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INSTRUCTIONAL DESIGN AND ASSESSMENT

Computer-based Simulation Training to Improve Learning Outcomes in Mannequin-based Simulation Exercises

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Objective. To assess the impact of computer-based simulation on the achievement of student learning outcomes during mannequin-based simulation.
Design. Participants were randomly assigned to rapid response teams of 5-6 students and then teams were randomly assigned to either a group that completed either computer-based or mannequin-based simulation cases first. In both simulations, students used their critical thinking skills and selected interventions independent of facilitator input.
Assessment. A predetermined rubric was used to record and assess students' performance in the mannequin-based simulations. Feedback and student performance scores were generated by the software in the computer-based simulations. More of the teams in the group that completed the computer-based simulation before completing the mannequin-based simulation achieved the primary outcome for the exercise, which was survival of the simulated patient (41.2% vs. 5.6%). The majority of students (>90%) recommended the continuation of simulation exercises in the course. Students in both groups felt the computer-based simulation should be completed prior to the mannequin-based simulation.
Conclusion. The use of computer-based simulation prior to mannequin-based simulation improved the achievement of learning goals and outcomes. In addition to improving participants' skills, completing the computer-based simulation first may improve participants' confidence during the more real-life setting achieved in the mannequin-based simulation.

Keywords: simulation, active learning, instructional design, advanced cardiac life support, resuscitation

INTRODUCTION

Simulation is used to train many professionals including pilots, military personnel, business managers, and health care professionals, and is an effective active-learning technique that encourages the application of knowledge and skills in real-world scenarios.[1-4] Simulation in medical education (eg, role-playing, standardized patients or patient actors, computer programs, and virtual reality) allows mastery of skill sets in a controlled environment and may result in improved patient outcomes in medical emergencies when caregivers are trained with simulation.[4-6] Simulation of clinical cases requires participants to have baseline clinical knowledge, demonstrate clinical skills, and have the ability to apply treatment algorithms, analyze patient response, and evaluate outcomes to be successful. Simulation has been shown to be superior to problem-based learning as a teaching method.[7]

The Philadelphia College of Pharmacy has used various simulation techniques for over 10 years, including MegaCode Kelly (Laerdal Medical AS, Stavanger, Norway), a high-fidelity mannequin, and more recently, the MicroSim Inhospital self-directed simulation learning system (Laerdal Medical AS, Stavanger) to practice the provision of critical care. The value of such simulation in pharmacy education is recognized and encouraged by the Accreditation Council for Pharmaceutical Education and has shown improvement in skills and improved retention of knowledge in doctor of pharmacy (PharmD) programs.[8-15] Additionally, simulation is consistent with the college's curricular assessment plan that focuses on independent critical thinking, optimization of pharmaceutical care, and integration of multidisciplinary care teams.

Despite the ongoing use of simulation in education and training, little data exist on the use of multimodal

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simulation, including optimal preparation for simulation and proper sequencing of simulation activities. A variety of outcomes from simulation have been investigated in pharmacy education, but there are no recommendations for integrating multiple modes of simulation.[10,11,13,15-18] In what we believe is a unique approach to simulation training, this study used computer-based simulation in addition to traditional teaching methods to prepare students for participation in mannequin-based simulation. The purpose of this study was to assess the impact of completing computer-based simulation sessions on student achievement of learning outcomes during mannequin-based simulation.

DESIGN

This study was developed after the acquisition of the computer-based simulation program and responded to the need to discover the best way to integrate 2 methods of simulation to achieve learning outcomes. This was a single-center, randomized, parallel-group, observational study of advanced cardiac life support (ACLS) outcomes in mannequin-based simulation. The study was conducted in a required multisection, multi-instructor pharmacotherapeutics practice laboratory course at a large, private pharmacy school. All students had completed prerequisite therapeutics courses that included pharmacotherapeutics of arrhythmias.

