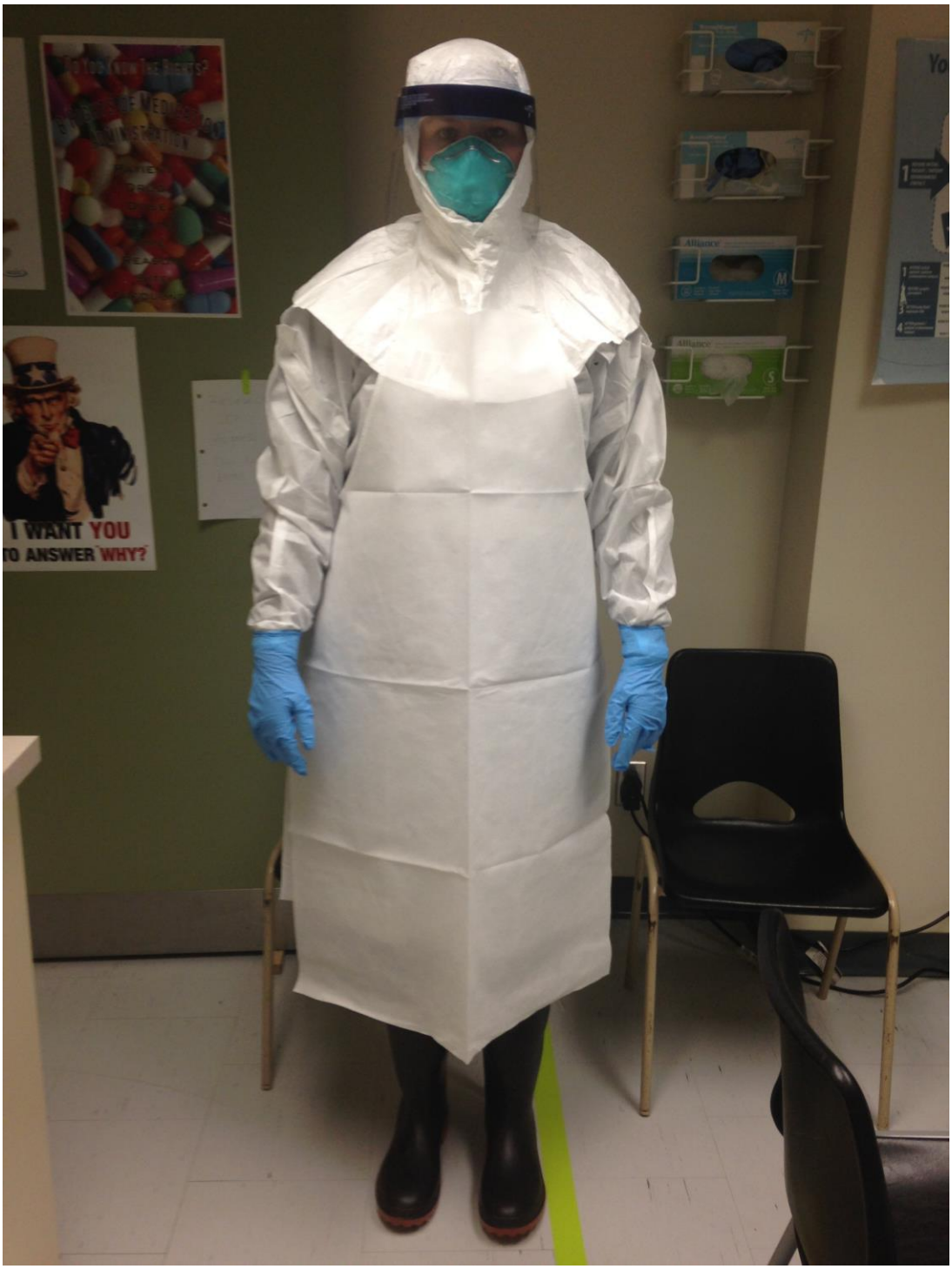


*Figure 3:* PPE donned. Illustrates Example of a participant with the PPE donned and currently standing in the green (clean) zone.

After the PPE was cleared of breeches and contamination by the TO, the participant entered the contaminated area (red zone), where they were sprayed with GloGerm by the researcher. Spraying did not contaminate the green or yellow zone. In order to simulate the transfer of contamination and potential PPE breaches, participants produced simulated nursing movements. These included raising the arms, twisting their torso to the side, and bending at the hip to replicate actions that are usually performed while providing patient care (Appendix P).

The participant then commenced the doffing process and was again, guided by a TO. As per the doffing protocol, the apron, outer gloves, and outer footwear were removed in the red zone. Once these items were doffed, participants entered the preparation zone (yellow zone). They doffed the remainder of the PPE in accordance with the directives listed in the PSHSA doffing protocol. Once the PPE was removed, the participant re-entered the clean zone where they were thoroughly examined for contamination using a UV light screening protocol (Appendix O) (National Criminal Justice System, 2015). Each step of the procedure is demonstrated chronologically in Figure 4.

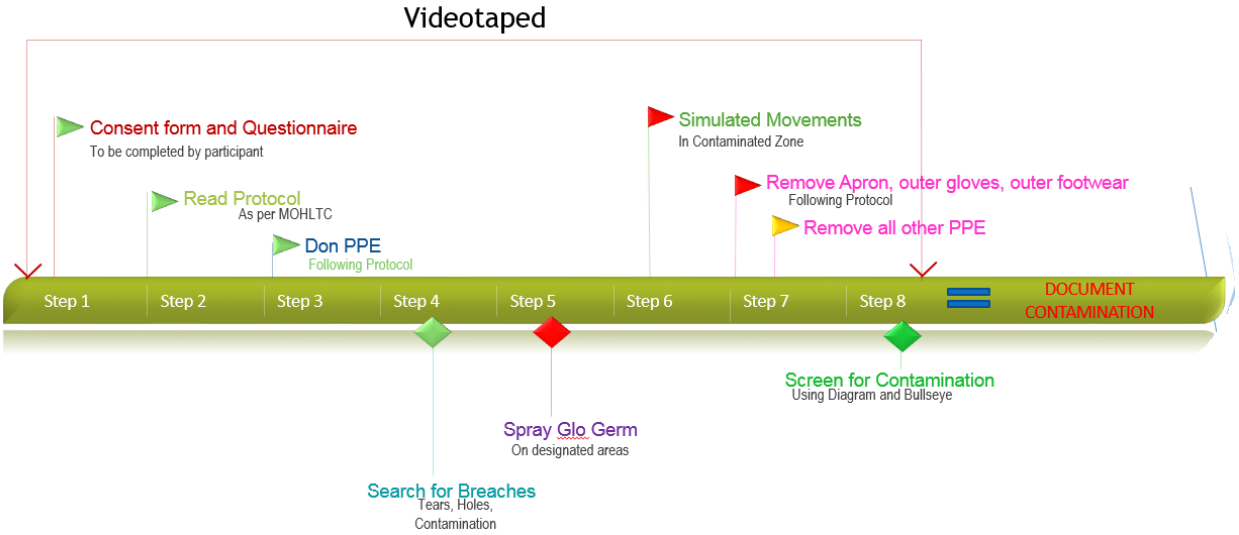


*Figure 4:* Study sequence. Illustration of the order of steps in this PPE study.

**Documenting Contamination**

Each area of contamination was noted by their size (in mm) and location using a circle stencil template (Figure 5).


*Figure 5:* Circle stencil template. Illustrates Stencil template used in study, measured in millimeters.

The location of the contamination was also documented on a body map that included 35 locations ranging from the face to the plantar area of the foot (Appendix N). When documenting contamination, the anatomical features of the location were also noted for precision (i.e. contamination found on greater tuberosity of shoulder), and a digital picture of the contaminated area was taken.

### Near-Miss Incidents

As per the National Safety Council definition (2013), near-miss incidents were defined as "*an unplanned event that did not result in injury, illness, or damage - but had the potential to do so*" (p.1). Near-misses were observed and noted by the primary researcher and TOs during the donning and doffing simulations when participants experienced breaches; failed to follow the recommended PSHSA procedures; or performed a donning or doffing step incorrectly. Near-miss incidents were also observed in the video recordings, which were played back to identify potential near-miss incidents. The near-miss incidents noted did not result in contamination.

## Data Analysis

Participant demographic information was summarized and percentages were calculated. The number of participants who experienced contamination were also reported and percentages of contaminations were calculated.

### Content Analysis

Data were also collected through an exit questionnaire, which asked participants and TOs if they had any comments or concerns about the donning or doffing protocols. Responses for both the TOs and the participants were analyzed using content analysis (Boyatzis, 1998; Granaheim & Lundman, 2004). Content analysis is used to determine the presence of certain words or concepts within texts or sets of texts. The responses to the exit question for both the

TOs and the participants were reviewed and sorted into categories. This method was previously used by Granaheim & Lundman (2004) for nursing research and education.

To analyse the exit questions, each answer was read and categorized in a way that offered a description of the comments. Major categories were created (pre-donning instructions, donning instructions, and doffing instructions) that allowed every answer to be linked. Minor categories (i.e. N95 respirator; outer footwear) were also created within each major category. Comments within each major and minor category was reviewed to ensure that each comment was sorted into the appropriate category and to ensure its relevance.

# Chapter 3: Results

The primary objective of this research was to determine the effectiveness of the PSHSA acute care donning and doffing protocols in preventing skin and clothing contamination. Results were obtained based on the observation and documentation of the PPE donning and doffing processes in an EVD simulated healthcare isolation scenario. The first section of this chapter describes the sample, followed by demographic information of the participants (N=10). The next sections present the results for participant donning and doffing simulations including the size and location of the contamination. Following this, near miss incident findings are presented. The last section presents the common categories developed from the participant's comments followed by a summary.

## Demographic Questionnaire Results

A total of 10 female third year Bachelor of Science in Nursing students (P) were recruited for this preliminary study. Participant ages ranged from 18 to 26 years old (18-20=50%; 21-23=30%; 24-26=20%) with the majority being between 18-20 years old. All participants reported that they had previous PPE training, with 9 reporting training in the school laboratories through their educational program, 8 reporting training during clinical placements, and 7 reporting training at work. Participants reported some familiarity with all PPE used in the current study with the exception of the hood (Figure 6).

The participants spent between 11 and 30 hours per week performing patient care (11-20=55.6%; 21-30=33.3%; 30+=11.1%). Nine participants stated that were had previously practiced donning and doffing over 16 times and one participant only practiced donning and doffing 6-10 times.

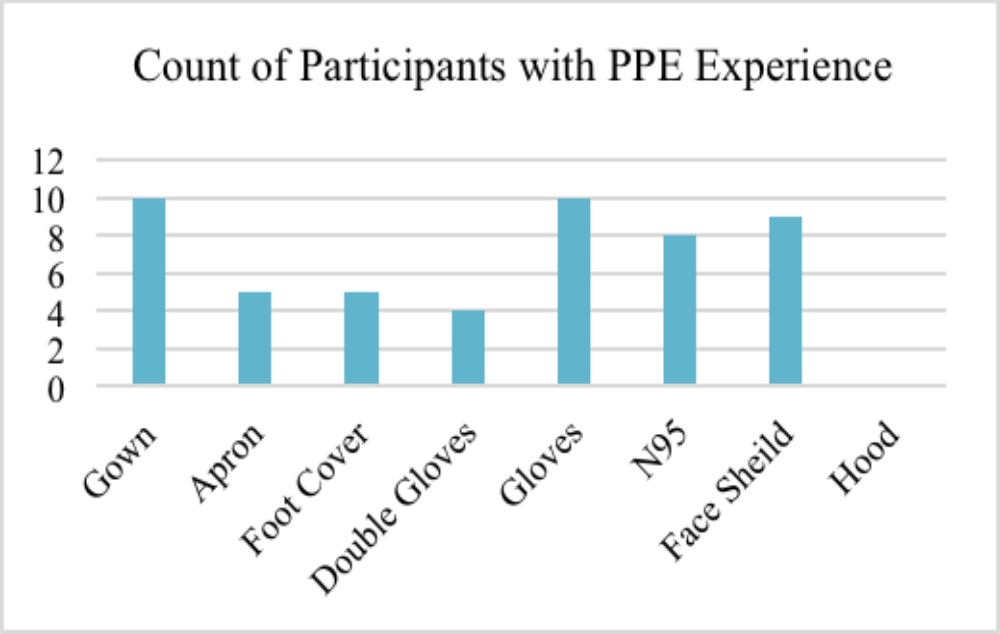


*Figure 6:* Number of participants with previous experience using each type of PPE. One hundred percent of the participant had experience donning and doffing a gown and gloves, 90% had experience with a face shield, 80% had experience with an N95 respirator, 50% had experience with the apron and the foot coverings, and 40% had experience with the double gloves

**Pre-Scan Fluorescence**

Prior to the donning process, each participant was scanned using a UV light to identify the presence of lint or other florescence not to be mistaken for GloGerm post-doffing. A lint roller was used to remove lint on 40% of participants (P1, P3, P4, P9). One participant (P9) was asked to change into a different pair of scrubs since 3 areas of fluorescence were observed on their clothing.

Florescence was observed on the skin of 2 participants (P4, P7). In the case of P4, florescence was on the left middle finger (2.0mm) and on the right palm (1.8mm). P7 had florescence on the left thumb (5.2mm), the left index (4.8mm), and on the right middle finger (3.2mm). Their hands were cleaned using an alcohol based disinfectant wipe to remove the fluorescence and re-scanned to ensure full removal of fluorescence.

## Contamination Detection

Results revealed that 40% of the participants (P) had at least one region of contamination subsequent to doffing PPE using the PSHSA protocol (Table 1). The size of the contaminations ranged from 1.6mm to 77.9mm with the average size of contamination being 36.5mm (Figure 7). Three participants (33%) experienced contamination on the lower limbs: on the left dorsal lower leg (P2: 41.3mm), left heel (P5: 9.5mm), left dorsal lower leg (P6: 64.0mm), and the right dorsal lower leg (P6: 77.9mm) (P6 had two lower limb contaminations). Two participants also experienced contamination on the upper body: on left scapula (P1: 38.1mm), left index finger (P6: 2.8mm), right middle finger (P6: 1.6mm), and right buttock (P6: 57.2mm) (P6 had three upper limb contaminations) (Table 1).

Equipment failure was found on the equipment worn by participant 6, including: the gown; which did not provide coverage posteriorly, as a result of improper donning and verification; and a tear in the right outer glove.

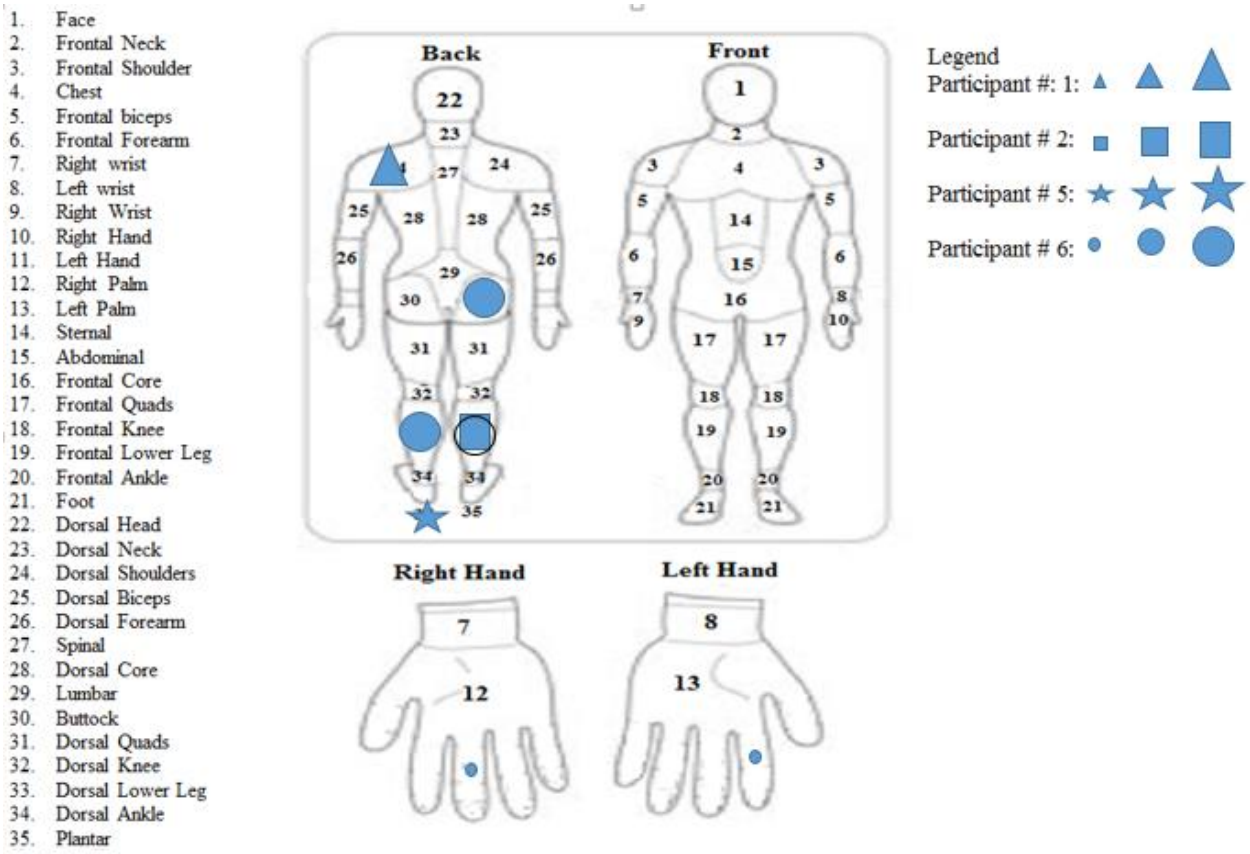


*Figure 7:* Summary of contamination observed post doffing PPE according to the PSHSA protocol. The numbers on the figure correspond to regions on the body (legend on the right). The shape and size of the icon refer to the participant and size of the measured contamination (legend top right corner). The small shapes indicate contamination between 0.1-5mm, medium shapes indicate 5.1-10mm contamination, and large shapes refer to contamination greater than 10mm.

Table 1

*Summary of Doffing Events Surrounding the Observed Contamination. The contamination event detected on each participant is demonstrated, which includes the protocol step in which it occurred, by the location, and by the size.*

| **Participant #** | **Protocol Procedure** | **Contamination** | **Location and size of contamination** |
|---|---|---|---|
| 2 & 5 | 2.1: Remove outer footwear and/or foot coverings carefully to avoid inadvertent contact or cross-contamination | P2: When the left rubber boot was removed, the participant's calf rubbed the upper boot cover and outer footwear.<br><br>P5: The participant removed the right rubber boot using the hands rather than sliding it off. | P2: Left Dorsal Lower Leg – 41.3mm<br><br>P5: Left Plantar – 9.5mm |
| 6 | 3.3: Inspect inner gloves for visible contamination, cuts, or tears. | The participant punctured the right outer glove while pulling on it with the left hand. | Left index finger – 2.8mm<br><br>Right middle finger – 1.6mm |
| 1 | 6.2: unzip or unfasten overall/gown completely before rolling down and turning inside out. | To doff the gown, the participant grabbed the gown at the left scapular area. | Left Scapula – 38.1mm |
| 6 | 12.1: Verify donning and doffing procedure to ensure that full coverage has been achieved | A breach in equipment was observed during the donning stage. This breach consisted of the gown not being properly secured at the back and it was exposed. The breach was not detected by the trained observer and the participant was sprayed with GloGerm as per the protocol. | Right Buttock - 57.2mm<br><br>Right Dorsal Lower Leg -77.9mm<br><br>Left Dorsal Lower Leg – 64.0mm |

## Near-Miss Incidents during PPE Donning and Doffing

In the current study, a near miss referred to incorrect donning or doffing, or a breach with the equipment that did not result in contamination, but had the potential to do so. A breach of equipment refers to a tear of the equipment, or the equipment failing to cover the skin or clothing of the participant. Every participant (N=10) experienced a near-miss incident. Near-miss incidents were observed in nine of the 24 steps in the protocol. Eighty percent of the participants experienced more than one near-miss incident (Table 2 and Table 3). Only one participant (P9) had more than one near miss incident in the donning phase (Table 2) and one had more than one near-miss during the doffing phase (P7) (Table 3).

With regards to the donning protocol, near-misses were seen once in step 1 (introduction), once in step 2 (donning boot cover), seven times in step 5 (donning gown), and twice in step 7 (donning N95 respirator). In the donning simulations (Table 2), the most common near-miss incident consisted of incorrectly tying the gown during step 5. Seventy percent of participants tied the gown at the back, rather than the side. Wrongful application of the N95 respirator was also an area of difficulty for 20% of participants, as the straps were crossed at the back. This means that the top strap was applied before the bottom strap. Incorrectly tying the hair and problems securing the boot covers were also noted as a near-miss incident for one participant.

