AEJ ANESTHESIA EJOURNAL
Volume 6 - No. 6 2018

Using Video-Assisted Technology and Simulation to Transform a Nurse Anesthesia Machine and Equipment Course

Rachel Marie Smith-Steinert, DNP, CRNA[1]
Melissa Willmarth-Stec, DNP, CNM, APRN, FACNM, FAAN[2]

Affiliation:
1. *Assistant Program Director-Nurse Anesthesia, University of Cincinnati, College of Nursing*
2. *Professor & Associate Dean for Evaluation and Educational Innovation, SUNY Downstate College of Nursing*

Funding/Conflict of Interest Disclosure:
The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest

KEYWORDS: anesthesia, simulation, anesthesia machine, nurse anesthesia curriculum, nurse anesthesia

Abstract

Introduction: Understanding how to use the anesthesia machine and how to troubleshoot when problems arise are paramount for nurse anesthesia practice. Simulation can provide a low-risk setting that allows students to learn in an environment representative of operational conditions. The purpose of this article was first to determine if simulation was an appropriate teaching modality to incorporate into the anesthesia machine course and second to explore the outcomes of utilizing such a modality in a traditional course.

Methods: This 2 group post-test design measured anesthesia machine learning in a traditional classroom and after introduction of simulated operating room experiences. Using the Food and Drug Administration (FDA)-approved anesthesia machine checklist, a simulation exercise was formulated to review the basic function of the machine. Students were divided into groups and taken to the hospital operating room twice. The first session reviewed the FDA checklist and focused on the components and their intended usage and proper function. The second session discussed plausible machine failure scenarios. Three written exams, a final oral exam, and course evaluations were used to measure pre- and post-exercise mastery of material, competency, student satisfaction, and confidence.

Results: There were no statistical differences in mastery of material or competency with the modified course. However, student satisfaction and perceived confidence increased.

Conclusion: Use of simulation in the nurse anesthesia machine and equipment course allowed students to practice infrequent events that have grave consequences. Changing the way that nurse anesthesia programs teach this course could not only provide safer, more competent providers but also improve anesthesia safety overall.

INTRODUCTION

Anesthesia safety has dramatically improved, and morbidity and mortality directly related to anesthesia are uncommon. Human error related to the *misuse* of the anesthesia machine and equipment, however, remains at 14% to 30% of all intraoperative problems.[1] According to the American Society of Anesthesiologists Closed Claims Project database, injury claims related to anesthesia machines have decreased to 1% of total claims but the results continue to be disastrous.[2] Patient outcomes in anesthesia-machine-related claims from 1990 to 2011 (n = 40) included anesthesia awareness (n = 9, or 23%), pneumothorax (n = 7, or 18%), and severe injury (death or permanent brain damage). The majority of these claims (85%) involved provider error with (n = 7) or without (n = 27) equipment failure.[2] Understanding how to use the anesthesia machine and how to troubleshoot when problems arise are paramount for nurse anesthesia practice.

One of the first courses in any nurse anesthesia curriculum is focused on the safe use of the anesthesia machine and equipment. Novice nurse anesthesia students must have a firm understanding of the function of the machine to begin to learn how to safely provide anesthesia. Traditionally, anesthesia machine and equipment courses have been taught with a didactic focus reinforced with some clinical observation time to see how the machine is used. The course can be difficult for students for numerous reasons. Students have usually had little to no exposure to anesthesia machines as registered nurses. The properties that guide the design and use of the machine are rooted in principles of chemistry and physics, both of which are scant in undergraduate nursing programs. The value of early observation time has been questioned owing to the novice student's lack of anesthetic knowledge. Varying teaching modalities must be considered to ensure students master this vital material.

The most recent Institute of Medicine initiative, *The Future of Nursing,* endorses simulation as a teaching methodology of the future.[3] Simulation can provide a low-risk setting that allows students to learn in an environment representative of actual operational conditions.[4] A course using simulation and active learning exercises was created for novice nurse anesthesia students to improve course delivery and achievement of the student learning outcomes. The goals of this program were to increase understanding of the material, increase the students' active participation, improve written and oral exam results, and improve student evaluations of the course. The purpose of this article was first to determine whether simulation was an appropriate teaching modality to incorporate into the anesthesia machine course and second to explore the outcomes of utilizing such a modality in a traditional course.

