High-Fidelity Mannequin Simulation versus Virtual Simulation for Recognition of Critical Events by Student Registered Nurse Anesthetists

Lisa Rose Erlinger, PhD, CRNA
Andrew Bartlett, PhD
Amelia Perez, PhD, RN

Early recognition of intraoperative critical events is essential in optimizing the health outcomes of surgical patients. Use of simulation in nurse anesthesia education allows students to practice recognizing changes in the patient's condition in a safe learning environment. Second- and third-year student registered nurse anesthetists were randomly assigned to 2 groups to explore differences in recognizing intraoperative myocardial infarction (MI) using high-fidelity mannequin simulation vs virtual simulation. One group participated in a virtual simulation first, followed by a high-fidelity mannequin simulation. The other group participated in a high-fidelity mannequin simulation first, then virtual simulation. Second-year students recognized an intraoperative MI faster when using high-fidelity mannequin simulation than when using virtual simulation. However, there was no significant difference among third-year students in the time it took to recognize a critical event when using high-fidelity mannequin simulation vs virtual simulation. These findings indicate that both simulation modalities are useful in evaluating student registered nurse anesthetists' timely recognition of intraoperative critical events such as MI. However, for students with less didactic and clinical practicum experience in the program, such as second-year students, the use of high-fidelity mannequin simulation for recognizing an intraoperative MI may be more beneficial than virtual simulation.

Keywords: Critical event, high-fidelity simulation, nurse anesthesia, patient simulation, virtual simulation.

The use of high-fidelity mannequins as patient simulators has increased greatly in nursing education over the years.[1,2] High-fidelity simulators are equipped with technologies to resemble many of the functions of the human body.[3] Simulation can be used to create interactive experiences that resemble clinical situations that could occur in various clinical settings, including the operating room.[2,4,5] Use of simulation to recognize intraoperative critical events in a timely manner can serve as a helpful tool in educating student registered nurse anesthetists (SRNAs) about critical thinking and patient safety in these situations. Hawkins et al[6] conducted a study to evaluate the perceptions of practicing Certified Registered Nurse Anesthetists (CRNA) about the use of human patient simulation. More than 88% of the participants indicated that human patient simulation is an important component of nurse anesthesia education, and that the use of simulation should be a requirement in all anesthesia provider curricula. Furthermore, about half of the participants noted that it should also be required as part of the recertification process.[6] In a needs assessment study by Cannon-Diehl et al,[4] 71% of practicing nurse anesthetist participants indicated that high-fidelity simulation would be useful for rarely encountered scenarios such as malignant hyperthermia, complications of cardiac life support complications, and malfunction of anesthesia machines.

The use of virtual simulation is another strategy that has become more common in nursing education, providing more options for students to learn and apply critical thinking skills in a variety of ways.[5,7,8] Virtual simulation uses a computer-based program to simulate a virtual patient and healthcare environment that responds to assessments and interventions performed by the students by selecting the appropriate actions on the computer.[9,10] Researchers have compared the use of virtual simulation vs mannequin-based simulation for the assessment of patient clinical deterioration by undergraduate nursing students,[11,12] anesthesia medical residents,[13] and preclinical nurse practitioner and SRNAs in an emergency department type of setting.[14] However, research comparing the use of these simulation modalities among SRNAs for recognition of intraoperative critical events is lacking.

The purpose of this study was to compare the use of high-fidelity mannequin-based simulation vs virtual simulation for recognition of intraoperative myocardial infarction (MI) by SRNAs. Early recognition of critical intraoperative complications such as MI and malignant hyperthermia may sometimes be difficult to teach in the clinical setting because these are complications that are not often encountered in clinical practice.[15-17] In an observational study consisting of patients undergoing noncardiac surgery between 2005 and 2013, less than 1% (0.9%) of the patients experienced a perioperative MI.[17] The in-hospital mortality rate for patients who experienced a perioperative MI was found to be 18%. When invasive management was implemented, the mortality rate was 8.9% compared with 18.1% with conservative management.[17] These findings highlight the importance of early recognition of perioperative MI so that timely intervention can be initiated. The use of simulation provides a safe setting for students to learn to identify key manifestations and early recognition of intraoperative MI. With a variety of simulation tools available for nurse anesthesia education, it is important to evaluate which strategies can be used to meet the objectives effectively, while also considering cost and available resources.[4,8-11,18]

