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A method for evaluating health care workers' personal protective equipment technique

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Background: Given the potential for the transfer of infectious diseases among patients in isolation, health care workers (HCWs), and other patients in the hospital environment, the proper use of personal protective equipment (PPE) is paramount. The literature is limited regarding studies of HCWs' use of PPE in patient care tasks.

Methods: A pilot study was conducted to examine the feasibility of using a simulated health care environment to assess HCWs' technique when implementing standard airborne and contact isolation precautions. The participants (n = 10) were assigned patient care tasks based on their specific professional roles. The encounters were digitally recorded during donning and doffing of PPE, as well as during interactions with the simulated patient. Powdered fluorescent marker was used as a measure of contamination.

Results: The pilot data show various inconsistencies in the HCWs' PPE technique. Each of the 10 participants committed at least one breach of standard airborne and contact isolation precautions.

Conclusion: An expanded research study of HCW behaviors is needed to properly examine these contamination and exposure pathways. Training programs should be developed that emphasize the common errors in HCWs' PPE technique.

Key Words: Infection control; patient care; contamination; simulation.

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Although infection control is recognized as a major patient safety issue, implementing intervention strategies has proven challenging.¹ The literature is limited regarding studies of the behaviors of health care workers (HCWs) while using personal protective equipment (PPE) in patient care activities. Conducting a study of this topic in an actual patient care area would raise both ethical and legal concerns. At the bedside, such a study would involve not only allowing an error to occur, but also documenting the occurrence of poor behavior. Consequently, we conducted a study in a simulated patient care environment to examine the feasibility of using a fluorescent marker to monitor for contamination

and videotaping to assess HCWs' adherence to the use of standard airborne and contact isolation precautions.

Compliance with such interventions as the use of PPE is an important line of defense to protect HCWs, their patients, and the community from contracting such infectious diseases as severe acute respiratory syndrome (SARS) and other contagious respiratory viruses.^{2,3} The proper use of PPE provides a safe barrier between the patient and the HCW by either preventing physical contact or actively filtering out infectious particles in the air. The potential for errors in PPE technique is significant. For instance, a poorly sealed respirator might not provide the necessary protection when caring for a patient with a contagious respiratory illness. Certain hairstyles could prevent the proper alignment of respirator straps for the best face seal. Touching a soiled bedsheet or patient gown with a glove or isolation gown could easily transfer microorganisms to the HCW's face or hands if PPE is removed in the improper order. Tying only one gown fastener or not placing the entire dirty gown inside a hamper in a contact isolation room could result in exposure of garments and later aerosolization of infectious particles. Many such errors occur repeatedly during patient care activities, given the lack quality control at the bedside. Infection control programs need to focus not only on the policies for the use of PPE, but also on the quality of the PPE techniques used while caring for patients.

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Without new system innovations in education of HCWs regarding the use of PPE, the risk of disease transmission in these situations becomes difficult to mitigate. Videotaping and the use of a fluorescent marker might allow HCWs to review their PPE technique and promote changes in behavior. The use of a simulated patient care environment might allow for safe training and compliance testing of infection control techniques.

Historically, simulation has been used in various educational strategies and tools in medical education, including skill trainers, computer-based modules, simulated patients (live actors), and high-fidelity human patient simulator manikins.⁴ In recent years, the nursing literature has exploded with content on simulation. Kaakinen and Arwood⁵ conducted a systematic review of this literature, with a focus on the use of learning theory. Of the 120 articles on nursing simulation that they cited, 94 discussed simulation as a teaching strategy. Only 16 articles described learning as the basis of the simulation development, and only 2 articles examined cognitive changes as a result of participation in the simulation.