With regards to the doffing protocol, near-misses were noted three times in step 2 (doffing outer footwear), once in step 4 (doffing face shield), once in step 7 (doffing boot cover), three times in step 10 (doffing N95 respirator), and once in the verification stage. During the doffing simulations, 30% of participants incorrectly removed the N95 respirator by pulling on the front to remove it (Table 3). Since the front of the N95 respirator is exposed to pathogens, it is considered contaminated. Another area of difficulty was the removal of the outer footwear,

which occurs in the second step of the doffing protocol. Thirty percent of the participants incorrectly doffed the outer footwear by either pulling on the boot with their hands, or unfastening it at the heel with the toe. Unfastening the boot at the toe is considered a near-miss incident due to the fact that the boot covers could become contaminated, which increases the likelihood of self-contamination. Touching the front of the face field, incorrect doffing of the boot covers, and a breach of equipment was also noted as a near-miss incident for one participant.

Table 2

*Summary Descriptions of Near-Miss Incidents during Donning. The protocol instructions indicates the exact wording in the PSHSA donning protocol. The near-miss incident indicates the discrepancy between the donning protocol instruction and the action produced by the participant.*

| **Participant #** | **Protocol Instruction** | **Near-Miss Incident** |
|---|---|---|
| 6 | Donning<br>Introduction: before you begin… tie back long hair and secure in place. | Hair was not tied back properly |
| 10 | Step 2 (don boot cover):<br>2.1: Select boot cover that extends to at least mid-calf<br>2.2: Ensure boot covers allow for ease of movement<br>2.3: Adjust and verify for proper fit | While in the yellow zone, the boot covers were sliding off feet |
| 1,3,4,5,7,8,9 | Step 5 (don gown):<br>5.4: Seal opening of coverall/gown and ensure no skin or clothing is exposed | Gown was tied in the back rather than on the side |
| 2 & 9 | Step 7 (don N95 respirator):<br>7.1: Apply respirator as per manufacturer's user instructions. | Straps of the N95 respirator were crossed at the back |

Table 3

*Summary Descriptions of Near-Miss Incidents during Doffing. The protocol instruction indicates the exact wording in the PSHSA doffing protocol. The near-miss incident indicates the discrepancy between the doffing protocol instruction and the action produced by the participant.*

| **Participant #** | **Protocol Instruction** | **Near-Miss Incident** |
|---|---|---|
| 2, 5, & 8 | Doffing<br>2.1: Remove outer footwear and/or foot coverings carefully to avoid inadvertent contact or cross-contamination | P2 & P5-Participant used left hand to remove right rubber boot<br>P8 - Participant used the tip of the toes to unfasten the opposing rubber boot at the heel |
| 7 | Step 4 (doff face shield):<br>4.1: Hold face shield or goggles by grasping band at the back of head and gently lifting over head and away from face. | Participant touched the front of face shield with inner gloves while doffing |
| 4 | Step 7 (doff outer footwear):<br>7.1: Remove outer footwear and/or foot coverings carefully to avoid inadvertent contact or cross-contamination | Participant grabbed the boot covers from the inside at the region of the calf rather than the outside |
| 1, 7 & 3 | Step 10 (doff N95 respirator):<br>10.1: Grab bottom strap and lift over head<br>10.2: Lean forward and grab top strap; gently lift over head and away from face<br>10.3: Take care not to touch the front of the respirator | Participant grabbed the N95 respirator from the front to remove it |
| 9 | N/A | Gown unfastened while doffing foot coverings, leaving back and buttock exposed for the remainder of doffing |

## Exit Question Results

Content analysis was used to describe the participant and TO comments and/or reflections related to each of their experiences donning and doffing PPE using the PSHSA protocols. Prior to exiting, the participants were asked: "*do you have any comments or concerns about the donning or doffing protocols*?" The comments were separated into three key categories: pre-donning instructions, donning protocol, and doffing protocol. Table 4 and Table 5 include exit question answers from the participants and reflections from TOs regarding the donning and doffing protocols, respectively.

### Pre-Donning Introductions

The PSHSA acute care donning protocol included a short introduction with the following information:

"*Note: establish clearly defined zones (e.g., hot, warm, and cold) and protocols to prevent and control secondary contamination during doffing*" (PSHSA, 2014, p.1)

The TOs suggested this step should be clarified and the zones of contamination should be clearly listed in the protocol:

"indicate zone in protocol" (TO1)

"Color code zones" (TO2)

The introduction also notes: "*Before you begin, instruct HCW(s) to don point-of-care scrubs and footwear, hydrate, tie back long hair and secure in place, and remove personal items such as hand and wrist jewellery…Ensure that the correct size is selected*"

These introduction directives are not listed as part of the 12-step checklist. While the equipment ordered was indicated to be appropriate for all workers (one-size fits all), some participants had concerns:

"[ensure] proper fit for each person (I personally am tall)" (P9)

"I think the boots could go higher for better coverage of lower legs" (P6)

In addition, participants and trained observers expressed that the improper treatment of hair affected their ability to effectively don and doff PPE.

"Recommend buns for long hair" (P9)

"Make sure hair is tucked" (TO2)

According to 20% of the participants and one trained observer, a mirror could be beneficial to donning and doffing:

"Needed a mirror, could not easily find the ties on anything" (P2)

"Recommend… mirror for checking for each step" (P9)

"Recommended to provide participants with mirror" (TO3).

Participants also commented on the importance of the TO for proper sequencing during donning and doffing:

"The workers were a great help" (P4)

"Trained observer was crucial to effective donning and doffing of PPE" (P10)

They felt the trained observers were imperative for safe procedures and for correct use of the protocol.

**Donning Protocol**

A concern noted in the exit questionnaires was the lack of detail in the donning protocol with regards to the application of the N95 respirator (step 7):

"Wrong application of the N95 respirator…put N95 respirator instructions (bottom strap first" (TO1)

This was also confirmed in the near-miss incidents (Table 2).

**Doffing Protocol**

A concern noted in the exit questionnaires was inadequate detail in the doffing protocol. Specifically, step two, which is the removal of the outer footwear, was a recurring mention in the questionnaire as it was referenced in four different responses. To remove the outer footwear, participants were advised to sit on the chair in the red zone, remove their boots, and then slide their feet into the yellow zone. One participant noted that the "swinging of legs" (P3) was troublesome and others did not understand how the outer footwear should be removed, indicating:

> "[participant] used feet to remove boots on chair" (TO1)
>
> "Can [participant] touch boot?" (TO2)

Participants and trained observers also expressed that the protocol was inadequate in terms of protecting the feet against contamination when the boots and foot coverings are removed:

> "After removing boot covers, we stay in the same area - if our boot covers where contaminated then our socks/bottom of pants would be too" (P8)

Step six, untying the gown was another area of concern. Two participants noted that it was difficult to remove the tie at the back of the gown during doffing. For example:

> "Gowns tied in back, often no one to help. No person observing in real setting. Rushed in real life" (P1)
>
> "Gown touched neck; trouble untying" (TO1)
>
> "Could not easily find the ties on anything face mask included" (P2)

In addition, hand protection was noted as being a source of concern during this study. As per PSHSA recommendations, nitrile gloves were used for both the inner and outer gloves. The PSHSA also suggests that two different colours of gloves be used for ease of doffing. This

increases awareness of perforation. While these guidelines were followed for this study, the following comments were noted:

"It is very difficult to remove gloves of same material" (P5)

"Wrists need to be cleaned with hand rub" (TO1)

In summary, participants and TOs made suggestions for the introductory paragraph, the donning protocol and the doffing protocol. Common suggestions that emerged within the introductory paragraph includes 1) clearly defining zones using a color coding system, 2) ensuring proper fit of the equipment prior to commencing donning, 3) ensuring proper treatment of hair, providing a mirror for ease of donning, and 4) ensuring availability of a TO. Comments with regards to the donning protocol were a lack of N95 directives. Comments made to the doffing protocol include 1) confusion with regards to the outer footwear, 2) tying the gown, and 3) removing outer gloves.

Table 4

*Donning Protocol Exit Question Answers from the Participants and Trained Observer Reflections*

| **Protocol Procedure** | **Trained Observer Quote** | **Participant Quote** |
|---|---|---|
| Donning: Introduction<br>Before you begin, instruct HCW(s) to don point-of-care scrubs and footwear, hydrate, tie back long hair and secure in place, and remove personal items such as hand and wrist jewellery. Gather and inspect PPE carefully. Enough that the correct size is selected and that the PPE is in good sanitary and working condition. Damaged or defective PPE should not be used. | • "Make sure hair is tucked" (TO2) | • "Proper fit for each person (I personally am tall), recommend buns for long hair" (P9)<br>• "Trained observer was crucial to effective donning and doffing of PPE" (P10)<br>• "The [trained observers] were a great help" (P4)<br>• "I think the boots could go higher for better coverage of lower legs" (P6) |
| Donning: Section 7<br>Put on fit-tested N95 respirator:<br>☐ Apply respirator as per manufacturer's instructions<br>☐ Fit flexible nose piece to bridge of nose<br>☐ Perform seal check | • "Put N95 respirator instructions (bottom strap first)" (TO1)<br>• "Wrong application of the N95 respirator" (TO1) | |

Table 5

*Doffing Protocol Exit Question Answers from the Participants and Trained Observer Reflections*

| **Protocol Procedure** | **Trained Observer Quote** | **Participant Quote** |
|---|---|---|
| Doffing: Introduction<br>Before you begin, instruct HCW(s) that PPE must be removed slowly and carefully within each appropriately designated zone (i.e moving from hot to warm to cold as per organizational set up) and utilizing the room configuration to minimize cross-contamination. | • "Color code zones" (TO2)<br>• "Indicate zones in protocol" (TO1) | |
| Doffing: Section 2<br>Remove outer footwear and/or foot coverings:<br>☐ Remove outer footwear and/or foot coverings carefully to avoid inadvertent contact and cross-contamination<br>☐ Take care not to slip or fall; use chair as needed<br>☐ Dispose into designated waste container | • "[Participant] used feet to remove boots on chair" (TO1)<br>• "mention [section 2.2] in [section 2.1] instead" (TO1)<br>• "Can [participant] touch boot?" (TO2) | • "swinging of legs" (P3) |
| Doffing: Section 3<br>Remove outer gloves:<br>☐ Remove outer gloves taking care not to touch inner gloves or bare skin<br>☐ Dispose into designated waste container<br>☐ Inspect inner gloves for visible contamination, cuts, or tears | • "Inner glove came off while taking off outer glove" (TO1) | • "It is very difficult to remove gloves of same material" (P5) |

Table 6

*Doffing Protocol Exit Question Answers from the Participants and Trained Observer Reflections*

| | | |
|---|---|---|
| Doffing: Section 6<br>Remove coverall/gown:<br>☐ Trained observer may assist but must be donned in adequate PPE based on risk<br>☐ Unzip or unfasten coverall/gown completely before rolling down and turning inside out. Avoid contact of inner clothing with outer surface of coverall during removal, touching inside the coverall/gown only<br>☐ Dispose into designated waste container | • "Gown touched neck; trouble untying" (TO1) | • "Gown tied in back, often no one to help. No person observing in real setting. Rushed in real life" (P1)<br>• "Needed a mirror, could not easily find the ties on anything face mask included" (P2) |
| Doffing: Section 7<br>Remove boot covers:<br>☐ Remove boot covers carefully to avoid inadvertent contact and cross-contamination<br>☐ Take care not to slip of fall; use chair as needed<br>☐ Dispose into designated waste container | • [participant] did not sit on clean chair (TO2)<br>• "mention [section 7.2] in [section 7.1 instead]" (TO1) | • "After removing boot covers, we stay in the same area – if our boot covers were contaminated then our socks/bottom of pants would be too" (P8) |
| Doffing: Section 9<br>Perform hand hygiene:<br>☐ Use alcohol-based rand rub (ABHR) or soap and water<br>☐ Allow hands to dry completely | "wrists need to be cleaned with hand<br><br>rub" (TO1) | |

# Chapter 4: Discussion

This study explored whether the PSHSA Acute Care Donning and Doffing Protocols for EVD are effective in preventing contamination for HCWs in a simulated environment. This section presents and discusses the key findings obtained from the donning and doffing simulations. In this section the factors influencing contamination will be explored and suggestions for improving the current protocol will be presented. A discussion of the study's limitations and future studies conclude this chapter.

## Contamination Analysis

Contamination was observed based on the presence of GloGerm on the skin or clothing of the participants. The current study found eight different contaminations ranging from 1.6 mm to 77.9mm in size. In this study, three participants (30 %) had contamination in one location post doffing, while one participant (10 %) had contamination over five different locations, although this participant also experienced equipment failure of two components of the PPE worn (glove and gown). Studies examining the effectiveness of other PPE protocol reported similar contamination results (Beam et al., 2011; Casanova et al., 2008; Guo, Li, & Wong, 2014). Casanova et al. (2008) found contamination on 100% of participants when analysing the effectiveness of a CDC protocol (Appendix C), with the scrubs (100%) and the right hand (90%) experiencing the greatest number of contaminations. It is important to note that the CDC and the PSHSA use the same technique for donning and doffing PPE. The difference between the CDC and PSHSA protocol is the sequence in which the PPE is applied and the amount of detailed instruction in each respective protocol, even though both protocols use a TO. While the PSHSA created the protocol analysed in the current study in collaboration with the MOHLTC, they refer to the CDC for proper procedures for each piece of PPE. Guo, Li, and Wong (2014), also studied the CDC protocol and found that participants (n=50) had an average of 1.58 to 2.48 florescent

strains on their clothing subsequent to doffing PPE. Finally, Beam et al. (2011), found fluorescence marker contamination on 80% of participants following the completion of a simulation experience. Six participants had contamination on the hands, three on the back of the head, and one on both the hands and the head (Beam et al., 2011).

**Contamination due to Incorrect Doffing Procedure of Gown**

In the current study, a participant (P1) experienced contamination to the left scapula (38.1mm). The donning and doffing video showed the participant grabbing the gown at the left scapular area, pulling until the left arm was free from the sleeve, and rolling the gown until it was completely away from the body. According to the CDC and the PSHSA donning checklist the proper method for gown removal is the following:

> *slip the fingers of one hand under the cuff of the opposite arm. Pull the hand into the sleeve, grasping the gown from inside. Reach across and pull the sleeve off the opposite arm. Fold the gown towards the inside and fold or roll into a bundle. Only the "clean" part of the gown should be visible (*CDC, n.d., slide 35).

Casanova et al. (2008) concluded that the amount of virus recovered from scrub shirts was significantly greater than that recovered from pants ($p=0.01$), possibly because of contact with hands when the gown is pulled away from the shoulder during removal. In a similar study, Babb, Davies, and Ayliffe (1983) recovered bacteria from 12.6% of gowns and 9.2% of aprons following contact with ill patients. Fewer bacteria were recovered from the uniform when aprons instead of gowns were worn, but gowns offered better shoulder protection. This validates the importance of the gown for contamination prevention. Beam et al. (2011) claimed that touching a soiled gown could easily transfer microorganisms to the patient's face or hands, which resulted in 80% of their participants becoming contaminated. Touching a soiled gown could result in exposure to garments and later, aerosolization of infectious particles, which could have occurred in the current study. Since the participant (P1) grabbed the gown from the back rather than the

cuff or the front of the shoulder, it could have increased the probability of contaminating the scapula (Table 1).

**Contamination to Lower Limbs due to Incorrectly Doffing Outer Footwear**

In the current study, P2 contaminated the left dorsal lower leg (41.3mm) whereas P5 contaminated the left plantar region (9.5mm). It is important to note that both of these participants used an incorrect doffing procedure and used the hands to remove outer footwear rather than sliding off the boots. This could have increased the probability of becoming contaminated

Specifically, the video recordings show that P2's calf rubbed on the upper boot cover and outer footwear during doffing. P5 removed the left rubber boot first and proceeded to slide the left foot into the yellow zone, all while keeping the right foot in the red zone. The participant then removed the right rubber boot using the gloved hands rather than slipping it off. At this point, contamination could have occurred to the right foot covering, since it was in slight contact with the edge of the rubber boot.

Standardized PPE including outer footwear would help to eliminate concerns of contaminating personal clothing (CDC, 2015c). Similar studies did not evaluate contamination to the lower limbs. However, scientific literature shows that hospitals floors are contaminated with resistant bacteria, making patients and HCWs susceptible to contamination (Dancer, 2009; Eckstein et al., 2007; Goodman et al., 2008; Thom et al., 2013). University of Maryland School of Medicine researchers found Acinetobacter baumannii bacteria on 16% of hospital room floors (Thom et al., 2013). Similar studies examined nosocomial pathogens on hospital floors and found the presence of Staphylococcus aureus, vancomycin-resistant Enterococcus, and Clostridium difficile (Dancer, 2009; Eckstein et al., 2007; Goodman et al., 2008; Thom et al., 2013). Scientific literature surrounding each of these illnesses suggest that more emphasis needs

to be placed on the cleaning and disinfection of floor surfaces and use of adequate protective footwear (Dancer, 2009; Eckstein et al., 2007; Goodman et al., 2008; Thom et al., 2013).

While the scientific literature may not be conclusive in determining the contamination percentages of lower limbs in HCWs following PPE removal, it does show that bacteria lives on hospital floors. This is enough to conclude that PPE offering protection of the lower limbs including the lower legs and plantar regions are important in preventing self-contamination and the spread of bacteria. Since two different participants (P2; P5) in the current study experienced contamination to the lower limbs, attention needs to be attributed to this section of the protocol to ensure greater levels of safety and protection (Table 1).

**Contamination due to Equipment Failures**

P6 experienced five separate contamination events: left index finger (2.8mm), right middle finger (1.6mm), right buttock (57.2mm), right dorsal lower leg (77.9mm), and left dorsal lower leg (64.0mm), which were all believed to be a result of an equipment failure. The nature of the equipment failure (torn right outer glove while pulling on it with the left hand) was verified through the observation of the video recording. At this point, traces of GloGerm could have transferred to both the left and right inner gloves. Since the index finger was used to grab the cuff of the glove while doffing, it is probable that the hands were in contact with GloGerm, leading to the left index finger and right middle finger contaminations. Despite the tear, this could have been avoided with better technique and additional detail in the protocol.

In addition, the video recordings showed P6 selecting two pairs of small gloves. She was the only participant to select two pairs of the same size for double gloving. The remainder of the participants selected a small inner glove and larger outer glove. Wilson, Sellu, and Jaffer (1996) studied glove tear rates in surgeons, using 4 different methods: 1) surgeon's normal size, 2) normal gloves inside and one size larger outside, 3) larger glove inside and normal glove outside,

4) two pairs of normal sized gloves. This study demonstrated that double gloving provided a 50% increase in protection, but that double gloving by method was not statistically significant (Wilson, Sellu, & Jaffer, 1996).

Surgical gloves offer effective protection against infections as long as their protective layer remains intact (Timler, Bonczac, Jonczyk, Iltchev, & Sliwczynski, 2014). In the event of a tear, the gloves no longer offer an adequate level of protection (Timler et al., 2014). In a study by Timler et al. (2014), glove tears occurred in 6.2% of orthopaedic surgeries. Those results are similar to data obtained by Korniewicz, Garzon, Seltzer, and Feinleib (2004), who reported a 6.8% defect rate in gloves during orthopedic procedures. Laine and Aarnio (2001), observed an 8.5% glove puncture rate during trauma and orthopedic surgeries. This is consistent with the tear rate by manufacturer, who stipulate that 6.5% and 7.0% of gloves are torn for the Mercator Medical and Sempermed brands, respectively (Timler et al., 2014). While the current study did not use either of those brands, a tear occurred to 5% of glove pairs. Informing HCWs about glove tear statistics may increase awareness, which may increase vigilance when doffing gloves.

As seen in the doffing description above, another implication of hand contamination could be improper doffing technique. Beam et al. (2011) determined that 20% of participants did not use the proper technique for glove removal. In addition, seven participants involved in Beam's study experienced contamination to the hands. According to Casanova et al. (2008), virus recovered from the right hand (the dominant hand of 90% of volunteers) was greater than that recovered from the left hand. Casanova et al. (2008) explained this by claiming that some steps in the protocol such as removing the gloves and gown require two hands while other tasks like removing the face shield require one hand. According to Casanova et al. (2008), this could justify why larger quantities of contamination was transferred to the dominant hand during

removal. In the current study, the participant (P6) used both hands to remove each piece of equipment, which could explain why contamination to both the right and left hand were equal. To reduce the risk of contamination to the hands, training needs to focus on best practices for gloves, including but not limited to: procedure for torn glove, procedure for highly soiled/contaminated glove, proper hand hygiene, and proper glove removal.

This participant (P6) also experienced a breach in equipment with her gown, which was not completely closed at the back. Gown tying directions are not specified in the protocol. In addition, there are no cues to help the TOs identify breach. As a result, the participant mistied the gown and entered the red zone for exposure to GloGerm. It is highly probable that the contamination to the participants' right buttock, right dorsal lower leg, and left dorsal lower leg was a result of this breach since the participant was not adequately shielded by the PPE when the GloGerm was sprayed by the researcher. These results provide information regarding how the current protocol can be improved, with regards to identifying breach. This is supported by Beam and colleagues, who also claimed that each of the 10 participants committed at least one breach of standard airborne and contact isolation procedures, often involving the gown. In addition, Bell et al. (2015), demonstrated that 25% of participants became contaminated following clinical tasks to care for a simulated EVD patient. They determined that contamination was a result of the gown being improperly tied, therefore, clothing was exposed during the clinical task, leading to significant contamination (Bell et al., 2015).