Materials and Methods

Institutional review board approval was obtained before implementation of this study. Each participant provided written consent to participate in the study. A within-subjects counterbalance design was used to evaluate differences in the length of time it took SRNAs to recognize an intraoperative MI using high-fidelity mannequin-based simulation vs virtual simulation. Students in their second and third year of a master's degree program in nurse anesthesia were recruited by email to volunteer to participate in this simulation study. A total sample of 39 students agreed to participate and were randomly assigned into 2 groups. One group participated in a virtual simulation first, followed by a high-fidelity mannequin simulation. The other group participated in a high-fidelity mannequin simulation first, followed by a virtual simulation. Of the total sample, 19 of the students were in their second year of the nurse anesthesia program and 20 were in their third year. Second-year students had completed 2 years of full-time coursework and 1 year of clinical practice as an SRNA. Third-year students had completed 3 years of full-time course work and 2 years of clinical practice as an SRNA.

Multiple scenarios were used during the simulations to minimize the chance of students sharing information about the scenarios or predicting which scenario they would be participating in during the simulation experiences. Students were asked to maintain confidentiality of the scenarios and simulation experience. In addition, immediate debriefing after the simulation did not occur, to avoid students who had completed the scenarios sharing information with other participants regarding what was expected during the simulations. In both simulation methods (high-fidelity mannequin simulation and virtual simulation), each student participated in an intraoperative MI scenario and another intraoperative critical event scenario (malignant hyperthermia or bronchospasm). The order in which each participant completed each scenario was also randomized. Only data collected from the MI simulations were used for this study.

Virtual simulation was conducted using Anesoft, a web-based simulation software.[19] The Anesoft anesthesia scenarios depict the virtual environment of an operating room. The students participate in the simulation by using the computer mouse to respond to the patient's situation and condition displayed on the screen. The Anesoft scenarios can be accessed by computer, tablet, or phone.[19] For the purpose of this study, all virtual simulation scenarios were accessed by computer. An office with a designated computer for the simulations was used to conduct the virtual simulations. A member of the research team was present in the office to keep track of the time when the student recognized that an MI or other intraoperative critical event was occurring. A digital timer was begun when the symptoms of the critical event began. The timer then was stopped when the student stated recognition that the patient was having an intraoperative critical event and what that event potentially was. If the student failed to recognize the intraoperative critical event for the scenario, the simulation was stopped at 7 minutes and 30 seconds after the symptoms of the critical event had begun. A data collection form was developed for the research team to record the time to verbal recognition of the critical event in both the virtual and the high-fidelity mannequin simulations.

The high-fidelity mannequin simulations were conducted in the university's School of Nursing simulation center. Simulation scenarios similar to those used in the virtual simulation program used for this study were developed for use with the high-fidelity mannequin simulations. Demographic aspects of the patient in the high-fidelity mannequin simulation, such as age, health history, and type of surgery being performed, were different from those in the virtual simulation to avoid participant anticipation that the same scenario was being repeated. One of the SimMan 3G[20] high-fidelity mannequins of the simulation center was used. An environment somewhat similar to that of an operating room, including anesthesia care equipment, was created in a room of the simulation center. All simulations were individual, with only one student at a time participating.

