Invited Commentary

The Increasing Visibility of the Threat of Health Care Worker Self-contamination

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The vulnerability of health care workers to acquisition and propagation of infectious agents has received global attention because of recent outbreaks of highly communicable and fatal diseases, including Ebola virus disease and severe acute respiratory syndrome. The emergence of these high-profile pathogens has prompted calls for better personal protective equipment (PPE), specifically, masks, gowns, and gloves, to protect health care workers and patients.

In this issue of *JAMA Internal Medicine*, Tomas and colleagues[1] provide a timely addition to the existing literature on the limitations of our current PPE. In a series of related studies that use previously described methods[2] to simulate contaminated PPE, the investigators convincingly document a high frequency of health care worker self-contamination when using PPE. The bulk of their data come from 435 simulations of donning and/or doffing of gowns and gloves contaminated with a fluorescent lotion: 234 were soiled glove simulations, and 201 were soiled gown simulations. Almost half (46.0%) of these simulations resulted in health care worker self-contamination of skin or clothing. Specific sites of contamination varied but most commonly involved the hands during glove removal and the neck during gown removal. Furthermore, 39.5% of participants were observed to be using improper technique by 2 independent observers who compared participants' techniques with the Centers for Disease Control and Prevention (CDC) procedure[3] for donning and/or doffing PPE. The probability of self-contamination was much greater when using improper technique (70.3% vs 30.0%). In a separate experiment, the investigators document that fluorescent lotion contamination is a reliable predictor of microbe contamination by mixing bacteriophage MS2 to the solution and performing additional simulations; contamination with the lotion vs MS2 was not statistically different.[1]

These results have clear implications for the safety of health care workers and the spread of hospital-acquired infections. It has been documented that higher levels of microbial contamination of hospital surfaces lead to higher rates of health care worker contamination with multidrug-resistant organisms.[4] Because environmental bioburden is a concern for the cross-transmission of hospital-acquired pathogens, the microbial burden of health care worker hands and apparel represents another element in this equation. Collectively, this increased contamination of the animate and inanimate environment contributes to the risk of hospital-acquired infections.

Tomas et al report a potential for improvement in the intervention portion of their study. A subset of participants were able to decrease self-contamination after a training session that included a 10-minute instructional video with structured practice using simulated contamination with fluorescent lotion. The authors found that this real-time assessment with "immediate visual feedback" was able to reduce health care worker self-contamination by 68% (from 60.0% to 18.9%). This reduction was sustained at 1- and 3-month follow-ups with no additional training.[1]

A standardized training procedure for health care workers on the recommended techniques for donning and/or doffing gowns and gloves is long overdue. The training should include educational context, proficiency monitoring, and feedback. The "immediate visual feedback" used by Tomas et al[1] appears to be particularly effective in altering staff behaviors. However, a standard, accepted, and validated training program has unfortunately not been developed, and debate remains as to what constitutes best practice for donning and doffing. The CDC's recommendations are widely adopted. However, even the CDC's procedures have been found by some to be insufficient.[2] In fact, notwithstanding the significant benefit of the intervention reported in this issue, there was still 30% residual contamination of intervention participants.[1] Double gloving and cleaning of gloves before doffing have been suggested as additions to the current CDC practices,[1,2] but evidence of the effectiveness of these interventions for routine patient care interactions is lacking. Any standardized procedure and training program will need to take into account the individual health care worker's comfort, scope of duty, previous training, and typical workload.

Minute attention to details of donning and/or doffing is of vital importance toward the goal of protecting patients and staff, yet these efforts are undercut by poor adherence to the use of PPE. Health care worker fatigue with contact precautions is well documented, with deficiencies increasing in proportion to workload and percentage of patients adhering to precautions in a given unit.[5,6] In addition, hand hygiene has been reported to decrease with increased glove use.[7] Therefore, a prioritization of patients for contact precautions is needed to optimize adherence with glove and gown precautions in the instances when it will be most important. Patients should be targeted for isolation based on the presence of highly transmissible, nonendemic organisms associated with significant morbidity and mortality. A selective approach to isolation maximizes staff attention to the transmission risk posed by priority organisms and limits the adverse effects of contact precautions on patients and staff. In the absence of such an organism, efforts are best focused on the fundamental horizontal infection control strategies that should be used for every patient care interaction.