The Center for Advanced Pharmacy Studies (CAPS) laboratory is a collaborative learning environment set up in 4-student working stations or "pods" equipped with 4 computers each. The MicroSim Inhospital simulation program is available to 26 working stations in the classroom portion of the CAPS laboratory, and the MegaCodeKelly high-fidelity human patient simulator is located in an adjacent simulated hospital room. Study participants were third-year PharmD students enrolled in the pharmacotherapeutics laboratory course.

Participants were organized randomly into teams of 5 or 6 to simulate a hospital rapid response team, which in acute care is a multidisciplinary team that responds to cardiac arrest alerts. Rapid response teams were assigned randomly to the group completing the mannequin-based simulation first or to the group completing the computer-based simulation first. If any team members had active ACLS certification or had completed computer-based simulation or mannequin-based simulation in the previous 6 months, the team was excluded from the study but still participated in the simulation session.

One week before the simulation-based laboratory session, an ACLS certified faculty member described the role of a hospital rapid response team and the specific responsibilities of each team member including team leader, recorder, provider of chest compressions, provider of ventilation, and pharmacist. Participants briefly toured the hospital room, which was equipped with the mannequin, heart rhythm monitor, and medication cart, and were instructed on how the simulation would proceed. Presimulation assignments included reading the 2005 American Heart Association (AHA) Basic Life Support (BLS) and ACLS guidelines, review of algorithms for pulseless ventricular tachycardia, pulseless ventricular fibrillation, asystole, and self-selection of ACLS roles for mannequin-based simulation.[19,20] Student completion of presimulation assignments was not monitored or assessed.

During the computer-based simulation activity, participants used MicroSim Inhospital computer program to complete 1 tutorial case and 3 assigned cardiac arrest cases in ascending order of difficulty. Each cardiac arrest case required that participants select appropriate interventions, including patient assessments, medication administration, and interpretation of laboratory and diagnostic studies. Summative feedback was automatically generated at the end of each case and included a final score for the students' performance in the simulation and a detailed debriefing. Laboratory instructors were available to assist with technical challenges, but did not contribute to decision making.

One ACLS certified faculty member served as the facilitator for all of the mannequin-based simulation sessions, and provided a brief introduction to the scenario to the rapid response team before the mannequin-based simulation began. The facilitator randomly selected one pulseless arrhythmia for each case and set the high-fidelity mannequin to be pulseless and unresponsive. To be successful, the rapid response team was required to provide basic life support and ACLS for a pulseless arrhythmia according to the 2005 AHA guidelines for basic life support and ACLS.[19,20] The simulation ended when the rapid response team completed all steps or when 10 minutes had elapsed. Participants could refer to the basic life support and ACLS algorithms during mannequin-based simulation and computer-based simulation. Students completed all interventions indepedently and were not prompted by the facilitator at any time during the simulation.

Most of the activities involving simulation encouraged student-centered learning including pre-reading for class, completion of computer-based simulations, and team decision making during mannequin-based simulation. The goal of the laboratory session was for teams to provide optimal BLS and ACLS care to a patient in cardiac arrest. This goal represented high-level learning, including application of knowledge, synthesis of clinical information, and evaluation of the patient scenario. Team learning objectives for mannequin-based simulation included:

- Demonstrate all basic life support skills in the appropriate sequence
- Identify a pulseless rhythm on a cardiac monitor
- Perform simulated defibrillation at the appropriate time for the appropriate rhythm
- Select the correct medications and doses to treat a pulseless rhythm

EVALUATION AND ASSEMENT

Sessions were evaluated using a standardized rubric preapproved by 4 critical care pharmacotherapy specialists and based on AHA guidelines.[19,20] Criteria were labeled major or minor based on the likelihood that failure to perform the individual skill would lead to patient death. To achieve survival of the simulation patient, participants could omit up to 3 minor criteria, but could not omit any major criterion. Student performance in computer-based simulation sessions was evaluated by the software program and assigned a percentage score. Teams self-reported their computer-based simulation scores. Activities completed during the simulations were not graded; however, students received participation points for attending class and engaging in each simulation activity. At the end of the laboratory session, participants completed a survey instrument that included demographic information, computer simulation scores, and satisfaction-related questions scored on a 5-point Likert scale. Participants received points for actively participating in class and were not graded on simulation outcomes. Survey instruments containing participant names were destroyed after data were entered into a spreadsheet and thereafter serial numbers were used as identifiers.