Immediately before the simulation, each student was given report and some background information about the patient. Each student began the simulation by administering the anesthetic agents necessary for the surgical procedure, and vital signs changed as expected. Soon after, symptoms of the intraoperative critical event started. The simulation was ended shortly after student

Variable	Test statistic	P value	Decision
Class level			
Screen-based	U_S=270.5	.0244	Reject H_0
Human-based	U_H= 195.5	.8881	Fail to reject H_0
Experience			
Screen-based	U_S=270.5	.0244	Reject H_0
Human-based	U_H= 149	.7031	Fail to reject H_0
Learning effect			
Screen-based	U_S=226	.1590	Fail to reject H_0
Human-based	U_H= 209.5	.2964	Fail to reject H_0
Recognition time			
Second year (junior)	W_{JR}=min(W_-,W_+)=29	.0130	Reject H_0
Third year (senior)	W_{SR}=min(W_-,W_+)=93	.6762	Fail to reject H_0

Table. Variables by Statistical Test and Results
Abbreviations: H_0, null hypothesis; min, minimum; Us, *U* test for screen-based (virtual) simulation; UH, *U* test for human-based simulation (high-fidelity mannequin); W_{JR}, Wilcoxon rank sum test for second-year students; W_{SR}, Wilcoxon rank sum test for third-year students.

recognition that the patient was experiencing an intraoperative critical event and what that event potentially was. If a student did not state verbal recognition that a critical event was occurring, but the appropriate interventions were noted for care of a patient experiencing the critical event of the scenario, this was noted in the data collection form. Similar to the virtual simulation, if a student did not recognize that the patient was having an intraoperative critical event, the timer was stopped at 7 minutes and 30 seconds after symptoms of the critical event initiated.

Results

The sample for this study consisted of 39 SRNAs in a master's degree program; 19 in their second year of the program and 20 in their third year. Students were randomly assigned to 2 groups: one participating in virtual simulation first, then high-fidelity mannequin simulation, and the other participating in high-fidelity mannequin simulation first, then virtual. A counterbalancing design was used to reduce the chances of exhibiting a better performance under the second simulation modality performed simply due to gained practice under the first simulation modality. By controlling for this, we were able to accurately determine if the type of simulation modality used was the reason for the difference in recognition time, as opposed to the order in which the students participated in the simulations.

Nonparametric tests were performed for the data analysis because of a small sample size and nonnormal distribution of the data. Nonparametric tests do not rely on distributions such as the normal distribution, where certain outcomes are more likely than others. They produce generated distributions from the actual data in order to determine significant differences. In addition, it allows us to detect with a higher level of confidence any significant differences between the groups, if they actually do exist. Q-Q plots and a Shapiro-Wilk normality test confirmed nonnormality of the data. With the main purpose being to detect differences between recognition times for the high-fidelity mannequin simulation vs the virtual simulation, the first step was to determine if there was any significant difference between recognition times based on the subject's class level. Mann-Whitney *U* statistical tests were performed. Results indicated that when using virtual simulation, there was a statistically significant difference between second- and third-year students in the time it took to recognize that an intraoperative MI was occurring (U – 270.5; P – .02). The third-year students were able to recognize the intraoperative MI quicker when using virtual simulation. However, when using high-fidelity mannequin simulation, there was no significant difference in recognition times between second- and third-year students (U – 195.5; P – .89).

A Mann-Whitney *U* test was used to evaluate a learning effect if there were differences in intraoperative MI recognition time between students who used virtual simulation first, followed by high-fidelity mannequin simulation compared with students who used high-fidelity mannequin simulation first, followed by virtual simulation. Results indicated that there was no significant difference in recognition time between these groups (U – 226; P – 0.16 vs and U – 209.5; P – .29).

We defined *experience* with the screen-based (virtual) simulator as using the device more than once before. On analyzing the data, we observed that the 19 students of 39 who did not have experience with the screen-based simulator were all second-year students. Therefore, it was not surprising that experience with the screen-based simulator resulted in the exact same test statistics as class level. However, the level of experience with the human-based simulator (high-fidelity mannequin) did not make a significant difference in recognition times (Table).

