Using a Critical Incident Scenario With Virtual Humans to Assess Educational Needs of Nurses in a Postanesthesia Care Unit

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Introduction: *During critical incidents, teamwork failures can compromise patient safety. This study provides evidence that virtual humans can be used in simulated critical incidents to assess the learning needs of health professionals, and provide important information that can inform the development of continuing education programs in patient safety. We explored the effectiveness of information transfer during a devolving medical situation between postanesthesia care unit (PACU) nurses and a virtual attending physician.*

Methods: *We designed a three-stage scenario: tutorial, patient transfer, and critical incident. We developed 2 checklists to assess information transfer: Critical Patient Information and Interprofessional Communication Skills. All participants were videotaped; 2 raters reviewed all videos and assessed performance using the checklists.*

Results: *Participants (n = 43) who completed all 3 stages scored 62.3% correct on critical patient information transfer and 61.6% correct on interprofessional communication skills. Almost 87% missed a fatal drug error. The checklists measured each item on a 1/0 (done/not) calculation. Additionally, no relationship was found between years of nursing experience and performance on either checklist.*

Discussion: *The PACU nurses in this study did not consistently share critical information with an attending (virtual) physician during a critical incident, and most missed a fatal dosage error. These findings strongly suggest a crucial need for additional structured team training among practicing health care teams, and they demonstrate the utility of using virtual humans to simulate team members.*

Key Words: *simulation, workplace learning*

Introduction

Medical errors continue to occur in health care settings and lead to considerable financial costs and human suffering.[1,2] Communication problems and inadequate information exchanges are commonly cited as 2 major contributors to these errors.[3]

From 35 to 60% of medical errors and adverse events occur because of handoff (patient transfer) breakdowns.[4,5] Core characteristics of these breakdowns include a variety of communication challenges (eg, hierarchy, language) and differing expectations between incoming and outgoing health care professionals. Safe and effective handoffs between different providers with different backgrounds can be very challenging. Stein-Parbury and colleagues found that in critical care venues, the different types of knowledge possessed by nurses versus physicians were a major contributor to teamwork failures.[6] Also, many surgical teams are *ad hoc* in nature—assembled "on the fly" as needed, with whatever resources

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are available. Riley and colleagues[7] found that during *in situ* simulated obstetrical crises, health care teams changed constantly, and leadership necessarily shifted among providers of varying backgrounds. They reported that the performance of such ad hoc teams during a critical event can be very inconsistent. This inconsistency extends to performance during handoffs.[7]

The vast number of combinations of potential team members in a health care crisis has one major implication for the design of educational interventions to improve team performance in the critical care setting. It means that the focus must be on developing individual team member competencies as well as whole-team competencies.[8] Although many recommendations have been developed to facilitate transitions of care and sharing of information, problems persist.[9–14] SBAR (Situation, Background, Assessment, and Recommendations) is a frequently cited tool for improving handoffs; it provides a structure that can be applied consistently across teams, disciplines, and institutions.[15] Certainly, such techniques lend themselves to improved situational awareness among members of the team, but other strategies, including those that focus on individual competence, are clearly needed to more fully realize the goal of improving patient safety.

This study was developed in the larger context of creating and using virtual humans (VHs) to demonstrate important individual communication responsibilities as well as teamwork principles for health care professionals, and to provide opportunities to practice application of these important skills. Virtual humans have been successfully applied to several training domains, including patient interviewing[16] and negotiation.[17] However, to the best of our knowledge, they have not yet been applied to medical team training.

Our overall goal in this study was to use virtual humans to provide individual team member and overall team training with a specific emphasis on handoffs. The authors of this study are collaborating on a grant funded by the National Science Foundation (#1161491) to investigate the use of virtual humans as acceptable and efficacious members of a health care team in the context of team training to reduce medical errors and improve patient safety. Several members of the grant team have already conducted extensive research on virtual humans in health care settings.[18–20]

Part of the rationale for using virtual humans is that a common barrier to team training in health care is the availability of all team members at the same time.[13] Further, the sheer number of possible combinations of ad hoc health care teams makes it almost impossible to train with the actual team that would be called on in a crisis.[8] If VHs could effectively "step in" to replace missing team members, training to reinforce effective communication in different contexts could still take place.[21] VHs can also potentially be used for needs assessment purposes, establishing baseline measurements against which the impact of subsequent training can be measured.