Malcolm Knowles, an American educator, is credited with the theory of andragogy, that is, the art and science of helping adults learn.[5] Knowles believed that 6 factors distinguish the adult learner. Self-directedness; accumulation of past experience, which becomes a resource for learning; readiness to learn; application of knowledge, which is problem-centered; internal motivation to learn; and the need to know why something should be learned all shape the adult learner.[6] Knowles's assumptions of the adult learner are applicable to nurse anesthesia students. These assumptions of adult learning are often in conflict with a traditional, teacher-centered approach of didactic lecturing. In order for one to effectively teach adults, one must know *how* adults learn.

Clapper[7] states in his review of literature concerning adult learning theory that adults learn from experience in a way that is simply not possible from instruction or information delivery alone. Clapper advises educators to put away PowerPoint (Microsoft) slide presentations and instead use project-based learning to teach for understanding. Clapper writes that health profession educators must move past old methodologies, despite their utility in the past.[7]

As Curtin et al[8] explain in their qualitative review of a simulation program, the 4 learning styles—visual, auditory, tactile, and kinesthetic—are all incorporated in a simulation activity. The authors explain how simulation promotes the learner's knowledge acquisition on a deeper level by the activity of active participation. Likewise, Lasater et al[9] describe how the active role permits deeper learning: understanding more, remembering longer, and more success in evaluation. In order for students to really learn, Lasater et al[9] state that educators must provide an environment that is proper for learning and resides in adult learning theory. Zigmont[6] also reiterates that simulation can allow a learner to move from basic knowledge to application, analysis, and finally synthesis, the highest level of comprehension. Simulation adheres to the 2 most important tenets of adult learning: hands-on experience in a safe environment and provided guided reflection.[6]

When reviewing the literature concerning the incorporation of simulation into curriculum, Issenberg et al's[10] expansive systematic review of 109 articles spanning from 1969 to 2003 must be included. High-fidelity simulation is demonstrated to be educationally effective and complements but does not duplicate medical education in patient care settings.[10] Issenberg at al[10] state that simulation is best served to prepare learners to care for real patients. This review explains that simulation is an excellent tool to facilitate learning under the right quality conditions.

Grant et al[11] echo the use of simulation in preparation for direct patient care, showing positive outcomes for learners involved in simulation activities before clinical practice commences. In a systematic review and meta-analysis by Cook et al,[12] a comparison with no intervention and technology-enhanced simulation training in health profession education was examined. A follow-up systematic review was performed by Cook et al[13] that reviewed 82 studies and included 3498 participants. This article showed that simulation-based medical education (SBME) is an effective instructional design feature. The authors concluded that educators should consider using this approach.[13]

In McGaghie et al's[14] systematic review, the meta-analysis was clear and unequivocal. Outcomes favor SBME, and a growing body of evidence suggests that clinical skills acquired via SBME transfer directly to patient care. The authors concluded that enhancement of the traditional clinical educational model with evidence-based practice like SBME should be a high priority for medical education policy and research.[14]

Learner satisfaction, confidence, and perceived competence are factors that are often discussed in the literature on the outcomes of simulation. In Harder's[15] systematic review, 23 articles are reviewed that discuss the use of simulation in health profession education. In 21 of the studies, students evaluated their confidence and perceived skill level higher than did those who did not participate in simulations. Laschinger et al[16] specifically reviewed confidence, knowledge, and satisfaction in their systematic review. Learner satisfaction was increased with simulation when used to learn clinical skills, with learners reporting that the models made learning easier.[16] Ruesseler et al[17] looked at the satisfaction of medical students after simulation training versus traditional clinical teaching. Statistically significant increases in satisfaction were noted for those students who completed simulations.[17]

A paucity of literature is available examining simulation use in nurse anesthesia education. However, in studies with anesthesia residents as participants, simulation has been demonstrated to be effective. Mudumbai et al[18] examined anesthesia residents in a prospective, descriptive study that evaluated basic anesthesia machine function and proper use. The authors created simulation scenarios in which participants had to troubleshoot machine malfunction in pairs. The authors suggested high-fidelity simulation as a means to teach trainees equipment and machine function and examine management during a machine malfunction crisis. Park et al[19] looked at crisis management in the novice anesthesia resident. Anesthesia residents completed either a traditional curriculum or one with added simulation to study infrequent but catastrophic events during anesthesia management. Hypotheses were confirmed that the addition of event-specific simulation accelerated the management skills for that specific event.[19]