Wilcoxon rank sum test results indicated that there was a significant difference in the time it took second-year SRNAs to recognize an intraoperative MI when participating in high-fidelity mannequin simulation compared with virtual simulation ($W = 29$; P – .01). Second-year students were able to recognize the intraoperative MI quicker when using high-fidelity mannequin simulation. However, for third-year students, there was no significant difference in the time to recognize an intraoperative MI while participating in high-fidelity simulation or virtual simulation ($W = 93$; P – .67).

Discussion

The findings from this study indicate that among second-year SRNAs, the use of high-fidelity mannequin simulation led to quicker recognition of intraoperative MI. However, among third-year SRNAs in our study, there was no difference between both simulation methods in the time it took to recognize an intraoperative MI. This difference may be in part due to third-year SRNAs having an additional year of didactic courses and clinical practicum experience compared with the second-year students. In addition, third-year students had previously started using the virtual simulation software to complete other scenarios during their third-year coursework. Having had exposure to how the program works may have had an influence in how quickly they responded to the prompts on the screen since they knew how to use the system and only had to focus on the critical problem that was occurring in the virtual simulation. In a study of undergraduate nursing students by Cobbett and Snelgrove-Clarke,[21] participants expressed that they preferred mannequin-based simulation because they believed that when using virtual simulation, the process was slower, and they had to worry about the technology aspect of it while completing the scenario and about trying to find the prompts on the screen that they wanted to use. In future studies, it would be helpful to include an orientation to the virtual simulation process to ease its use among students who have not had experience using virtual simulation.

Wunder[22] conducted a study to evaluate the ability of first-year SRNAs to recognize and intervene in intraoperative emergencies after implementation of an educational intervention. Consistent with the findings from our study, mannequin-based simulation in a laboratory setting was useful in evaluating the ability to recognize intraoperative critical events in students who are early in the nurse anesthesia program, such as first-year students.[22] However, no other simulation modalities were compared. Studies comparing the use of high-fidelity mannequin simulation vs virtual simulation among SRNAs appear to be scarce in the literature. Johnson et al[14] conducted a study to evaluate knowledge level, skills, and overall performance among acute care nurse practitioner students and SRNAs managing the care of critically ill patients using high-fidelity mannequin simulation vs virtual simulation. Although observed performance and self-assessed knowledge significantly improved with both methods, high-fidelity mannequin simulation resulted in higher levels of observed performance and higher levels of self-assessed practice ability. Only 5 of the 32 total participants were SRNAs, and all 5 of them were in the preclinical phase of the program. Nyssen et al[13] found no significant difference in the use of high-fidelity mannequin simulation vs computer-based simulation to evaluate management of intraoperative anaphylactic shock by anesthesia medical residents. However, the participants in this study who were categorized as novice had 2 to 3 years of anesthesia medical training experience, and the ones categorized as experienced had 4 to 5 years of anesthesia training experience. Therefore, it is difficult to compare these findings with the ones in our study among SRNAs.

Cobbett and Snelgrove-Clarke[21] found that although there was no difference in knowledge gain and self-confidence among undergraduate nursing students after participating in a maternal-newborn nursing high-fidelity mannequin simulation vs a virtual simulation, students indicated preference for the high-fidelity mannequin simulation. Some of the rationales noted for this preference were increased anxiety with virtual simulation due to technology issues, perceptions of the high-fidelity mannequin simulation setting resembling a more realistic environment, and being able to debrief immediately after the high-fidelity mannequin simulation.[21] Wilson et al[12] conducted a study to evaluate diagnostic reasoning skills among undergraduate nursing students using high-fidelity mannequin simulation vs computer-based simulation. Although both teaching methods were effective, the students performed significantly better when using high-fidelity mannequin simulation compared with computer-based simulation. However, in a study to evaluate undergraduate nursing students' ability to assess and manage patients experiencing clinical deterioration, Liaw et al[11] found no significant differences between the use of mannequin-based simulation vs virtual simulation. They concluded that both simulation modalities were equally effective in improving nursing students' ability to manage and assess clinically deteriorating patients.

