

# Contamination during doffing of personal protective equipment by healthcare providers

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**Objective** In this study, we aimed to describe the processes of both the donning and the doffing of personal protective equipment for Ebola and evaluate contamination during the doffing process.

**Methods** We recruited study participants among physicians and nurses of the emergency department of Samsung Medical Center in Seoul, Korea. Participants were asked to carry out doffing and donning procedures with a helper after a 50-minute brief training and demonstration based on the 2014 Centers for Disease Control and Prevention protocol. Two separate cameras with high-density capability were set up, and the donning and doffing processes were videotaped. A trained examiner inspected all video recordings and coded for intervals, errors, and contaminations defined as the outside of the equipment touching the clinician's body surface.

**Results** Overall, 29 participants were enrolled. Twenty (68.9%) were female, and the mean age was 29.2 years. For the donning process, the average interval until the end was 234.2 seconds (standard deviation [SD], 65.7), and the most frequent errors occurred when putting on the outer gloves (27.5%), respirator (20.6%), and hood (20.6%). For the doffing process, the average interval until the end was 183.7 seconds (SD, 38.4), and the most frequent errors occurred during disinfecting the feet (37.9%), discarding the scrubs (17.2%), and putting on gloves (13.7%), respectively. During the doffing process, 65 incidences of contamination occurred (2.2 incidents/person). The most vulnerable processes were removing respirators (79.2%), removing the shoe covers (65.5%), and removal of the hood (41.3%).

**Conclusion** A significant number of contaminations occur during the doffing process of personal protective equipment.

**Keywords** Disasters; Medical devices; Equipment contamination; Communicable disease control; Ebolavirus

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## Capsule Summary

### What is already known

*Ebola is a significant threat to healthcare workers. A healthcare worker could be contaminated if protective equipment is removed in a manner that does not prevent exposure.*

### What is new in the current study

*We found a significant number of contamination incidents in a simulated process of donning and doffing of personal protective equipment.*

## INTRODUCTION

Ebola was first identified 40 years ago.<sup>1,2</sup> However, little interest has given to this highly contagious pathogen until an outbreak was confirmed by the World Health Organization in 2014 in Congo.<sup>3,4</sup> Disease spreads across nine countries and its death toll of over 11,000 person in three West African nations, and people around the world began to concern about the Ebola nowadays. Ebola spreads through human-to-human transmission via direct contact (through broken skin or mucous membranes) or indirect contact with infected materials, such as clothing.<sup>5-7</sup>

As other infectious diseases, healthcare workers are at risk of infection because they have to work at the frontline, often without protections.<sup>8,9</sup> Cases of contamination while treating Ebola patients rose rapidly during the current outbreak, and the Centers for Disease Control and Prevention (CDC) announced the new personal protective equipment (PPE) guidelines for healthcare providers treating Ebola patients.<sup>10-12</sup>

However, even with protective clothing, a healthcare worker can be contaminated if removal is not done in a manner that prevents exposure.<sup>13-15</sup> A limited numbers of studies have been performed regarding contamination with PPE usage. In this study, our primary aim was to evaluate contamination during doffing. The secondary purpose was to describe errors and delays during donning and doffing.

## METHODS

### Study setting and selection of participants

This study was performed in a single tertiary-level academic hospital (Samsung Medical Center, Seoul, Korea). The hospital has a disaster plan and equipment such as PPE. However, no official training or education was provided before this study. We recruited 29 participants for the study from the emergency department physician and nursing staff. They were informed of the purpose of the study, and each gave written consent.

Participants received a 20-minute lecture. After the lecture, a 20-minute demonstration with PPEs was given, along with an educational movie produced by the Korea Centers for Disease Control and Prevention. The course content contains donning and doffing procedure for PPE (gowns, gloves, respirators, and goggles), according to a 2014 CDC protocol. A 10-minute question and answer session followed the demonstration. The lecturer was a certified advanced disaster life support instructor, experienced with several training sessions.