METHODS

Institutional review board (IRB) approval was achieved before implementing this project. The project was granted IRB exemption status owing to its quality improvement nature. Consent was not necessary from participants owing to the quality improvement nature of the project; however, participants were informed of the project details, and clear objectives and desired outcomes were discussed. The setting of this project was a nurse anesthesia program in a college of nursing within a large, urban university. Students included in this project were 25 first-semester, novice nurse anesthesia students enrolled in the anesthesia machine and equipment course. Additionally, the students were registered nurses with 2 to 5 years of critical care nursing experience.

Planning for this project began 2 years before implementation, with a formal needs assessment. Students (n=25) completed a comprehensive survey in which they were asked, at the completion of the course, what could have made the material easier to comprehend. Students stated (84% of respondents) that machine component and function were difficult to understand when lectured on in class. Students requested to see a "live" machine function and malfunction in a safe environment. Additionally, faculty responses were solicited. All faculty (n=6) stated that simulation was an area the program needed to develop and explore how to incorporate into the curriculum. The director stated that program applicants often inquired about the use of simulation and its role in clinical preparedness. Developing simulation usage in the program was seen as paramount by the nurse anesthesia faculty. These results demonstrated the faculty's desire to implement simulation as a component in the curriculum. Current students desired more hands-on time during the machine course and believed that additional time working on the machine checkout would improve comprehension and knowledge retention.

On the basis of these data, several changes were made to the anesthesia machine course. These changes were supported by the literature on adult learning theory and simulation utilization in health care education. Previously, the students spent the first weeks of the semester in the operating room. This activity was eliminated, which allowed more time for more active learning exercises with live machines. The course was examined to determine which lectures could be transferred from in-class lecture to an online delivery format. Lectures covering basic scientific principles, patient equipment, and fire and electrical safety were chosen for video conversion, thus decreasing lecture time by 16 hours.

Using the anesthesia machine checklist approved by the Food and Drug Administration (FDA), an active learning exercise was formulated to review the basic function of the machine. Students were divided into 4 groups with 6 students per group and were taken to the operating room twice for 1-hour periods. Participants were encouraged to watch an online video covering the basic FDA checkout of the Fabius GS anesthesia machine (Draeger) before their scheduled session. Each session was completed in small groups led by an instructor. The first session reviewed the FDA checklist with a focus on the components and their intended usage and proper function. Students reviewed the checkout procedure once, step by step, to show the appropriate function of each component of the machine. Students were able to ask questions and discuss each component (**Figure 1**). The second session discussed plausible machine failure scenarios. Students were then provided hands-on time to work in small groups to review the checkout procedure. Checklists using the FDA checkout of the anesthesia machine and possible anesthetic emergencies related to equipment error and misuse provided structure for these exercises (**Figure 2**).

During the modified course, the students completed the existing 3 written exams given in the initial course. At the completion of the course, a uniform oral exam was conducted in the operating room during which students completed the FDA checklist from memory to demonstrate safety and proper function of the machine and answered questions on machine and equipment failure scenarios. Students simulated checking the machine, determining its safety for use, and preparing for the induction of a patient by using a low-fidelity mannequin. At the completion of the exam, the exercise was reviewed and students were given feedback on their performances. Time was also allotted for student questions to be answered.

The written exams, final oral exam, and student evaluations of the course were evaluated after implementation of the new curricular changes. The outcomes measured were mastery of material, competency, and student satisfaction and confidence. Mastery of course material was demonstrated by the 3 written exams. Competency using the anesthesia machine and troubleshooting problems with its function was shown in the oral exam performance. Student evaluations of the course were used to measure student satisfaction and confidence. Means of the results of the written and oral exams were compared by using an unpaired t-test to determine statistical differences after implementation of the program. Qualitative data from the student evaluation of the course were used to measure student satisfaction before and after implementation of the simulation and active learning exercises.

