INSTRUCTIONAL DESIGN AND ASSESSMENT

Retention of Advanced Cardiac Life Support Knowledge and Skills Following High-Fidelity Mannequin Simulation Training

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Objective. To assess pharmacy students' ability to retain advanced cardiac life support (ACLS) knowledge and skills within 120 days of previous high-fidelity mannequin simulation training.

Design. Students were randomly assigned to rapid response teams of 5-6. Skills in ACLS and mannequin survival were compared between teams some members of which had simulation training 120 days earlier and teams who had not had previous training.

Assessment. A checklist was used to record and assess performance in the simulations. Teams with previous simulation training (n=10) demonstrated numerical superiority to teams without previous training (n=12) for 6 out of 8 (75%) ACLS skills observed, including time calculating accurate vasopressor infusion rate (83 sec vs 113 sec; $p=0.01$). Mannequin survival was 37% higher for teams who had previous simulation training, but this result was not significant (70% vs 33%; $p=0.20$).

Conclusion. Teams with students who had previous simulation training demonstrated numerical superiority in ACLS knowledge and skill retention within 120 days of previous training compared to those who had no previous training. Future studies are needed to add to the current evidence of pharmacy students' and practicing pharmacists' ACLS knowledge and skill retention.

Keywords: simulation, retention, instructional design, advanced cardiac life support

INTRODUCTION

Simulation training has been utilized for decades in various fields including aviation, military, business, and health care as a means to apply knowledge and skills learned in a real-world scenario.¹⁻⁴ Simulation training encompasses many formats including the use of role-playing, patients or patient actors, computer simulation, virtual reality, and low-fidelity and high-fidelity mannequins. High-fidelity mannequin simulation (eg, computerized full-body mannequin programmed to provide realistic physiologic responses) provides maximal realism; by contrast, low-fidelity mannequin simulation (eg, cardiopulmonary resuscitation (CPR) mannequin) is static and provides the learner with less realism.⁴ Health care providers who typically have significant experience with simulation training include physicians, nurses, and emergency personnel. Pharmacists are increasingly using simulation training in their education. In the pharmacy literature, simulation training publications were non-existent before 2006, but since that time there have been at least 30 published manuscripts on the use of simulation-based teaching.⁵

The majority of this evidence includes the use of high-fidelity mannequin simulation instruction.⁶⁻²³ A number of outcomes (eg, self-perceived clinical skills, teamwork and interprofessional teamwork skills, blood pressure assessment) have been assessed using high-fidelity mannequins. Although it has been shown that high-fidelity mannequin simulation can increase knowledge retention in pharmacy education, data is lacking on retention of advanced cardiac life support (ACLS) knowledge and skills following simulation training.⁸

The Philadelphia College of Pharmacy has incorporated high-fidelity mannequin simulation into its doctor of pharmacy (PharmD) curriculum since 1999 and computer-based simulation since 2010. Both forms of simulation have been integrated with pharmacotherapeutics and critical care therapeutics courses. This integration is consistent with the vision of the Accreditation Council for Pharmaceutical Education (ACPE), which endorsed the use of simulation in ACPE-accredited PharmD programs because of its positive impact on students' critical-thinking and problem-solving skills.²⁴ Simulation may also be used to teach the principles of patient-centered care, a subdomain in the Center for the Advancement of Pharmacy Education (CAPE) Educational Outcomes.²⁵ In addition, the expanded use of simulation is consistent with the college's

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continued curricular assessment plan focusing on independent critical thinking, optimization of pharmaceutical care, and development of life-long learner skills.