Nominal data were compared using chi-square test or Fisher's exact test. Continuous parametric data were compared using the student's unpaired *t* test. Non-parametric unpaired data were compared using the Mann-Whitney U test. Data were analyzed with SPSS, version 18.0 (Chicago, IL).

Although 228 students were in the course, 28 were excluded from participation because they had completed computer-based simulation and/or mannequin-based simulation activities prior to enrollment, leaving 200 students eligible for inclusion in the study. No students had active ACLS certification. Forty mannequin-based simulation and 120 computer-based simulation cases were completed in five 2-hour sessions. Baseline characteristics of participants were similar between groups (Table 1). Most participants reported community or hospital internship experience; only 14 (7%) claimed "other pharmacy experience," which included nuclear pharmacy, hospital pharmacy with clinical projects, long-term care pharmacy, and pharmaceutical industry.

Primary and secondary outcomes are listed in Table 2. More of the teams in the group that completed the computer-based simulation first achieved learning goals and objectives as demonstrated by a higher rate of simulated patient survival (41.2% vs. 5.6%; $p = 0.018$) and a higher number of teams completing all basic life support skills in proper sequence (52.9% vs. 0%; $p < 0.001$) compared with the group that completed the mannequin-based simulation first. Average scores on the set of 3 cardiac arrest cases completed using computer-based simulations were similar between the groups (49.8% for students completing the mannequin-based simulation first vs. 58.2% for students completing the computer-based simulation first; $p = 0.942$). The average scores for all teams on computer-based simulation cases 1, 2, and 3 were 40.9%, 37.5%, and 53.0%, respectively. "Patient" survival during mannequin-based simulation did not differ significantly between teams with average computer simulation scores greater than 50.0% and those with scores less than 50.0% (21% survival vs. 25% survival; $p = 0.548$).

Survey data from individual participants are reported in Table 3. The majority of students (> 90%) reported that they enjoyed both the computer-based and the mannequin-based simulations and recommended the continuation of both activities in future classes. Participants in both groups rated their level of enjoyment, preparedness from pre-session readings, and anticipation of the activities similarly. Students in both groups preferred that the

Table 1. Experience and Qualifications of Pharmacy Students Who Participated in a Study Comparing Performance in Computer-based vs Mannequin-based Simulation Exercises.

	Completed MBS First (n = 105), No. (%)	**Completed CBS First (n = 95), No. (%)**	***P***
CPR certification	71 (68.3)	65 (68.4)	1.00
Hospital pharmacy experience	41 (39.4)	31 (32.6)	0.38
Community pharmacy experience	79 (76.0)	82 (86.3)	0.08
Other pharmacy experience	7 (6.7)	7 (7.4)	0.85
No pharmacy experience	4 (3.8)	4 (1.7)	0.89

Abbreviations: MBS = mannequin-based simulation; CBS = computer-based simulation; CPR = cardiopulmonary resuscitation

Table 2. Impact of Computer Simulation on Pharmacy Students' Achievement of Learning Goals and Objectives

	Completed MBS First n = 18 (%)	**Completed CBS First n =17 (%)**	***P***
Simulated patient survived in MBS	1 (5.6)	7 (41.2)	0.018
Completed BLS sequence correctly	0	9 (52.9)	<0.001
Checked for responsiveness	6 (33.3)	17 (100)	<0.001
Called for help	12 (66.6)	7 (41.2)	0.06
Performed airway opening	9 (50)	15 (88.2)	0.027
Assessed breathing	13 (72.2)	17 (100)	0.045
Administered rescue breaths	4 (22.2)	16 (94.1)	<0.001
Checked pulse	14 (77.8)	15 (88.2)	0.41
Started CPR within 90 seconds	18 (100)	17 (100)	–
Identified initial arrhythmia correctly	11 (61.1)	8 (47.1)	0.51
Decision to shock was appropriate	18 (100)	15 (88.2)	0.07
Medication selection was appropriate	18 (100)	17 (100)	–

Abbreviations: MBS = mannequin-based simulation; CBS = computer-based simulation; BLS = basic life support; CPR = cardiopulmonary resuscitation

computer-based simulation be completed before the mannequin-based simulation.