Data from the Exposure Prevention Information Network (EPIN) (2013) points to the fact that HCWs are experiencing patient blood and body fluid exposure to skin, and also that exposures are occurring with gaps in protective clothing that allow fluids to leak through barrier garments. These findings demonstrate that breaches were a likely source of contamination while

donning and doffing. Since contamination may have grave consequences when caring for EVD patients due to the high fatality rate, the importance of proper PPE procedures, including correcting any breaches should be carefully considered (International Safety Centre, 2013). The high error rates demonstrated in this study as a result of incorrect doffing procedures or breaches in equipment are indicative of the fact that the protocols are not error resistant. This points to flaws within the current protocol. It is very important for the protocols to provide clear donning and doffing instruction to ensure that new and young workers are safe, to ensure that experienced nurses understand current donning and doffing processes, and to ensure that in a stressful situation, the likelihood of incorrect doffing due to human error is reduced. Ensuring that the protocols include clear checkpoint could allow this. The design strategy may also need modification; potentially requiring the integrated hood and gown one-piece PPE to be used for EVD patients, following additional research.

## Near Miss Incidents

Near-miss incidents provide insights into possible accidents and provide an opportunity to further improve safety margins (Grabowski, Ayyalasomayajula, Merrick, Harrald, & Roberts, 2007; Wu, Yang, Chew, Yang, Bigg, & Li., 2010). Statistically, 90.9% of accidents produce no injuries, while 8.8% of accidents result in minor injury and 0.3% cause major injury (Heinrich, 1959; Wu et al., 2010).

In order to develop safety improvements in healthcare, it is important to learn from previous near-miss incidents by tracking them. This can result in appropriate action being taken before a potential up-coming adverse event (Wu et al., 2010). A recent study by the US National Academy of Sciences (2004), which is formed by experts on risks (engineers, practitioners, and policy makers) focused on the signals, conditions, events, and sequences that preceded an accident (Phimister, Bier, & Kunreuther, 2004; Wu et al., 2010). They found that many

organizations had benefitted from developing programs to identify accident precursors (Phimister, Bier, & Kunreuther, 2004; Wu et al., 2010).

In the current study, the primary researcher, and the TOs were asked to make note of any near-miss incident, during PPE donning and doffing. The most common near-miss incidents included incorrect donning of the gown (Table 2), incorrect donning of the N95 respirator (Table 2), and incorrect doffing of the outer footwear (Table 3).

**Incorrect Donning of Gown**

During the donning process, a recurring error amongst the participants was incorrectly tying the gown (Table 2). This was considered a near-miss incident because literature supports that tying the gown to the side reduces the likelihood of self-contamination (Beam et al., 2011; CDC, 2014c). CDC training videos viewed by participants also assert that tying the gown to the side further prevents the chance of contamination (CDC, 2014c). When the gown is tied at the back versus the side, it increases the risk of breach and self-contamination by impeding access to the ties and requiring users to reach at the back to access the ties. Since they do not have a proper visual of their back side, they often have difficulties locating the ties, which increases gown-to-glove contact.

Seventy percent of the participants incorrectly donned the gown by tying it at the back. This is consistent with a study performed by Beam et al. (2011), who claimed that incorrectly trying the gown contributed to the majority of their near-miss incidents. Sixty percent of their participants used poor technique for gown removal (Beam et al., 2011). Beam et al. (2011) also stated that 70% of HCWs failed to secure the gown using the ties. Similarly, Casanova et al. (2008) determined that the gown was the most contaminated piece of PPE following an isolation procedure. Tying the gown on the side permits the user to remove it with ease by simply pulling at the side rather than reaching on the back (CDC, 2014c). When reaching for the tie at the back,

there is increased likelihood of contaminating the clothing due to the fact that the opening of the gown is located at that area. There is also an increased risk for gaps when the gown is tied at the back because it does not form to the user.

Another participant (P9) experienced a near-miss due to the fact that the gown unfastened while in the red zone. This could have been avoided by properly tying the gown at the side, as the user would have been able to see the knot of the tie and ensure it was secured. This finding validates the significance of correctly applying the gown in order to prevent cross-contamination.

In healthcare, gowns are identified as the second-most-used piece of PPE, following gloves, which highlights the importance of having clear donning and doffing procedures for gowns (Kilinc, 2015). The PSHSA donning protocol includes the following information for applying the gown:

> *Select coverall/gown large enough to allow unrestricted freedom of movement, Ensure cuffs of inner gloves remain tucked under sleeves, Ensure a continuous barrier between boot covers and coverall/gown, Seal opening of coverall (if applicable), ensure no skin or clothing is exposed, Sit on clean chair, as needed* (PSHSA, 2014, p.1).

The gown donning directives in the PSHSA protocol (and other comparable protocols such as CDC) do not indicate exactly how it should be donned, who should be tying the ties, and it does not specify that the gown should be tied on the side rather than the back to ensure optimal protection. In order to reduce the level of contamination and near-miss incidents associated with donning the gown, the importance of the side-tie could be included in the protocol as a checklist item.

**Incorrect Donning and Doffing of N95 Respirator**

The N95 respirator was incorrectly donned or doffed by 50% of participants (Table 2; Table 3). Results from this study indicate that 20% of participants applied the top strap of the

N95 respirator first, resulting in crossed straps at the back of the head. Half of those who incorrectly donned the N95 respirator did not have prior experience with this piece of equipment

To remove the N95 respirator, the user is no longer gloved, and is required to reach over the head to remove the bottom strap (Appendix B) (CDC, 2014d; PSHSA, 2014). When the straps are crossed as a result of incorrect donning, there is an increased chance for cross-contamination between the head (hair), the hands, and the N95 respirator. These findings are consistent with a study conducted by Beam et al. (2011) who claimed that 20% of participants incorrectly used the N95 respirator.

In addition, findings revealed that 30% of the participants removed the N95 respirator by grabbing it at the front, where the filtering mechanism is located. Each of these participants claimed to have prior experience with the N95 respirator in the demographic questionnaire. At this point in the protocol, the outer gloves and the inner gloves are removed, which caused the participants to touch contaminated PPE with unprotected areas of their own bodies (i.e. the front of the N95 respirator with bare hands). The gloves are removed prior to doffing the N95 respirator in an attempt to avoid contamination to the mucus membrane during doffing. While this is deemed a precautionary principle, it does increase the risk of contaminating the hands, especially when doffed incorrectly (Office of the Provincial Health Officer, 2015). Beam et al. (2011) also concluded that unclear N95 respirator directives lead to improper seal-checks and N95 doffing in their study. This is problematic because when the N95 respirator is in use, the highest risk of exposures occurs while doffing the PPE, especially around the mucous membranes such as the nose and the mouth (Office of the Provincial Health Officer, 2015). This is also validated by Casanova et al. (2008), who studied viral transfer following a routine healthcare task by measuring blood pressure on a mannequin. Once PPE was doffed, it was

collected, immersed in eluent solution and analysed for virus. Virus was found on the right side of N95 respirator following the isolation scenario.

Correctly donning and doffing the N95 respirator is important because it offers a high degree of protection (BC Centre for Disease Control, 2014). Meta analyses determine that N95 respirators were effective against the transmission of SARS (Casanova et al., 2008). When it is correctly donned and used properly, the N95 respirator has the ability to reduce the exposure 10x better than without its use (BC Centre for Disease Control, 2014). While 80% of participants in this study self-reported to have used N95 respirators previously, 5 near-miss incidents were observed in this study while donning and doffing (Table 2; Table 3). Although third year nursing students in this study are all required to have N95 respirator training throughout their studies, there appears to be a gap between previous training and self-reported knowledge. This demonstrated that training and education on the topic and PPE is important. According to Hunnum et al. (2006) fit testing as part of training significantly enhanced the N95 respirator performance of their participants. On the other hand, it was more time consuming and costly. Perhaps more detail could be included in the protocol to ensure its proper and safe use. At the present time, the donning protocol includes the following directives for N95 respirator donning: "*Apply respirator as per manufacturer's user instructions; fit flexible nose piece to bridge of nose; perform seal check*" (PSHSA, 2014, p.2). With regards to the N95 respirator, the donning protocol does not include details about how to hold the respirator in the palm of the hand, or how to apply the straps to ensure that they are not crossed. More details regarding N95 respirator donning and doffing is required in the protocols to reduce potential contamination. At the very least, the protocol should instruct that straps should not be crossed at the back of the head and that the front of the respirator should not be touched while doffing.

**Incorrect Doffing of Outer Footwear**

Included in the near-miss incidents were several notes regarding the removal of outer foot protection. Twenty percent of participants (P2, P8) experienced a near-miss incident as a result of incorrectly doffing the outer footwear, which consisted of a rubber boot. One participant (P2) used the left hand to remove the right rubber boot and a second participant (P8) used the tip of the toes to unfasten the opposing rubber boot at the heel. It appears that doffing the outer footwear was an area of confusion amongst the TOs as well as the participants, as noted in the exit questionnaire and TO reflections (Table 4). For example, the TOs stated: "Can [participant] touch boot?" and "[Participant] used feet to remove boots on chair". Finally, a participant (P3) noted "swinging of legs" as an area of difficulty. Therefore, future versions of the PSHSA protocol should clarify the steps regarding the removal of outer footwear by adding action items to the checklist.

According to the CDC (2015) the outer footwear should extend to at least mid-calf. In addition, single-use (disposable) boot covers may be worn over the outer footwear to facilitate the doffing process, reducing contamination of the floor in the doffing area and thereby reducing contamination of underlying outer footwear. There was a lack of detail in the protocol regarding doffing of outer footwear. The PSHSA protocol indicates the following: "*Remove outer footwear carefully to avoid inadvertent contact and cross-contamination, take care not to slip or fall, use chair as needed, dispose into designated waste container*" (PSHSA, 2014, p.4). The protocol states that the outer footwear should be removed carefully but no instruction on how to remove the footwear are provided, leaving participants with doubt and confusion, as seen through the exit questionnaire (Table 4). As a result of the contamination, near-miss incidents, and exit questions observed, the need for additional outer footwear directives in the protocol is needed.

According to Dunowska, Morley, Patterson, Hyatt, and Van Metre (2006), foot mats and footbaths containing peroxygen-based disinfectant are effective in reducing bacterial contamination on the soles of boots when used in hospitals. To further protect HCWs against the risks of contamination, the use of footbaths and foot mats containing effective disinfectants could be considered as an extra precaution during doffing (Dunowska et al., 2006).

## Limitations

The limitations to this study included the following: cross-sectional study design, GloGerm application, lack of simulation, lack of inter-observer reliability, and a lack of training and education for the participants.

A cross-sectional design was used for this study to determine the effectiveness of the PSHSA protocol in preventing skin and clothing contamination. A cross-sectional design does not allow participants to be observed at multiple time points and participants were only observed for one donning and doffing simulation. Participants were not studied longitudinally to determine whether their understanding of PPE and protocol developed over time or with experience (Sedgwick, 2014). Due to the fact that the donning and doffing simulation was only performed once, it is difficult to deduce that the protocols were the sole contributors to the contaminations (Segwick, 2014).

GloGerm was applied to PPE using an aerosol spray at a distance of 30cm on multiple pre-determines sites. However, the exact amount of GloGerm on each participant may have varied. Equal contamination for all participants was not verified systematically. Therefore, GloGerm application was likely not consistent for each participant and the exact location of the GloGerm application may have differed. GloGerm was not added to the environment, which did not allow the research team to gather a full understanding of contamination spread. In addition, the yellow and green zones were not scanned or cleaned between each donning and doffing

simulation. It is likely that traces of GloGerm remained on floor surfaces and that more GloGerm was present for latter donning and doffing simulations. Guo et al. (2014) found environmental contamination on the disposal bins following a donning and doffing simulation. It is possible that GloGerm remained on these surfaces throughout the donning and doffing simulations, which is a limitation to this study.

There was a lack of patient care simulation during the study. The study was a simulation of donning and doffing PPE - rather than performing care on a patient, the participants performed simulated movements, which are often performed during patient care (i.e. raising arms and leaning forward). It is possible that in a true patient care scenario, there would be increased chance of further contamination spread or breach in equipment. In a long or physically intensive patient care scenario, there are movements involved such as rubbing, friction, and contact stress on PPE, meaning that the ability for the PPE including gloves, cuffs, and sleeves to remain intact as a barrier is especially important (Hogan-Mitchell, 2016). While this study did analyse contamination subsequent to doffing, it did not replicate a real-life isolation procedure. Results may have differed had the participants performed a nursing duty for a prolonged period of time. However, the use of a simulated patient care environment allowed for a safe preliminary study.

The consistency of trained observers could be a limitation in this study. Three different trained observers were used in this study, which is a limitation since inter-observer reliability was not measured. Each TO took part in a 1-hour training session, facilitated by the researcher. In this training session, they viewed a PowerPoint presentation containing segments from the CDC PPE donning and doffing training video, which demonstrated how to don and doff each piece of equipment (CDC, 2014e). The video also demonstrated the verification process (CDC,

2014e). TOs were instructed to read each step aloud and to verify and correct breaches during the verification process. The TOs ability to identify breach may have differed.

There were also limitations with the PowerPoint file used to provide training to the participants and the range of time that elapsed between training and donning and doffing simulations. While the protocol evaluated in the current research was created by the PSHSA, the training video used was developed by the CDC. It would have been preferable to use both resources from the same organization to ensure consistent directives; however, the PSHSA had not created a training video. In addition, 22 days elapsed between the training session and the last donning and doffing simulation. The donning and doffing simulations occurred two weeks after the training session. It is possible that the participants did not remember as much detail from the video, potentially leading to further contamination and near-miss incidents. Furthermore, the training video session was hosted by the primary researcher, who does not have a nursing background. Despite these limitations, this study provided a valuable first step in the examination of the effectiveness of the PSHSA acute care donning and doffing protocol.

# Chapter 5: Recommendations and Future Studies

## PPE Protocol Recommendations

PPE is crucial for the protection of nurses against occupationally acquired contamination (Casanova et al., 2008; Weber, & Rutala, 2008). PPE is typically used for short periods of time, under conditions where contamination risk is either low, or the personal risk associated with the contamination is low. This is problematic given that viruses such as influenza (Bean et al., 1982), SARS, and EVD (Rabenau, Cinatl, Morgenstern, Bauer, Preiser, Doerr et al., 2005) can survive for hours on surfaces, and the virulence and/or personal risk for the HCW for these viruses is high (Gwaltney, & Hendley, 1982). Since the global outbreaks of these viral infections, specifically, developing and validating a protocol for the donning and doffing of PPE that prevents contamination of the skin and clothes is key to preventing disease transmission to and amongst HCWs.

In healthcare, protocols exist because HCWs are susceptible to human error (Thomassen et al., 2011). In order to reduce the potential for human error, redundancy is to be built into the protocol. In areas that are associated with near misses and contamination, more information, and more action items could be added to the protocols. This could include more prompts for the TO to identify breaches (i.e. was the gown tied to the side?; are skin or clothing visible?) and more support statements for the HCWs (i.e. tie gown to the side) to reduce the potential for contamination and near-misses. Some recommendations that might prevent such contamination, include modifications to the current protocol, specifically, a check point for the gown tie and N95 respirator. The proper design and use of PPE protocols, including properly selecting appropriate PPE, is vital in preventing the spread of infectious diseases and has significant implications for safety in healthcare (Mitchell et al., 2014). As a result, it is important for

protocols to be clear, concise, and include enough information for safe donning and doffing procedures.

As stated above, scientific literature demonstrates that training sessions alone are not always most successful in transmitting information and even with training, HCWs are susceptible to risks (Aziz, 2009; Carrico et al., 2007; McGovern et al., 2000). As a result, the PPE protocols need to include a sufficient amount of detail to ensure that HCWs can effectively don and doff the equipment if the steps in the protocols are followed. In context of the contamination, near miss incidents, and exit question results reported in this study, revisions to the current PSHSA protocol are recommended to protect HCWs against self-contamination. Table 6 and Table 7 will demonstrate each protocol revision as well as justification for each change.

**Donning Protocol Recommendations**

The donning protocol includes 12 steps to assist with applying PPE for EVD (PSHSA, 2015). Forty percent of participants experienced contamination subsequent to doffing and near-miss incidents were observed in 4 steps in the donning protocol. Table 5 demonstrated steps that were noted as an area of difficulty as a result of contamination, near-miss incidents, or exit question responses. Table 6 includes the directive in the current PPE donning protocol, followed by a protocol recommendation. Based on the results of this study, revisions to the original PSHSA protocol have been suggested and are outlined in Appendix Q.

The modified protocol (Appendix Q) includes an introductory checklist with hair directives, color coding, mirror availability, and jewellery removal. As per the responses of the TOs and participants, additional detail is required in the introduction with regards to ensuring a correct size and tying hair. Prior to commencing donning, it is important to ensure that the PPE fits the worker correctly (PIDAC, 2012). It should offer full-coverage from the toes to the hair,

ensuring that no skin or clothing is exposed (PIDAC, 2012). Participants and TOs equally expressed that hair should be tied in a low bun prior to commencing donning. This would permit the hair to be completely tucked away from their face and would not hinder the fit of the equipment such as the hood, face shield, and N95 respirator. The revised checklist also includes further details regarding: hand hygiene, gown application, N95 respirator application, glove application, and the verification process. These suggestions could potentially reduce the occurrence of near-miss incidents, and subsequently, contamination to the skin or clothing.

Table 7

*Summary of Suggested Recommendations to Improve the Donning Protocol (bolded). This table also illustrates the observed events leading to recommendations.*

| **Current Protocol** | **Contamination Event** | **Near-Miss Event** | **Exit Question Answers** | **Protocol Recommendation (bolded)** | **Supporting Literature** |
|---|---|---|---|---|---|
| No introductory checklist | | | P9 - "recommend buns for long hair"<br>TO2- "Make sure hair is tucked"<br><br>2 - "Needed a mirror, could not easily find the ties on anything face mask included"<br><br>TO2 - "Color code zones"<br><br>TO1 -"Indicate zones in protocol" | **Step 1: Ensure the following:**<br>☐ **Hair is tied in a low bun**<br>☐ **A mirror is present in the yellow and red zone**<br>☐ **Jewelry has been removed**<br>☐ **Defined zones are clearly established**<br>☐ **Ensure that a footbath with disinfectant is available in red zone for outer footwear doffing** | Fischer et al. (2015) - hair should be contained as best possible.<br><br>The CDC (2015) - a mirror in the room can be useful for the HCW during donning.<br><br>Chiang et al. (2008) - clear demarcation between clean and contaminated zones both on the floor surface and in the protocols could help reduce contamination. |
| Step 4: Put on Inner gloves<br>☐ Extend cuffs as far up arms as possible<br>☐ Adjust and verify proper fit of PPE | P6 - left index finger (2.8mm)<br>P6 - right middle finger (1.6mm) | | P5 - "It is very difficult to remove gloves of same material" | Step 4: Put on Inner gloves<br>☐ **Select normal sizes gloves**<br>☐ **Ensure gloves provides unrestricted freedom of movement and are snug around the wrist**<br>☐ Extend cuffs as far up arms as possible<br>☐ Adjust and verify proper fit of PPE | PIDAC (2012) - Gloves that fit snugly around the wrist are preferred for use with a gown because they will cover the gown cuff and provide a better barrier for the arms, wrists and hands.<br><br>PIDAC (2012) "Select correct size of glove"<br><br>Casanova et al. (2008) - 90% of HCW's transferred bacteria to their right hand and 70% on their left hand |

Table 8

*Summary of Suggested Recommendations to Improve the Donning Protocol (bolded). This table also illustrates the observed events leading to recommendations.*

| | | | | | |
|---|---|---|---|---|---|
| Step 5: Put on single-use (disposable) coverall/gown:<br>☐ Select coverall/gown large enough to allow unrestricted freedom of movement<br>☐ Ensure cuffs of inner gloves remain tucked under sleeves<br>☐ Ensure a continuous barrier between boot covers and coverall/gown<br>☐ Seal opening of coverall (if applicable) and ensure no skin or clothing is exposed | P1 - left scapula (38.1mm) | P1, P3, P4, P5, P6, NS8, P10 - Gown was tied in the back rather than on the side | P1 - "Gown tied in back, often no one to help. No person observing in real setting. Rushed in real life" | Step 6: Put on single-use (disposable) coverall/gown:<br>☐ **Sit on clean chair, as needed**<br>☐ Select coverall/gown large enough to allow unrestricted freedom of movement<br>☐ Ensure cuffs of inner gloves remain tucked under sleeves<br>☐ Ensure a continuous barrier between boot covers and coverall/gown<br>☐ Seal opening of coverall (if applicable) and ensure no skin or clothing is exposed<br>☐ **Ensure waist tie is tied to the side of the gown to reduce contamination during doffing**<br>☐ **Ensure the tie at the neck is fastened** | CDC (2014c) - Tying the gown on the side permits the user to remove it with ease by simply pulling at the side rather than reaching on the back.<br><br>Beam et al. (2011) - 70% of participants failed to tie the gown at the neck and the waist |
| Step 7: Put on fit-tested N95 respirator:<br>☐ Apply as per manufacturer's instructions<br>☐ Fit flexible nose piece to bridge of nose<br>☐ Perform seal check | | P2, P4 - Straps of the N95 respirator were crossed at the back | TO1 - "Put N95 respirator instructions (bottom strap first)"<br>TO1 - "Wrong application of the N95 respirator" | Step 8: Put on fit-tested N95 respirator:<br>☐ **Hold the respirator in the palm of your hand with the straps facing the floor.**<br>☐ **Place the N95 on your face covering your nose and mouth.**<br>☐ **Pull the bottom strap out and over your head.**<br>☐ **Take the upper straps and put it behind your head at the crown of your head**.<br>☐ **Ensure straps are not** | Beam et al. (2011) - 20% of participants incorrectly used the N95 respirator |