The purposes of the present study were to assess the transfer of patient information between practicing health care professionals during an evolving medical crisis and to demonstrate how virtual humans can be used to assess learning needs. This work is intended to provide a baseline assessment from which to make recommendations for future training of practicing health care professionals using virtual humans.

Methods

The authors view this study as a pilot needs assessment to determine contexts in which we can pinpoint where patient safety is at risk, so that relevant and appropriate training can be designed, implemented, and delivered. Therefore, we undertook a prospective, observational study of the quality of information transfer and teamwork principles among practicing postoperative care unit nurses during a simulated critical event in a postanesthesia care unit (PACU).

The assessment described here was designed to measure the performance of a single human team member in an interprofessional scenario involving 2 virtual humans. The point of this particular study was to assess how the human subject gathered and shared critical information to assure patient safety in a complex, evolving medical crisis. Teamwork skills were measured broadly, but we were primarily interested in whether the nurse participant provided the (virtual) anesthesiologist all of the relevant information he needed to care for a patient in distress.

Setting and Participants

The organizational setting of the study was Shands Hospital/UFHealth, a large academic health system in Gainesville, Florida, with more than 800 beds and over 100 intensive care unit (ICU) beds. Shands is a level-one trauma center and has an average surgical volume of more than 25,000 cases per year. The study took place in a simulated PACU at the University of Florida (UF) Center for Safety Simulation and Advanced Learning Technologies (CSSALT).

Participants were practicing PACU nurses. At the time of the study, there were no specific educational requirements for nurses working in a PACU setting except an active Florida nursing license.[20] In Florida, the nursing license requires graduation from an accredited nursing program, a minimum educational background, successful completion of appropriate standardized testing, and satisfaction of continuing education requirements. Previous work experience in the operating room or critical care setting is considered desirable among job candidates but was not required at the time of this study.

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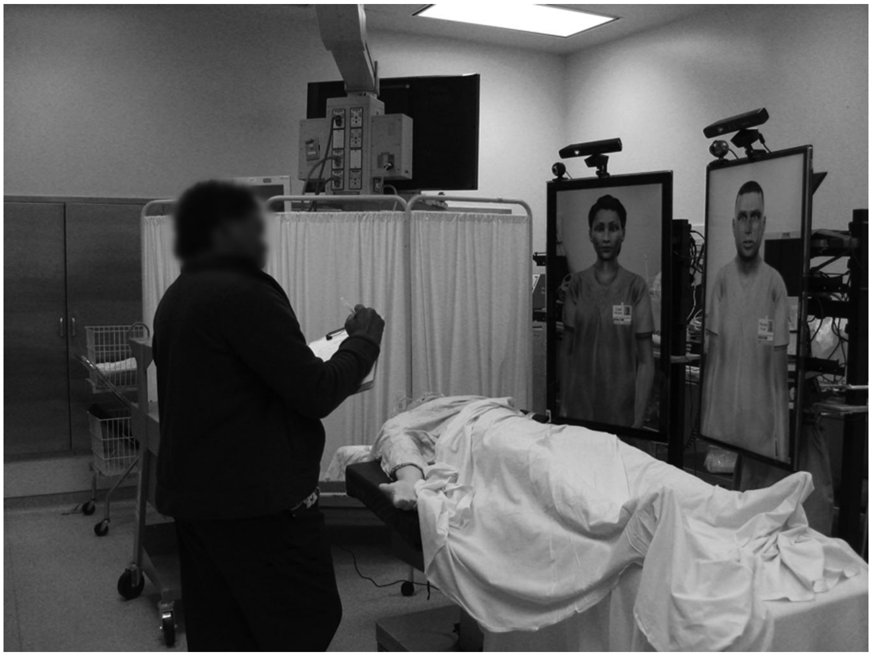

FIGURE 1. Nurse Participant in Stage 3 of the Scenario

PACU nurses were recruited by one of the authors (AW). All nurses included in this study signed informed consent forms before beginning the scenario. The study received approval from the UF Institutional Review Board (U-740-2011), Shands/UFHealth.