Advanced cardiac life support is an integrated, team-based response utilizing treatment strategies and algorithms to optimize survival of patients with cardiac events. In acute care, a rapid response team (RRT) is a multidisciplinary team that responds to life-threatening events. Members of an ACLS RRT, including pharmacists, are required to maintain ACLS certification. Traditionally, ACLS recertification is recommended every 2 years.²⁶ Despite this recommendation, data for the optimum time interval needed to retain ACLS knowledge and skills are mixed.^{27,28} Experts have advocated that refresher courses be added to current training recommendations to increase ACLS knowledge and skill retention.^{29,30} Pharmacy students have demonstrated the retention of knowledge and skills following training in the use of an automated external defibrillator for a period up to 4 months.³¹ However, the authors are not aware of published data assessing retention of ACLS knowledge and skills among pharmacy students. Health care professionals need to understand the full scope of ACLS, but the focus for medical, nursing, and pharmacy learners is different. Since previous studies have addressed ACLS knowledge and skill retention in medical and nursing learners, the purpose of this study was to assess pharmacy students' ability to retain ACLS knowledge and skills within 120 days of ACLS high-fidelity mannequin simulation training.

DESIGN

A high-fidelity mannequin was used in ACLS simulation training to provide a learner-focused, active-learning platform modeling a real world experience for members of an RRT. The goal was for teams to provide optimal ACLS care to a simulated patient in cardiac arrest. Application of knowledge, synthesis of clinical information, and evaluation of a cardiac arrest scenario were intended to facilitate high-level learning.

This study was single center, parallel-group observational and deemed exempt by the college's institutional review board. Mannequin survival (primary outcome) and ACLS skills (secondary outcomes) were compared between teams for whom this simulation was their first ACLS training and teams who had some members with previous ACLS training. Students were informed that the mannequin-based simulation training was part of the usual activities of both courses included in the study, but that success rates in the simulation training would not directly affect their grades. Additionally, students were informed their activities would be recorded with audio/visual capture and recordings would be used for debriefing and analysis.

This study was conducted in Practice Laboratory IV and Critical Care Therapeutics courses. Practice Laboratory IV was the final course in a required 4-semester laboratory sequence in the PharmD curriculum of third-year students (P3) in the spring 2013 semester. All students enrolled in Practice Laboratory IV participated in the ACLS simulation training, which was a standard laboratory session of this multi-section course. Prior to the students' participation in the simulation training, their didactic education included cardiovascular pharmacotherapeutics (including arrhythmias) in the spring 2012 semester. Earlier in the curriculum, students completed coursework in medication infusion calculations, physical assessment, and sterile product preparation. Students were required to complete CPR certification for lay responders through an outside organization prior to their experiential training. At the time of this experience, 76% of students reported having active CPR certification (Table 1).

Twenty-three students in our study completed ACLS simulation training in Critical Care Therapeutics during fall 2012, 120 days before the experience in Practice Laboratory. For the remaining 171 students, the ACLS simulation training in the spring 2013 Practice Laboratory IV

Table 1. Characteristics of Students Enrolled in Practice Laboratory IV (n=191)

Characteristic	n (%)
Gender	
Female	115 (60)
Work/volunteer experience	
Retail	123 (64)
Hospital	41 (21)
LTCF	3 (2)
Other	11 (6)
No work/volunteer experience	13 (7)
CPR certification	145 (76)
Previous health care experience	
EMT/paramedic	6 (3)
Respiratory therapist	1 (0.5)
Nurse	1 (0.5)
Other (eg, pharmacy internship)	109 (57)
UA	74 (39)
Career goal	
Retail pharmacist	62 (32.5)
Hospital clinical pharmacist	53 (28)
Pharmaceutical industry pharmacist	31 (16)
Hospital staff pharmacist	29 (15)
LTCF pharmacist	12 (6)
Professor/ academia	3 (2)
UA	1 (0.5)

EMT=emergency medical technician; LTCF=long-term care facility; UA=unanswered

was their first exposure. In both courses, students were randomized into teams of 5 or 6 to simulate a RRT. Regardless of prior experience, students assumed roles typical of an RRT: provider of chest compressions, provider of ventilation, provider of cardiac defibrillation, recorder, and pharmacist. Prior to the mannequin-based simulation training, students were assigned to read the 2010 American Heart Association's (AHA) Basic Life Support (BLS) and ACLS Guidelines and to review algorithms for pulseless ventricular tachycardia, ventricular fibrillation, and asystole.^{32,33} A video of a simulation experience from a prior year and slides of various cardiac rhythms were also assigned for students to review in advance of simulation training.