The findings of this study add information to the literature by comparing 2 simulation modalities across 2 different class levels of SRNAs. However, it is important to acknowledge some limitations of this study. The sample size was small, and the research was conducted in only one nurse anesthesia program at a single university, which makes it difficult to generalize the findings to all SRNAs. In addition, although debriefing is usually most effective when conducted immediately after the simulation,[23] the debriefing session for the simulations in this study was to occur the following week. The purpose of the delay in the planned debriefing session was to minimize compromising the integrity of the scenarios by students potentially talking to their classmates after the debriefing. Because of distance, work schedules, and being done for the semester, the students were not able to return to campus for the debriefing session. In future studies, offering a web-based video conferencing debriefing session may be a more feasible option for the students.

Conclusion

High-fidelity mannequin simulation and virtual simulation can both be effectively used to evaluate SRNAs' ability to recognize rarely encountered intraoperative critical events such as MI. If educators need to prioritize the resources of the simulation center because of time, space, and faculty workload, the use of virtual simulation for recognition of intraoperative critical events may be an effective alternative for third-year SRNAs. For students who have had less didactic and clinical practicum experience such as first- and second-year students, the use of high-fidelity mannequin simulation would be preferred if possible. Further research is needed, including in larger sample sizes of students from various nurse anesthesia programs across multiple universities, to further compare the effectiveness of high-fidelity mannequin simulation vs virtual simulation for evaluating recognition and management of intraoperative critical events.