Study Scenario

The VHs we created for this purpose are computer programs that look and sound like human beings, and converse with trainees using free-form speech. In our studies, they are life-sized and displayed on large, 40-inch LCD televisions (FIGURE 1).

There were 3 stages in this scenario for each (human) PACU nurse to complete. In Stage 1, each participant was introduced to the session by reading a set of goals and scope for each scenario (TABLE 1), followed by a tutorial designed to introduce them to the technology (ie, VHs and mannequin patient simulator) (FIGURES 1–3). This was the only introduction they received to the technology.

In Stage 2, a virtual anesthesiologist transferred care of a patient who had undergone a high-risk surgery (laparoscopic esophagectomy) from the operating room to the PACU nurse participant. During this stage, the participants were instructed to take notes about the patient's surgery and past medical history, just as they would in the course of regular patient care.

At the start of Stage 3, participants were advised that 30 minutes had elapsed since they had received the handoff from the anesthesiologist. During that time, the patient had continued to experience nondescript pain despite a large dose of opioids, and had developed signs of myocardial ischemia including tachycardia and ST-segment depression. Participants were then told that they had called the attending anesthesiologist for additional evaluation. Participants were instructed that when the anesthesiologist requested medications to be administered to the patient, they should verbally delegate this request to the virtual charge nurse, who would then administer the medication. Participants were also instructed to use their notes from the transfer (Stage 2) to answer the attending anesthesiologist's questions about the patient.

While the nurse and the anesthesiologist were attempting to evaluate and treat the patient's nondescript pain, the patient began displaying hypotension. At that point the anesthesiologist asked the nurse participant to administer a medication to increase the patient's blood pressure ("The patient is hypotensive. Give him phenylephrine 50 *micrograms* IV"). As instructed, participants passed this request on to the virtual charge nurse assisting with the patient. Immediately after the virtual charge nurse received this request, she verbally confirmed the instructions she was given but stated an incorrect dose ("I'm giving phenylephrine 50 *milligrams* IV"). This is a fatal error because the dose has been increased by 1000.

The questions and answers spoken by the VHs in all 3 stages were prerecorded by professional voice actors. Scripts were developed by anesthesiologists and experienced

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TABLE 1. Goals and Scope of Each Stage

Stage 1: Tutorial The goal of this tutorial is to familiarize you with the virtual humans and the training system.	**Stage 1: Scope** In this tutorial you will: • Learn to talk to the virtual humans. • Have a chance to familiarize yourself with the mannequin patient simulator and patient monitor. • Practice the first minute of a handoff (transfer of care) from a virtual anesthesiologist. • Practice the first minute of a critical incident.
Stage 2: Handoff (Transfer) The goal of the handoff is to provide you with the patient information you will use later in the critical incident scenario.	**Stage 2: Handoff (Transfer)** During the handoff you should: • Record patient information received from a virtual anesthesiologist. • Ask any questions you feel necessary to fill in details.
Stage 3: Critical Incident[a] The goal of the critical incident is to let you practice a critical incident that you may not have experienced or practiced often. The critical incident in this scenario is myocardial ischemia.[b]	**Stage 3: Critical Incident** During the critical incident you will: • Work with a virtual resident and virtual charge nurse to treat a patient. • Answer the virtual resident's questions about the patient. • Make any suggestions you feel appropriate to the virtual resident or virtual charge nurse.

[a]This stage is the focus of the study reported in this manuscript.
[b]Myocardial ischemia occurs when blood flow to the heart muscle is decreased by a partial or complete blockage of the heart's coronary arteries. The decrease in blood flow reduces the heart's oxygen supply.

perioperative nurses based on "gold standard" interactions in a patient transfer setting and in a critical incident setting. The VH's speech and the mannequin human patient's functions were operated using a "Wizard of Oz" (woz) setup, in which a concealed operator is behind the scenes, interpreting the participant's questions and comments, and choosing the correct comment, question, or answer to converse with the nurse participant (TABLE 2).