DISCUSSION

The use of computer-based simulation prior to mannequin-based simulation promoted achievement of higher-level and lower-level learning outcomes among pharmacy students, although much of the impact appears to be a result of improvement in students' general knowledge of BLS skills and their ability to execute each of these skills. There were no differences in computer-based simulation scores between teams that achieved the learning outcome and teams that did not, which suggests that simply completing a computer-based simulation may improve outcomes. Previously published studies have measured outcomes and student response to one type of simulation or compared outcomes from a few types of simulation without measuring how each one impacts the other.

Our results show the participants who completed mannequin-based simulation first did not perform BLS as well as those who completed computer-based simulation first. The students' relative unfamiliarity with BLS techniques and sequencing may be attributed to participants more aggressively focusing on ACLS than on BLS skills. Participants may have been nervous during the

Table 3. Participant Responses to Post-Class Survey

	Completed MBS First (n=105)		**Completed CBS First (n=95)**		
Question Theme	**Median (IQR)**	**Mean (SD)**	**Median (IQR)**	**Mean (SD)**	***P*[a]**
Looking forward to CBS	4 (4-5)	3.94 (0.6)	4 (4-5)	3.79 (0.6)	0.39
Looking forward to MBS	4-(4-5)	4.20 (0.5)	4 (4-5)	4.14 (0.5)	0.88
Enjoyed CBS	5 (5)	4.63 (0.5)	5 (5)	4.6 (0.6)	0.96
Enjoyed MBS	5 (5)	4.49 (0.8)	5 (5)	4.6 (0.7)	0.15
Recommend CBS	5 (5)	4.70 (0.5)	5 (5)	4.74 (0.5)	0.54
Recommend MBS	5 (5)	4.71 (0.9)	5 (5)	4.71 (0.7)	0.58
Confident during CBS	4 (4)	3.62 (1.0)	4 (4)	3.71 (0.9)	0.64
Confident during MBS	3 (3-4)	3.36 (1.1)	4 (4-5)	3.89 (0.9)	<0.001
Pre-reading adequate preparation for CBS	4 (4)	3.39 (0.9)	4 (4)	3.76 (1.0)	0.47
Pre-reading adequate preparation for MBS	4 (4)	3.63 (0.9)	4 (4)	3.69 (1.0)	0.47
Review of roles adequate preparation for MBS	4 (4)	3.47 (1.1)	4 (4-5)	3.88 (1.1)	0.005
CBS adequate preparation for MBS			5 (5)	4.66 (0.6)	
Prefer MBS before CBS			1 (1-2)	1.62 (0.9)	
Felt prepared without CBS	3 (3-4)	2.75 (1.3)			
Prefer CBS before MBS	5 (4-5)	4.37 (1.1)			

Abbreviations: MBS = mannequin-based simulation; CBS = computer-based simulation; IQR = interquartile range; SD = standard deviation

[a] Mann Whitney U test used to compare p values.

mannequin-based simulation and needed time to acclimate to the setting, thus poorly performing skills required earlier in the scenario like providing basic life support.

While many participants reported looking forward to the simulation activity prior to the laboratory session, nearly all recommended the continued use of the activity in future laboratory sessions, which suggests that participants were receptive to this active-learning technique and found value or enjoyment in this type of learning. However, there was a difference in students' feelings of preparedness and confidence that may have impacted outcomes in the mannequin-based simulation. This difference may be attributed to a lack of previous experience with mannequin-based simulation and few if any previous learning experiences using computer or mannequin-based simulation.

