





Personal protective equipment doffing practices of healthcare workers

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ABSTRACT

During the doffing of personal protective equipment (PPE), pathogens can be transferred from the PPE to the bodies of healthcare workers (HCWs), putting HCWs and patients at risk of exposure and infection. PPE doffing practices of HCWs who cared for patients with viral respiratory infections were observed at an acute care hospital from March 2017 to April 2018. A trained observer recorded doffing performance of HCWs inside the patient rooms using a pre-defined checklist based on the Centers for Disease Control and Prevention (CDC) guideline. Doffing practices were observed 162 times during care of 52 patients infected with respiratory viral pathogens. Out of the 52 patients, 30 were in droplet and contact isolation, 21 were in droplet isolation, and 1 was in contact isolation. Overall, 90% of observed doffing was incorrect, with respect to the doffing sequence, doffing technique, or use of appropriate PPE. Common errors were doffing gown from the front, removing face shield of the mask, and touching potentially contaminated surfaces and PPE during doffing. Deviations from the recommended PPE doffing protocol are common and can increase potential for contamination of the HCW's clothing or skin after providing care. There is a clear need to change the approach used to training HCWs in PPE doffing practices.

KEYWORDS

Doffing; healthcare workers; infection prevention; personal protective equipment


Introduction

Although personal protective equipment (PPE) falls at the lowest level of the hierarchy of controls due to the dependence of PPE effectiveness on individual behavior, it is a primary strategy to prevent disease transmission in healthcare settings. Specifically, the Healthcare Infection Control Practices Advisory Committee (HICPAC), who provide advice and guidance regarding the practice of control of healthcare-associated infections to the Centers for Disease Control and Prevention (CDC) and the Secretary of the Department of Health and Human Services, recommends the use of PPE in standard and transmission-based infection control precautions.^[1] Standard precautions require the HCW to anticipate exposures and select appropriate PPE, while transmission-based precautions include a specific PPE ensemble for use by HCWs providing care to patients with an infectious disease or disease syndrome classified as being transmitted through the airborne, contact, or droplet route.

To prevent disease transmission in healthcare settings, PPE must be used consistently and correctly by HCWs to prevent exposure and the transport of pathogens to their bodies. The infection of two nurses with Ebola Virus Disease (EVD) in Dallas, Texas has been attributed to PPE failure or incorrect PPE use.^[2] Simulation studies in which the PPE of HCWs are contaminated with pathogen surrogates have shown that improper PPE doffing practices may result in contamination of HCWs skin and clothing.^[3,4]

In this study, we characterized the PPE use and PPE doffing practices of HCWs providing care for patients with viral respiratory infections in an acute care hospital. Our approach was direct observation performed inside of patient rooms. Previous work has documented that HCWs compliance with PPE use is relatively low and that doffing practices are inconsistent, but much of that work involved observations outside of patient rooms, or in the context of simulation.^[5–7] The contribution of this work is the description of doffing

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 Supplemental data for this article can be accessed at tandfonline.com/uoh. AIHA and ACGIH members may also access supplementary material at <http://oeh.tandfonline.com/>.

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practices following routine patient care among diverse worker types inside the rooms of patients with viral respiratory infections and labeled for transmission-based precautions.

Methods

PPE doffing practices of HCWs who cared for patients with viral respiratory infections were observed at a 465-bed acute care hospital from March 2017 to June 2017 and September 2017 to April 2018. HCW and patient participants provided written informed consent. HCWs were eligible to participate if they were adults, able to communicate in English, and provided care to a patient with a viral infection that had consented to participate in the study. Eligible HCW participants were recruited at staff meetings and at patient rooms before HCWs entered the room. HCW participants could participate more than one time because HCWs performed different types of care activities and/or on different patients during each observation. The doffing practice results were not reviewed with HCWs following the observations. This study was approved by the University of Illinois at Chicago Institutional Review Board, protocol number 2015-0990.

Patients having respiratory infections were identified through the hospital MedMined surveillance system. Patients were eligible to be recruited if they were adults, fluent in English or Spanish, and had a positive respiratory pathogen panel test within three days prior to the day of observation. The patients had a variety of acute viral respiratory infections including: influenza A ($n = 23$), influenza B ($n = 8$), and rhinovirus ($n = 15$); and respiratory syncytial virus ($n = 3$), coronavirus ($n = 1$), parainfluenza ($n = 1$), and adenovirus ($n = 1$).