Table 9

*Summary of Suggested Recommendations to Improve the Donning Protocol (bolded). This table also illustrates the observed events leading to recommendations.*

| | | | | | |
|---|---|---|---|---|---|
| | | | | ☐ **crossed at the back to prevent contamination during doffing**<br>☐ Fit flexible nose piece to bridge of nose<br>☐ Perform seal check | |
| Step 11: Put on outer gloves with extended cuffs<br>☐ Ensure gloves cover cuffs of coverall/gown and that no skin is exposed<br>☐ Adjust and verify proper fit of PPE | P6 - left index finger (2.8mm)<br>P6 - right middle finger (1.6mm) | | P5 - "It is very difficult to remove gloves of same material" | Step 4: Put on Inner gloves<br>☐ **Select one size bigger that normal glove size**<br>☐ **Ensure gloves provides unrestricted freedom of movement and are snug around the wrist**<br>☐ Extend cuffs as far up arms as possible<br>☐ Adjust and verify proper fit of PPE | PIDAC (2012) - Gloves that fit snugly around the wrist are preferred for use with a gown because they will cover the gown cuff and provide a better barrier for the arms, wrists and hands.<br><br>PIDAC (2012) "Select correct size of glove"<br><br>Casanova et al. (2008) - 90% of HCW's transferred bacteria to their right hand and 70% on their left hand |
| Step 12: Verify donning PPE procedure:<br>☐ Inspect to ensure that it is secure and full coverage has been achieved<br>☐ Visually confirm sequence has been completed correctly | P6 - Right Buttock (57.2mm), Right Dorsal Lower Leg (77.9mm), Left dorsal lower leg (64.0mm) | P9 – Gown unfastened when doffing began (breach in equipment) | | Step 13: Verify donning PPE procedure:<br>☐ Inspect to ensure that it is secure and full coverage has been achieved<br>☐ **Ensure gown has been tied to the side of the waist**<br>☐ **Ensure N95 respirator straps are not crossed at the back of the head**<br>☐ **Ensure that there is no breach in equipment**<br>☐ **Ensure that no clothing or skin is exposed**<br>☐ Visually confirm sequence has been completed correctly | Bell et al. (2015) - 25% of participants became contaminated following clinical tasks to care for a simulated EVD patient as a result of a breach in the equipment. |

**Doffing Protocol Recommendations**

The proper removal and disposal of contaminated PPE is the arguably the most difficult challenge in averting unintended exposure to infectious diseases (CDC, 2014d). As a result, a high regard for precision, attention, and safety is required. The doffing protocol used in the current study was a 12-step framework designated to guide the user to safely remove the PPE (PSHSA, 2015). The doffing process is typically performed in a manner that protects the portals of entry in order of importance (CDC, 2014b). First, the highly soiled equipment are removed; this includes the apron, outer footwear, gloves, face protection, hood, gown, boot covers, inner gloves, and then N95 respirator (since it is close to the mucous membrane and needs to be removed with uncontaminated hands) (PSHSA, 2015).

Based on the results of this study (Table 2; Table 3; Table 4) several modifications are recommended to the PSHSA doffing protocol (Appendix R) including colour coding and changes to the outer footwear, hood cover, gown, boot cover, and hand hygiene steps. These modifications were intended to provide clear directives to reduce the potential for self-contamination and near-miss incidents. In addition, research suggests that the use of foot baths can aid with the reduction of contamination by reducing the contamination on the rubber boots. As a result, a footbath was also included in the doffing protocol as a checklist item. Table 7 demonstrated steps that were noted as an area of difficulty as a result of contamination, near-miss incidents, or exit question responses. The revised protocol found in Appendix R could lead to safety improvements by decreasing the probability of self-contamination to the skin or clothing.

Table 7

*Summary of Suggested Recommendations to Improve the Doffing Protocol (bolded). This table also illustrates the observed events leading to recommendations*

| **Current Protocol** | **Contamination Event** | **Near-Miss Event** | **Exit Question** | **Protocol Recommendation (bolded)** | **Supporting Literature** |
|---|---|---|---|---|---|
| Step 3: Remove outer gloves:<br>☐ Remove outer gloves taking care not to touch inner gloves or bare skin<br>☐ Dispose into designated waste container<br>☐ Inspect inner gloves for visible contamination, cuts or tears | P6 - left index finger (2.8 mm)<br>P6 - right middle finger (1.6mm)<br>P6 – Tore glove during doffing | | TO1 - "Inner glove came off while taking off outer glove"<br><br>P5 - "It is very difficult to remove gloves of same material" | Step 2: Remove outer gloves:<br>☐ Remove outer gloves taking care not to touch inner gloves or bare skin<br>☐ **With both hands gloved, grasp the outside of one glove at the top of your wrist and pull, rolling the glove down**<br>☐ **Hold the glove you just removed in a ball with the opposite gloved hand.**<br>☐ **Peel off the second glove by inserting your fingers inside between the outer and inner glove at the top of your wrist.**<br>☐ Dispose into designated waste container<br>☐ Inspect inner gloves for visible contamination, cuts or tears | Beam et al. (2011) - 20% of participants did not use the proper technique for glove removal. |
| None | P2 - Left Dorsal Lower Leg (41.3mm)<br>P5 - Left Plantar (9.5mm) | P2 - Participant used left hand to remove right rubber boot<br>P8 - Participant used the tip of the toes (while wearing boot cover only) to unfasten the opposing rubber boot at the heel | P8 - "After removing boot covers, we stay in the same area - if our boot covers where contaminated then our socks/bottom of pants would be too" | Step 3: Disinfect outer footwear<br>☐ **Stand in the shuffle pit filled with disinfectant solution for one minute.**<br>☐ **The shuffle pit will be located inside the patient room adjacent to the door** | Dancer (2009), Eckstein et al. (2007), Goodman et al. (2008) – more emphasis needs to be attributed to cleaning and disinfection of surfaces<br><br>Dunowska et al. (2006) – To further protect HCWs against the risk of contamination, the use of footbaths containing |

Table 7

*Summary of Suggested Recommendations to Improve the Doffing Protocol (bolded). This table also illustrates the observed events leading to recommendations*

| | | | | | |
|---|---|---|---|---|---|
| | | | | | effective disinfectants could be considered as an extra precaution during doffing |
| Step 2: Remove outer footwear and/or foot coverings:<br>☐ Remove outer footwear and/or foot coverings carefully to avoid inadvertent contact and cross-contamination<br>☐ Take care not to slip or fall; use chair as needed<br>☐ Dispose into designated waste container | P2 - Left Dorsal Lower Leg (41.3mm)<br>P5 - Left Plantar (9.5mm) | P2 - Participant used left hand to remove right rubber boot<br>P8 - Participant used the tip of the toes (while wearing boot cover only) to unfasten the opposing rubber boot at the heel | TO1 - "[Participant] used feet to remove boots on chair"<br>TO1 - "mention [section 2.2] in [section 2.1] instead"<br>P3 - "swinging of legs" | Step 4: Remove outer footwear and/or foot coverings:<br>☐ Take care not to slip or fall by using chair<br>☐ **Slip off the rubber boots in by unfastening them at the feet with the toe of your boot.**<br>☐ **Make sure to keep the mid-calf foot covering on.**<br>☐ **Once the boot is removed, step into the yellow zone, carefully to avoid contact with the floor in the red zone.** | Thom et al. (2011) - Acinetobacter baumannii bacteria found on 16% of hospital room floors.<br><br>Dancer (2009), Eckstein et al. (2007), Goodman et al. (2008) - Staphylococcus aureus, vancomycin-resistant Enterococcus, and Clostridium difficile on hospital floors.<br><br>WHO (2014b) - If wearing rubber boots, remove them without touching them with your hands. Place them in a container with disinfectant. |
| Step 6: Remove the Coverall/Gown:<br>☐ Trainer observer may assist, but must be donned in adequate PPE based on risk<br>☐ Unzip or unfasten coverall/gown completely before rolling down and | P1- Left Scapula (38.1mm) | | TO1 - "Gown touched neck; trouble untying"<br><br>P1 - "Gown tied in back, often no one to help. No person observing in real setting. Rushed in real life" | Step 7: Remove the Coverall/Gown:<br>☐ Trained observer may assist, but must be donned in adequate PPE based on risk<br>☐ **Unzip or unfasten coverall/gown completely using mirror, if needed**<br>☐ **Remove the gown by unfastening the cuff, then tugging at the shoulder,** | Beam et al. (2011) - 60% of participants used poor technique for gown removal<br><br>Casanova et al. (2008) - the gown was the most contaminated piece of PPE following an isolation procedure. |

Table 7

*Summary of Suggested Recommendations to Improve the Doffing Protocol (bolded). This table also illustrates the observed events leading to recommendations*

| | | | | | |
|---|---|---|---|---|---|
| turning inside out. Avoid contact of inner clothing with outer surface of coverall during removal, touching inside of the coverall/gown only | | | | **and rolling down to turn gown inside out**<br>☐ Avoid contact of inner clothing with outer surface of coverall during removal, touching inside of the coverall/gown only<br>☐ Dispose into designated waste container. | |
| Step 7: Remove boot covers:<br>☐ Remove boot covers carefully to avoid inadvertent contact and cross-contamination<br>☐ Take care not to slip or fall; use chair as needed<br>☐ Dispose into designated waste container | | P4 - Participant grabbed the boot covers from the inside at the region of the calf rather than the outside | P8 - "After removing boot covers, we stay in the same area – if our boot covers were contaminated then our socks/bottom of pants would be too"<br><br>TO1 - "mention [section 7.2] in [section 7.1 instead]"<br><br>TO2 – "[participant] did not sit on clean chair" | Step 8: Remove boot covers:<br>☐ **Take care not to slip or fall; use chair as needed**<br>☐ Remove boot covers carefully to avoid inadvertent contact and cross-contamination<br>☐ **Do not touch the inside of the boot cover; instead tug on the outer layer**<br>☐ Dispose into designated waste container | Thom et al. (2011) - Acinetobacter baumannii bacteria found on 16% of hospital room floors<br><br>Dancer (2009), Eckstein et al. (2007), Goodman et al. (2008) - Staphylococcus aureus, vancomycin-resistant Enterococcus, and Clostridium difficile on hospital floors |
| Step 9: Perform hand hygiene:<br>☐ Use alcohol-based hand rub (ABHR) or soap and water<br>☐ Allow hands to dry completely before | P6 - left index finger (2.8 mm) NS6 - right middle finger (1.6mm) | P1, P3, P7 - Participant grabbed the N95 respirator with bare hands to remove it | TO1 - "wrists need to be cleaned with hand rub" (TO1) | Step 10: Perform hand hygiene:<br>☐ Use alcohol-based hand rub (ABHR) or soap and water<br>☐ **Ensure wrists and nails are thoroughly cleaned**<br>☐ **Ensure hands are interlaced to clean between** | Casanova et al. (2008) - virus recovered from the right hand was greater than that recovered from the left hand.<br><br>Timler et al. (2014) - |

Table 7

*Summary of Suggested Recommendations to Improve the Doffing Protocol (bolded). This table also illustrates the observed events leading to recommendations*

| | | | | | |
|---|---|---|---|---|---|
| putting on any PPE | | | | ☐ **the fingers**<br>☐ Allow hands to dry completely before putting on any PPE | glove tears occurred in 6.2% of orthopaedic surgeries.<br><br>Korniewicz et al. (2004) - 6.8% defect rate in gloves during orthopedic procedures.<br><br>Laine & Aarnio (2001) - 8.54% glove puncture rate during trauma and orthopedic surgeries.<br><br>Ayliffe et al. (1993) The finger tips and the area between fingers are most commonly missed during hand hygiene. |
| Step 10: Remove N95 respirator<br>☐ Grab bottom strap and lift over head<br>☐ Lean forward and grab top strap; gently lift over head and away from face<br>☐ Take care to not touch the front of the respirator<br>☐ Dispose into designated waste container | | P1, P3, P7 – Touched the front of the N95 respirator during doffing. | | Step 11: Remove N95 respirator:<br>☐ **Do not touch the front of the respirator**<br>☐ **Tilt your head forward and use two hands to grab the bottom strap and lift over head.**<br>☐ **Use both hands to grab the upper strap, pull over your head.**<br>☐ **Keep tension on the upper strap as you remove it, which will let the mask fall forward.**<br>☐ Dispose into designated waste container | Beam et al. (2011) - unclear N95 respirator directives lead to improper seal-checks and N95 doffing. |

## Additional Implications for Increasing Donning and Doffing Safety

Donning and doffing protocols were revised based on the findings of the study. Scientific literature also supported each protocol revision, as seen in Tables 6 and 7. While the revised protocols address the contamination events, near-misses, and participant and TO suggestions, more should be done to ensure the safety of nurses charged with caring for EVD patients. In addition to improvements to donning and doffing protocols, other recommendations should be considered to further improve health and safety for nurses.

### Logbook Checklists

The introduction of a logbook checklist proved to be a successful intervention in dentistry (Chadwick, & Mason, 1997). In response to a lack of staff consistency in assessing clinical work, a checklist scheme of assessment was devised (Chadwick, & Mason, 1997). The checklist was comprised of multiple questions regarding the key stages of conservative dentistry procedures. The participants were asked to indicate whether each key stage was completed satisfactorily or not (yes/no). Compared to the former grading system, the new logbook gave a significantly ($P < 0.001$) more meaningful measure of performance, indicated what was being assessed to a higher degree ($P<0.001$), and gave better feedback of those points requiring attention to improve performance. Given the successful use of checklists in the dentistry field, perhaps this type of checklist could help prevent contamination in nurses by reducing breaches and ensuring consistency when donning and doffing. Logbook questions could include “is the gown secured at both the neck and the waist” to which the TO would need to answer “yes” before proceeding to the next step. At the present time, there are no prompts on the PSHSA doning and doffing checklist and there are even fewer directives for the TOs. For example, the TOs are simply instructed to give verbal commands to the PPE wearer but there are very few details on the best way to provide direction and then confirm compliance.

Future versions of the PSHSA donning and doffing checklist should include information about each step of the donning and doffing process to aid with the reduction of self-contamination. The PSHSA checklists have boxes to check once the action has been completed; however, more detail is required. Detailed checklists have the ability to standardize processes and aid with memory and they are common recommended strategies for increasing safety, which is well reported in the literature as a tool to aid in reducing errors of human omission (Frakes, & VanVoorhis, 2007).

**PPE Training and Education in Healthcare**

While hospitals and HCWs are required to comply with applicable provisions of the Occupational Health and Safety Act and its Regulations regarding PPE training, hospitals are free to develop their own training materials and training strategies (MOHLTC, 2015). Hospitals have various resources at their disposal including a sample curriculum created by the MOHLTC, which is titled: Ebola Personal Protective Equipment (PPE) Training for Hospitals. It was created to support hospitals in training staff on the proper and safe use of PPE for EVD (MOHLTC, 2015). This curriculum may be accessed by trainers designated by hospitals to deliver applied training on the use of PPE, as outlined in the Chief Medical Officer of Health (CMOH) Directive for Hospitals.

The contamination and near-misses observed in this study demonstrated that donning and doffing protocols are not error resistant. As a result, future research should evaluate various training strategies and determine best practices for knowledge translation, retention, and compliance. Scientific literature suggests that HCWs require regular education and training in order to be reactive to ever-changing PPE guidelines and protocols (Aziz, 2009; Carrico et al., 2008; Chan et al., 2008; McGovern et al., 2000). PPE literature continues to stress the need for education as a mean for improving safety practices (Carrico et al., 2007). To assess the impact of

PPE training on HCWs, McGovern et al. (2000) asked participants to respond to the following item, "I have been trained to use PPE (e.g., goggles, gloves, etc.)". Workers who had some PPE training were 5.7 times more likely to be compliant with PPE precautions compared to workers without any training (McGovern et al., 2000). In order for training to successfully increase safety with regards to PPE, different types of teaching methods should be studied to determine which method is more effective in increasing the proper use of PPE by team members (Aziz, 2009).

Methods such as weekly lectures, posters, classroom training, demonstrations, or videos should be cross-compared to determine which technique results in a greater increase in PPE understanding (Aziz, 2009; Carrico et al., 2008; Chan et al., 2008). Carrico et al. (2007) determined that participants who took part in supplemental visual training rather than standard classroom training were more likely to use PPE correctly. Similarly, Batcheller, Brennan, Braslow, Urrutia, and Kaye (2000), determined that video self-instruction (VSI) was more effective than traditional classroom training for the performance of cardiopulmonary resuscitation (CPR). In this case, VSI was a combination of practicing on an inexpensive mannequin while watching a 34-minute videotape without an instructor or textbook (Batcheller et al., 2000). The participants' CRP skills improved on 4 measured components: the percentage of ventilations performed correctly, the percentage of compressions performed correctly, the number of assessment and sequent skills performed correctly, and overall rating of CPR competence (Batcheller et al., 2000). Idrose, Adnan, Villa, and Abdullah (2006) found that the use of classroom training and simulation significantly increased the knowledge of airport medical responders. They also deemed this type of training "low cost, relatively-easy to conduct, fun, and holistic" (Idrose et al., 2006, p.7).

According to scientific literature, an effective classroom-based training is enhanced with self-instruction, simulation, or visual training to maximize favorable results (Batcheller et al., 2000; Carrico et al., 2007; Idrose et al., 2006). Adding these components to training sessions tailored to HCWs could significantly increase knowledge and/or performance (Batcheller et al., 2000; Carrico et al., 2007; Idrose et al., 2006).

**PPE Certification**

In healthcare, comprehensive PPE programs demand commitment and active participation at the planning, development, and implementation levels (Canadian Centre for Occupational Health and Safety, 2011). While training is currently provided at healthcare institutions, more should be done to certify the safety of HCWs. Since deficiencies were observed within the current PPE protocols, the implementation of a program to "certify" the competence of HCWs on the donning and doffing protocols, when dealing with infectious diseases, could be considered. Certification is the stringent development by which a certifying agency confirms a nurse's knowledge, skill, or ability in a defined role and clinical area of practice, based on fixed standards (The American Nurses Credentialing Center, 2010). Nurses can attain certification credentials by engaging in specialized training, education, experience in a specialty area, and by passing a qualifying exam (The American Nurses Credentialing Center, 2010). When a worker achieves certification, they are officially recognised as having the expertise and clinical judgement to successfully overcome certain situations. It requires continued learning and skill development to maintain, which is required to heighten the safety of HCW's.

According to literature, certification leads to better patient care by increased knowledge, techniques, and judgement, which in turn, affect patient and HCW safety (Niebuhr & Biel, 2007; Robison, 2002; Scarpaci, Tsoukleris, & McPherson, 2007; Strongberg et al., 2005; Aulkowski,

Ayello, & Wexlet, 2007). Niebuhr & Biel (2007) found correlations indicating that the more certified nurses in an intensive care unit, the lower the risk of falls. In addition, similar research indicated that nurses certified in wound care could better manage pressure ulcers (Robison, 2002), that oncology-certified nurses had a better understanding of pain management (Scarpaci, Tsoukleris, & McPherson, 2007), that hospice-certified nurses had a better performance with regards to inhaler use (Strongberg et al., 2005), and finally, that emergency and critical care-certified nurses had a greater performance in a mass-casualty triage test (Aulkowski, Ayello & Wexlet, 2007).

Having a certification program for donning and doffing PPE and for dealing with infectious diseases would assure that HCWs meet the standards of practice required to maintain safety at work. Certification programs could include information on how to fit, wear, verify, and maintain PPE. Exemplary donning and doffing procedures and sequences should be accentuated during certification. Certification should also focus on topics relating to human factors including but not limited to: organizational factors, communication, and workspace layout, which all contribute to the reduction of error. Refining the skills of error recognition is as important as ensuring that people are aware of how errors arise to begin with, which highlights the importance of certification.

**Human Factors**

The mining and aviation industries have long been viewed as a gold standard for safety (Spiess, 2011). The health field has attempted to increase their standards of patient and HCW safety, but still fall short in terms of progression compared to mining and aviation industries (Spiess, 2011). The reality is that the risk of dying from medical error and infections is far greater than it is of dying from a plane crash (Chan, 2011; WHO 2011). Understanding the complexity of medical practice, it is not shocking that a high error rate can occur. Literature

pertaining to aviation and mining have examined various components of human factors leading to errors, which have increased their ability to communicate and incorporate sufficient team dynamics into their work. The practice of medicine could learn from these industries and incorporate the lessons to increase the level of safety offered to patients and HCWs.