After the training, each participant was paired with another, and completed the donning and doffing procedures with help from

the partner. Each team was blinded from the others; however, the second participants were more exposed to the process after watching the first. Each person was allowed to watch the protocol and to consult their partners. Though the 2014 CDC protocol was close to level D (level of PPE is divided A to D and level D is the lowest protection), we modified the airway protection by upgrading the N95 mask (particulate filtering face-piece respirators) to a gas mask. We also modified the 2014 CDC leg cover process. Fig. 1 demonstrates the overall look of our study PPE. Table 1 shows the difference between the CDC guideline and study protocol.

### Variable measurement

A demographic survey was performed with all participants. The survey also included questions on job experience and previous training with PPE. During a simulation study, two separate cameras with high-density capability were set up at an approximate 120 degree angle to document the process. All processes were videotaped during PPE donning and doffing. Afterward, a trained examiner reviewed all video recordings and coded timer intervals and errors. Time stamps were determined according to a 2014 CDC protocol. Each procedure was initiated when the participant picked up the equipment. The procedure ended when the next procedure was initiated. Errors were determined when the participants violated the order of procedures even with the help of their partners. For example, if a participant skipped putting on a second glove and proceeded to the next procedure, this was counted as an error. Errors during the process were explained by partners and instructors, so participants could resume the normal process.

### Outcome measures

The primary outcome was a potential incident of self-contamination during the doffing procedure, defined as the touch of the outside of PPE to the participant's body or clothing. The determination of contamination was performed by a single examiner on the basis of two recordings. If one of the recordings did not have sufficient information, the determination was carried out with only one. If two recordings suggested opposite conclusions, the outcome was determined as negative. A single trained examiner was considered sufficient for the examination because the outcome measure was relatively simple. This choice was supported by pilot cases before the study began.

### Statistical methods

Statistical analysis was performed with STATA ver. 13 (Stata Corp., College Station, TX, USA). Demographic data were reported in a descriptive manner. Continuous variables were presented as means with standard deviations, medians and interquartile ranges, or



Fig. 1. Pictures describing personal protective equipment. Tape sealing was omitted from procedures. (A) Front view, (B) side view, and (C) back view.

Table 1. Comparison of personal protective equipment between the CDC guideline and study protocol

CDC guideline (level B)	Study protocol (level C)
Gloves	Latex gloves
Fluid repellent gown	Fluid repellent gown
Face shield	Face shield
Goggles	Goggles
Surgical mask	Gas mask
Double gloving	Double gloving
Leg coverings/overshoes	NA
Plastic apron	NA
Boots or shoes	NA
Boot covers	Boot covers

CDC, Center of Disease Control and Prevention; NA, not applicable.

frequencies. Categorical variables were described as numbers and percentages. Differences between the two groups were tested using the independent two-sample t-test or the Mann-Whitney U-test for continuous variables and the chi-square test for categorical variables.  $P < 0.05$  was considered significant.

Table 2. Demographic data of participants

Characteristics	Doctor (n=20)	Nurse (n=9)	P-value
Female (%)	11.0 (55.0)	9.0 (100.0)	0.02
Age (yr)	29.0 ± 3.4	29.8 ± 3.4	0.52
Height (cm)	167.2 ± 7.5	160.8 ± 4.3	0.03
Weight (kg)	63.2 ± 13.3	52.6 ± 4.7	0.004
Work experience (yr)	1.9 ± 1.3	6.4 ± 2.3	< 0.001
Any previous training on PPE (%)	4.0 (20.0)	2.0 (22.2)	0.73

Values are presented as number (%) or mean ± standard deviation. PPE, personal protective equipment.

## RESULTS

Demographic characteristics of the study participants are shown in Table 2. Overall, 29 participants enrolled in the study. Twenty (69.0%) were female, and mean age was 29.2 years (standard deviation [SD], 2.39). The mean work experience was 3.33 years (SD, 2.67). Among participants, 20.7% had previously received PPE training (Table 2).