The students were assessed on the readings and video with a 5-point, multiple-choice graded quiz prior to simulation training. Students were not graded on the simulation activity because this was the first time most (n=171) of them were introduced to it, which many students may have considered stressful. As in all classes of the laboratory course, however, professionalism was assessed, including students' active participation during simulation training.

At the beginning of the laboratory class, the faculty facilitator demonstrated bag-valve-mask ventilation, introduced components in the code cart, described the capabilities of the mannequin, and explained the importance of treating the simulation as a real-life scenario for approximately 30 minutes. Following this introduction, 80 minutes of class time was used to conduct the simulation for all students in each class, with 20 minutes per simulation scenario. The last 10 minutes of class consisted of a debriefing on the simulation experience.

The laboratory coordinator would call 2 random RRTs to report to the hospital simulation rooms to manage cardiac arrest events. Students not involved remained in the pharmacy practice laboratory under the direction of instructors. Once in the simulated hospital rooms, students began performing their prespecified team role. They were instructed to use effective resuscitation team dynamics including knowledge sharing and constructive intervention.³⁴ Students were allowed to assist with other roles during the simulation to encourage a collaborative team approach. An ACLS-certified faculty member served as facilitator and "attending physician" for the 2 simulations occurring simultaneously. The facilitator maintained a high-stress, emergency-like environment to simulate a real-life rapid response scenario. Patient comments such as "My chest hurts" or "I'm scared" were vocalized through the simulated patient by the facilitator's microphone to intensify the realism of the event. For each team, the facilitator chose a pulseless arrhythmia (ie, ventricular

tachycardia, ventricular fibrillation, asystole) and programmed the high-fidelity mannequin accordingly. The facilitator directed a laboratory instructor in an observation/control room to manipulate the mannequin and cardiac monitor response to the team interventions. Students could refer to BLS and ACLS algorithms and worked as a group to complete all interventions without faculty guidance.

The simulation continued until the team completed all steps or until the simulated patient expired due to inappropriate management (eg, wrong drug or dose selection, inaccurate dose calculation). A debriefing was conducted immediately after each event, during which the teams shared their observations about the experience, discussed strategies to improve performance, and explained how this experience impacted their view of a pharmacist's role as a member of the RRT.

Students then returned to other laboratory activities and completed an anonymous, electronic survey about the experience while the coordinator randomly called 2 more teams for the ACLS events. A classroom debriefing was conducted by the ACLS-certified faculty member after all teams completed the ACLS event. The debriefing included the opportunity to listen to and view audio/visual materials to highlight activities, performance level, and team-building elements.

The learning objectives for the simulation included demonstrating BLS skills in the appropriate sequence, identifying a pulseless rhythm on a cardiac monitor, performing defibrillation appropriately, selecting the correct medications and doses to treat a pulseless rhythm, communicating effectively with team members, demonstrating patient empathy, and performing basic pharmaceutical calculations.

The time and resources required to implement this learning approach included conducting a tutorial on the use of high-fidelity mannequin, computer simulation software, and associated technology systems, coordinating the activity, and executing the activity in each section of the course. Technologies used in this activity included the MegaCode Kelly, a high-fidelity mannequin, and Laerdal SimMan Software, Version 3.5.0 (both from Laerdal Medical AS, Stavanger, Norway), and a microphone to communicate patients' responses. In addition, audio/video capture was accomplished with Panopto (Panopto, Inc., Pittsburgh, PA) and integrated with the learning management system Blackboard (Blackboard, Inc., Washington, DC). The laboratory coordinator and facilitator learned how to use the technology systems with help from members of the information technology department. The facilitator was then able to teach 2 laboratory instructors from each section to operate the high-fidelity mannequin and audio/visual capture.