To begin, decision making is a major component of aviation pilot training. They receive supplemental training with regards to judgement and analytical thinking. This type of training should be offered to HCWs and should underline various scenarios that could occur during an isolation procedure in order to sufficiently prepare them for situations that could place them at risk for contamination. In aviation, error reduction also stems from their potential to adopt superior communication models through their interactions (McKinney et al., 2005). In healthcare, high-stakes processes, such as isolation procedures, often rely on a combination of HCW knowledge, technology, and communication. To succeed, HCWs should adopt an action team, where tasks, actions, and decisions are highly structured and dynamic (Mathieu & Day, 1997). To have a successful action team: individual tasks need to be specialized; roles need to be assigned; interdependence needs to be reiterated; and expertise should be established among individuals composing the team (Mathieu & Day, 1997). When applying these principles to healthcare, it is important to ensure that a linear relationship is created between the TO and the attending HCW. Literature suggests that 30% of HCWs believe that junior team members should not question the decisions made by a senior team member (Sexton, Thomas & Helmreich, 2000). This type of attitude towards hierarchy does not allow a safe work environment or an appropriate team dynamic. This should be highlighted in training to ensure that the TO feels comfortable enough to exercise control on the isolation procedure by providing corrective feedback to the HCW regardless of hierarchy.

According to Sexton, Thomas & Helmreich (2000), aviation recognizes that fatigue, error, and stress are key factors of safety. Those topics continue to be discussed during training sessions and as a result, progress has been made to deal effectively with error. Conversely, healthcare shows a pattern of covering up mistakes, rather than addressing them (Sexton, Thomas & Helmreich, 2000). Vulnerability to stress and a lack of teamwork are often overlooked in healthcare, but these factors need to be further researched to prevent errors and to offer an opportunity for safety improvements (Sexton, Thomas & Helmreich, 2000; Helmreich, 2000).

**Protocol Standardization**

Currently, there is no standard algorithm for the donning of doffing of PPE for protection against EVD. The CDC, WHO, and PSHSA have developed PPE protocols, which all differ in the level of detail offered within the protocols and in the sequence of donning and doffing. Despite the success of standardization in other industries, standardization of PPE protocols in healthcare has been slow to progress (Leotsakos et al., 2014). Standardization, by definition, is "the process of developing, agreeing upon and implementing uniform technical specifications, criteria, methods, processes, designs or practices that can increase compatibility, interoperability, safety, repeatability and quality" (Leotsakos et al., 2014). Standardizing protocols presents the challenge of determining best ways to implement evidence-based interventions and best practices in a universal way (Leotsakos et al., 2014). It is difficult to seek agreement within a hospital, across hospitals within a country or even, ideally, in multiple countries (Leotsakos et al., 2014).

Based on the findings of this study, more research is needed to determine best practices with regards to donning and doffing PPE. By combining funding and knowledge from HCWs, researchers, and organization across the world, new learnings would allow for more successful PPE protocols. To increase the safety of HCW dealing with infectious diseases, it would be

important to determine the best validated equipment and the best validated protocol and ensure that they are adopted universally.

## Future Studies

Research is still needed to systematically evaluate the multiple PPE protocols that have been recently published by the CDC, WHO and the PSHSA. Each of these protocols merit validation by means of quantitative studies prior to being used. In order to determine which sequence is more effective and in order to implement proper recommendations, these methods could be compared to each other in a single study along with the revised PSHSA protocol (Table 5; Table 6).

Future studies could also examine the likelihood of self-contamination using different types of PPE with varying materials. For example, the Powered Air Respirator suits should be compared with the separate hood and gown suits used in this study to determine which option is most effective in preventing self-contamination. Different types of materials could also be studied to determine the most effective options to reduce breach, tears, and strike-through.

## Conclusion

The purpose of this thesis was to determine the effectiveness of a newly designed acute care donning and doffing protocol, created by the PSHSA for EVD. In past epidemics, the health and safety of nurses has been jeopardized as a result of poor protocols and inadequate precautionary practices (Campbell, 2006). In addition, scientific literature has demonstrated insufficiencies with regards to other PPE protocols through quantitative scientific literature (Beam et al., 2011; Casanova et al., 2008; Guo et al., 2014; Mitchell et al., 2013).

Based on the findings of this study, 40% of participants were exposed to contamination while using the PSHSA donning and doffing protocols. There were 5 lower limb contaminations and 3 upper body contamination, resulting in a total of eight contamination events documented

post-doffing. In addition, every participant experience at least one near-miss incident, with 80% of participants experiencing more than one. Near-miss incident occurred in nine of the 24 steps in the protocols.

During donning, instructions on hair directives, proper fit/sizing, tying the gown, and applying the N95 respirator were lacking, as seen in the exit question responses, near-misses, and contamination events. Likewise, during doffing, areas of difficulties included: removing gown, removing face shield, removing outer footwear, and removing the N95 respirator. Based on the observed contamination and exit questionnaire, 19 recommendations have been made to improve the PSHSA protocol. Therefore, future research should determine whether fewer contaminations would occur with the revised PSHSA protocols (Appendix Q; Appendix R), which addresses the recommendations stemming from the results of this study.

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# Appendices

## Appendix A: PSHSA acute care PPE protocol for donning

# Acute Care Donning Training Checklist

**Suspect/Confirmed EVD Cases and/or Care Environment**
**Coveralls/Gowns with Separate Hood and Boot Covers**

This checklist is designed to assist with training healthcare workers (HCWs) on the correct donning of personal protective equipment (PPE) when caring for suspect/confirmed cases of EVD and their care environment. **Please Note: This is a sample checklist** that may need to be adapted to meet relevant standards of practice and/or specific manufacturer's user instructions for variations of approved PPE. The tool can be used to verify and document that all necessary donning steps are performed and in the proper sequence. Any errors or omissions identified during practice and skill proficiency demonstrations must be communicated immediately, to ensure specific instructions are provided and so appropriate corrective action are taken for the protection of the HCW.

Note: Establish clearly defined zones (e.g., hot, warm, and cold) and protocols to prevent and control secondary contamination during doffing.

**Before you begin, instruct HCW(s) to don point-of-care scrubs and footwear, hydrate, tie back long hair and secure in place, and remove personal items such as hand and wrist jewelry. Gather and inspect PPE carefully. Ensure that the correct size is selected and that the PPE is in good sanitary and working condition. Damaged or defective PPE should not be used.**

| TRAIN. | PRAC. | PROF. | DONNING PPE PROCEDURE | COMMENTS (May include size of PPE) |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | **Perform hand hygiene:**<br>☐ Use alcohol-based hand rub (ABHR) or soap and water<br>☐ Allow hands to dry completely before putting on any PPE | |
| ☐ | ☐ | ☐ | **Put on single-use (disposable) impermeable boot covers:**<br>☐ Select boot covers that extend to at least mid-calf<br>☐ Ensure boot covers allow for ease of movement<br>☐ Adjust and verify for proper fit of PPE<br>☐ Sit on clean chair, as needed | |
| ☐ | ☐ | ☐ | **Perform hand hygiene:**<br>☐ Use ABHR or soap and water<br>☐ Allow hands to dry completely before putting on any PPE | |
| ☐ | ☐ | ☐ | **Put on inner gloves**<br>☐ Extend cuffs as far up arms as possible<br>☐ Adjust and verify proper fit of PPE | |
| ☐ | ☐ | ☐ | **Put on single-use (disposable) coverall/gown:**<br>☐ Select coverall/gown large enough to allow unrestricted freedom of movement<br>☐ Ensure cuffs of inner gloves remain tucked under sleeves<br>☐ Ensure a continuous barrier between boot covers and coverall/gown<br>☐ Seal opening of coverall (if applicable) and ensure no skin or clothing is exposed<br>☐ Sit on clean chair, as needed | |

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Note:
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# Acute Care Donning Training Checklist

**Suspect/Confirmed EVD cases and/or Care Environment**
**Coveralls/Gowns with Separate Hood and Boot Covers**

| TRAIN. | PRAC. | PROF. | | DONNING PPE PROCEDURE | COMMENTS (May include size of PPE) |
|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | 6 | Put on impermeable outer footwear and/or foot coverings:<br>☐ Select an appropriate layer of outer footwear and/or foot coverings (e.g., water-proof boots, disposable non-slip boot/shoe covers) to wear over the coverall socks for foot protection and/or as an additional barrier to facilitate doffing in the hot zone<br>☐ Adjust and verify proper fit of PPE | |
| ☐ | ☐ | ☐ | 7 | **Put on fit-tested N95 respirator:**<br>☐ Apply respirator as per manufacturer's user instructions<br>☐ Fit flexible nose piece to bridge of nose<br>☐ Perform seal check | |
| ☐ | ☐ | ☐ | 8 | **Put on single-use (disposable) hood cover:**<br>☐ Ensure hood cover extends past shoulders and provides complete coverage of head, neck, and ears<br>☐ Adjust and verify proper fit of PPE | |
| ☐ | ☐ | ☐ | 9 | **Put on single-use (disposable) eye/face protection:**<br>☐ Select and use eye/face protection as per manufacturer's user instructions and based on a risk assessment<br>☐ When safety goggles are to be worn in combination with other PPE ensure they do not interfere with the proper fit of each component and are positioned under the hood<br>☐ Ensure face shield provides coverage of entire front and sides of face; adjust to fit | |
| ☐ | ☐ | ☐ | 10 | **Put on a single-use (disposable) impermeable apron (if used):**<br>☐ Check apron covers the torso to the level of the mid-calf | |
| ☐ | ☐ | ☐ | 11 | **Put on outer gloves with extended cuffs:**<br>☐ Ensure gloves cover cuffs of coverall/gown and that no skin is exposed<br>☐ Adjust and verify proper fit of PPE | |
| ☐ | ☐ | ☐ | 12 | **Verify donning PPE procedure:**<br>☐ Inspect to ensure that it is secure and full coverage has been achieved<br>☐ Visually confirm sequence has been completed correctly | |

Name of Trainer: _____ Name of Worker: _____ Signature: _____ Date: _____

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Appendix B: PSHSA acute care PPE protocol for doffing

# Acute Care Doffing Training Checklist

**Suspect/Confirmed EVD Cases and/or Care Environment**
**Coveralls/Gowns with Separate Hood and Boot Covers**

This checklist is designed to assist with training healthcare workers (HCWs) on the correct doffing of personal protective equipment (PPE) for suspect/confirmed cases of EVD and their care environment. **Please Note: This is a sample checklist** that may need to be adapted to meet relevant standards of practice and/or specific manufacturer's user instructions for variations of approved PPE. The tool can be used to verify and document that all necessary doffing steps are performed and in the proper sequence. Any errors or omissions identified during practice and skill proficiency demonstrations must be communicated immediately, to ensure specific instructions are provided and so appropriate corrective action are taken for the protection of the HCW.

Note: Hand hygiene should be performed after removing PPE, before hands approach the face and any time hand contamination is identified or suspected during the doffing process.

**Before you begin, instruct HCW(s) that PPE must be removed slowly and carefully within each appropriately designated zone (i.e. moving from hot to warm to cold as per organizational set up) and utilizing the room configuration to minimize cross contamination.**

| TRAIN. | PRAC. | PROF. | | DOFFING PPE PROCEDURE | COMMENTS (May include size of PPE) |
|---|---|---|---|---|---|
| ☐ | ☐ | ☐ | 1 | **Remove apron (if used):**<br>☐ Trained observer may assist with ties but must be donned in adequate PPE based on risk<br>☐ Remove apron by gently rolling inside out; taking care to avoid contact with outside surface of coverall/gown<br>☐ Dispose into designated waste container | |
| ☐ | ☐ | ☐ | 2 | **Remove outer footwear and/or foot coverings:**<br>☐ Remove outer footwear and/or foot coverings carefully to avoid inadvertent contact and cross-contamination<br>☐ Take care not to slip or fall; use chair as needed<br>☐ Dispose into designated waste container | |
| ☐ | ☐ | ☐ | 3 | **Remove outer gloves:**<br>☐ Remove outer gloves taking care not to touch inner gloves or bare skin<br>☐ Dispose into designated waste container<br>☐ Inspect inner gloves for visible contamination, cuts or tears | |
| ☐ | ☐ | ☐ | 4 | **Remove eye/face protection:**<br>☐ Hold face shield or goggles by grasping band at back of head and lifting gently over head and away from face<br>☐ Dispose into designated waste container | |
| ☐ | ☐ | ☐ | 5 | **Remove hood cover:**<br>☐ Trained observer may assist with removal, but must be donned in adequate PPE based on risk<br>☐ Gently remove hood cover without self contamination<br>☐ Dispose into designated waste container | |

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# Acute Care Doffing Training Checklist

**Suspect/Confirmed EVD Cases and/or Care Environment**
**Coveralls/Gowns with Separate Hood and Boot Covers**

| TRAIN. | PRAC. | PROF. | DOFFING PPE PROCEDURE | COMMENTS (May include size of PPE) |
|---|---|---|---|---|
| ☐ | ☐ | ☐ | **Remove coverall/gown:**<br>☐ Trained observer may assist, but must be donned in adequate PPE based on risk<br>☐ Unzip or unfasten coverall/gown completely before rolling down and turning inside out. Avoid contact of inner clothing with outer surface of coverall during removal, touching inside of the coverall/ gown only<br>☐ Dispose into designated waste container | |
| ☐ | ☐ | ☐ | **Remove boot covers:**<br>☐ Remove boot covers carefully to avoid inadvertent contact and cross-contamination<br>☐ Take care not to slip or fall; use chair as needed<br>☐ Dispose into designated waste container | |
| ☐ | ☐ | ☐ | **Remove inner gloves:**<br>☐ Inspect gloves for visible contamination, cuts or tears before removing<br>☐ Take care to avoid touching the outside of the gloves with bare skin<br>☐ Dispose into designated waste container | |
| ☐ | ☐ | ☐ | **Perform hand hygiene:**<br>☐ Use alcohol-based hand rub (ABHR) or soap and water<br>☐ Allow hands to dry completely | |
| ☐ | ☐ | ☐ | **Remove N95 respirator:**<br>☐ Grab bottom strap and lift over head<br>☐ Lean forward and grab top strap; gently lift over head and away from face<br>☐ Take care to not touch the front of the respirator<br>☐ Dispose into designated waste container | |
| ☐ | ☐ | ☐ | **Perform hand hygiene:**<br>☐ Use ABHR or soap and water<br>☐ Allow hands to dry completely | |
| ☐ | ☐ | ☐ | **Verify doffing PPE procedure:**<br>☐ Visually confirm sequence has been completed correctly and no contamination has occurred | |

Name of Trainer: _____ Name of Worker: _____ Signature: _____ Date: _____

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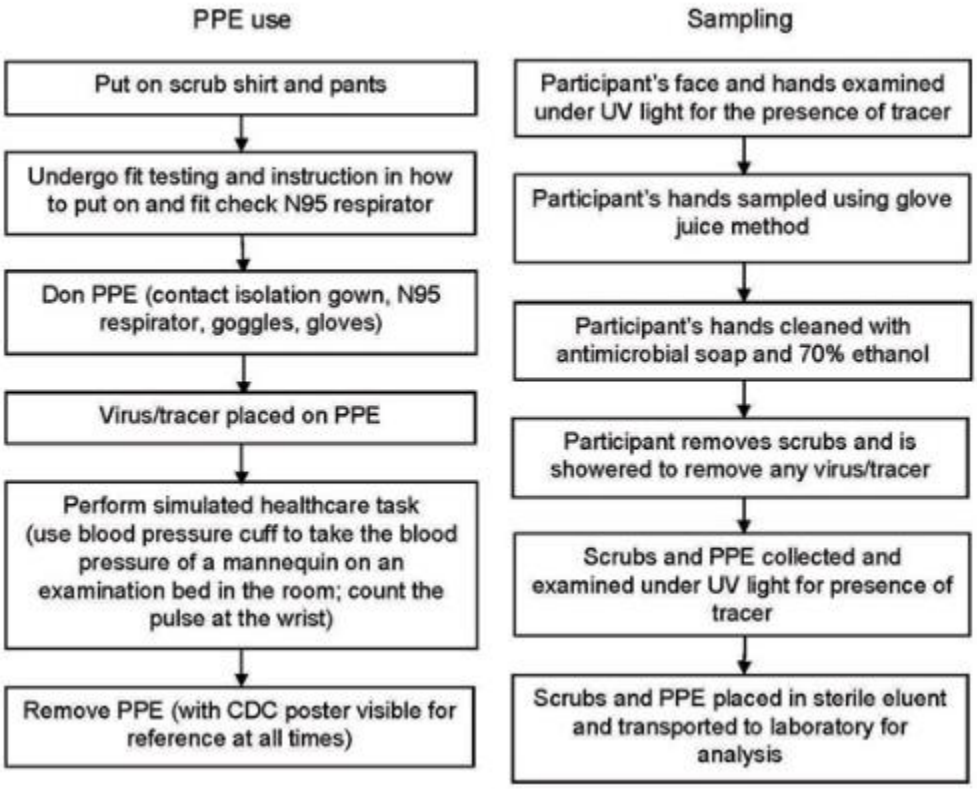
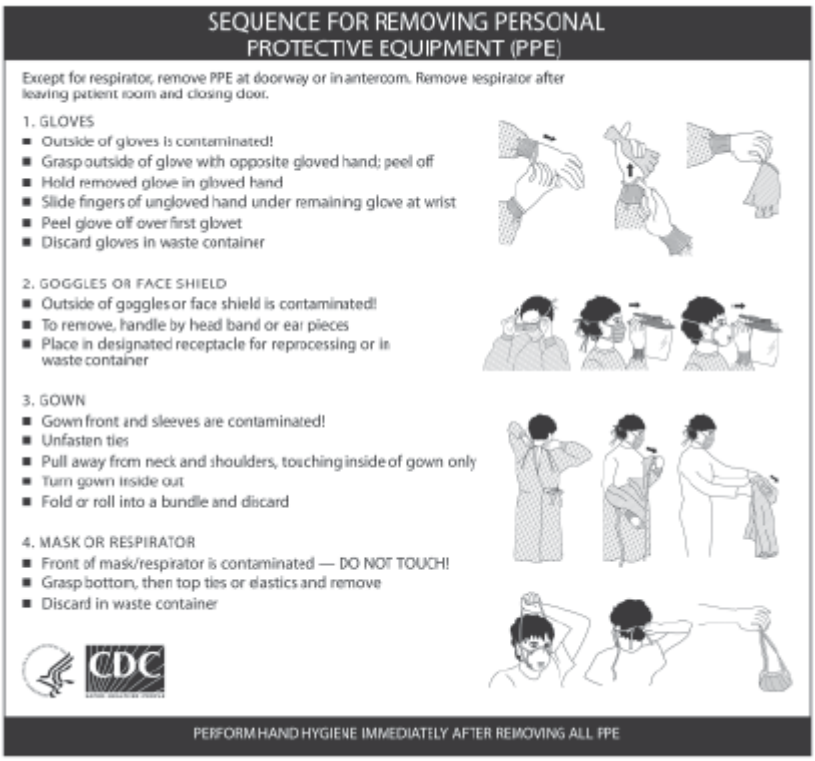
Appendix C: Protocol for Casanova et al. study produced by the CDC



Appendix D: CDC protocol used in study by Beam et al., 2011 and Guo et al., 2014



SEQUENCE FOR REMOVING PERSONAL PROTECTIVE EQUIPMENT (PPE)

Except for respirator, remove PPE at doorway or in anteroom. Remove respirator after leaving patient room and closing door.

1. GLOVES
- Outside of gloves is contaminated!
- Grasp outside of glove with opposite gloved hand; peel off
- Hold removed glove in gloved hand
- Slide fingers of ungloved hand under remaining glove at wrist
- Peel glove off over first glovet
- Discard gloves in waste container

2. GOGGLES OR FACE SHIELD
- Outside of goggles or face shield is contaminated!
- To remove, handle by head band or ear pieces
- Place in designated receptacle for reprocessing or in waste container

3. GOWN
- Gown front and sleeves are contaminated!
- Unfasten ties
- Pull away from neck and shoulders, touching inside of gown only
- Turn gown inside out
- Fold or roll into a bundle and discard

4. MASK OR RESPIRATOR
- Front of mask/respirator is contaminated — DO NOT TOUCH!
- Grasp bottom, then top ties or elastics and remove
- Discard in waste container

CDC

PERFORM HAND HYGIENE IMMEDIATELY AFTER REMOVING ALL PPE

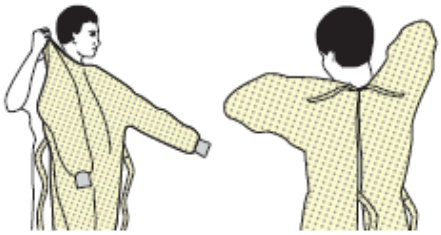
Appendix E: CDC acute care donning and doffing protocols for EVD

## SEQUENCE FOR PUTTING ON PERSONAL PROTECTIVE EQUIPMENT (PPE)

The type of PPE used will vary based on the level of precautions required, such as standard and contact, droplet or airborne infection isolation precautions. The procedure for putting on and removing PPE should be tailored to the specific type of PPE.