The study occurred in nine units in the hospital, which were classified into three groups: (1) Intensive Care Units (ICUs), which included the Neurological ICU, the Medical ICU and the Step Down unit; (2) non-ICUs, which included the Rehabilitation/Orthopedics unit, the Clinical Decision/Observation unit, the General Medical Surgical unit and the Liver/Gastroenterology unit; and (3) specialty units, which included the Bone Marrow Transplant and Hematology-Oncology units. The unit groupings were based on unit workflow and patient medical conditions.

Researchers waited outside patient rooms and performed observations during a 3-hr period, typically from 8 a.m. to 12 p.m. One trained observer

recorded the PPE use and doffing practices of HCWs inside patient rooms using a pre-defined checklist based on the CDC guideline that included: PPE worn, sequence of doffing, carefulness of doffing, disposal location, doffing PPE inside out, removing PPE from the front, and performance of hand hygiene.^[8] The check list is available in the [Supplementary Materials](#). The correct PPE to be worn by HCWs was based on the isolation signs mounted outside the patient room door. For patients on contact isolation, HCWs were to wear gloves and a reusable isolation gown. For patients on droplet isolation, HCWs were to wear a surgical mask with eye shield. For patients on droplet and contact isolation, HCWs were to wear gloves, a reusable isolation gown, and a surgical mask with eye shield (visor). According to the CDC recommendations, the correct doffing sequence includes removing gloves first, followed by the gown, the mask, and then hand hygiene. In our study, hand hygiene was not included in the correct doffing sequence evaluation but reported separately. Gloves should be removed by holding the outside palm area of one glove, pulling it off, and then holding it in the other gloved hand. The second glove should be peeled off inside-out using fingers of the ungloved hand. A washable, reusable fabric gown with ties at the neck should be taken off by unfastening gown ties, pulling away from the shoulder inside-out, and folding into a bundle. A surgical mask should be removed by taking off elastic ear bands of the mask without touching the front of the mask. All PPE must be removed before leaving the patient room at the doorway or in anteroom.^[8] In addition, we evaluated the doffing carefulness, defined as a removal process not involving strong or vigorous movements, which may generate infectious aerosols from contaminated PPE.

Data were recorded on paper forms and entered into a database using double data entry (Access, 2016; Microsoft, Redmond, WA). All data analysis was performed with the R project for Statistical Computing (The R Foundation for Statistical Computing, Vienna, Austria). Differences in proportions among HCW job role groups, hospital unit groups, and patient isolation categories were tested with the χ^2 test where expected values were determined using the overall mean proportion. Statistical significance was set at $\alpha = 0.05$ for all tests. Although HCWs could participate more than one time, observations were treated as independent in the statistical analyses because HCWs performed different type of care activities and/or on different patients during each observation.

Results

In total, we observed the PPE doffing practices of 107 HCWs, with 23 HCWs participating more than once for a total of 166 observations during care of 52 patients. Four observations were excluded from the analysis because the observer was not able to record the doffing activities of HCWs, giving a final sample size of 162 observations. Sample sizes vary slightly for some variables because not all variables were recorded in all observations. Observations involved: nurses (n = 63), nurse technicians (n = 37), attending physicians (n = 18), resident physicians (n = 15), respiratory therapist (n = 9), nurse practitioners (n = 7), environmental service workers (ESWs, n = 4), nursing students (n = 3), physical therapists (n = 3), medical students (n = 2), and a dietician (n = 1). We grouped observations of attending physicians, resident physicians, nurse practitioners, and medical students into the “provider” group; nurses and nursing students into the “nurse” group; and physical therapists, ESWs, and dieticians into the “others” group. The provider and nurse groupings were based on the observation that these HCWs performed similar care activities. Of the 52 patient participants, 30 were in droplet and contact isolation, 21 were in droplet isolation, and 1 was in contact isolation.

HCWs chose the correct pieces of PPE in 39 of 61 (64%) observations of care for patients in droplet isolation and in 55 of 97 (57%) observations of care for patients in for droplet and contact isolation. The overall adherence to wearing the PPE specified for each isolation categories was 60% (98 of 162). The droplet isolation signs showed that surgical mask with eye shield should be used, but in 36% of observations when this piece of equipment was used, the HCWs took the eye shield off the mask (Table 1).