Education for implementing the technology systems required approximately 8 hours. Additionally, the laboratory coordinator invested 2 hours preparing materials, which included readings, a simulation video from a prior year, role-playing assignments, and an instruction guide for students and instructors. Executing the activity required 2 simulation rooms equipped with the technology systems and 10 hours for instruction (2 hours each for 5 classes). No additional instruction time beyond the routine laboratory period was required for completion of this activity.

An evaluation tool based on AHA guidelines was preapproved by 2 critical care pharmacotherapy specialists and was used to assess the students' ACLS skills and the primary simulation scenario outcome (mannequin survival or death) (Table 2).^{32,33} In order to assess retention of ACLS skills among pharmacy students who had training 120 days prior to the class (ie, the 23 students that completed ACLS training in Critical Care Therapeutics), simulation scenarios were evaluated based on review of the audio/visual capture. For the purpose of this study, to achieve mannequin survival, teams were required to correctly identify the cardiac arrhythmia and implement all correct ACLS skills. In addition to correct drug and dose administration, a time to administer the correct vasopressor infusion rate could not exceed 180 seconds. Skill performance on BLS

was documented, but not included in determination of mannequin survival because this certification occurred outside the curriculum.

In addition to the objective data, student perceptions regarding the experience were evaluated by the survey completed after the simulation training. Responses were based on a 5-point Likert scale. The survey instrument also included demographic information.

Nominal data were compared using the Fisher exact test. Non-parametric unpaired data were compared using the Mann-Whitney U test. A *p* value less than 0.05 indicated significance. Data were analyzed with SigmaPlot (Systat Software, San Jose, CA).

EVALUATION AND ASSESSMENT

One hundred ninety-four students participating in Practice Laboratory IV were divided into 36 teams. Simulation scenarios for 14 teams were excluded because the audio/visual capture did not record their experiences. The remaining 22 scenarios included in the study consisted of 10 teams with some members with previous ACLS training in the elective course and 12 teams for whom the ACLS activity in the practice laboratory was the initial training (Figure 1).

For the primary objective, mannequin survival was 37% higher for teams with previous ACLS simulation

Table 2. Comparison of BLS^a Skills, ACLS^b Skills, and Mannequin Survival between Teams with Previous ACLS Simulation Training 120 Days Earlier and Teams Receiving Initial Training

Skills/outcomes	Previous ACLS training x/y ^c (%) (n=10 teams)	Initial ACLS training x/y ^c (%) (n=12 teams)	<i>P</i>
BLS skills			
Checked for responsiveness	6/10 (60)	3/12 (25)	0.19
Started CPR < 30 seconds	9/10 (90)	10/12 (83)	1.00
Checked breathing	4/10 (40)	3/12 (25)	0.65
Checked pulse	4/10 (40)	4/12 (33)	1.00
Administered rescue breaths	4/10 (40)	3/12 (25)	0.65
ACLS skills			
Correctly identified dysrhythmia	10/25 (40)	8/16 (50)	0.75
Defibrillated appropriately	20/20 (100)	20/20 (100)	—
Administered correct drug and dose of epinephrine or vasopressin	20/24 (83)	24/30 (80)	1.00
Administered correct antiarrhythmic drug and dose	4/4 (100)	9/13 (69)	0.52
Calculated correct vasopressor infusion rate (mL/hr)	7/9 (78)	5/12 (42)	0.18
Time needed to successfully calculate infusion rate (mean secs)	83	113	0.01
Administered correct crystalloid if warranted	6/8 (75)	6/10 (60)	0.64
Administered appropriate drugs	5/8 (63)	7/12 (58)	1.00
Mannequin survival ^d			
Survival	7/10 (70)	4/12 (33)	0.20

^a BLS: basic life support

^b ACLS: advanced cardiac life support

^c x=successful completion of activity; y=frequency of activity

^d Mannequin survival: correct identification of the cardiac arrhythmia and implementation of all ACLS skills

training, but the difference was not significant ($p=0.20$). For secondary outcomes, ACLS skills were assessed. Teams with previous ACLS simulation training demonstrated numerical superiority (but not significant improvement) over teams without previous training for 6 out of 8 (75%) ACLS skills assessed including administering correct antiarrhythmic drug and dose (100% vs 69%, $p=0.52$) and calculating correct vasopressor infusion (78% vs 42%, $p=0.18$). For teams with previous ACLS simulation training, the only significant skill improvement was time calculating accurate vasopressor infusion rates (83 sec vs 113 sec, $p=0.01$; CI 9.38-47.95) (Table 2).