Learning theory can drive the simulation design chosen for a particular educational activity. Kaakinen and Arwood⁵ described Schön's theory of reflective practice as a thoughtful, self-regulated process that lends itself to nursing and other caring professions. They discussed using video recording to teach a skill, allowing students to repeat the task until they do it correctly, as a reflective practice educational intervention. Videotaping a patient care skill to demonstrate competency along with performance feedback has been used successfully in nursing students.⁶ Kinsella⁷ described Schön's theory of reflective practice as balancing technical rationality and research-based knowledge with the wisdom of experience. Achieving this balance seems to be especially important in complicated skills, such as those involving aseptic technique or infection control, where numerous factors could affect the process.

Although the use of PPE is meant to prevent disease transmission, contamination errors can actually result in the spread of infection. Step-by-step directions for the use of PPE are available from the Centers for Disease Control and Prevention (CDC),⁸ but the sequence of PPE application or removal may be altered by the patient's status or the patient care task being performed. The Healthcare Infection Control Practices Advisory Committee⁹ has published an updated guide for isolation in health care facilities emphasizing standard precautions, respiratory hygiene, and cough etiquette as new components. The World Health Organization¹⁰ also has published a quick reference guide on infection control strategies for specific procedures in health care facilities. The World Health Organization guide specifically addresses epidemic and

pandemic-prone respiratory illness and categorizes infection control measures by clinical setting and procedure. An method for observing compliance with these PPE guidelines would be helpful in developing performance-enhancing interventions.

Much of the current literature on PPE use and compliance is derived from experiences during the 2003 SARS outbreak.¹¹⁻¹³ Those studies were conducted to ascertain the risk factors for transmission of SARS within the health care setting. Inconsistent or improper use of PPE was significantly associated with SARS infection. A review of the response to the 2009 H1N1 pandemic has led to increased attention to the proper use of respiratory PPE.

Some studies have used monitoring of contamination to examine the use of PPE. Casanova et al¹⁴ evaluated a CDC PPE removal protocol using bacteriophage MS2 and Glo Germ. Following the current CDC PPE doffing protocol did not protect HCWs from all contamination in that study. The authors did not evaluate the HCWs' actions that might have led to contamination through direct observation, and they did not report the study participants' health care experiences.

Videotaping also has been used to evaluate infection control behaviors. Chiang et al¹⁵ conducted a prospective observational study in a metropolitan Taiwan hospital involving videotaping of 44 consecutive cases of out-of-hospital adult cardiac arrest. A review of the tapes using time-motion analysis revealed poor compliance with basic infection control measures during resuscitation, showed frequent contamination events among rescuers, and identified two major systemic sources resulting in >80% of the contaminations: lack of task assignments among rescuers and poor procedure preparation. In another study, Hassan et al¹⁶ investigated hand hygiene using videotaping and self-reporting in a private hospital in Jordan. The major findings included overall low compliance, lower levels of compliance in higher-acuity settings, and sex-related differences in hand hygiene. In that study, the observer waited in the nursing station and accompanied the nurse subject to the bedside, filming only the nurse's hands during a care episode. The study reported on compliance with hand hygiene, but did not explore how to discern the quality of hand hygiene.

In response to a CDC survey following the 2009 H1N1 pandemic, HCWs with likely patient-to-HCW transmission reported inconsistent use of PPE.¹⁷ In fact, none of the HCWs who completed the detailed report for the CDC reported always using gloves, a gown, and a mask or respirator when caring for the presumed source patient. The study assessed the feasibility of studying a simulated encounter and established best practices for a larger study in which several educational interventions may be tested. A simulated patient care environment

with a reasonable level of realism and discrete video recording provided a convincing experience for HCWs without putting actual patients at risk. This approach might allow for more robust training and compliance testing of HCWs in the future.