REFERENCES

1. Shin S, Park JH, Kim JH. Effectiveness of patient simulation in nursing education: meta-analysis. *Nurse Educ Today*. 2015;35(1):176-182. doi:10.1016/j.nedt.2014.09.009
2. Solnick A, Weiss S. High fidelity simulation in nursing education: a review of the literature. *Clin Simul Nurs Educ.* 2007;3(1):e41-e45. doi:10.1016/j.ecns.2009.05.039
3. Cooper JB, Taqueti VR. A brief history of the development of mannequin simulators for clinical education and training. *Qual Safe Health Care.* 2004;13(suppl 1):i11-i18. doi:10.1136/qhc.13.suppl_1.i11
4. Cannon-Diehl MR, Rugari SM, Jones TS. High-fidelity simulation for continuing education in nurse anesthesia. *AANA J.* 2012;80(3):191-196.
5. Holland B, Landry K, Mountain A, Middlebrooks MA, Heim D, Missildine K. Weaving the tapestry of learning: simulation, standardized patients, and virtual communities. *Nurse Educ.* 2013;38(6):269-272. doi:10.1097/01.NNE.0000435265.53612.06
6. Hawkins R, Bendickson L, Benson P, et al. A pilot study evaluating the perceptions of Certified Registered Nurse Anesthetists toward human patient simulation. *AANA J.* 2014;82(5):375-384.
7. Foronda C, Bauman EB. Strategies to incorporate virtual simulation in nurse education. *Clin Simul Nurs.* 2014;10(8):412-418. doi:10.1016/j.ecns.2014.03.005
8. Padilha JM, Machado PP, Ribeiro AL, Ramos JL. Clinical virtual simulation in nursing education. *Clin Simul Nurs.* 2018;15:13-18. doi:10.1016/j.ecns.2017.09.005
9. Jenson CE, Forsyth DM. Virtual reality simulation: using three-dimensional technology to teach nursing students. *Comput Inform Nurs.* 2012;30(6):312-318. doi:10.1097/NXN.0b013e31824af6ae
10. Singh PM, Kaur M, Trikha A. Virtual reality in anesthesia 'simulation.' *Anesth Essays Res.* 2012;6(2):134-139. doi:10.4103/0259-1162.108289
11. Liaw SY, Chan SW, Chen F, Hooi SC, Siau C. Comparison of virtual patient simulation with mannequin-based simulation for improving clinical performances in assessing and managing clinical deterioration: randomized controlled trial. *J Med Internet Res.* 2014;16(9):e214. doi:10.2196/jmir.3322
12. Wilson RD, Klein JD, Hagler D. Computer-based or human patient simulation-based case analysis: which works better for teaching diagnostic reasoning skills? *Nurs Educ Perspect.* 2014;35(1):14-18.
13. Nyssen A, Larbuisson R, Janssens M, Pendeville P, Mayné A. A Comparison of the training value of two types of anesthesia simulators: computer screen-based and mannequin-based simulators. *Anesth Analg.* 2002;94(6):1560-1565.
14. Johnson MP, Hickey KT, Scopa-Goldman J, et al. Manikin versus web-based simulation for advanced practice nursing students. *Clin Simul Nurs.* 2014;10(6):e317-e323. doi:10.1016/j.ecns.2014.02.004
15. Hirshey Dirksen SJ, Van Wicklin SA, Mashman DL, Neiderer P, Merritt DR. Developing effective drills in preparation for a malignant hyperthermia crisis. *AORN J.* 2013;97(3):329-353. doi:10.1016/j.aorn.2012.12.009
16. Seifert PC, Wahr JA, Pace M, Cochrane AB, Bagnola AJ. Crisis management of malignant hyperthermia in the OR. *AORN J.* 2014;100(2):189-202. doi:10.1016/j.aorn.2014.06.014
17. Smilowitz NR, Gupta N, Guo Y, Berger JS, Bangalore S. Perioperative acute myocardial infarction associated with non-cardiac surgery. *Eur Heart J.* 2017;38(31):2409-2417. doi:10.1093/eurheartj/ehx313
18. Motola I, Devine LA, Chung HS, Sullivan JE, Issenberg SB. Simulation in healthcare education: a best evidence practical guide. AMEE Guide No. 82. *Med Teacher.* 2013;35(10):e1511-e1530. doi:10.3109/0142159X.2013.818632
19. Anesthesia simulator. Laguna Niguel, CA: Anesoft Corp. https://anesoft.com/ Accessed March 12, 2018.
20. SimMan 3G. Stavanger, Norway: Laerdal Medical. https://www.laerdal.com/us/products/simulation-training/emergency-care-trauma/simman-3g/ Accessed March 12, 2018.
21. Cobbett S, Snelgrove-Clarke E. Virtual versus face-to-face clinical simulation in relation to student knowledge, anxiety, and self-confidence in maternal-newborn nursing: a randomized controlled trial. *Nurse Educ Today.* 2016;45:179-184. doi:10.1016/j.nedt.2016.08.004
22. Wunder LL. Effect of a nontechnical skills intervention on first-year student registered nurse anesthetists' skills during crisis simulation. *AANA J.* 2016;84(1):46-51.
23. INACSL Standards Committee. INACSL standards of best practice: SimulationSM debriefing. *Clin Simul Nurs.* 2016;12(suppl):S21-S25. doi:10.1016/j.ecns.2016.09.008

AUTHORS

Lisa Rose Erlinger, PhD, CRNA, is the director of surgical services and director of anesthesia at Wickenburg Community Hospital, Wickenburg, Arizona. Dr Erlinger is also an assistant professor at Midwestern University in Glendale, Arizona. Email: lisa.erlinger@wickhosp.com.

Andrew Bartlett, PhD, is a clinical assistant professor in the Department of Agricultural Statistics at the University of Arkansas, Fayetteville, Arkansas.

Amelia Perez, PhD, RN, is an associate professor and coordinator of the Simulated Learning Center for Health Sciences at Southern Illinois University Edwardsville School of Nursing, Edwardsville, Illinois.

DISCLOSURES

The authors have declared no financial relationships with any commercial entity related to the content of this article. The authors did not discuss off-label use within the article. Disclosure statements are available for viewing upon request.