Attitudes, perceptions, and behaviors of the students regarding the simulation activity were compiled in the postsimulation training survey (Table 3). The rate of survey completion was 98% (191/194). The majority of students agreed or strongly agreed that they felt more confident after simulation training performing the following ACLS skills: recommending a drug (59%), calculating medication doses (62%), and recording the event (79%). Ninety-six percent (183/191) of the students agreed or strongly agreed that more simulation activities should be incorporated into other courses.

DISCUSSION

The authors hypothesized students would retain ACLS knowledge and skills within 120 days of previous training with a high-fidelity mannequin. Overall, teams with members who had previous ACLS simulation training showed numerical superiority, but not statistical superiority for 75% of ACLS knowledge and skills assessed. Retention of certain ACLS knowledge and skills for 120 days in our study matches findings from Kopacek and colleagues, who demonstrated retention of knowledge and skills following training with an automated external defibrillator for up to 4 months.³¹ Moreover, Vyas and colleagues showed that high-fidelity mannequin simulation used to augment introductory pharmacy practice experiences was associated with knowledge retention at 3 months.⁸

While ACLS skills were the focus of the training, teams were inconsistent in terms of BLS techniques and

sequencing even though many students had completed CPR certification the preceding year and were instructed to read the 2010 AHA BLS guidelines prior to simulation. Less than optimal performance of BLS skills may have been attributable to students' difficulty acclimating to the high-stress environment early in the scenario. Another contributing factor may have been students' completion of a CPR course intended for lay responders rather than health care professionals.

Overall, students were receptive to simulation as an active-learning technique. The majority of students agreed or strongly agreed that they felt more confident recommending drugs, calculating medication doses, and performing other ACLS skills after completing simulation training. Most students recommended that similar simulation experiences should be implemented throughout the curriculum.

Previous studies used multiple-choice questionnaires or simulation to test ACLS knowledge and skill retention.²⁷ The authors believe that evaluation of simulation scenarios offers a more realistic situation for assessment of student ability than the evaluation of pretests and posttests. Additionally, the use of audio/visual capture to review simulation scenarios may have allowed greater accuracy in evaluation than real-time assessment.

Several limitations were identified in this study. Completion of presession readings was not directly assessed during the laboratory course, which may have introduced varied student preparation. Final performance outcomes of the simulation may not have reflected true student potential because students were aware their final grade would not be impacted by the activity. Four percent of the students were identified as having had previous health care experience in EMT/paramedics, respiratory therapy, or nursing, and their experience may have impacted the results of their assigned RRT. Only ACLS skills such as time for accurate vasopressor calculation infusion rate were assessed as a measure of simulated patient survival; incorporating BLS skill outcomes in the analysis may have altered the results. The number of members in teams with previous exposure to simulation training was not uniform because they were randomized. The loss of 14 simulated scenarios because of technical difficulties with the audio/visual capture may have impacted statistical results. Finally, although having only 1 facilitator score all interventions during mannequin-based simulation diminished inter-rater variability, potential bias was introduced because the facilitator was not blinded to team assignments.

Implementing high-fidelity mannequin simulation for an ACLS activity was associated with challenges including the cost of simulation equipment and software.