Last, the residual contamination of health care workers, even with optimal donning and/or doffing technique, highlights the ongoing importance of hand hygiene on completion of doffing activities. Of interest, Tomas et al applied their

fluorescent lotion simulations to Ebola training sessions and documented a small but alarming rate of contamination of 7%. However, they eliminated hand hygiene steps from the CDC protocol for the purpose of these simulations.[1] Perhaps a more relevant measure of health care worker self-contamination would deploy the black light at the completion of *all* steps of the doffing process, including the paramount hand hygiene at the end. The authors do not specify which body parts remained contaminated after the intervention portion of their study; if these were primarily hand contamination, then the residual rate may not be nearly so significant after routine hand hygiene.

The current debate surrounding the utility of contact precautions is interpreted by some health care workers outside infection prevention to mean that data are scant for infection control measures in general. Providing health care workers with scientific evidence that they can see and experience, such as that provided by the "immediate visual feedback" intervention used by Tomas and colleagues,[1] is essential to improving understanding and adherence. Given the limitations of current infection control methods and given the specter of multidrug-resistant pathogens, the time for achievable solutions that health care workers will follow is now. Leaders in public health have launched efforts to ensure availability of PPE and improved PPE designs via stockpiling at various local, state, and national levels, as well as incentives to inspire public and private partnerships for PPE innovations; these efforts have been successful in the development of prototypes that are breathable, are fluid impervious, and use pull-away tabs to guide a simplified fall-away doffing process.[8] It is now up to individual hospitals to ensure effective use of PPE through selective and judicious use of contact precautions and mastering of PPE donning and doffing techniques. Optimizing the removal of PPE via targeted training with adherence assessments and feedback and an ongoing emphasis on rigorous hand hygiene are critical steps toward empowering health care workers to practice consistent infection prevention, not only for special pathogen protection but also for routine care interactions. Effective use of PPE requires not only the availability of well-designed PPE but also the consistent, precise use of this equipment. Achieving the maximum benefit from PPE necessitates a collaborative effort from the entire health care industry and must be a priority initiative for health care worker and patient safety.

ARTICLE INFORMATION

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Original Investigation

Contamination of Health Care Personnel During Removal of Personal Protective Equipment

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IMPORTANCE Contamination of the skin and clothing of health care personnel during removal of personal protective equipment (PPE) contributes to dissemination of pathogens and places personnel at risk for infection.

OBJECTIVES To determine the frequency and sites of contamination on the skin and clothing of personnel during PPE removal and to evaluate the effect of an intervention on the frequency of contamination.

DESIGN, SETTING, AND PARTICIPANTS We conducted a point-prevalence study and quasi-experimental intervention from October 28, 2014, through March 31, 2015. Data analysis began November 17, 2014, and ended April 21, 2015. Participants included a convenience sample of health care personnel from 4 Northeast Ohio hospitals who conducted simulations of contaminated PPE removal using fluorescent lotion and a cohort of health care personnel from 7 study units in 1 medical center that participated in a quasi-experimental intervention that included education and practice in removal of contaminated PPE with immediate visual feedback based on fluorescent lotion contamination of skin and clothing.

MAIN OUTCOMES AND MEASURES The primary outcomes were the frequency and sites of contamination on skin and clothing of personnel after removal of contaminated gloves or gowns at baseline vs after the intervention. A secondary end point focused on the correlation between contamination of skin with fluorescent lotion and bacteriophage MS2, a nonpathogenic, nonenveloped virus.

RESULTS Of 435 glove and gown removal simulations, contamination of skin or clothing with fluorescent lotion occurred in 200 (46.0%), with a similar frequency of contamination among the 4 hospitals (range, 42.5%-50.3%). Contamination occurred more frequently during removal of contaminated gloves than gowns (52.9% vs 37.8%, $P = .002$) and when lapses in technique were observed vs not observed (70.3% vs 30.0%, $P < .001$). The intervention resulted in a reduction in skin and clothing contamination during glove and gown removal (60.0% before the intervention vs 18.9% after, $P < .001$) that was sustained after 1 and 3 months (12.0% at both time points, $P < .001$ compared with before the intervention). During simulations of contaminated glove removal, the frequency of skin contamination was similar with fluorescent lotion and bacteriophage MS2 (58.0% vs 52.0%, $P = .45$).