Data Collection

Before Stage 1 began, each participant was asked to complete a survey that asked for demographic data, including years in the nursing profession and years as an operating room nurse. The survey also asked participants to provide a self-assessment of their knowledge of myocardial ischemia in six areas (etiology, presentation, evaluation, treatment, risk factors, when to ask/call for help) using a Likert-type 5-point scale (1 = None at all, 5 = Very familiar).

Each encounter was video recorded. Data extraction from the recordings focused on whether the nurses shared appropriately comprehensive and relevant information with the anesthesiologist. A checklist (TABLE 3) was developed by one of the authors (AW) to assess the information provided to the anesthesiologist. Content validity of the items was established following Lawshe's methodology.[22] Nine anesthesiologists were given a clinical vignette describing the myocardial ischemia scenario and asked which items were critical to know and which items were unnecessary in that particular scenario. Items with a content validity ratio of at least .555 were included on the final checklist, which means an alpha value of up to .10. Based on the content validity testing, the number of items considered to be critical in this type of incident was reduced from 34 to 9. A second checklist, adapted from several different documents that described characteristics of teamwork that fostered communication, was used to assess interprofessional skills such as eye contact, closed-loop communication[a], and 6 other items (TABLE 4).[24–29]

Data Analysis

When all of the participants had completed the scenario, one of the authors (AW) viewed every video and used both checklists to assess performance. A medical student was recruited as a second reviewer to watch and score the videos as well. Interrater reliability testing revealed a Cohen's kappa of .62 (substantial) for both checklists combined. Where the 2 scores were not the same, we used the score of the experienced anesthesiologist (AW).

All items from both checklists were assigned a "yes" or "no" response based on whether or not the nurse participant was observed during video playback to have successfully completed the checklist item by the rater. Subsequently, all item responses were translated into numerical scores for statistical analysis, with "1" being assigned to a "yes" response and "0" assigned to a "no" response.

To determine each individual's performance score on the 2 checklists, item scores were summed, divided by the total number of items on the checklist, and multiplied by 100.

[a] Closed-loop communication involves the initiation of a message by a sender, the receipt and acknowledgment of the message by the receiver, and verification by the initial sender that the message was understood.[23]

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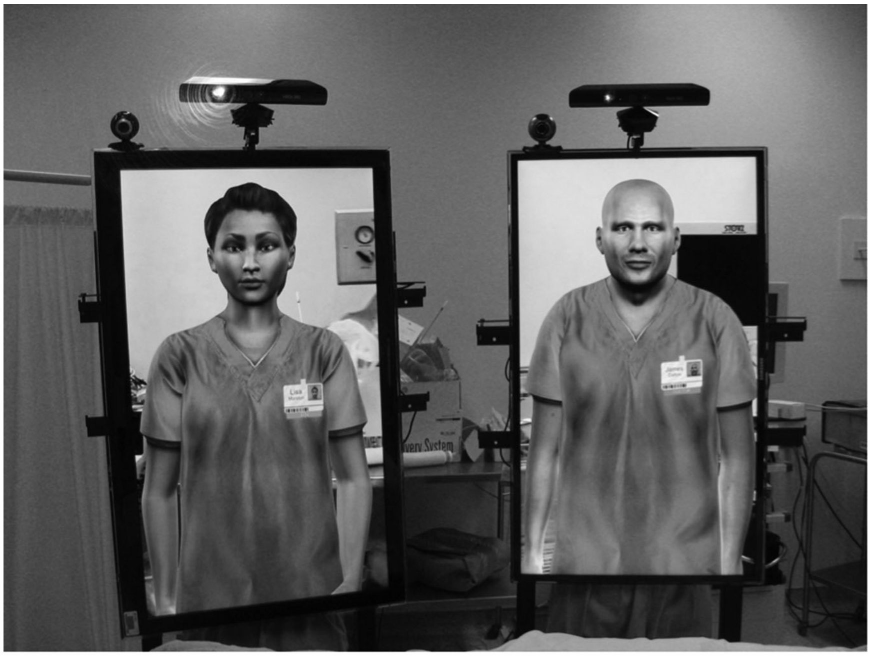

FIGURE 2. Virtual Charge Nurse and Virtual Anesthesiologist in Stage 3 of the Scenario

FIGURE 3. Virtual (Mannequin) in Scenario

The result was an overall performance score for each checklist that could range from zero to 100. At the group level, frequencies were generated for the scores on each item on the 2 checklists. In addition, an average overall performance score for the total group of participants was calculated for each checklist.