Table 2 summarizes observed doffing errors. In 32 of 153 (21%) of observations in which gloves were worn, HCWs removed their gloves incorrectly. The most frequent glove doffing mistake, occurring in 9.8% of observations, was not removing gloves inside-out. In 79 of 122 (65%) of observations in which gowns were worn, HCWs failed to remove their gowns correctly. The most common gown doffing errors were removing gown from the front (58%), followed by not pulling away from shoulder inside-out (24%). In 35 of 136 (26%) of observations when masks were worn, HCWs touched the front of the mask while removing the mask. In approximately half of the observations (78 of 160), HCWs touched potentially contaminated surfaces or PPE with a bare hand during doffing. Hand hygiene was not performed after leaving the patient room in 9 of 137 observations (6.6%). Among these 9 observations, HCWs touched potentially contaminated surfaces in 6 of them (67%).

The overall incorrect doffing percentage was 90% (Table 3), based on the doffing sequence, doffing technique, and use of correct PPE. The percentage of observations in which HCWs did not remove their PPE in the correct sequence was 52%, while 40% of observations involved HCWs not wearing all the required PPE. The percentage of doffing errors did not differ significantly among HCWs groups ($\chi^2 = 1.66$ p = 0.79, Table 3), nor among the groups of hospital units ($\chi^2 = 1.10$ p = 0.57, Table 3).

When evaluated by patient isolation category, the percentage of observations involving incorrect doffing sequence and overall incorrect doffing differed ($\chi^2 = 12.8$, p = 0.002). Errors were less common among HCWs providing care to patients in droplet isolation compared to when providing care to patients in droplet and contact isolation. Table 4 shows the types of

Table 1. Combinations of pieces of personal protective equipment (PPE) worn by healthcare workers (HCWs) by patient isolation category.

PPE combinations	Number of observations		
	Isolation category		
	Contact	Droplet	Contact and droplet
Gloves only	0	0	0
Gown only	0	0	0
Mask only	0	1	1
Mask with eye shield only	0	2*	0
Gloves and mask, only	0	11	1
Gloves and mask with eye shield, only	0	18**	5
Gloves and gown, only	0*	1	1
Gown and mask with eye shield, only	0	0	1
Gloves, gown, and mask	4**	9	33
Gloves, gown, and mask with eye shield	0	19**	55*
Total number of observations	4	61	97
Total wore sufficient PPE	4 (100%)	39 (64%)	55 (57%)

*HCWs wore the correct PPE, according to hospital isolation signs

**HCWs wore more PPE than required by the hospital isolation sign

Table 2. Errors observed in the doffing of personal protective equipment (PPE) by healthcare workers.

PPE or body part	Error	Observed errors					
		By error type			By PPE		
		No. observed	Total no.	%	No. observed	Total no.	%
Gloves	Not careful	14	153	9.2	32	153	21
	Not inside-out	15	153	9.8			
	Wore outside patient room	8	154	5.2			
Gown	Not careful	40	122	33	79	122	65
	Remove from the front	71	122	58			
	Not inside-out	24	122	25			
	Wore outside patient room	4	122	3.3			
Mask w/ or w/o eye shield	Not careful	25	136	18	49	136	36
	Remove from the front	35	136	26			
Bare hand	Touched contaminated surfaces or PPE during doffing	78	160	49	6	9	67
	Not perform hand hygiene after care	9	137	6.6			

Table 3. Doffing practices of healthcare workers (HCWs) by job roles, hospital units, and patient isolation category.

Category	Incorrect doffing sequence			Not wearing all required/ correct PPE			Overall incorrect doffing		
	No. observed	Total no.	%	No.			No.		
				observed	Total no.	%	observed	Total no.	%
All observations	82	157	52	64	162	39	142	157	90
Job roles									
Providers	19	41	46	18	42	43	37	40	92
Nurses	30	64	47	25	66	38	58	66	88
Nurse technicians	21	35	60	16	37	43	32	35	91
Respiratory therapists	6	9	67	1	9	11	8	8	100
Others	6	8	75	4	8	50	7	8	88
Test for differences between groups	p = 0.33			p = 0.42			p = 0.79		
Hospital unit									
ICU	14	34	41	13	35	37	31	35	89
Non-ICU	54	97	56	35	100	35	87	97	90
Specialty	14	26	54	16	27	59	24	25	96
Test for differences between units	p = 0.34			p = 0.07			p = 0.57		
Isolation category									
Droplet	16	57	28	22	61	36	47	59	80
Droplet/contact	64	96	67	42	97	43	91	94	97
Contact	2	4	50	0	4	0	4	4	100
Test for differences between groups	p < 0.001			p = 0.17			p = 0.002		

Table 4. Personal protective equipment (PPE) doffing practices by patient isolation category.