CONCLUSIONS AND RELEVANCE Contamination of the skin and clothing of health care personnel occurs frequently during removal of contaminated gloves or gowns. Educational interventions that include practice with immediate visual feedback on skin and clothing contamination can significantly reduce the risk of contamination during removal of PPE.

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Personal protective equipment (PPE) reduces, but does not eliminate, the risk of skin and clothing contamination with pathogens among health care personnel.[1-3] Even when gloves and gowns are worn, 2% to 5% of personnel caring for patients colonized with multidrug-resistant bacteria acquire the pathogens on their hands after glove removal.[4-6] In addition, 24% of personnel caring for patients with *Clostridium difficile* infection (CDI) had spore contamination on their hands after glove removal.[7] High-risk exposures, such as handling contaminated body fluids, prolonged exposure, and failure to correctly use PPE, increased the risk of contamination.[4-7] Contamination of the skin and clothing of health care personnel contributes to transmission of pathogens and places personnel at risk for infection with potentially fatal pathogens, such as Ebola virus, severe acute respiratory syndrome, and Middle East respiratory syndrome coronaviruses.[1,8-11] Moreover, personnel frequently acquire norovirus infections during health care facility outbreaks and are at risk of acquiring CDI if they receive antibiotics.[12-14]

The risk of inadvertent contamination of skin and clothing despite use of PPE may be particularly high during removal of contaminated equipment. In simulations of contaminated PPE removal, use of protocols recommended by the Centers for Disease Control and Prevention (CDC) has been associated with less frequent hand and clothing contamination compared with nonstandardized methods, suggesting that use of the appropriate technique can reduce contamination.[15,16] However, others have found frequent contamination of skin and clothing during PPE removal despite use of these protocols.[17] In conjunction with recent evidence of Ebola virus acquisition despite use of PPE,[1] these studies highlight the urgent need for improved strategies to prevent contamination during PPE removal.

In this study, we examined the frequency and sites of contamination of the skin and clothing of health care personnel from 4 hospitals during PPE removal using their usual technique. In one hospital, we tested the hypothesis that an educational intervention, including practice in removal of contaminated PPE with immediate visual feedback based on fluorescent lotion contamination of skin and clothing, would be effective in reducing contamination during PPE removal.

Methods

Contributing Hospitals and Participants

We performed a point-prevalence study and quasi-experimental intervention from October 28, 2014, through March 31, 2015. Data analysis began November 17, 2014, and ended April 21, 2015. Health care personnel from 4 Cleveland-area hospitals participated in the evaluations of contamination during removal of contaminated gloves or gowns, including tertiary care university and county hospitals, a Veterans Affairs medical center, and a community hospital. Additional evaluations that involved interventions to decrease contamination were conducted in the Veterans Affairs medical center. The research protocols were approved by each hospital's institutional review board. Participants gave oral informed consent; the one exception was the evaluation of fluorescent lotion contamination of personnel after education at the Veterans Affairs medical center because this evaluation was performed as a quality improvement initiative.

Fluorescent Lotion vs Bacteriophage MS2 for Evaluation of Contamination During PPE Removal

Bacteriophage MS2 is a nonpathogenic, nonenveloped RNA virus commonly used to study the spread of pathogens.[18-20] However, use of this organism requires microbiological expertise and does not provide visualization of contamination. The use of fluorescent lotions or powders has previously been used to simulate contamination with pathogens, including transfer to skin, clothing, and environmental surfaces during PPE removal.[15-17,21]

Bacteriophage MS2 15597-B1 (ATCC) was propagated in *Escherichia coli* 15597.[19] Fifty simulations were performed in a research laboratory. Participants donned contact isolation gowns (SafetyPlus Polyethylene Gown; TIDI Products) and nitrile gloves (Denville Scientific Inc) in their usual manner. Using a modification of the method of Casanova et al,[17] we inoculated gloved hands with 0.5 mL of phosphate-buffered saline containing 10^8 plaque-forming units of MS2 and 0.5 mL of fluorescent lotion, and volunteers rubbed both solutions over their gloved hands for 15 seconds or until dry. Volunteers removed their gloves and gowns in their usual manner, and hand and wrist contamination with the fluorescent lotion was assessed using a black light (Ultra Light UV1, Grizzly Gear). Volunteers then wiped both hands and wrists with a sterile, premoistened, 4 × 4 gauze pad that was placed into a sterile container holding 10 mL of phosphate-buffered saline and was vortexed for 1 minute to elute the bacteriophage. Aliquots of each elutant were serially diluted and cultured to quantify virus particles.[18]