RESULTS

This quasi-experimental, nonequivalent control group design compared 2 groups of students: students from the previous semester enrolled in the lecture-based course and students from the simulation and active learning integrated course. Written exam scores were used to demonstrate student mastery of course material. The mean scores on the written exam for the pre-intervention group were 81.36% for exam 1 (SD=4.58), 84.0% for exam 2 (SD=6.89), and 86.08% for exam 3 (SD=4.31). In the modified course, the mean scores for the written exams were

80.36% for exam 1 (SD=3.77), 80.43% for exam 2 (SD=6.32), and 84.96% for exam 3 (SD= 6.36). An unpaired *t*-test was used to determine whether the changes in exam scores were statistically significant. For all 3 written exams, there was no statistically significant difference in scores from before to after the intervention. Therefore, mastery of the course material was unchanged.

Results of the oral exam were used to demonstrate competency in troubleshooting and determining functionality of the anesthesia machine in the lecture-based course as well as the simulation and active learning integrated course. The mean result on the oral exam before the intervention was 92.5% (SD= 4.89) and that after the intervention was 94.25% (SD= 5.06). Using the unpaired *t*-test, the difference between the 2 groups was statistically insignificant. Thus, the ability to demonstrate competency after the course was modified was unchanged.

University course evaluations are used annually to determine student satisfaction with the course and to give students an opportunity to give feedback to the instructor. These qualitative and quantitative data are compiled at the conclusion of the course. Before the intervention, 82% of the students agreed with the statement that "course material was presented at an adequate pace." Qualitative data after intervention revealed statements such as:

- "Reviewing the machine checkout in small groups would be helpful. This information was overwhelming."
- "I think I would retain more information if I could have touched the machine."
- "It's difficult to see and hear the components of the machine with 25 people in the room."
- "It would be nice to go over the checkout and have more hands-on time."

Nine of 25 students (36%) commented on the need for more hands-on time with the machine and the instructor.

After changes were made to the course, 91.7% (n=12) of the respondents strongly agreed with the statement, "[the] course material was presented at an adequate pace," and 100% of the respondents strongly agreed with the statements, "this course strengthened my knowledge base and clinical skill as an anesthesia provider" and "physical and learning resources were adequate to meet course objectives." Qualitative data included:

- "Going to the OR [operating room] in small groups was beneficial."
- "I feel adequately prepared to manage the machine."
- "Going to the OR with the instructor, for hands-on time with the machines, was helpful."

Overall, the qualitative data showed increased satisfaction with the course and improved confidence of the students after the active learning exercises.

DISCUSSION

The results of this quality improvement initiative indicated that the use of simulation in the machine course was beneficial to student outcomes. Although the results were equivalent in terms of mastery of information and demonstrated competency on the basis of the results of the written and oral exams, improvements were noted in active participation, student satisfaction, and confidence with program implementation. Similar improvements were noted by Harder[15] and Lashinger et al.[16] These results and the literature support the use of simulation and active learning exercises in the anesthesia machine and equipment course.

The limitations of this project include threats to internal validity such as selection bias. The design did not allow the same groups of students to be surveyed on both courses, before and after the intervention, because of the nurse anesthesia curriculum. Each group of anesthesia students is composed of different age groups, genders, previous experiences, and learning styles. Therefore, the group comparison was also biased by the composition of the class. Additionally, only first-year, novice nurse anesthesia students are enrolled in the course. Although the student input from the evaluations was helpful, this was the first course the students had taken in the nurse anesthesia program. Therefore, they did not have other nurse anesthesia machine courses with which to compare this experience. Threats to external validity were minimal because cohorts of nurse anesthesia students nationwide are required to meet similar standards for admission into programs. Therefore, this sample can be considered representative of cohorts across programs.

This intervention was strongly based on the addition of simulation to the course. For most of this project, the simulation laboratory was in its formative phase, under construction, with equipment slowly being purchased. Low-fidelity mannequins were used because of their portability to the operating room. More realistic and accurate scenarios should be developed with high-fidelity equipment. Simulation equipment and laboratory space is an immense investment for programs; high-fidelity mannequins cost close to $100,000. The cost benefit for anesthesia programs must be evaluated before making this investment.