### 1. GOWN

- Fully cover torso from neck to knees, arms to end of wrists, and wrap around the back
- Fasten in back of neck and waist



### 2. MASK OR RESPIRATOR

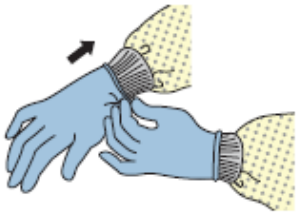
- Secure ties or elastic bands at middle of head and neck
- Fit flexible band to nose bridge
- Fit snug to face and below chin
- Fit-check respirator

### 3. GOGGLES OR FACE SHIELD

- Place over face and eyes and adjust to fit

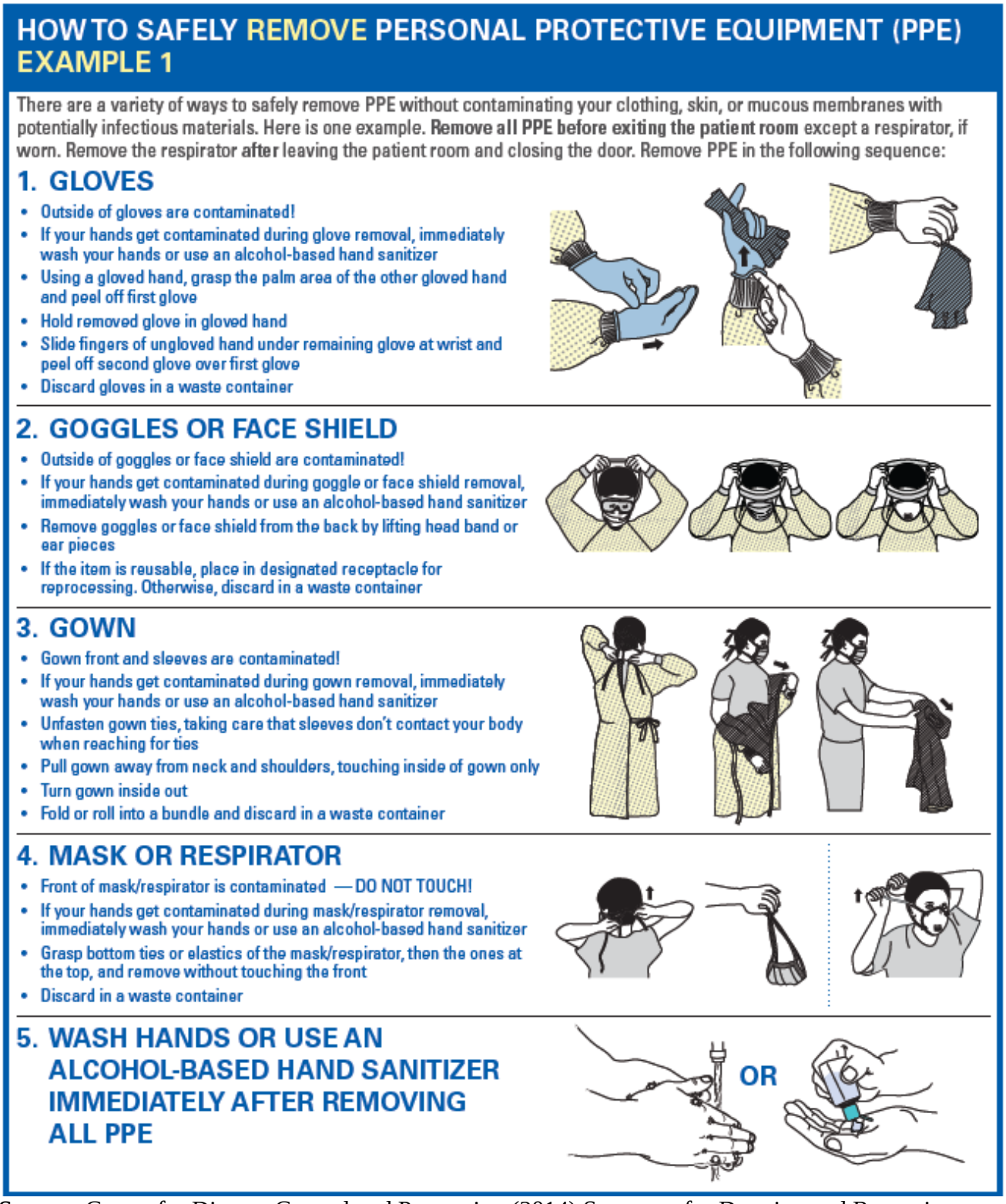
### 4. GLOVES

- Extend to cover wrist of isolation gown



## USE SAFE WORK PRACTICES TO PROTECT YOURSELF AND LIMIT THE SPREAD OF CONTAMINATION

- Keep hands away from face
- Limit surfaces touched
- Change gloves when torn or heavily contaminated
- Perform hand hygiene




**Source:** Centre for Disease Control and Prevention (2014) Sequence for Donning and Removing Personal Protective Equipment. Retrieved on September 7th 2015 from http://www.cdc.gov/HAI/prevent/ppe.htm

Appendix F: WHO donning and doffing protocols

## Steps to put on personal protective equipment (PPE) including gown

**1** Remove all personal items (jewelry, watches, cell phones, pens, etc.)

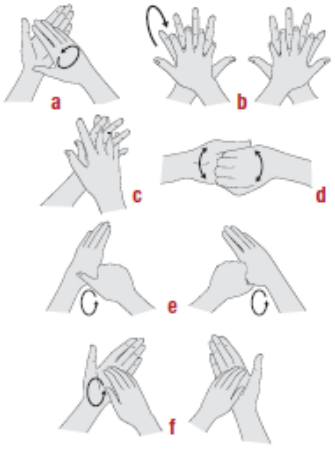
**2** Put on scrub suit and rubber boots[1] in the changing room.

**3** Move to the clean area at the entrance of the isolation unit.

**4** By visual inspection, ensure that all sizes of the PPE set are correct and the quality is appropriate.

**5** Undertake the procedure of putting on PPE under the guidance and supervision of a trained observer (colleague).

**6** Perform hand hygiene.




**7** Put on gloves (examination, nitrile gloves).

**8** Put on disposable gown made of fabric that is tested for resistance to penetration by blood or body fluids OR to blood-borne pathogens.

**9** Put on face mask.

**10** Put on face shield OR goggles.


**11** Put on head and neck covering surgical bonnet covering neck and sides of the head (preferable with face shield) OR hood.


**12** Put on disposable waterproof apron (if not available, use heavy duty, reusable waterproof apron).

**13** Put on second pair of (preferably long cuff) gloves over the cuff.

[1] If boots are not available, use closed shoes (slip-ons without shoelaces and fully covering the dorsum of the foot and ankles) and shoe covers (nonslip and preferably impermeable)

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# Steps to take off personal protective equipment (PPE) including gown

**1** Always remove PPE under the guidance and supervision of a trained observer (colleague). Ensure that infectious waste containers are available in the doffing area for safe disposal of PPE. Separate containers should be available for reusable items.

**2** Perform hand hygiene on gloved hands.[1]

**3** Remove apron leaning forward and taking care to avoid contaminating your hands. When removing disposable apron, tear it off at the neck and roll it down without touching the front area. Then untie the back and roll the apron forward.

**4** Perform hand hygiene on gloved hands.

**5** Remove outer pair of gloves and dispose of them safely.
Use the technique shown in Step 17

**6** Perform hand hygiene on gloved hands.

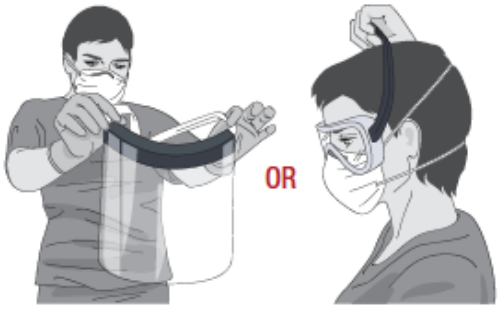
**7** Remove head and neck covering taking care to avoid contaminating your face by starting from the bottom of the hood in the back and rolling from back to front and from inside to outside, and dispose of it safely.


**8** Perform hand hygiene on gloved hands.

**9** Remove the gown by untying the knot first, then pulling from back to front rolling it from inside to outside and dispose of it safely.

**10** Perform hand hygiene on gloved hands.

**11** Remove eye protection by pulling the string from behind the head and dispose of it safely.




**12** Perform hand hygiene on gloved hands.

**13** Remove the mask from behind the head by first untying the bottom string above the head and leaving it hanging in front; and then the top string next from behind head and dispose of it safely.

**14** Perform hand hygiene on gloved hands.

**15** Remove rubber boots without touching them (or overshoes if wearing shoes). If the same boots are to be used outside of the high-risk zone, keep them on but clean and decontaminate appropriately before leaving the doffing area.[2]

**16** Perform hand hygiene on gloved hands.

**17** Remove gloves carefully with appropriate technique and dispose of them safely.

**18** Perform hand hygiene.

1 While working in the patient care area, outer gloves should be changed between patients and prior to exiting (change after seeing the last patient)

2 Appropriate decontamination of boots includes stepping into a footbath with 0.5% chlorine solution (and removing dirt with toilet brush if heavily soiled with mud and/or organic materials) and then wiping all sides with 0.5% chlorine solution. At least once a day boots should be disinfected by soaking in a 0.5% chlorine solution for 30 min, then rinsed and dried.

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Appendix G: Comparison of PPE donning protocols

| **Protocol** | **Implementation date** | **Utilised by** | **Number of steps** | **First Step** | **Last Step** | **Potential Issues** | **Unique Features** |
|---|---|---|---|---|---|---|---|
| World Health Organisation – Steps to put on personal protective equipment (PPE) including gown | 2008 | This checklist was created by WHO International. No mention of specific target area, but it`s accessible to anyone. | 13 steps for donning | Remove all personal jewellery | Application of second pair of gloves. | -Brief N95 respirator directives (it says "put on face mask". | -perform hand hygiene prior to doffing gloves |
| Centre for Disease Control and Prevention – Sequence for Putting on Personal Protective Equipment (PPE) | Last Updated in 2014 | To be used by healthcare workers during management of patients with Ebola Virus Disease in U.S. hospitals, including procedures for putting on (donning) and removing (doffing) | 4 steps for donning | Gown application | Glove application | -The first step consists of applying the gown. It would be important that an assessment of the PPE be completed and that proper hand washing is conducted prior to donning. | -Safe work practice information |
| Public Services Health & Safety Association – Acute Care Donning Training Checklist | 2014 | Ontario hospitals | 12 steps for donning | Hand Hygiene | Inspect to insure full coverage and confirm sequence has been completed accordingly | -No information about zones of contamination<br>-In the 7th step, the protocol states to ‘’apply respirator as per manufacture's user instructions``. It would be important to include more information in case the user instructions aren`t provided or available. | -Instructions provided for hand hygiene<br>-Details for PPE selection (no fabric details, but there is information about length of equipment) |

Appendix H: Comparison of PPE doffing protocols

| **Protocol** | **Implementation date** | **Utilised by** | **Number of steps** | **First Step** | **Last Step** | **Potential Issues** | **Unique Features** |
|---|---|---|---|---|---|---|---|
| World Health Organisation – Steps to put on personal protective equipment (PPE) including gown | 2008 | This checklist was created by WHO International. No mention of specific target area, but it`s accessible to anyone. | 18 steps for donning | -Ensure waste containers are available | Hand Hygiene | -No mention about the role of the trained observer<br>-No information about zones of contamination | -Hand hygiene is performed with gloves on. |
| Centre for Disease Control and Prevention – Sequence for Putting on Personal Protective Equipment (PPE) | Last Updated in 2014 | To be used by healthcare workers during management of patients with Ebola Virus Disease in U.S. hospitals, including procedures for putting on (donning) and removing (doffing) | 4 steps for donning | -Remove gloves | Remove Gloves | - Recommends that all PPE be removed before exiting the patient room (with the exception of the respirator). This causes concern for recontamination | -DO NOT TOUCH front of respirator. This is an important details that was omitted in other protocols. |
| Public Services Health & Safety Association – Acute Care Donning Training Checklist | 2014 | Ontario hospitals | 12 steps for donning | -Remove apron | Verify doffing procedure (proper sequence has been conducted and no contamination occurred) | -No information about zones of contamination.<br>-Suggests using chair to remove foot coverings but doesn't note to decontaminate chair subsequently. | -Trained observer role in protocol. |

Appendix I: Recruitment flyer draft

# Nursing Students Needed

**Third and fourth year Laurentian University Nursing Students are needed for a quantitative research study on personal protective equipment, which will evaluate skin and clothing contamination subsequent to donning and doffing using the PSHSA acute care donning and doffing protocols (PPE will be provided).**

**Participation requires 2 separate visits - a 1 hour training session and a 30 minute PPE donning and doffing trial in the school of nursing which are expected to take place in January. Each session will be scheduled at a date and time that is convenient for participants.**

**Please contact Chelsie at cs_desrochers@laurentian.ca for more information or to register. This experience will look great on your résumé!**

Appendix J: Informed consent form

**Information and Consent for Prospective Nursing Student Participants**

**Study Title:** Are nurses protected? Observing the risk of skin contamination when donning and doffing personal protective equipment

**Institution:** Laurentian University, School of Rural and Northern Health

**Principal Investigator:** Chelsie Desrochers, B.Sc, M.Sc Candidate.

**Co-Investigators:** Dr. Tammy Eger, Ph.D. (Supervisor)
Dr. Sandra Dorman, Ph.D. (Committee Member)
Judith Horrigan, Ph.D Candidate. (Committee Member)

**Introduction**

My name is Chelsie Desrochers and I am an M.Sc candidate in the Interdisciplinary Health program in the school of Rural and Northern Health at Laurentian University in Sudbury, Ontario, Canada. I am the main investigator for this research study, which is evaluating the effectiveness of the newly designed donning and doffing protocols developed by the Public Services Health and Safety Association (PSHSA). These protocols were created to use for the care of suspect and confirmed cases of Ebola Virus Disease (EVD).

I invite you to participate in this study designed to give insight into the strengths and weaknesses of the PSHSA donning and doffing protocol. The following information will help you to decide whether or not you are willing to be a participant in this quantitative research. This letter explains the purpose of this study and includes potential risks and benefits. It will also explain your prospective involvement in the study and your rights as a participant. Your participation in this study is entirely voluntary, and you may choose to withdraw at any point with no consequences or judgement.

**Purpose of this research**

The use of personal protective equipment (PPE) is a crucial element in effective occupational health and safety. Previous pandemics such as the Severe Acute Respiratory Syndrome (SARS), Middle Eastern Respiratory Syndrome (MERS), and Ebola have prompted the PSHSA to create an acute-care donning and doffing PPE protocol in collaboration with the Ministry of Health and Long Term Care (MOHLTC). Through previous research, ineffective use of PPE has been linked to the misuse of protocols, resulting in exposure to avoidable hazards. As a result, the purpose of this study is to evaluate the effectiveness of the PSHSA PPE donning and doffing protocol to determine if they are effective at preventing skin contamination.

**Involvement in the study**

Your experiences as a nursing student are invaluable to this study. As a participant, you will be asked to attend a 1 hour group-training session, which will be presented by the primary researcher. During this session, you will be presented a PowerPoint presentation containing clips from the Centre for Disease Control and Prevention training video. This session will be scheduled at a date and time that is convenient for participants. This session will permit you to better understand the protocols prior to the study. It will educate you on the protocols and will permit you to visualise the donning and doffing process.

Following this training session, you will be asked to attend a second session (on a separate day) in the nursing lab at Laurentian University, which will be scheduled in January in accordance with your schedule. At this time, you will be asked to don PPE (provided) using the PSHSA acute care PPE protocol. PPE consists of the following equipment: hood, face shield, apron, N95 respirator, gloves, gown, pants, and boot covers. You will be sprayed with GloGerm once the equipment is applied. Once complete, you will perform 7 simulated movements to mimic typical nursing tasks. They will hold each movement for 5 seconds. Movements include: Raising both arms up, reaching sideways with the left arm, reaching sideways with the left arm, twisting to the left, twisting to the right, reaching down by bending 90° at the waist, and bending 45° at the waist and reaching forward. Then you will doff the PPE following the protocol. The entirety of the study will be competed with the assistance of a trained observer, as per the PSHSA protocol requirements. A screening process will then take place using an ultraviolet light to examine transfer of the GloGerm to the skin and clothing. Before leaving, the participants will be provided with an exit questionnaire. This session is expected to take 30 minutes.

Participants' names will not be used in this study. All identifiers, including demographics, age, and sex will only be presented in group results. No individual information or results will be shared with other participants, peers, staff, or faculty. All identifying information will be removed for the data to protect confidentiality.

All information collected in the study will only be used for research purposes. Group statistics will be reported following the study and the research findings will be used for statistical analyses and for the research document. The end results will be available to all involved including participants, the nursing department, and stakeholders. If preferred, you may withdraw from receiving the findings. The finding will be in the form of a thesis, as per the requirement for an M.Sc in Interdisciplinary Health at Laurentian University which can be obtained by contacting the principle investigator. Several copies of a brief summary report of the main findings of the study will be available from the main office of the School of Nursing. Anyone interested in the results of the study can pick up a summary report at the School of Nursing anytime between January 2017 and March 2017.

The research team will present study findings at the 2016 Faculty of Health Conference on the Laurentian University campus. The thesis defence is public and posters will be displayed throughout the Laurentian University campus and posted in the School of Nursing. Study participants will be open to attend the public presentation. Findings from the study will be also be available on the CROSH website after January 2017.

**Potential benefits**
This experiment will simulate a typical isolation procedure as seen in Ontario hospitals. This will be conducted in a safe manner to replicate the contamination patterns often seen with infectious diseases. Through this study, future nurses will get a better comprehension of safe work practices by enhancing their understanding of the protocol used in Ontario hospitals. They will also get to practice the donning and doffing process in a safe environment.

Through the results of this study, healthcare professionals may have an improved understanding of the areas that are subject to contamination and with that, will hopefully modify their future actions to reduce the spread of infectious diseases. This can have a beneficial impact on the quality of a care provided to patients, improve health outcomes for nurses, and diminish overall costs to the healthcare system. Results of the study will also be shared with the PSHSA who developed the PPE donning and doffing protocol. If breaches or contamination occur, the findings could be used to improve the training video and/or the protocols.

**Potential harms, risks, or discomforts**
There is an inconvenience associated with this study since there is a time commitment involved. As mentioned, you will be required to attend a 1 hour training session and a second 30 minute session to evaluate the PPE donning and doffing protocols. It is foreseeable that the PPE evaluation will cause a temporary stressful reaction due to the fact that the protocols are very detailed. A trained observer will be assisting you with the donning and doffing process to minimize this pressure.

A second potential risk is exposure to GloGerm. Since it is composed of 100% melamine resin, there are some potential risk factors which include eye contact, skin contact, ingestion, inhalation, and allergy. In the event where the GloGerm is accidently transferred to the eye of the participant, they will be directed to an eye washing station to flush the eyes until the discomfort is ceased. If redness or irritation of the skin occurs, the participants will be asked to wash off the GloGerm immediately with soap and water. If ingested, they will seek medical attention if any discomfort occurs. If inhaled, they will be moved to an environment with fresh air immediately. Anyone with allergies to GloGerm will be excluded from the study. Since 3$^{rd}$ and 4$^{th}$ year nursing students have been exposed to GloGerm for handwashing techniques, they should be aware of allergies to the product. In the event that an allergic reaction occurs, they will be asked to wash off the GloGerm and seek medical attention if reaction persists. Since PPE will be donned when the GloGerm is introduced, the risks are minimal.

Participants will also be exposed to a UV light during the screening process since a UV lamp will be used to detect the GloGerm. NASA (1998) suggests that wavelengths for the sun can reach 504nm whereas the UV lamp used for the study has wavelength outputs between 300 and 400 nm. Since the participants will only be exposed to the UV light for approximately 3 minutes, the risks associated are minimal and are much lower than those found in nature. To reduce the potential risks, participants will be asked not to look at the light directly. They will also be wearing scrubs or clothing, which will further reduce the risks since their skin will not be directly exposed to the light.

**Participants' rights**
Your participation in the study is entirely voluntary. You are not required or forced under any circumstances, to participate. You may choose to end your participation at any time, without question and without consequence from your professors, or potential employers.

**Confidentiality and anonymity**
Your privacy and confidentiality will be respected during the study and after the study. All Information will remain completely confidential and will only be presented in group results. The individual information obtained from this study will not be accessible by other participants, peers, professors, staff, or faculty. Any identifiers will be removed stripped from the data. If the findings of this study are published or presented, only group information will be presented.

To ensure confidentiality, all research data collected including paper files, will be kept in a locked file cabinet at the School of Human Kinetics (in the Centre for Research in Occupational Safety where the research supervisor has an office. Professors, staff, faculty, or peers will not have access to this data. Only the research team (Chelsie Desrochers, Dr. Tammy Eger, Ph.D., Dr. Sandra Dorman, Ph.D., and Judith Horrigan, Ph.D. candidate) will be able to access to the data in order to defend anonymity and confidentiality. The research data, including consent forms and individual results will be kept secured in a locked filing cabinet for five years.