Multicenter Evaluation of Contamination of Personnel Skin and Clothing During Removal of Contaminated Gloves or Gowns

During a 12-week period, personnel from 4 study hospitals were recruited to participate in simulations of removal of contaminated gloves or gowns. The profession of the participants was recorded. Participants donned contact isolation gowns and nitrile gloves using their usual technique. After they donned the gloves, 0.5 mL of fluorescent lotion was placed in the palm of one hand. To simulate contaminated gloves, participants rubbed the fluorescent lotion over their gloved hands for 15 seconds. To simulate contaminated gowns with no glove contamination, participants smeared the fluorescent lotion over the front surface of their gown, including the chest and abdomen, after which contaminated gloves were exchanged for clean gloves.

For both contaminated glove and gown simulations, participants were asked to remove their gloves and gown in their usual manner. A black light was used to assess for contamination of skin sites (hands, forearms, neck, and face), hair, and clothing (shirt sleeves, chest, and back). Each simulation was observed by 1 of 3 trained research assistants (M.E.T., S.K., or P.T.), and any breaks in technique based on the CDC donning

Table. Comparison of Bacteriophage MS2 and Fluorescent Lotion Contamination During Removal of Contaminated Gloves

Fluorescent Lotion Contamination	Bacteriophage MS2 Contamination		
	Positive	Negative	Total
Positive	24	5	29
Negative	2	19	21
Total	26	24	50

and/or doffing protocol were recorded using a standardized checklist.[22,23] During training sessions, there was greater than 90% agreement among the research assistants in assessments of whether the PPE technique was correct. The PPE technique was considered correct if the following 4 criteria were met: (1) correct donning order (gown first followed by gloves); (2) gloves extended to cover the wrist of the isolation gown; (3) gown doffed by pulling away from the neck, shoulders, and body; and (4) gloves removed by peeling off the gloves at the same time as the gown or using a glove-in-glove technique wherein gloves are removed one at a time, making sure that bare skin does not touch the contaminated outside surface of the glove.

At the Veterans Affairs medical center, we evaluated the frequency of contamination in Ebola virus training sessions during removal of full-body–coverage PPE, including cover gown, knee-high shoe and leg covers, N95 respirator, hood covering the head and neck, and double gloves. The fluorescent lotion was applied to the gloves and anterior surfaces of the gown before doffing. For these simulations, gloved hands were not disinfected between removal steps as is recommended by the CDC.[23]

Intervention to Reduce Skin and Clothing Contamination During Removal of Contaminated Gloves

Because of the finding of frequent contamination of personnel during PPE removal, the Infection Control Department at the Veterans Affairs medical center implemented a facility-wide intervention to reduce the risk for contamination during PPE removal. Two infection control staff members (M.O., T.F.Z.) and 1 geriatric research fellow (M.E.T.) provided educational sessions for personnel from long-term care facility and hospital wards. The sessions included a 10-minute video presentation and 20 minutes of demonstrations and practice in the PPE donning and/or doffing technique. Nine to 15 trainees attended each session. The donning and/or doffing protocols recommended by the CDC were presented.[23] Pictures of contamination of the skin and clothing with fluorescent lotion during removal simulations were shown, and the most common breeches in technique leading to contamination were emphasized. Personnel practiced removal of fluorescent lotion–contaminated gloves with use of a black light to identify sites of contamination. Personnel were encouraged to practice removal multiple times as needed until they were confident they could use the correct technique and avoid contamination.

On completion of the initial training sessions and 1 and 3 months later, staff members performed simulations to determine the frequency of contamination of skin and clothing with fluorescent lotion after doffing. A poster highlighting the initiative was displayed throughout the facility (eFigure in the Supplement). The costs associated with the intervention were minimal, including standard gowns and gloves provided by the institution, fluorescent lotion ($0.15 per simulation), and a black light ($6 each).