Figure 1. ACLS simulation scenario completion and team distribution in the Practice Laboratory IV course

Table 3. Student Responses to Survey Questions (n=191)

	Student response, n (%)					
	SA	A	N	D	SD	UA
ACLS response questions						
Do you feel more confident recommending a drug during an ACLS event?	33 (17.3)	80 (41.9)	49 (25.6)	24 (12.6)	3 (1.6)	2 (1)
Do you feel more confident calculating medication doses during an ACLS event?	28 (14.7)	90 (47.1)	45 (23.6)	23 (12)	4 (2.1)	1 (0.5)
Do you feel more confident performing other ACLS skills including recording an ACLS event?	51 (26.7)	100 (52.4)	30 (15.7)	4 (2.1)	2 (1)	4 (2.1)
Curriculum questions						
Would you like more simulation activities in other courses?	115 (60.2)	68 (35.6)	8 (4.2)	0 (0)	0 (0)	0 (0)
Do you believe you should be graded individually on this activity?	3 (1.6)	26 (13.6)	42 (22)	70 (36.6)	49 (25.7)	1 (0.5)
Do you believe you should be graded as a group on this activity?	38 (19.9)	79 (41.4)	29 (15.2)	25 (13)	19 (10)	1 (0.5)
Do you believe simulations should be included in your IPPEs ^a or APPEs ^b ?	51 (26.7)	87 (45.5)	33 (17.3)	15 (7.9)	4 (2.1)	1 (0.5)
Would you like to participate in simulation activities with other professionals?	81 (42.4)	93 (48.7)	13 (6.8)	2 (1)	1 (0.5)	1 (0.5)

SA=strongly agree; A=agree; N=neutral; D=disagree; SD=strongly disagree; UA=unanswered

^a IPPEs: introductory pharmacy practice experiences

^b APPEs: advanced pharmacy practice experiences

Also, preparation and delivery using this model was time intensive, and scheduling was challenging with large classes and limited mannequins. For example, not all students were given an opportunity to perform all team member roles, which would have expanded their experiences beyond the traditional pharmacist role. Although debriefing was a strength of the activity by allowing gaps in teamwork to be identified, it was challenging to implement because time was limited and difficulties were encountered with video-capture results.

The authors are considering modifications to increase the value of this high-fidelity simulation activity. To better prepare future students, didactic instruction for ACLS will be incorporated into the pharmacotherapeutics lecture course. The study results indicated that students would benefit from repetition of this activity. Mannequin survival was higher for teams with members who had previous ACLS simulation training. However, these teams only achieved a survival rate of 70%, so increased repetition may improve student performance even more. Incorporating high-fidelity mannequin-based simulation and computer-based simulation in the second and third professional years of the curriculum is under consideration and supported by student requests

for earlier exposure to the ACLS environment, including practice interpreting cardiac arrhythmias and use of the respiratory equipment. The grading strategy for this activity is also being revisited. Historically, grades were not based on simulation performance because students were performing ACLS in a high-stress environment for the first time. However, assigning a professionalism grade may prompt students to take greater responsibility for their learning. In the future, the importance of demonstrating high-quality BLS skills for patient survival should be emphasized. As a result of our findings, program requirements have changed to require that students complete CPR certification courses intended for health care providers or professional rescuers rather than for lay responders.

This activity could be adapted for interprofessional ACLS high-fidelity mannequin simulation training in the future. Students from various health professions participating in this activity could develop interdisciplinary team skills as a result.¹² Interprofessional simulation has been reported to teach patient safety, collaboration, and communication.¹⁷ As an interprofessional simulation experience, this activity would address the CAPE Outcome related to providing pharmaceutical care with an

“interprofessional healthcare team based upon sound therapeutic principles and evidence-based data.”²⁵

SUMMARY

Teams who had members with previous simulation training demonstrated numerical superiority in ACLS knowledge and skill retention within 120 days of previous training. As an educational tool to promote the retention of ACLS knowledge and skills, simulation training with high-fidelity mannequins will continue to be improved upon and incorporated into the Critical Care and Practice Laboratory courses. The authors intend to evaluate student retention further to assess statistical significance and improve outcome measures. Additional studies are needed to add to the evidence of ACLS knowledge and skill retention among pharmacy students and practicing pharmacists using simulation training.

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