PPE	Contact			Droplet			Droplet and contact			p-value*
	No. observed	Total no.	%	No. observed	Total no.	%	No. observed	Total no.	%	
Gloves incorrect	0	4	0	14	57	25	18	92	19	0.23
Gown incorrect	3	4	75	14	29	48	62	89	70	0.02
Mask w/ or w/o eye shield correct	4	4	100	14	50	28	31	82	38	0.12
Overall incorrectness	4	4	100	47	59	80	91	94	97	<0.01

*p-value comparison of PPE incorrectness between droplet and droplet/contact precautions

PPE errors made by patient isolation: the most common errors involved gown removal.

To evaluate the assumption that observations could be treated independently, despite the repeated participation of 23 HCWs, we repeated the analyses using only a single observation for each participating HCW and found the same results.

Discussion

Proper use and doffing of PPE protects HCWs and patients from infectious diseases. Previous studies

have evaluated doffing practices of HCWs in hospital and laboratory settings using both direct observations and video recording methods, and our results are relatively consistent with that of others, given differences in study designs. Katanami et al.^[5] assessed PPE use by HCWs using cameras outside of patient rooms identified for contact precautions and reported that adherence to wearing all required PPE was only 34%. We observed much higher compliance of PPE use during care for patients in contact isolation (100%, Table 1), but the comparison is limited by our small numbers of observations (n = 4). Beam et al.^[6] found

that 91% of HCWs in a simulated care study made contact between unprotected body areas and potentially contaminated surfaces, while our study found HCWs touched potentially contaminated surfaces with bare hands in 50% of observations. Part of the difference in these results may be due to the fact that we counted contact made by a bare hand only, while Beam et al. considered contact made by any unprotected body part. We found that HCWs removed PPE in the wrong sequence in 52% of observations, which was similar to percentage of HCWs observed by Zellmer et al.^[9] Zellmer et al., however, made direct observations outside the patient rooms, so several components of the doffing protocol, including removing glove inside-out and removing gown from the front, were not captured in that study.

We found that gown doffing was the most common doffing problem among HCWs, as HCWs removed the gown by grasping the front of the gown in 58% of observations. This finding was consistent with the Beam et al.^[6] study, which found that 75% of HCWs did not remove the gown as recommended. Reusable fabric gowns tie in the back, and the CDC recommends that these gowns be removed from the back—taken off by unfastening gown ties, pulling away from the shoulder inside-out, and folding into a bundle. However, there are different recommendations for gown removal for different types of gowns. In particular, the CDC recommends removing disposable gowns by pulling the gown in the front, away from the body, until the ties break, and then rolling the gown inside out and removing the gloves with the gown.^[8] This approach is not feasible with reusable fabric gowns that have woven textile ties, such as were worn by HCWs observed in this study, as these ties are difficult to break. A possible reason that HCWs may frequently doff gowns incorrectly is that they have been trained in both doffing approaches, but over time have forgotten that the best doffing strategy depends upon the type of gown. The impact of gown doffing method on self-contamination, however, is uncertain. Osei-Bonsu et al.,^[10] in a doffing simulation study involving disposable gowns, found that use of the CDC-recommended doffing sequence that includes removing the gown by pulling from the front was associated with fewer participants with any contamination by the surrogate microorganism *Staphylococcus dermidis* than use of the doffing sequence that includes removing the gown from the back (2 of 15 [13%] vs. 8 of 12 [70%]), but no difference was observed in the number of participants with

any contamination by the fluorescent tracer (12 of 15 [80%] vs. 11 of 12 [92%]).