Statistical Analysis

Data were analyzed using R statistical software, version 3.1.1 (R Foundation for Statistical Computing). To detect an effect size of Cohen w = 0.25 in a χ^2 test of contamination across 4 hospitals with 90% power and a 2-sided α of .05, 57 participants per hospital were required. To detect an effect size of Cohen w = 0.25 in a χ^2 test of contamination across 3 health care personnel types with 90% power and a 2-sided α of .05, 68 participants of each health care personnel type were required. The χ^2 or Fisher exact test was used to compare categorical data. Agreement between contamination detected by fluorescent lotion and bacteriophage MS2 was assessed using the Cohen κ.[24,25]

Results

Fluorescent Lotion vs Bacteriophage MS2 for Evaluation of Contamination During Glove Removal

Of 50 simulations performed by 50 health care personnel, 24 (48.0%) resulted in contamination with bacteriophage MS2 and fluorescent lotion, 2 (4.0%) with MS2 alone, and 5 (10.0%) with fluorescent lotion alone (**Table**). The mean (SD) concentration of bacteriophage MS2 recovered was 2.05 (1.25) $\log_{10}$ plaque-forming units (95% CI, 1.54-2.55). No significant difference was found in the overall percentage of contamination with fluorescent lotion and bacteriophage MS2 (58.0% vs 52.0%, P = .45). The Cohen κ of contamination assessed by fluorescent lotion and bacteriophage was 0.72, indicating substantial agreement based on Landis and Koch ranges.[25]

Multicenter Evaluation of Contamination of Personnel Skin and Clothing During Removal of Contaminated Gloves or Gowns

A total of 435 fluorescent lotion simulations were conducted in the 4 study hospitals (range, 74-155 simulations). Of the 435 simulations, 246 (56.6%) were performed by nurses, 117 (26.9%) by allied health care personnel, and 72 (16.6%) by physicians. Allied health care personnel included phlebotomists, respiratory therapists, physical therapists, radiology technicians, dieticians, environmental services personnel, and social workers. Of the 435 simulations, 234 (53.8%) were simulations of glove contamination and 201 (46.2%) were simulations of gown contamination.

Figure 1 shows the frequency of contamination of skin and/or clothing during removal of contaminated gloves and gowns. Overall, fluorescent lotion contamination occurred during 200 simulations (46.0%), with more frequent contamination during removal of contaminated gloves than gowns (52.9% vs 37.8%, P = .002). The contamination rates did not differ significantly among the 4 hospitals (range, 42.5%-50.3%, P = .56). Incorrect donning and/or doffing technique was observed in 172 simulations (39.5%), with no significant differences among

different hospitals (P = .13) or health care personnel types (P = .26). Contamination occurred more frequently when incorrect vs correct technique was observed for contaminated glove and gown removal (70.3% vs 30.0%, P < .001). The reasons for incorrect technique included gloves not covering the wrist (113 observations), removing the gown by pulling over the head instead of away from the body (44 observations), donning gloves before the gown (33 observations), and touching the contaminated outside surface of the glove during removal (31 observations).

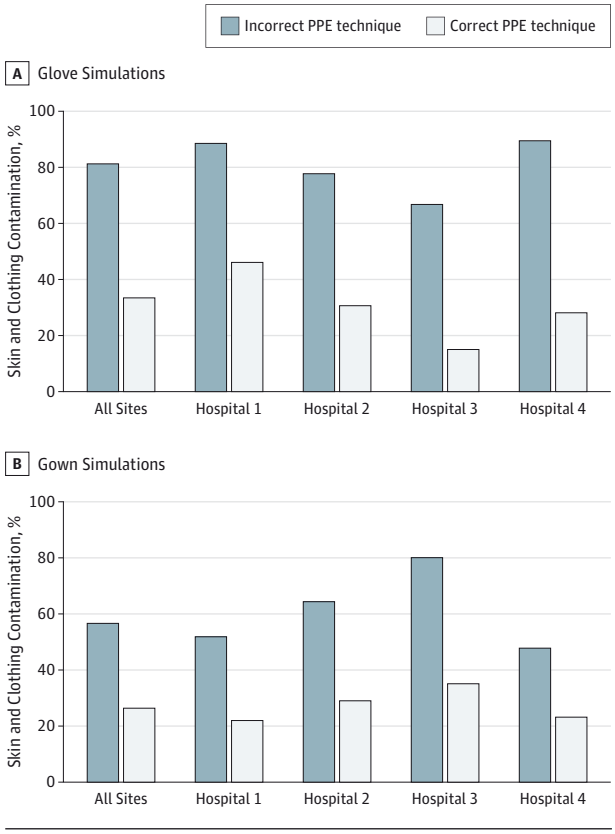
Figure 2 shows the distribution of sites of contamination during removal of contaminated equipment. During 234 simulations of removal of contaminated gloves, 19 different sites of skin or clothing contamination were identified in 124 participants (53.0%). During 201 simulations of gown contamination, 18 different sites of contamination were identified in 76 participants (37.8%). The hands were most frequently contaminated during glove simulations, whereas the neck was most frequently contaminated during gown simulations. When contaminated gowns were removed by pulling overhead instead of away from the body, contamination of the anterior neck and chin was seen. Contamination of the posterior neck occurred with removal of ties securing the back of reusable synthetic and disposable trilayer SMS (spunbond meltblown spunbond) polypropylene gowns.