METHODS

The study was approved by the University of Nebraska Medical Center's Institutional Review Board through an expedited review process. The study was conducted in a simulated patient care environment, with a study team member acting as the patient. The simulated patient followed a specific narrative for the scenario and engaged in conversation with the HCW during the patient care encounter. The simulation room had features of a typical patient care room, including a hospital bed, wall unit with pressurized air, storage cabinets, television, bedside table, and tray table. Immediately outside the room were an isolation cart and handwashing facilities. The room had two discretely mounted cameras in the ceiling that could be positioned and focused in real time from a neighboring viewing room. The cameras fed into an audiovisual retrieval system to which the digital videos could be downloaded from secured system servers for data analysis. In addition, another high-definition digital camera was strategically placed outside the room to better capture the HCW's PPE donning and room exiting behaviors. This allowed for consistent capturing of the underlying sources of contamination for each HCW during the 3 stages of the simulation: PPE donning, patient care, and PPE doffing. All study participants were made aware of the videorecording during the consent process.

The participants ($n = 10$) included registered nurses, respiratory therapists, and nursing assistants from various units in the hospital. Each participant was assigned patient care tasks based on his or her specific professional role. Registered nurses were asked to assess the patient and administer an intravenous (IV) medication for pain. The simulated patient's IV site was connected to IV tubing, and an empty reservoir was hidden under the gown to collect the running IV fluid and simulated IV pain medication. Respiratory therapists assessed the patient and administered a nebulizer treatment consisting of normal saline instead of a medication. Nursing assistants repositioned the patient from bed to chair, took vital signs, and conducted input and output documentation. The simulated patient had a Foley bag attached to the leg under the gown, filled with a solution of tap water with a small amount of povidone-iodine added to simulate urine.

The participants were randomized to a group that had access to a CDC poster on the sequence PPE

donning and doffing⁸ or to a group without access to any additional guidance. The poster was printed on 8.5- × 11-inch paper and posted on the wall in the donning and doffing areas. Although this randomization was not necessary for a feasibility study with such a small sample, it allowed for observation of the participants' responses to the additional guidance and may guide interventions considered for future studies. The isolation cart was stocked 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 and typical isolation signage were posted at the room's door. No other guidance on appropriate PPE was given. A powdered fluorescent marker 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. Contaminated areas were assessed between study participants using an ultraviolet light to ensure that the same areas of contamination were dusted with fluorescent marker for each participant. Other areas in the room potentially contaminated with fluorescent marker during the simulated patient care were assessed using the ultraviolet light after each encounter and cleaned. The fluorescent marker is easily removed using a damp towel. The study participants consented to the study fully aware that the fluorescent marker was present in the simulated patient care room, due to the minor risk for sensitivity to the powder.

Fluorescent marker exposure on each participant's body was assessed after PPE removal and handwashing using a standard case report form and digital photography of the contaminated areas. The encounters were digitally recorded during the PPE donning and doffing and during the interaction with the simulated patient. Digital video footage was reviewed by the research team and evaluated for compliance using an observation tool.

The same 3 members of the research team performed the video scoring for all 10 participants, to reduce variability. The reviewers had no administrative responsibilities over the study participants and had the necessary expertise to competently evaluate all of the video captures. For evaluation, each reviewer watched the video capture and independently recorded his or her evaluation with the observation tool. Then all 3 reviewers viewed the video capture as a group until a consensus was reached on each participant's final score. The observation tool was based on a combination of local hospital and national guidelines.⁹ Contamination and exposure pathways were observed during 3 periods: PPE donning activities, in-room activities, and PPE doffing activities. The observation tool elicited information on the PPE donning and doffing

sequences, and also included structured and open-ended questions for complete data collection.

RESULTS

Each of the 10 participants committed at least one breach of standard airborne and contact isolation precautions. These breaches were classified as either risk factors detected during the PPE donning and doffing processes (Table 1) or risk factors observed while the HCW was in the room with the patient (Table 2). The most common breaches in PPE donning were not conducting a seal check on the respirator, failing to tie the gown at both the neck and the waist, and donning the equipment in the improper sequence. The most common breaches in PPE doffing were related to the sequence of equipment removal, removing the respirator, and removing potentially contaminated items from the room. The most common breaches detected in the patient room included touching unprotected areas of the participant's own body with contaminated PPE and the unnecessary touching of surfaces in the room during patient care activities.