To assess correlations between performance as measured by the 2 checklists (Critical Patient Information and Interprofessional Communication Skills) and demographic data, Pearson Product Moment Correlation Coefficients were calculated. Spearman's Rank Correlation Coefficients were conducted for the correlations involving self-ratings on knowledge of myocardial ischemia.[30]

All analyses were conducted using SPSS, version 22.

Results

Forty-six nurses took part in the study. Of these, 43 completed the Stage 1 survey. All 46 were included in the analysis of checklist scores. The 3 participants with missing data were excluded from the correlation analyses. The average age of the participants was 44.7 years old, and average years of nursing experience was 18.2. Forty of the participants were women, and 3 were men.

Checklist Performance

PACU nurse participants who completed all 3 stages ($n = 43$) had an overall average percentage score of 62.3 on Checklist 1 (Critical Patient Information), and 61.6% score on

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TABLE 2. Sample Exchanges Between Participants and VHs

Nurse Participant 21320	
Virtual anesthesiologist	Does [the patient] have any known problems?
Participant	Chronic renal insufficiency—his urine output was 200. History of smoking, history of diabetes. So we probably want to treat him for a potential MI.
Virtual anesthesiologist	Can we give him sublingual nitro, one tab?
Participant	Lisa, can you give sublingual nitro to our patient?
Virtual charge nurse (Lisa Marsden)	Okay, administering the nitroglycerin.
Participant 20806	
Virtual anesthesiologist	His blood pressure is low. Give him phenylephrine, 50 micrograms IV.
Participant	Nurse Marsden, can you give him phenylephrine, 50 mics, please?
Virtual charge nurse	Okay, administering 50 milligrams phenylephrine.

Checklist 2 (Interprofessional Communication Skills). A substantial percentage of participants did not share 3 critical items with the anesthesiologist: the patient's history of coronary stents (82.2% missed), report of vital signs to the oncoming attending physician at the time of his arrival (63.0% missed), and awareness of vital signs (participants were expected to demonstrate awareness/concern that the patient's vital signs were unstable during the scenario) (47.8% missed). Almost 87% of the participants missed the phenylephrine dosage error. Items on the Interprofessional Skills Checklist missed by a substantial number of participants included introduction of self and task (89.1% missed), and closed-loop communication (47.8% missed).

Correlations: Performance With Demographic Data

No statistically significant relationship was found between scores on the Critical Patient Information checklist and years of nursing experience ($r = .066$, $p = .684$), or between the Interprofessional Communication checklist and years of nursing experience ($r = .007$, $p = .966$).

No statistically significant relationship was found between the Critical Patient Information Checklist scores and the 6 knowledge of MI domains items (etiology: rho = .142, $p = .377$; presentation: rho = .166, $p = .300$; evaluation: rho = .037, $p = .818$; treatment: rho = .184, $p = .248$; risk factors: rho = .063, $p = .696$; when to ask/call for help: rho = .184, $p = .250$).