Of 29 assessments conducted during removal of full-body PPE during Ebola virus training sessions, contamination of skin and/or clothing occurred in 2 assessments (6.9%). In the first case, the contamination was present on the right leg and occurred during removal of the left boot cover. In the second case, contamination was identified on the posterior right shoulder and occurred when removing a hood.

Interventions to Reduce Skin and Clothing Contamination During Removal of Contaminated Gloves

Figure 3 shows the frequency of fluorescent lotion contamination of personnel before vs after the intervention for the first 7 wards that participated in the intervention. Immediately after the intervention, contamination was significantly reduced for all health care personnel types (60.0% vs 18.9%, P < .001). The reduction in contamination with fluorescent lotion was sustained at 1 and 3 months after the intervention (12.0% at both time points, P < .001 compared with before the intervention).

Figure 1. Frequency of Skin and Clothing Contamination With Fluorescent Lotion During Removal of Personal Protective Equipment (PPE)



Overall and hospital-specific rates of contamination of skin and clothing of health care personnel after removal of contaminated gloves or gowns.

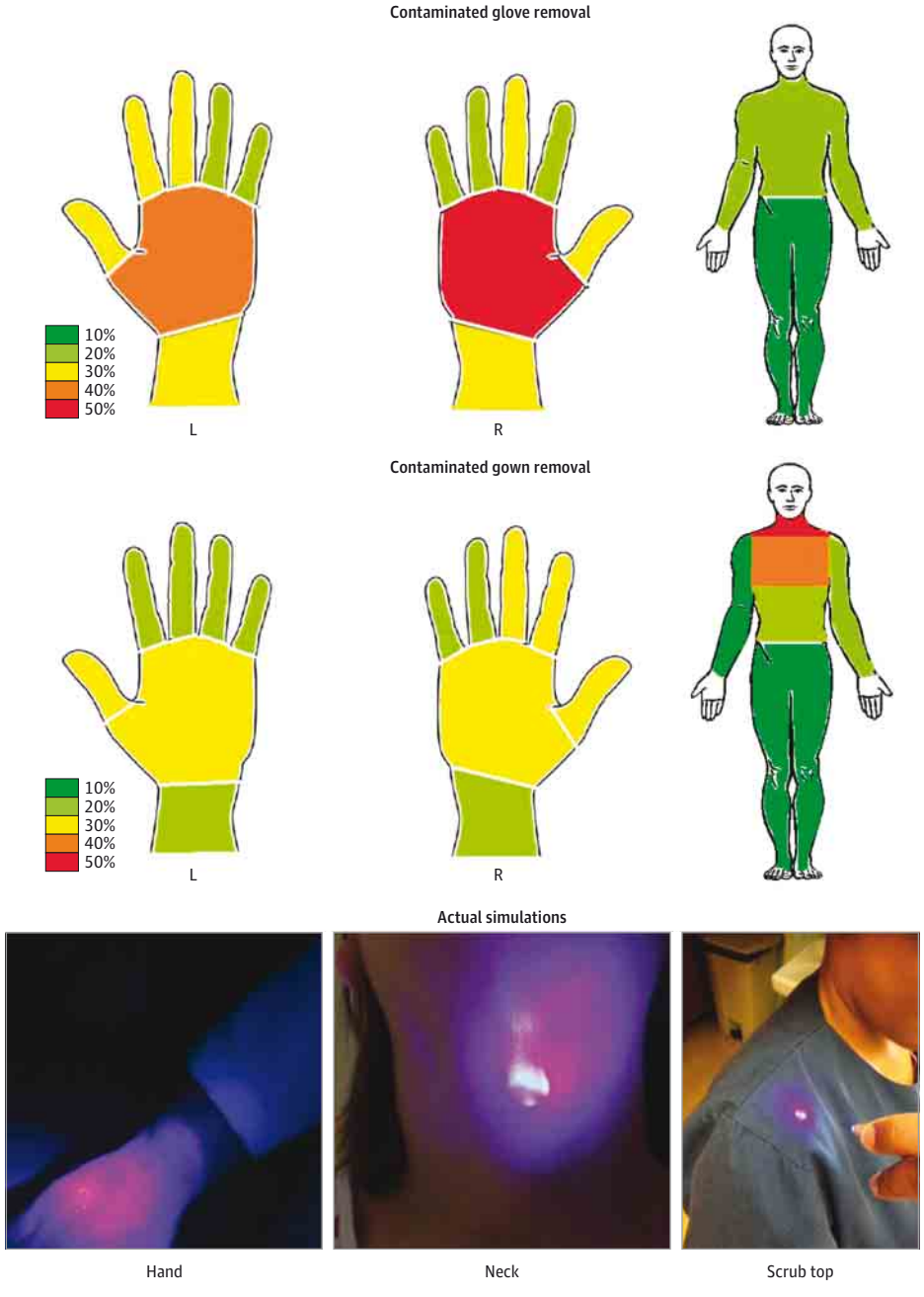
Discussion

In 4 hospitals, contamination of the skin and clothing of health care personnel occurred frequently during removal of gloves or gowns contaminated with fluorescent lotion. Contamination was more common when removal technique was incorrect, but even when no lapses in technique were observed, contamination occurred in approximately one-third of the simulations. An educational intervention that included practice in PPE removal with immediate