There exists a paucity of research using computer adaptive technology and simulation in nurse anesthesia curricula. Any research in this field will advance this area of study. Future areas to further develop this project would include increased lectures online, availability of videos covering machine troubleshooting, and further troubleshooting scenarios with higher fidelity mannequins. Developing more realistic scenarios incorporating rare events such as power outages, machine failure, and various equipment malfunctions could give novice students experience that they may never encounter in their training with live patients in the operating room. Recording the oral exams and allowing students to watch their performance may also aid in the debriefing phase and provide more valuable feedback.

Simulation has been shown in the literature to improve the performance of health care providers, providing valuable experience in a low-risk setting. Although rare, anesthesia machine and equipment errors can result in disastrous consequences, causing patient injury and death. The Institute of Medicine's[20] recent report describes the importance of improving patient safety in health care through the use of educational technologies to improve teaching and competence. Use of simulation in the nurse anesthesia machine and equipment course allows students to practice infrequent events that have grave consequences. Changing the way nurse anesthesia programs teach this course could not only provide safer, more competent providers but also improve anesthesia safety overall.

SUMMARY OF KEY POINTS

Simulation has been shown in the literature to improve the performance of health care providers, providing valuable experience in a low-risk setting. Although rare, anesthesia machine and equipment errors can result in disastrous consequences, causing patient injury and death.

- Understanding how to use the anesthesia machine and troubleshoot when problems arise is paramount for nurse anesthesia practice.
- Use of simulation in the nurse anesthesia machine and equipment course allows students to practice infrequent events that have grave consequences.
- Although increased mastery of material was not demonstrated to improve, confidence and satisfaction were increased.
- Changing the way nurse anesthesia programs teach this course could not only provide safer, more competent providers but also improve anesthesia safety overall.

Simulation Session One Activities
• Reviewed all steps of FDA Anesthesia Machine Checkout Procedure
• Demonstrated automated and manual check of anesthesia machine
• Located backup cylinder supply and emergency airway equipment
• Discussed location and proper function of the following internal components 1. Cylinder supply (high pressure leak determination) 2. First stage regulator 3. Oxygen flush 4. Flowmeters 5. Pressure sensor shutoff valve 6. Oxygen supply alarm 7. Proportioning system 8. Auxiliary flowmeter
• Reviewed proper function and check of the following external components 1. Vaporizer (filling, changing, checking for a leak, competency) 2. Absorber (changing canister, determining exhaustion & desiccation) 3. Ventilator 4. Scavenger system (suction supply, competency of positive and negative pressure relief valves) 5. Breathing system (low pressure leak determination)
• Reviewed setting and tested function of following alarms 1. Positive pressure alarm 2. Volume alarms 3. Pressure alarms 4. Subatmospheric pressure alarm 5. Oxygen analyzer 6. Machine power failure alarm
• Reviewed function of various OR tables
• Reviewed inclusion of ASA monitors and determined competency

Figure 1. Simulation Session One on the Fabius GS Anesthesia Machine (Draeger).
Abbreviations: ASA, American Society of Anesthesiologists; FDA, Food and Drug Administration; OR, operating room.

Simulation Session Two Activities
• Discuss and demonstrate possible machine component failures and troubleshooting 1. Look for vaporizer and nitrous flowmeters being "left on" 2. Troubleshooting machine automated tests (internal software checks) 3. Calculating oxygen cylinder and emergency supply 4. Deciphering safety of pipeline supply 5. Determining conditions when one would switch from pipeline to cylinder supply 6. Troubleshooting suction issues 7. Replace all "missing hoses" correctly 8. Mimic obstruction in ventilator hoses (clinical scenarios when this might occur) 9. Mimic obstruction in scavenger hoses (clinical scenarios when this might occur) 10. Putting together breathing circuit components correctly 11. Replacing galvanic/paramagnetic oxygen supply monitor 12. Recognizing exhausted/expired carbon dioxide absorber canister 13. Recognize high and low pressure leaks ▪ Is the leak acceptable? Quantify the leak ▪ Where is the location of the leak? ▪ How to "fix" the leak

Figure 2. Session 2 on the Fabius GS Anesthesia Machine (Draeger).

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