**Expected costs**
While there is no cost to participate in this study, your time is very valuable to us and we understand the time commitment required. We really appreciate your willingness to participate and we will be offering water, soft drinks (water, juice, pop) at the training session.

**Ethical Approval**
Ethics approval has been received from the Research Ethics Office at Laurentian University.

Should you have any questions regarding this approval process or your rights as a participant, you can contact:
Research Ethics Officer
Laurentian University Research Office
E-mail: ethics@laurentian.ca
Telephone: 1-705-675-1151 ext. 2436 or 1-800-675-1151 ext. 2436

**Questions and contact information**
We really appreciate your time and value your participation. Should you have any questions, you may contact Chelsie Desrochers via email: cs_desrochers@laurentian.ca. You may also contact Dr. Tammy Eger (Ph.D. Supervisor) at the Centre for Research in Occupational Safety and Health at 1-705-675-1151 Ext. 1005 or via email: teger@laurentian.ca.

Warmest Regards,

Chelsie Desrochers
M.Sc Interdisciplinary Health – Rural and Northern Health

**Information and Consent for Prospective Nursing Student Participants**

**Study Title:** Are nurses protected? Observing the risk of skin contamination when donning and doffing personal protective equipment

**Institution:** Laurentian University, School of Rural and Northern Health

**Principal Investigator:** Chelsie Desrochers, B.Sc, M.Sc Candidate.

**Co-Investigators:** Dr. Tammy Eger, Ph.D. (Supervisor)
Dr. Sandra Dorman, Ph.D. (Committee Member)
Judith Horrigan, Ph.D Candidate. (Committee Member)

I have read and agree with the information provided in this information letter, which outlines the implications of this study.

I understand that I am being asked to participate in a quantitative study examining skin contamination patterns subsequent to donning and doffing personal protective equipment. I know that I will be asked to apply and remove the following equipment: hood, face shield, N95 respirator, gloves, gown, pants, and boot covers. I also consent to being sprayed with GloGerm, to which I have no known allergies. I am aware that by signing this consent form and participating in the study, I have consented to be a participant for the above mentioned study. I acknowledge that my participation in this study is completely voluntary and that I can end my participation at any point without repercussion. I understand the potential benefits and risks associated with my involvement as indicated in the information letter that I was provided with. As a result, I agree and consent to participate in this study. If my e-mail is signed below, I consent to receiving a summary of the findings between January 2017 and March 2017

_____ Date: _____
Name of Participant (Please Print)

_____ E-mail: _____
Signature of Participant

Chelsie Desrochers, B.Sc, M.Sc. Candidate
School of Rural and Northern Health,
Laurentian University
E-mail: cs_desrochers@laurentian.ca

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LU Toll Free: 1-800-263-4188

Appendix K: Demographic questionnaire

Gender:

☐ Male

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Age:

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Appendix L: PIDAC guidelines for the selection of PPE

**Health care settings must ensure that staff have sufficient supplies of, and quick, easy access to, the PPE required. Health care settings should have a process for evaluating PPE to ensure it meets quality standards where applicable,[6] including a respiratory protection program compliant with the Ministry of Labour requirements.[6, 11]**

**Education in the proper use of PPE must be provided by the health care setting to all health care providers and other staff who have the potential to be exposed to blood and body fluids.**

*Gloves*

**Gloves must be worn when it is anticipated that the hands will be in contact with mucous membranes, non-intact skin, tissue, blood, body fluids, secretions, excretions, or equipment and environmental surfaces contaminated with the above.[8]**

**BOX 2: Appropriate Glove Use**

- Select glove appropriate to task.
- Wear the correct size of gloves.
- Gloves should be put on immediately before the activity for which they are indicated.
- Clean hands before putting on gloves for a clean/aseptic procedure.
- Gloves must be removed and discarded immediately after the activity for which they were used.
- Hand hygiene must be performed immediately after glove removal.
- Change or remove gloves if moving from a contaminated body site to a clean body site within the same client/patient/resident.
- Change or remove gloves after touching a contaminated site and before touching a clean site or the environment.
- Do not wash or re-use gloves.
- The same pair of gloves must not be used for the care of more than one client/patient/resident.

Gloves are not required for routine health care activities in which contact is limited to intact skin of the client/patient/resident (e.g., taking blood pressure, bathing and dressing the client/patient/resident). Compliance with hand hygiene should always be the first consideration.

Indiscriminate or improper glove use has been linked to transmission of pathogens.[41] Gloves are **task-specific** and **single-use** for the task. Re-use of gloves has been associated with transmission of methicillin-resistant *Staphylococcus aureus* (MRSA) and Gram-negative bacilli.[42, 43]

See Box 2 for the appropriate use of gloves.

Sterile gloves are used in operating theatres and when performing sterile procedures such as central line insertions.

**Selection of Gloves**

It is important to assess and select the best glove for a given task. Selection of gloves should be based on a risk assessment of [44]:

- the type of setting (e.g., operating room, environmental cleaning, laboratory)
- the task that is to be performed (e.g., invasive or non-invasive)
- the likelihood of exposure to body substances
- the anticipated length of use
- the amount of stress on the glove.

The barrier integrity of gloves varies on the basis of:

- type and quality of glove material
- intensity of use
- length of time used
- manufacturer
- whether gloves were tested before or after use
- method used to detect glove leaks.

It is preferable to provide more than one type of glove to health care providers, because it allows the individual to select the type that best suits his/her care activities[18]. Some additional points to consider:

- good quality vinyl gloves are generally sufficient for most tasks
- latex or synthetic gloves, such as nitrile or neoprene gloves, are preferable for clinical procedures that require manual dexterity and/or will involve more than brief patient contact[18]
- powdered latex gloves have been associated with latex allergy
- new types of latex gloves are being developed which may be safe for those with an allergy to rubber latex[45]
- gloves that fit snugly around the wrist are preferred for use with a gown because they will cover the gown cuff and provide a better barrier for the arms, wrists and hands.[18]

➢ Refer to Appendix M, *Advantages and Disadvantages of PPE*, for advantages and disadvantages of different types of medical gloves.

➢ For more information about standards for gloves, visit the Canadian General Standards Board website at: http://www.tpsgc-pwgsc.gc.ca/onec-cgsb/programme-program/certification/prog/gants-medical-eng.html.

**Gloves and Hand Hygiene**

Because gloves are not completely free of leaks and hands may become contaminated when removing gloves,[5] hands must be cleaned before putting on gloves for an aseptic/clean procedure and after glove removal.[8] Gloves must be removed immediately and discarded into a waste receptacle after the activity for which they were used and before exiting a client/patient/resident environment.

Gloves may be adversely affected by petroleum-based hand lotions or creams. Verify with the glove manufacturer that the gloves are compatible with the hand hygiene products in use in the health care setting (e.g., lotions).

To reduce hand irritation related to gloves[12]:

- wear gloves for as short a time as possible
- ensure hands are clean and dry before putting on gloves
- ensure gloves are intact and clean and dry inside.

### *Gowns*

**A gown is worn when it is anticipated that a procedure or care activity is likely to generate splashes or sprays of blood, body fluids, secretions, or excretions.[8]**

Long-sleeved gowns protect the forearms and clothing of the health care provider from splashing and soiling with blood, body fluids and other potentially infectious material.

➢ See Box 3 for the appropriate use of gowns.

**Selection of Gowns**

The type of gown selected is based on the nature of the interaction with the client/patient/resident, including[18]:

- anticipated degree of contact with infectious material
- potential for blood and body fluid penetration of the gown (e.g., water-resistant gowns should be used in the operating theatre when soaking is anticipated)
- requirement for sterility (e.g., sterile gowns are worn in operating theatres and when performing sterile procedures such as central line insertions).

Gowns used as PPE should be cuffed and long-sleeved, and offer full coverage of the body front, from neck to mid-thigh or below. Clinical and laboratory coats or jackets are not a substitute for gowns where a gown is indicated. Several gown sizes should be available in a health care setting to ensure appropriate coverage for staff.

**BOX 3: Appropriate Gown Use**

- Gowns should only be worn when providing care for clients/patients/residents.
- When use of a gown is indicated, the gown should be put on immediately before the task and must be worn properly, i.e., tied at top and around the waist.
- Remove gown immediately after the task for which it has been used in a manner that prevents contamination of clothing or skin and prevents agitation of the gown.
- Discard used gown immediately after removal into appropriate receptacle. Do not hang gowns for later use.
- Do not re-use gown. Do not go from patient-to-patient wearing the same gown.

### *Masks*

**A mask is used by a health care provider (in addition to eye protection) to protect the mucous membranes of the nose and mouth when it is anticipated that a procedure or care activity is likely to generate splashes or sprays of blood, body fluids, secretions or excretions,[8, 46] or within two metres of a coughing client/patient/resident.[18, 47]**

- Masks are also required in operating theatres[48] and when performing aseptic procedures (e.g., central line insertions,[49, 50] spinal epidural/myelogram procedures[51-54]).

- A mask should be placed on a coughing client/patient/resident when outside his/her room, if tolerated, to limit dissemination of infectious respiratory secretions.[18, 55, 56, 57]
- A mask should be worn for wound irrigation procedures if there is any risk of sprays or splashes.[58]

➢ See Box 4 for the appropriate use of masks.

**Selection of Masks**

Mask selection is based on a risk assessment that includes:

- type of procedure/care activity
- length of procedure/care activity
- likelihood of contact with droplets/aerosols generated by the procedure or interaction.

Criteria for selecting masks include:

- mask should securely cover the nose and mouth
- mask should be substantial enough to prevent droplet penetration
- mask should be able to perform for the duration of the activity for which the mask is indicated (e.g., surgery).

**BOX 4: Appropriate Mask Use**

- Select a mask appropriate to the activity
- Mask should securely cover the nose and mouth
- Change mask if it becomes wet.
- Do not touch mask while wearing it.
- Remove mask correctly immediately after completion of task and discard into an appropriate waste receptacle.
- Do not allow mask to hang or dangle around the neck.
- Clean hands after removing the mask.
- Do not re-use disposable masks.
- Do not fold the mask or put it in a pocket for later use.

### *N95 Respirators*

**An N95 respirator is used to prevent inhalation of small particles that may contain infectious agents transmitted via the airborne route.[18]**

N95 respirators should also be worn for aerosol-generating procedures that have been shown to expose staff to undiagnosed tuberculosis, including:

- sputum induction
- diagnostic bronchoscopy
- autopsy examination.

➢ See Section 2.B, *Airborne Transmission and Airborne Precautions*, for more information about N95 respirators and their indications.

➢ Refer to Appendix M, *Advantages and Disadvantages of PPE*, for advantages and disadvantages of different types of masks and N95 respirators.

### *Eye Protection*

**Eye protection is used by health care providers (in addition to a mask) to protect the mucous membranes of the eyes when it is anticipated that a procedure or care activity is likely to generate splashes or sprays of blood, body fluids, secretions or excretions,[8, 46, 59] or within two metres of a coughing client/patient/resident.[18, 47, 60] Eye protection should also be worn for wound irrigation procedures if there is any risk of sprays or splashes.[58]**

**BOX 5: Appropriate Use of Eye Protection**

- Eye protection should be used whenever there is a potential for splashes or sprays to the eyes, such as operating room procedures, labour and delivery and wound irrigation.
- Eye protection must be removed immediately after the task for which it was used and discarded into waste or placed in an appropriate receptacle for cleaning.
- Prescription eye glasses are not acceptable as eye protection.

Eye protection includes:

- safety glasses
- safety goggles
- face shields
- visors attached to masks

Prescription eye glasses are not acceptable by themselves as eye protection; they may be worn underneath face shields and some types of protective eyewear.

Eye protection may be disposable or, if reusable, should be cleaned prior to re-use. Due to the risk of contamination, it is recommended that reusable eye protection be sent to a central area for reprocessing after use.

Eye protection should be comfortable, not interfere with visual acuity and fit securely. A health care setting may need to provide several different types, styles and sizes of protective eye equipment.[18]

➢ See Box 5 for the appropriate use of eye protection.

**Selection of Eye Protection**

The eye protection chosen for specific situations depends on:

- the type of activity and risk of exposure
- the circumstances of exposure (e.g., droplet exposure vs. sprays/splashes of fluid)
- other PPE used
- personal vision needs.

Criteria for selecting eye protection include:

- eye protection must provide a barrier to splashes from the side
- eye protection may be single-use disposable or washable before re-use
- prescription eye glasses are not acceptable as eye protection.

➢ Refer to Appendix M, *Advantages and Disadvantages of PPE*, for advantages and disadvantages of different types of eye protection.

### *Routine Practices for Procedures that Generate Droplets and/or Aerosols*

Certain procedures may generate droplets/aerosols that may expose staff to respiratory pathogens and are considered to be a potential risk for staff and others in the area. PPE (mask and either protective eyewear or face shield) must be used by staff when within two metres of procedures generating droplets/aerosols on any client/patient/resident, with or without symptoms of an acute respiratory infection, to prevent deposition of droplets/aerosols on staff mucous membranes.[2] See Box 6 for a list of procedures that generate droplets/aerosols where transmission has been documented.

There is debate about whether other medical procedures generate droplets/aerosols, leading to transmission of respiratory infection. For these procedures, to date, there is inconclusive or no published literature documenting transmission. Examples of such procedures include:

- nebulized therapies
- high-frequency oscillatory ventilation
- tracheostomy or tracheostomy care
- chest physiotherapy
- collection of nasopharyngeal swabs or nasopharyngeal aspirates
- tube or needle thoracostomy.

For these procedures, use of PPE should be determined by risk assessment. Facial protection is also required routinely for:

- breaches to the integrity of a mechanical ventilation system (e.g., open suctioning, filter changes)
- disposal of filters used in mechanical ventilation and cleaning/disposal of bags and filters.

All units and crash carts should be equipped with:

- a manual resuscitation bag with hydrophobic submicron filter
    - in-line suction catheters
    - non-rebreather mask that allows filtration of exhaled gases
    - PPE (gloves, gowns, masks, eye protection).

**BOX 6: Procedures Generating Droplets/Aerosols where Transmission Has Been Documented**

- Endotracheal intubation, including during cardio-pulmonary resuscitation[1]
- Cardio-pulmonary resuscitation[2]
- Open airway suctioning
- Bronchoscopy*
- Surgery and autopsy
- Sputum induction*
- Non-invasive positive pressure ventilation for acute respiratory failure (CPAP, BiPAP[3-5])
- High flow oxygen therapy[3]

* For diagnostic (but not therapeutic) bronchoscopy or sputum induction, wear an N95 respirator, due to risk from undiagnosed TB

## APPENDIX M: ADVANTAGES AND DISADVANTAGES OF PPE

### MEDICAL GLOVES

| Type | Use | Advantages | Disadvantages |
|---|---|---|---|
| Vinyl | • Protection for:<br>o Minimal exposure to blood/body fluids/infectious agents<br>o Contact with strong acids and bases, salts, alcohols<br>o Short duration tasks<br>• Protection for staff with documented skin breakdown | • Good level of protection but based on the quality of manufacturer<br>• Medium chemical resistance | • Not recommended for contact with solvents, aldehydes, ketones<br>• Quality varies with manufacturers<br>• Punctures easily when stressed<br>• Rigid – non elastic |
| Latex | • Activities that require sterility<br>• Protection for:<br>o Heavy exposure to blood/body fluids/infectious agents<br>o Contact with weak acids and bases, alcohols | • Good barrier qualities<br>• Strong and durable<br>• Has re-seal qualities<br>• Good comfort and fit<br>• Good protection from most caustics and detergents | • Not recommended for contact with oils, greases and organics<br>• Not recommended for individuals in the vicinity of those who have allergic reactions or sensitivity to latex |
| Nitrile | • Protection for:<br>o Heavy exposure to blood/body fluids/infectious agents<br>o Tasks of longer duration<br>o Tasks with high stress on glove<br>o Tasks requiring additional dexterity<br>o Chemicals and chemotherapeutic agents<br>o Recommended for contact with oils, greases, acids, bases<br>o Sensitivity to vinyl<br>• Preferred replacement for vinyl gloves when a documented allergy or sensitivity occurs | • Offers good dexterity<br>• Strong and durable<br>• Puncture-resistant<br>• Good comfort and fit<br>• Excellent resistance to chemicals | • Not recommended for contact with solvents, ketones, esters |
| Neoprene | • Replacement sterile glove for latex when a documented allergy or sensitivity occurs<br>• Recommended for contact with acids, bases, alcohols, fats, oils, phenol, glycol ethers | • Good barrier qualities<br>• Strong and durable<br>• Good comfort and fit<br>• Good protection from caustics | • Not recommended for contact with solvents |

[Adapted from Sunnybrook Health Sciences Centre, Patient Care Policy Manual Section II: Infection Prevention and Control [Policy No: II-D-1200, '*Gloves*'. Revised July, 2007 and London Health Sciences Centre, Occupational Health and Safety Services, '*Glove Selection and Use*'. Revised April 26, 2005.]

### MASKS AND N95 RESPIRATORS

| Type of Mask | Use | Advantages | Disadvantages |
|---|---|---|---|
| Standard Face Mask ('procedure' mask or 'isolation' mask) | ▪ Protection for:<br>o Minimal exposure to infectious droplets<br>o Short duration tasks<br>o Tasks that do not involve exposure to blood/body fluids<br>▪ Protection from client/patient/resident during transportation outside of room | ▪ Inexpensive | ▪ Not fluid or water resistant |
| Fluid Resistant Mask | ▪ Protection for:<br>o Heavy exposure to infectious droplets or blood/body fluids | ▪ Good comfort and fit<br>▪ Fluid resistant | ▪ Expensive |
| Surgical Mask | ▪ Protection for:<br>o Exposure to infectious droplets or blood/body fluids<br>o Long duration tasks | ▪ Good comfort and fit<br>▪ Fluid resistant<br>▪ Inexpensive | |
| NIOSH- certified N95 respirator | ▪ Protection for airborne pathogens | ▪ Provides protection from small particle aerosols<br>▪ Better face seal prevents leakage around mask | ▪ Requires fit-testing, training and seal-checking<br>▪ Expensive<br>▪ Uncomfortable for long periods of use |

### EYE PROTECTION

| Type of Eyewear | Use | Advantages | Disadvantages |
|---|---|---|---|
| Safety Glasses | ▪ Protection for:<br>o Exposure to infectious droplets or blood/body fluids | ▪ may be cleaned and re-used until visibility is compromised<br>▪ may be worn over prescription eyeglasses<br>▪ good visibility | ▪ with continued use, visibility may be compromised |
| Goggles | ▪ Protection for:<br>o Exposure to infectious droplets or blood/body fluids | ▪ may be cleaned and re-used until visibility is compromised<br>▪ may be worn over prescription eyeglasses | ▪ poor visibility |
| Face Shield | ▪ Protection for:<br>o Exposure to infectious droplets or blood/body fluids | ▪ may be worn over prescription eyeglasses<br>▪ good visibility | |
| Visor attached to Mask | ▪ Protection for:<br>o Minimal exposure to infectious droplets or blood/body fluids | ▪ May be worn with prescription eyeglasses<br>▪ Quick to put on | |

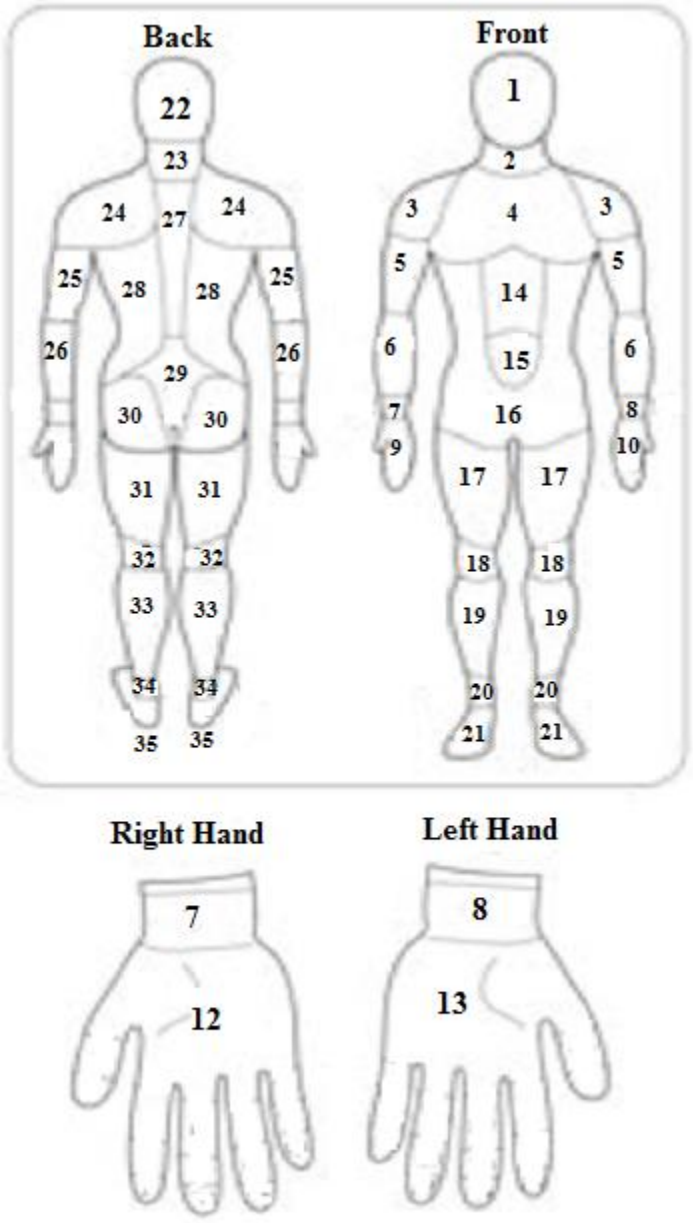
Appendix M: PIDAC guideline summary for the proper selection of PPE

**Note: This is used by Health Sciences North as stated by a member of the Infection Control Department. It is also recommended by the PSHSA.**

| **Type of PPE** | **Recommendation** |
|---|---|
| **Gloves** | • Good quality vinyl gloves are generally sufficient for most tasks<br>• Latex or synthetic gloves, such as nitrile or neoprene gloves, are preferable for clinical procedures that require manual dexterity and/or will involve more than brief patient contact18<br>• Powdered latex gloves have been associated with latex allergy<br>• New types of latex gloves are being developed which may be safe for those with an allergy to rubber latex45<br>• Gloves that fit snugly around the wrist are preferred for use with a gown because they will cover the gown cuff and provide a better barrier for the arms, wrists and hands. |
| **Gown** | • Long-sleeved gowns protect the forearms and clothing of the healthcare provider from splashing and soiling with blood, body fluids and other potentially infectious material.<br>• Gowns used as PPE should be cuffed and long-sleeved, and offer full coverage of the body front, from neck to mid-thigh or below. |
| **Respirator** | • N95 Respirator |
| **Eye Protection** | Eye protection includes:<br>• safety glasses<br>• safety goggles<br>• face shields<br>• visors attached to masks |

**Source:** Public Health Ontario (2012). Routine Practices and Additional Precautions in All Health Care Settings. 3rd edition. Toronto, ON. https://www.publichealthontario.ca/en/eRepository/RPAP_All_HealthCare_Settings_Eng2012.pdf

Appendix N: Body maps




1- Face
2- Frontal Neck
3- Frontal Shoulder
4- Chest
5- Frontal biceps
6- Frontal Forearm
7- Right wrist
8- Left wrist
9- Right Wrist
10- Right Hand
11- Left Hand
12- Right Palm
13- Left Palm
14- Sternal
15- Abdominal
16- Frontal Core
17- Frontal Quads
18- Frontal Knee
19- Frontal Lower Leg
20- Frontal Ankle
21- Foot
22- Dorsal Head
23- Dorsal Neck
24- Dorsal Shoulders
25- Dorsal Biceps
26- Dorsal Forearm
27- Spinal
28- Dorsal Core
29- Lumbar
30- Buttock
31- Dorsal Quads
32- Dorsal Knee
33- Dorsal Lower Leg
34- Dorsal Ankle
35- Plantar

Appendix O: UV light screening protocol

- Ask the participant to stand with their arms and feet abducted

- Start at the top of one shoulder of the participant. With the UV light held horizontally and parallel to the front of the body, sweep down one side of the front of the torso, down the leg to the ankle, then move to the other ankle and sweep back up the front of this opposite leg and torso, ending with the opposite shoulder.