visual feedback resulted in significantly reduced contamination with fluorescent lotion during glove and gown removal. Our findings suggest that contamination of health care personnel with pathogens occurs frequently when contaminated PPE is removed, and simple interventions have the potential to markedly reduce the risk of contamination.

Our results are consistent with previous studies[17,18,21] in demonstrating that simulations with fluorescent lotions or powders can be useful in understanding the spread of pathogens and in devising effective control strategies. During removal of gloves contaminated with fluorescent lotion and bacteriophage MS2, the frequency of contamination of hands and forearms was similar with both agents. The major advantage of the fluorescent lotion method for training of personnel is that it provides immediate visual feedback on sites and routes of contamination. Our findings suggest that simulations using fluorescent lotions can be useful to improve techniques for standard glove and gown removal and for training in removal of full-body coverage PPE used in the care of patients infected with pathogens such as Ebola virus. Fluorescent lotions are also inexpensive, easy to use, and safe.

Although contamination of skin and clothing was reduced by the intervention, it was not reduced to zero despite the fact that PPE removal was being observed

Figure 2. Sites of Contamination During Removal of Gloves or Gowns Contaminated With Fluorescent Lotion



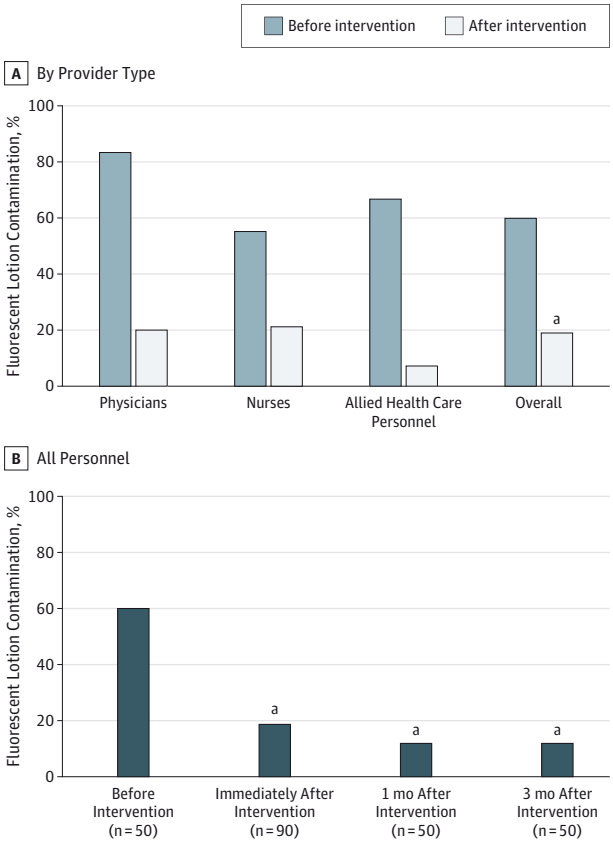
Frequency of contamination by site during contaminated glove removal (n = 234), frequency of contamination by site during contaminated gown removal (n = 201), and contamination on the hands, neck, and scrub top after actual simulations.