**Table 3.** Intervals and errors during the donning process

Procedure	Time (sec)	Task error (n = 29)
1. Inspect PPE prior to donning	13 (7–23)	2 (6.9)
2. Perform hand hygiene	5 (4–6)	3 (10.3)
3. Put on inner gloves	17 (9–23)	0 (0)
4. Put on boot or shoe covers	43 (36–50)	0 (0)
5. Put on gown or coverall	50 (44–60)	1 (3.4)
6. Put on respirator	31 (22–39)	6 (20.7)
7. Put on goggles	9 (8–15)	1 (3.4)
8. Put on head hood	7 (5–12)	6 (20.7)
9. Put on outer gloves	30 (20–34)	8 (27.6)
10. Put on face shield	7 (5–10)	2 (6.9)
11. Verify	5 (5–5)	0 (0)
12. Disinfect outer gloves	3 (3–6)	1 (3.4)
Total	219 (195–266)	30

Values are presented as median (interquartile range) or number (%). One to twelve number of the Table 3 shows step by step process. PPE, personal protective equipment.

**Table 4.** Intervals and errors during the doffing process

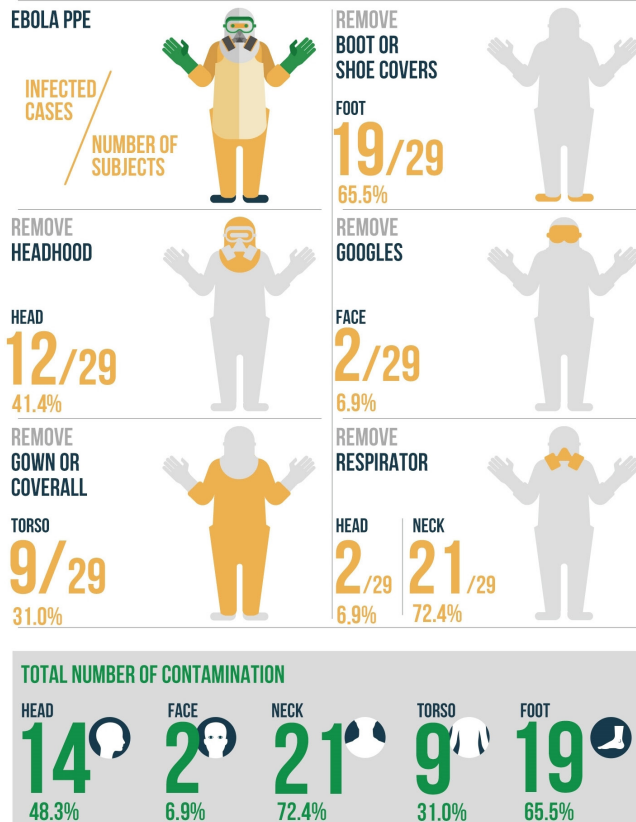
Procedure	Time (sec)	Task error (n = 29)
1. Inspect	5 (4–8)	1 (3.4)
2. Disinfect outer gloves	3 (2–6)	2 (6.9)
3. Remove boot or shoe covers	36 (26–41)	1 (3.4)
4. Disinfect and remove outer gloves	7 (5–13)	2 (6.9)
5. Inspect and disinfect inner gloves	3 (2–4)	0 (0)
6. Remove face shield	4 (3–5)	0 (0)
7. Disinfect inner gloves	3 (2–4)	2 (6.9)
8. Remove head hood	5 (4–8)	0 (0)
9. Remove goggles	5 (3–6)	0 (0)
10. Remove gown or coverall	55 (42–60)	0 (0)
11. Disinfect & remove inner gloves	4 (3–6)	2 (6.9)
12. Put on gloves	20 (11–29)	4 (13.8)
13. Remove respirator	6.5 (4–8)	3 (10.3)
14. Disinfect inner gloves	3 (2–3)	3 (10.3)
15. Disinfect feet	5 (3–5)	11 (38.0)
16. Disinfect & remove inner gloves	5 (3–7)	2 (6.9)
17. Scrubs	2 (1–3)	5 (17.2)
Total	187 (154–209)	38

Values are presented as median (interquartile range) or number (%). One to seventeen number of the Table 4 shows step by step process

The average donning process interval was 234.2 seconds (SD, 65.7) from start to finish. The most time-consuming process was putting on the gown, putting on shoe covers, and putting on the respirator. The most frequent errors occurred while putting on outer gloves (27.6%), respirator (20.7%), and hood (20.7%). The entire donning procedures refer to Table 3.