There is an uncertainty in the CDC recommendations regarding whether HCWs should wear a mask with eye shield, or simply a mask, when in close contact with a patient in droplet isolation.^[11] In our study, the hospital required HCWs to wear a surgical mask with eye shield in patient rooms identified for droplet isolation, and this was indicated on the isolation sign mounted on the room door. However, we found that in more than one-third of observations when the mask was used, HCWs took off the eye shield while providing care for patients. It may be that HCWs remove the eye shield when wearing prescription eye glasses, but this aspect of the PPE use was not specifically recorded. Removal of the eye shield can increase the risk of exposure to splashes of infectious material to the facial mucous membranes of HCWs, but the eye shield offers much less protection than indirectly vented goggles with anti-fog coating or chin-length face shield in conjunction with a mask, as recommended by the National Institute for Occupational Safety and Health to protect the conjunctiva from infectious aerosols.^[12]

In our study, we had a very high incorrect overall doffing rate (90%) because we evaluated the doffing technique, doffing sequence and the use of correct PPE. However, all doffing errors are not likely to contribute equally to the risk of disease transmission to HCWs or patients. It is plausible that touching contaminated surfaces with bare hand and not performing hand hygiene are the highest risk doffing errors because they increase the likelihood that a HCW leaves the patient room with pathogens on his or her hands. This issue will be explored in future work that integrates measures of virus presence and concentration on environmental surfaces, PPE, and HCWs.

Many factors may contribute to lack of compliance with PPE use during care for patients in contact and/or droplet isolation and with incorrect doffing, including: incorrect interpretation of the isolation signs, workload, under valuing the importance of PPE, under estimation of risk, or lack of knowledge of the correct PPE and correct doffing protocol.^[13] Although more complex than the PPE ensembles used in transmission-based precautions, human factors analyses of the doffing process for enhanced PPE ensembles used to care for patients with EVD, have highlighted numerous opportunities for PPE failure and self-contamination.^[3] Gurses et al.^[14] concluded that safe doffing of PPE requires knowledge, skills and attitudes, not just instructions for the sequence and

technique for how to remove pieces of PPE. Our observations suggest that HCWs are not familiar with the sequence and technique for how to remove pieces of PPE, but training that builds knowledge and skills and changes attitudes may motivate HCWs to utilize the correct sequence and technique. This requires a more comprehensive approach to training than is commonly employed today; one that includes knowledge and practical, hands-on experience. Hands-on training in PPE was commonly used with enhanced PPE ensembles during the Ebola Virus Disease outbreak of 2014–2015, and trainees identified hands-on training as having the greatest influence on their confidence to care for Ebola Virus Disease patients.^[15] Such training could be integrated into HCWs' clinical competency skills tests. Clearly, the evidence in this and other work demonstrate that the current approaches are inadequate to obtaining the desired PPE doffing behaviors from HCWs.

Our study had more observations of nurses and nurse technicians than HCWs with other roles (Table 3), which is consistent with the relative number of room entries that other studies have reported for HCWs of different job titles.^[16] Although the PPE use and doffing practices of nurses and nurse technicians were not different from HCWs with other job roles (Table 3), nurses and nurse technicians have frequent, intimate contacts with patients that may increase their exposure to pathogens, putting them at increased risk for occupationally acquired infectious disease and transferring pathogens outside of the patient room.

Our study is subject to several limitations. First, our study only observed HCWs who provided care for patients with viral respiratory diseases, and it is possible that HCWs behave differently when patients have different diseases, including those that result in contact and/or droplet isolation, due to the perception of risk. Second, there is a concern that HCWs may change their behaviors when being directly observed. In this study, however, the poor compliance with the recommended PPE doffing protocol suggests that HCWs were unable to implement the correct practices, even when observed. Finally, our study was conducted at a single acute care hospital, which may affect the generalizability of our findings to other healthcare settings, as work practices may vary between hospitals.

Conclusions

We found that deviations from the recommended PPE doffing protocol by CDC were common, which

could increase the risk of self-contamination on HCW's clothing and skin after providing care for patients having acute respiratory virus infections. In more than 90% of the observations, doffing practices involved errors with respect to the doffing sequence, doffing technique, and/or use of appropriate PPE. Common errors were doffing gown from the front, removing the eye shield of the mask, and touching potentially contaminated surfaces and PPE during doffing. Given the complexity of PPE doffing and deficiencies in HCWs' doffing practices, a new approach to education and training is needed.

Acknowledgments

We thank Maryshe Zietsman for assisting with data entry and data collection.

Funding

This work was funded by the Centers for Disease Control and Prevention cooperative agreement 1U54CK000445-01 with the Prevention Epicenters Program.

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