and personnel were striving to avoid contamination. Thus, our findings highlight the need for additional measures to reduce contamination during PPE removal. One potentially useful adjunctive measure might be disinfection of PPE before removal. Current guidelines from the CDC recommend that personnel disinfect their gloves at multiple steps during doffing of PPE used in the care of patients with suspected or confirmed Ebola virus infection.[23] This approach could also potentially be useful during the care of patients in contact precautions. For example, glove disinfection with bleach wipes after the care of patients with CDI was associated with a reduction in acquisition of spores on hands of personnel.[26] However, glove disinfection alone may be insufficient because contamination occurred frequently when only the gown was contaminated. Therefore, strategies for disinfection of contaminated gowns and other PPE before removal are needed, particularly for settings that involve the care of patients with suspected or confirmed infection due to potentially fatal pathogens. UV-C light, for example, is effective for disinfection of whole-body coverage PPE in laboratory testing.[27,28]

Another potential measure to reduce contamination during PPE removal is to have a trained coach monitor each step of the removal process, as has been recommended when caring for patients with suspected or confirmed Ebola virus infection.[23] This measure is likely to be beneficial but would not be feasible in routine clinical settings. Moreover, contamination with fluorescent lotion occurred in 6.9% of observations of removal of full-body PPE during Ebola virus training sessions despite the presence of a trained coach. The contamination was not appreciated until visualized, suggesting that it would be valuable to incorporate use of fluorescent lotion into Ebola virus training sessions. Finally, there is a need for a redesign of PPE to provide products that are easy to remove while minimizing the risk for self-contamination.[29] One basic design problem identified during the current study was that only one size of cover gown was available at each hospital; ill-fitting gowns made prevention of contamination difficult for petite and large or tall personnel.

Our study has several limitations. First, although 4 hospitals were included in the baseline assessment, the intervention was conducted in only one facility, was quasi-experimental, and had a relatively short follow-up period. To achieve sustained improvements, we recommend that initial training sessions be followed by annual refresher training sessions. Second, for the assessments of contamination before vs at 1 and 3 months after the intervention, nonpaired comparisons were used because identifiers were not collected from the participants being tested at each time point and pairing of test results was not possible. Third, the outcome was based on simulations with fluorescent lotion rather than on hand contamination with pathogens during patient care or infection rates. Fourth, the frequency of contamination of skin and clothing was relatively high compared with studies[4-7] that involved personnel caring for patients colonized with multidrug-resistant bacteria or CDI. Our findings are therefore likely to mimic situations in which PPE is heavily contaminated and may not reflect findings when lower levels of contamination are present. The finding that contamination occurred frequently even when no lapses in technique were observed likely reflects the high risk of contamination when PPE is heavily contaminated. In addition, this finding suggests that the fluorescent lotion method is more sensitive than observations in identifying minor deficiencies in technique that result in contamination. Finally, only 29 individuals from one center were included in the observations of removal of full-body PPE during Ebola virus training sessions, and glove disinfection was not included between removal steps. Additional studies are needed to evaluate the use of fluorescent lotion as a training tool in this setting.

Figure 3. Contamination of Personnel During Removal of Fluorescent Lotion–Contaminated Gloves Before and After an Intervention



Frequency of fluorescent lotion contamination before and immediately after an educational intervention and overall frequency of contamination for all personnel types before, immediately after, and 1 and 3 months after the intervention.

[a] $P < .001$ compared with before the intervention.

Conclusions

In 4 hospitals, contamination of the skin and clothing of health care personnel occurred frequently during removal of contaminated gloves or gowns. A quasi-experimental educational intervention that included practice with immediate visual feedback on skin and clothing contamination significantly reduced contamination during PPE removal in 1 hospital. These findings highlight the urgent need for additional studies to determine effective strategies to minimize the risk of contamination during PPE removal, to improve PPE design, and to identify optimal methods for training of personnel in PPE use.

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Study concept and design: Tomas, Kundrapu, Sunkesula, Cadnum, Zabarsky, Donskey.
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