The average interval during doffing was 183.7 seconds (SD, 38.4) from start to finish. The most time-consuming processes were removing the shoe covers, putting on gloves, and removing outer gloves. The most frequent errors occurred during disinfecting feet

## CONTAMINATION RATES DURING DOFFING PROCEDURE



**Fig. 2.** Infographic showing the contamination during doffing procedure. Overall contamination occurred 65 times (2.2/person). The most frequent site was neck, foot, and head. PPE, personal protective equipment.

(38.0%), discarding scrubs (17.2%), and putting on gloves (13.8%). The entire doffing procedures refer to Table 4.

Fig. 2 illustrates contamination locations. During the overall doffing process, 65 contamination incidents occurred. The most vulnerable process was removing respirators, which caused 23 contaminations (79.3%). Two of these were on the head (6.9%), and 21 were on the neck (72.4%). Removal of shoe covers was also associated with a high probability of contamination; 19 incidents (65.5%) were reported. All locations of contamination were consistent with the doffing step related to that part of the body.

Even after standardized education, 65 numbers of contamination were reported, or 2.2 per participant. Further studies are required to minimize this number.

## DISCUSSION

This study provides a valuable first step in the evaluation of PPE used by healthcare workers. This study suggests healthcare work-

ers should be cautious about decontamination and that they need training. Donning, doffing, and decontamination procedures should be optimized for specific clinical situations. The strengths and limitations of each protective system need to be considered when recommendations are made about PPE implementation.

This study shows that a significant number of contamination incidents occurred during the process of removing PPE. This is consistent with previous reports, which have pushed the CDC into announcing recommendations for PPE handling.<sup>16,17</sup> Although the study could not conclude which factors resulted in contamination, it is important to comment that more training with technical support is required for the safety of workers. Potential measures include interactive audiovisual devices to guide the procedures, or trained personnel specialized in assisting others with the procedures. Intensive and repetitive training is also required.

Recommendations for decontamination mainly emphasize hand washing. However, despite hand washing, healthcare workers could touch other parts of their bodies or clothing that has not been properly decontaminated and consequently infect themselves.<sup>18</sup> More intensive education and training is required for safe doffing. Evaluation of the effectiveness of training is also required.

Previous studies have focused on the importance of PPE, potential risks of doffing procedures, and doffing procedure experiments comparing different systems with a few subjects.<sup>18</sup> One study demonstrated contamination rates of 26% and 96% with two distinct methods; this study included only one subject for each arm, which makes it difficult to compare the outcome with the current study.<sup>18</sup> This study gives additional information because of the larger numbers of subjects, and because the scenario has more generalizability than previous studies.

This study does have some limitations. First, the study setting is a single center without an existing PPE training program. In-hospital staff people were inexperienced, which may have been a factor increasing errors and contamination rates. However, a majority of hospitals are inexperienced with hazmat and PPE incidents, so these study results have general applicability.

Second, the study number was very small, including only emergency department staff people. This makes it difficult to generalize to a broader population of hospital staff.

Third, contamination sometimes appeared obscure on video and was subject to examiner's decision. Though the examiner reviewed recordings several times from different angles, there could be blind spots and unobservable touches. This could have made the rates underestimated, in other words the false negative rate of the outcome measure could have increased. Also, the video review could have missed subtle contacts. Depending on a single examiner also could have influenced the accuracy of the outcome.

However, even if contaminations were underestimated, the number of reported incidents is still alarming.

Finally, the study protocol was not identical to 2014 CDC guidelines. It excluded aprons, leg covers, and tape seals between parts of the gear. The donning and doffing procedures refer to Tables 3 and 4. This could be the reason that donning and doffing procedures were finished in very short intervals.

The advantage of this study is as a pilot study, exploring the need of further, more accurate investigations.

## CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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