- Sweep the UV light over the outside top of the arm from the top of the shoulder to the bottom of the wrist, then up the inside of the arm to the armpit. Repeat the sweep of the inside and outside of this arm

- Sweep down that side of the body to the ankle, then up the inside of that leg and down the inside of the opposite leg, then back up the other leg from the ankle to the underarm. Repeat the sweep of the inside and outside of this arm.

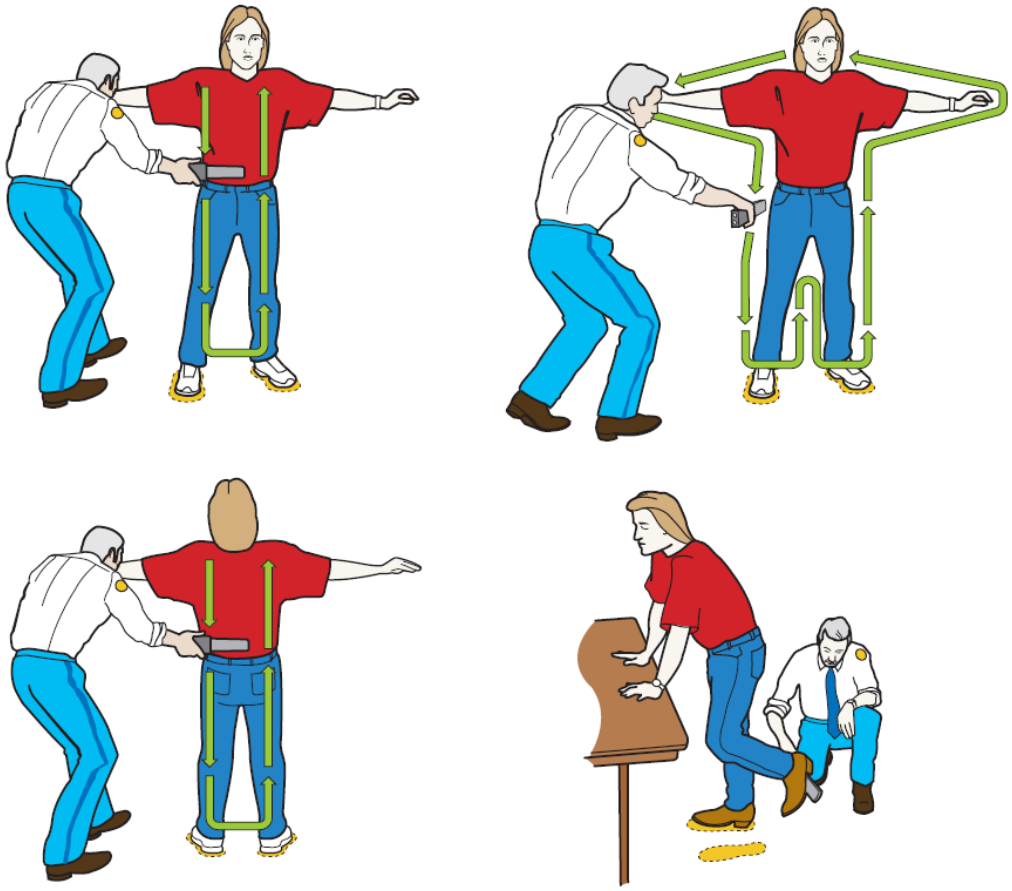
- Ask the participant to turn around. (Arms can be put down now.) The pattern used to scan the front of the body should now be repeated over the back of the body.

- Scan the hands by starting at the wrists and making your way down to the fingers. Start with the left hand and then scan the right

- Ask participants to rotate their hand, making the palm face the ceiling. Once again, scan from the wrist to the fingers. Start with the left hand and then scan the right

- Ask the participant to grab the edge of the table for support, then to lift one foot up in back of him- or herself. Scan across the bottom of the shoe. Repeat for the other foot.

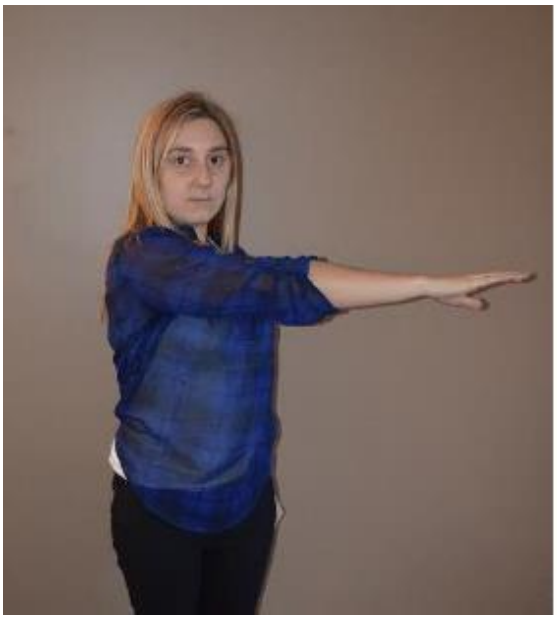
- For the head area, start at the top of the forehead and scan around the top of the head down to the back of the neck.



**Source:** https://www.ncjrs.gov/school/178265_9.pdf

Appendix P: Simulated movements to be performed in red zone following GloGerm application

1) Raise both arms up as if you are reaching for an IV pole
2) Reach forward as if you are attending to your patient and performing a blood pressure check



3) Extend your right arm to the left side as if you are reaching for a tool
4) Extend your left arm to the right side as if you are reaching for a tool

5) Bend 90° at the waist as if you are picking up an item from the ground
6) Bend 45° at the waist and extend arms forward as if you are reaching for the bed sheets to make a bed.

7) Twist waist and arms to the left side, which is required when giving a bed bath
8) Twist waist and arms to the right side, which is required when giving a bed bath

Appendix Q: Proposed revised donning protocol (**bolded areas indicate suggested revisions**)

# Acute Care Donning Training Checklist

**Suspect/Confirmed EVD Cases and/or Care Environment**
**Coveralls/Gowns with Separate Hood and Boot Covers**

This checklist is designed to assist with training healthcare workers (HCWs) on the correct donning of personal protective equipment (PPE) when caring for suspect/confirmed cases of EVD and their care environment. **Please Note: This is a sample checklist** that may need to be adapted to meet relevant standards of practice and/or specific manufacturer's user instructions for variations of approved PPE. The tool can be used to verify and document that all necessary donning steps are performed and in the proper sequence. Any errors or omissions identified during practice and skill proficiency demonstrations must be communicated immediately, to ensure specific instructions are provided and so appropriate corrective action are taken for the protection of the HCW.

Note: Establish clearly defined zones (e.g., hot, warm, and cold) and protocols to prevent and control secondary contamination during doffing.

**Before you begin, instruct HCW(s) to don point-of-care scrubs and footwear, hydrate, tie back long hair and secure in place, and remove personal items such as hand and wrist jewelry. Gather and inspect PPE carefully. Ensure that the correct size is selected and that the PPE is in good sanitary and working condition. Damaged or defective PPE should not be used.**

| # | TRAIN. | PRAC. | PROF. | DONNING PPE PROCEDURE | COMMENTS (May include size of PPE) |
|---|---|---|---|---|---|
| 1 | ☐ | ☐ | ☐ | **Ensure the following:**<br>☐ **Hair is tied in a low bun**<br>☐ **A mirror is present in the yellow and red zone**<br>☐ **Jewelry has been removed**<br>☐ **Defined zones are clearly established**<br>☐ **Footbath is available for outer footwear doffing** | |
| 2 | ☐ | ☐ | ☐ | **Perform hand hygiene:**<br>☐ Use alcohol-based hand rub (ABHR) or soap and water<br>☐ **Ensure wrists and nails are thoroughly cleaned**<br>☐ Allow hands to dry completely before putting on any PPE | |
| **3** | ☐ | ☐ | ☐ | **Put on single-use (disposable) impermeable boot covers:**<br>☐ **Sit on clean chair, as needed**<br>☐ Select boot covers that extend to at least mid-calf<br>☐ Ensure boot covers allow for ease of movement<br>☐ Adjust and verify for proper fit of PPE | |
| **4** | ☐ | ☐ | ☐ | **Perform hand hygiene:**<br>☐ Use ABHR or soap and water<br>☐ **Ensure wrists and nails are thoroughly cleaned**<br>☐ Allow hands to dry completely before putting on any PPE | |
| **5** | ☐ | ☐ | ☐ | **Put on inner gloves**<br>☐ **Select normal sizes gloves** | |

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| | | | | ☐ **Ensure gloves provides unrestricted freedom of movement and are snug around the wrist**<br>☐ Extend cuffs as far up arms as possible<br>☐ Adjust and verify proper fit of PPE | |
| **6** | ☐ | ☐ | ☐ | **Put on single-use (disposable) coverall/gown:**<br>☐ **Sit on clean chair, as needed**<br>☐ Select coverall/gown large enough to allow unrestricted freedom of movement<br>☐ Ensure cuffs of inner gloves remain tucked under sleeves<br>☐ Ensure a continuous barrier between boot covers and coverall/gown<br>☐ Seal opening of coverall (if applicable) and ensure no skin or clothing is exposed<br>☐ **Ensure waist tie is tied to the side of the gown to prevent contamination during doffing**<br>☐ **Ensure the tie at the neck is fastened** | |
| **7** | ☐ | ☐ | ☐ | **Put on impermeable outer footwear and/or foot coverings:**<br>☐ Select an appropriate layer of outer footwear and/or foot coverings (e.g., water-proof boots, disposable non-slip boot/shoe covers) to wear over the coverall socks for foot protection and/or as an additional barrier to facilitate doffing in the hot zone<br>☐ Adjust and verify proper fit of PPE | |
| **8** | ☐ | ☐ | ☐ | **Put on fit-tested N95 respirator:**<br>☐ **Hold the respirator in the palm of your hand with the straps facing the floor.**<br>☐ **Place the N95 on your face covering your nose and mouse.**<br>☐ **Pull the bottom strap out and over your head.**<br>☐ **Take the upper straps and put it behind your head at the crown of your head.**<br>☐ **Ensure straps are not crossed at the back of the head to reduce contamination during doffing**<br>☐ Fit flexible nose piece to bridge of nose<br>☐ Perform seal check | |
| **9** | ☐ | ☐ | ☐ | **Put on single-use (disposable) hood cover:**<br>☐ Ensure hood cover extends past shoulders and provides complete coverage of head, neck, and ears<br>☐ Adjust and verify proper fit of PPE | |
| **10** | ☐ | ☐ | ☐ | **Put on single-use (disposable) eye/face protection:** | |

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| | | | | ☐ Select and use eye/face protection as per manufacturer's user instructions and based on a risk assessment<br>☐ When safety goggles are to be worn in combination with other PPE ensure they do not interfere with the proper fit of each component and are positioned under the hood<br>☐ Ensure face shield provides coverage of entire front and sides of face; adjust to fit | |
| **11** | ☐ | ☐ | ☐ | **Put on a single-use (disposable) impermeable apron (if used):**<br>☐ Check apron covers the torso to the level of the mid-calf<br>☐ **If possible, tie the apron at the front for ease of doffing** | |
| **12** | ☐ | ☐ | ☐ | **Put on outer gloves with extended cuffs:**<br>☐ **Select gloves one size bigger that normal glove size**<br>☐ **Ensure gloves provides unrestricted freedom of movement and are snug around the wrist**<br>☐ Ensure gloves cover cuffs of coverall/gown and that no skin is exposed<br>☐ Adjust and verify proper fit of PPE | |
| **13** | ☐ | ☐ | ☐ | **Verify donning PPE procedure:**<br>☐ Inspect to ensure that it is secure and full coverage has been achieved<br>☐ **Ensure gown has been tied to the side of the waist**<br>☐ **Ensure N95 respirator straps are not crossed at the back of the head**<br>☐ **Ensure that there is no breach in equipment**<br>☐ **Ensure that no clothing or skin is exposed**<br>☐ Visually confirm sequence has been completed correctly | |

Note: TRAIN. (Trained); PRAC. (Practiced

Name of Trainer: _____ Name of Worker: _____ Signature: _____ Date: _____

Appendix R: Proposed revised doffing protocol (**bolded areas indicate suggested revisions**)

# Acute Care Doffing Training Checklist

**Suspect/Confirmed EVD Cases and/or Care Environment**
**Coveralls/Gowns with Separate Hood and Boot Covers**

This checklist is designed to assist with training healthcare workers (HCWs) on the correct doffing of personal protective equipment (PPE) for suspect/confirmed cases of EVD and their care environment. **Please Note: This is a sample checklist** that may need to be adapted to meet relevant standards of practice and/or specific manufacturer's user instructions for variations of approved PPE. The tool can be used to verify and document that all necessary doffing steps are performed and in the proper sequence. Any errors or omissions identified during practice and skill proficiency demonstrations must be communicated immediately, to ensure specific instructions are provided and so appropriate corrective action are taken for the protection of the HCW.

Note: Hand hygiene should be performed after removing PPE, before hands approach the face and any time hand contamination is identified or suspected during the doffing process.

**Before you begin, instruct HCW(s) that PPE must be removed slowly and carefully within each appropriately designated zone (i.e. moving from hot to warm to cold as per organizational set up) and utilizing the room configuration to minimize cross contamination.**

| # | TRAIN. | PRAC. | PROF. | DOFFING PPE PROCEDURE | COMMENTS (May include size of PPE) |
|---|---|---|---|---|---|
| 1 | ☐ | ☐ | ☐ | **Remove apron (if used):**<br>☐ Trained observer may assist with ties but must be donned in adequate PPE based on risk<br>☐ Remove apron by gently rolling inside out; taking care to avoid contact with outside surface of coverall/gown<br>☐ Dispose into designated waste container | |
| **2** | ☐ | ☐ | ☐ | **Remove outer gloves:**<br>☐ Remove outer gloves taking care not to touch inner gloves or bare skin<br>☐ **With both hands gloved, grasp the outside of one glove at the top of your wrist and pull, rolling the glove down**<br>☐ **Hold the glove you just removed in a ball with the opposite gloved hand.**<br>☐ **Peel off the second glove by inserting your fingers inside between the outer and inner glove at the top of your wrist.**<br>☐ Dispose into designated waste container<br>☐ Inspect inner gloves for visible contamination, cuts or tears<br>☐ **Move completely into the yellow zone** | |
| **3** | ☐ | ☐ | ☐ | **Disinfect outer footwear :**<br>☐ **Stand in shuffle pit filled with disinfectant solution for one minute. The shuffle pit will be located inside the patient room adjacent to the door.** | |

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| | | | | ☐ Take care not to slip or fall; use chair as needed<br>☐ **Slip off the rubber boots in red zone by unfastening them at the feet with the toe of your boot. Make sure to keep the mid-calf foot covering on.**<br>☐ **Once the boots are disinfected, enter the yellow zone** | |
| **4** | ☐ | ☐ | ☐ | **Remove Outer Footwear:**<br>☐ **Use chair, as needed**<br>☐ **Slip off the rubber boots by unfastening them at the feet with the toe of your opposing boot.**<br>☐ **Make sure to keep the mid-calf foot covering on.**<br>☐ **Once the boot is unfastened, step into the yellow zone, carefully to avoid contact with the floor in the red zone.** | |
| **5** | ☐ | ☐ | ☐ | **Remove eye/face protection:**<br>☐ Hold face shield or goggles by grasping band at back of head and lifting gently over head and away from face<br>☐ Dispose into designated waste container | |
| **6** | ☐ | ☐ | ☐ | **Remove hood cover:**<br>☐ Trained observer may assist with removal, but must be donned in adequate PPE based on risk<br>☐ Gently remove hood cover without self-contamination **by tugging at the crown of the hood. Use mirror, if needed**<br>☐ Dispose into designated waste container | |
| **7** | ☐ | ☐ | ☐ | **Remove coverall/gown:**<br>☐ Trained observer may assist, but must be donned in adequate PPE based on risk<br>☐ Unzip or unfasten coverall/gown completely **using mirror, if needed**<br>☐ Remove the unfastening the cuff, then tugging at the shoulder, and **rolling down to turning inside out**<br>☐ Avoid contact of inner clothing with outer surface of coverall during removal, touching inside of the coverall/gown only<br>☐ Dispose into designated waste container | |
| **8** | ☐ | ☐ | ☐ | **Remove boot covers:**<br>☐ Take care not to slip or fall; use chair as needed<br>☐ Remove boot covers carefully to avoid inadvertent contact and cross-contamination<br>☐ **Do not touch the inside of the boot** | |

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| | | | | **cover; instead tug on the outer layer**<br>☐ Dispose into designated waste container | |
| **9** | ☐ | ☐ | ☐ | **Remove inner gloves:**<br>☐ Inspect gloves for visible contamination, cuts or tears before removing<br>☐ Take care to avoid touching the outside of the gloves with bare skin<br>☐ Dispose into designated waste container | |
| **10** | ☐ | ☐ | ☐ | **Perform hand hygiene:**<br>☐ Use alcohol-based hand rub (ABHR) or soap and water<br>☐ **Ensure that wrists and nails are cleaned thoroughly**<br>☐ Allow hands to dry completely | |
| **11** | ☐ | ☐ | ☐ | **Remove N95 respirator:**<br>☐ **Do not touch the front of the respirator**<br>☐ **Tilt your head forward and use two hands to grab the bottom strap and lift over head.**<br>☐ **Use both hands to grab the upper strap, pull over your head.**<br>☐ **Keep tension on the upper strap as you remove it, which will let the mask fall forward.**<br>☐ Dispose into designated waste container | |
| **12** | ☐ | ☐ | ☐ | **Perform hand hygiene:**<br>☐ Use ABHR or soap and water<br>☐ Ensure that wrists and nails are cleaned thoroughly<br>☐ Allow hands to dry completely | |
| **13** | ☐ | ☐ | ☐ | **Verify doffing PPE procedure:**<br>☐ Visually confirm sequence has been completed correctly and no contamination has occurred | |

Note: TRAIN. (Trained); PRAC. (Practiced); PROF

Name of Trainer: _____ Name of Worker: _____ Signature: _____ Date: _____