Other observations noted by the reviewers included one instance of an HCW adjusting both the respiratory protection and the protective goggles with contaminated gloved hands during simulated patient care. The participant complained of visual disturbance from condensation in the goggles. In addition, 6 participants touched various surfaces in the room for no reason. In one notable case, the participant who touched various surfaces did not use proper glove-in-glove technique or the recommended doffing sequence.

Flourescent marker contamination was documented on 8 of the 10 participants after completion of the simulation experience. Six participants had contamination on the hands, 3 participants had contamination on the back of the head, and one participant had contamination on both the hands and the head.

DISCUSSION

There is a need for improved evaluation and training of HCWs in the proper use of PPE when caring for patients in isolation. Our findings in the present study support the need for larger studies to examine the effectiveness of various teaching approaches. In a pandemic simulation exercise conducted over 24 hours in a nursing unit following procedures mandated by the United Kingdom pandemic influenza infection control guideline, HCWs demonstrated uncertainty in such areas as donning and removal of PPE and decontamination of room equipment.¹⁸ Retrospective reviews of outbreaks such as SARS and novel H1N1 have shown inconsistent use of PPE in HCWs who developed infection. Possible barriers to adherence in these outbreaks

may include personal beliefs, fatigue, inadequate training or systematic approaches, and lack of PPE supplies.^{12,16} The results of these previous studies support the need for further studies related to training in and reinforcement of PPE techniques for HCWs.

Through video recording, the present study found that each participant made at least one error that could have resulted in self-contamination or contamination of future patients. Reasons for noncompliance with hand hygiene have been studied in depth.¹⁹ Our finding that 3 participants entered the patient room and 2 participants exited the room without performing hand hygiene is notable, especially considering that the participants knew that they were being evaluated. As noted previously, a compliance study using videotaping by Hassan et al¹⁶ found similar low levels of compliance with handwashing in an actual patient care setting. Actions such as neglecting to check the seal of the mask or neglecting to tie the gown at both the neck and the waist have been commonly observed in practice by the research team. Some of the actions observed in the present study were less predictable, such as leaving the room without completing the doffing sequence and unnecessarily touching surfaces in the room. The number of participants who performed PPE donning and doffing out of sequence was higher than expected. We had anticipated a smaller number in the group that had access to the CDC guideline poster in the donning and doffing areas, but that did not prove to be the case.

We used a fluorescent marker for comparison with the video recording of participants' behavior. The participants sometimes put their gloved hands on surfaces contaminated with the fluorescent marker and then touched an area such as the face. We were not always able to document the transfer to the face under the black light when we evaluated the individual for fluorescent marker contamination once he or she completed the simulation experience. In some other cases, small paper towel fragments on the participant's hands following hand hygiene initially appeared to be massive contamination of the hands with the fluorescent marker. This might have skewed our data related to hand contamination. This problem possibly could be resolved in future studies by using a different color of powdered fluorescent marker. The most common location of actual fluorescent marker contamination was on the back of the head, which the review of the video capture identified as resulting from an incorrect PPE doffing sequence. Casanova et al¹⁴ used the same fluorescent marker in their study on removing PPE in 10 participants, but they directly contaminated the surface of the PPE before the patient care task and PPE removal. They also found the fluorescent marker to be an inconsistent contamination indicator. The use of a

Table 1. Number of participants (total n = 10) observed committing a breach in standard airborne and contact isolation precautions during PPE donning and doffing

Observation	Number of participants
Donning issues	
Did not perform hand hygiene before entering the room.	3
Did not tie the gown at both the neck and waist.	7
Selected a procedure mask instead of the N95 disposable respirator.	2
Did not place mask straps properly.	5
Did not properly seal the mask to the face.	5
Did not conduct a seal check.	10
Did not use eye protection.	0
Glove cuff did not cover gown cuff.	0
Did not don equipment in the CDC-recommended sequence.	7
Gloves were not donned last as part of the donning sequence.	6
Doffing issues	
Did not use proper glove-in-glove technique for glove removal.	2
Gloves were not placed in the trash.	0
Removed potentially contaminated eye protection from the room.	6
Used poor technique for gown removal.	6
Did not use the foot pedal, but instead touched the hamper lid with bare hand.	4
Did not place all or part of the gown into the designated hamper.	3
Did not use proper mask removal technique.	9
Did not place the mask into the trash.	0
Did not use wall mounted hand sanitizer before exiting the room.	6
Removed other potentially contaminated items from the room.	7
Did not perform hand hygiene after exiting the room.	2
Did not doff equipment in the CDC recommended sequence.	9
Did not remove gloves first.	7