The study was designed in accordance with normal laboratory procedures so results of the study could be generalized to the delivery of education within a typical laboratory course. However, this design lends itself to the introduction of some limitations. Participants' completion of pre-session readings and baseline knowledge was not assessed; therefore, teams that completed the computer-based simulation first may have been better prepared prior to computer-based simulation. Grading based on participation rather than students' performance during the simulation sessions may have impacted their preparation and promoted greater reliance on the algorithms for delivering basic life support, which they could refer to during the simulations. This lack of preparation may have been a greater disadvantage for the group that completed the mannequin-based simulation first because the group that completed the computer-based simulation first had practice in performing basic life support skills prior to completing the mannequin-based simulation. One facilitator recorded all interventions during mannequin-based simulation to eliminate inter-rater variability, but, the facilitator was not blinded to team assignments introducing potential bias. The study investigated the impact of computer-based simulation on activities completed immediately after computer-based simulation; therefore, the authors are able to report on short-term effects of computer-based simulation only. It is unclear whether computer-based simulation had an impact on retention of information after the 2-hour period of time in which this study was conducted. The outcome of simulated patient survival in mannequin-based simulation was assessed with a predetermined rubric created by pharmacotherapy specialists with expertise in critical care. The experts used the 2005 ACLS guidelines to complete the rubric and assign impact of each intervention on patient survival. This rubric, while not externally validated, placed importance on basic life support skills such as rescue breaths and completion of the head-tilt chin-lift; however, the 2010 update to the guidelines in which most skills exclusive of chest compressions were deemphasized was released shortly after the completion of the study. A post-hoc review of the assessment rubric revealed that even if the rubric was changed to reflect the updated guidelines, the difference in patient survival would not be impacted due to the negligence of students' in the group completing the mannequin-based simulation first in performing most of the basic life support skills.

Developing a way for simulation to fit into programmatic outcomes and established assessment standards may present challenges to colleges and schools of pharmacy. Also, simulation equipment, including mannequins and facility space, and software licenses can be expensive to purchase and properly maintain. Preparing for a simulation session can be time intensive, and conducting a simulation requires competent facilitators with adequate background knowledge, adaptability to unforeseen simulation scenarios, and comfort with providing real-time feedback. Each mannequin-based simulation can comfortably accommodate up to 8 participants, which allows for an intimate learning experience, but leads to scheduling challenges with large classes and limited availability of mannequins. Computer-based simulation may be better at accommodating the learning needs of large classes, but may not provide an experience that is authentic to the participant's health care specialty. Additionally, the instructor may spend countless hours navigating the computer-based simulation program to find scenarios that best match the intended learning outcomes for the session only to find that an ideal scenario does not exist on that program. Also, software may become outdated as new guidelines or dosing recommendations are published. For example, the publication of the 2010 update will affect the way we teach ACLS in the classroom, but we are unable to change the computer-based simulation program until a new version or updates are released. Simulation may be challenging to assess as clinical scenarios may be complex, with many ways to arrive at the same outcome.

Despite the challenges and potential barriers to using simulation in pharmacy education, there are many advantages including better achievement of learning outcomes, high levels of participant engagement and satisfaction, and compliance with overarching standards of pharmacy education. Simulation offers a unique learning medium to explore additional areas of need such as interprofessional education through multidisciplinary problem solving, cultural sensitivity training through practice with simulated patient interviews, and honing of medication therapy management skills by completing simulations in which specialized patient cases are addressed.

SUMMARY

Participating in a computer-based simulation prior to completing a mannequin-based simulation improved pharmacy students' achievement of learning goals and course outcomes. In addition to better preparing the participant for mannequin-based simulation, the sequencing of computer-based simulation prior to mannequin-based simulation may improve participant satisfaction with the activity and their confidence and comfort level during the simulation. While the majority of previously published studies focused on one mode of simulation, this study may encourage educators to use multiple modes of simulation to enhance achievement of learning outcomes. Future areas of focus for simulation in pharmacy education should include enhancement of students' preparation for participating in various types of simulation and assessment of the impact of simulation exercises on students' long-term retention of knowledge and skills.

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