TABLE 3. Checklist of Critical Patient Information (Checklist 1)

a.	Constant abdominal/chest/neck pain *(at a minimum must say chest pain)*	Yes	No
b.	Working diagnosis *(acceptable = possibly having a having myocardial ischemia or heart attack/ischemia/ST changes or ST depressions or flattening of his T waves)*	Yes	No
c.	Surgery the patient underwent: laproscopic esophogectomy (*okay to mispronounce*)	Yes	No
d.	History of coronary artery disease: MI 18 months ago *(acceptable = CAD, history of MI or both, with or without 18 months)*	Yes	No
e.	Coronary stents with drug eluding stents (DES) 18 months ago *(acceptable = any statement of stents, or cardiac vascularization)*	Yes	No
f.	Allergies (*none*)	Yes	No
g.	Intraoperative events *(acceptable = no events out of the ordinary or gave some intermittent boluses of phenylephrine)*	Yes	No
h.	Report of vital signs *(acceptable = desaturating or heart rate is elevated)*	Yes	No
i.	Awareness of vital signs *(acceptable = any indication they looked at the vital signs or they are concerned with the patient's condition through the scenario)*	Yes	No
j.	Detected and corrected dosing of phenylephrine	Yes	No

Note: Text italics comprise minimum responses to receive a Yes on that item.

TABLE 4. Checklist of Interprofessional Communication Skills

1.	Greeted and (rapidly) introduced self and role/task.	Yes	No
2.	Addressed colleagues by name.	Yes	No
3.	Made eye contact during interaction.	Yes	No
4.	Said "please" and "thank you."	Yes	No
5.	Spoke clearly and firmly.	Yes	No
6.	Used unambiguous statements.	Yes	No
7.	Checked on understanding of the receiver of information.	Yes	No
8.	Closed-loop communication style.	Yes	No

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Discussion

As a result of this study, we were able to determine that a substantial number of the PACU nurses who participated (1) did not share all of the critical patient information with the attending physician, (2) did not catch a fatal dosage error, and (3) did not consistently practice closed-loop communication, regardless of their years of nursing experience or their self-assessed knowledge of myocardial ischemia.

The first finding comprises an error in judgment—results indicated that the participants did not fully understand what components of the history and the patient's current status were vital to share with the attending physician in an evolving medical crisis. The second finding comprises an error in communication among team members. Even those who used closed-loop communication did not do so consistently, which likely contributed to why so many missed the medication dosage error. Participants should have closed the loop by actively listening to the nurse charged with administering medication to the patient when she stated the incorrect dosage immediately after receiving her instructions. It was clear from video review that once most of the participants had asked the charge nurse to administer the medication, they turned their attention to the next task, thereby missing the charge nurse's error.

Limitations include this particular study's focus on a PACU environment, and a single patient experiencing myocardial ischemia. However, this study provides preliminary evidence of the need for communication and skills training to assure patient safety in one health care system. The findings suggest the need for additional inquiry into health care professionals' ability to identify and communicate information that is critical to the patient's safety—especially during an evolving medical crisis when time is extremely important. Neither length of experience nor cognitive knowledge related to the patient's deteriorating condition (myocardial ischemia) was correlated with omissions of information or missing a serious error. Therefore, many nursing staff who work in PACU and OR environments may be in need of training.

This study also demonstrates how virtual humans can be integrated into the training process. As we noted in the introduction, it is well known that the logistics of bringing an entire team together, especially during work hours, makes team training—along with periodic refresher sessions—extremely challenging. The sheer number of combinations of team members in a large medical center makes training of this kind impractical. VHs portraying team members can facilitate patient safety and team training, since scheduling would not require an entire human team to be available, and individuals could participate in scenarios as often as needed or required. VHs can be programmed to mirror the "gold standard" team-based practices in a variety of medical contexts/situations, and video review or other types of feedback could be provided immediately after completion of the team training exercise to serve as skills reinforcement. Self-assessment, so critical in medical practice, could also be integrated into the feedback intervention.

Lessons for Practice

- Health care institutions should evaluate, in an ongoing manner, the role of health care team members in fostering practices to ensure patient safety.
- Understanding of policies designed to ensure patient safety appears to be inconsistent; ongoing education is critical.
- Technology—in this case virtual health care team members—can make important contributions in training health care team members in practices that can help to ensure patient safety across contexts.

This study adds to the growing evidence that VH team members can be effective tools in the continuing education of health professionals.[21,31] Future studies planned include the use of virtual team members in different contexts and environments, and continued assessment of the impact of VH simulations on human participants' knowledge and use of critical principles of team communication.

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