fluorescent marker alone in training scenarios might not adequately demonstrate the potential for transfer of infectious materials and might inadvertently reinforce poor technique. The video recording seems to provide a more reliable account of HCW behaviors.

Two of our participants selected a procedure mask over a disposable N95 filtering face piece respirator when providing care to a patient known to be in airborne and contact precautions. There are conflicting guidelines regarding the proper type of PPE for HCWs to wear when faced by such threats as H1N1 along with a lack of strong evidence supporting these various guidelines.²⁰ In response to the H1N1 pandemic of 2009, a large randomized study comparing surgical masks and N95 respirators appeared to show similar protection from both types of masks in routine health care settings.²¹ That study had many limitations given

Table 2. Number of participants (total n = 10) observed committing a breach in standard airborne and contact isolation precautions during in-room patient care

Observation	Number of participants
Touched unprotected areas of the body, which could have resulted in self-contamination.	8
Adjusted the mask in the room, breaking the seal and potentially resulting in self-contamination.	1
Touched surfaces in the room that were unnecessary, which could have resulted in greater contamination of the gloved hands.	6

its size and scope, however, and further research in this area is needed.

Given the potential for the transfer of infectious diseases among patients in isolation, HCWs, and other patients within the hospital environment, the proper use of PPE is paramount. Our findings demonstrate the feasibility of evaluating proper PPE use in a simulated health care environment using video capture and a fluorescent marker. The environment allowed for the safe collection of data without the legal ramifications associated with harm to actual patients. In addition, the video capture can allow the HCWs to observe their own techniques both with the infection control specialists and on their own, thereby promoting changes in behavior. The simulation environment may have many applications for the safe training and compliance testing of HCWs in the future.

This study was completed at a minimal cost using primarily such educational training materials as expired syringes, IV tubing, and catheters. The use of the technology and simulation center space was donated by the health sciences center. The participating hospital unit supplied the necessary PPE. All data were collected during one 8-hour day. This time frame included setup, data collection, and return of the technology and simulation center space to its previous condition. On the day of data collection, the study was administered by 3 personnel and one standardized patient. There was no external source of funding for this study.

CONCLUSION

This study was conducted to evaluate the use of video capture and a powdered fluorescent marker for evaluating HCWs' use of PPE for airborne and contact isolation procedures in a simulated patient care environment. The video quality was found to be adequate for evaluating the HCWs' techniques. Camera repositioning and minimal study participant cueing should address situations in which details were indistinct in

the video recording. An example of cueing might be asking the participant in advance to stand in a certain direction while donning PPE.

The need for further study of HCWs' behaviors related to the use of PPE is relevant and feasible given the simulation technology and environments available today. Simulation centers with video recording capabilities are becoming more widely available, and high-quality video technology is becoming more accessible and less expensive. A more portable video system for use in actual health care facilities might be a valuable tool to extend this research beyond the educational laboratory setting.

Video recording in a simulated patient care environment is an effective technique for observing risk factors for noncompliance with infection control practices. The use of a powdered fluorescent marker was found to be less effective in terms of assessing behaviors. Noncompliance with infection control practices puts both HCWs and their patients at risk. An expanded research study of these HCW behaviors is needed to properly examine these contamination pathways. Future studies also should focus on such areas of concern as equipment challenges and working conditions. Training should be developed that specifically addresses common errors in HCWs' PPE technique.

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