A COMPARISON OF STUDENT REGISTERED NURSE ANESTHETISTS
PHARMACOLOGY KNOWLEDGE ACQUISITION AND LONG-TERM
RETENTION FOLLOWING EXPOSURE TO DIDACTIC INSTRUCTION
AND EXPERIENTIAL LEARNING VERSUS DIDACTIC
INSTRUCTION ALONE

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By

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ABSTRACT

High fidelity simulation (HFS) is a useful method to teach practical information without
the risk of harming a live patient. It is a teaching method used in at least half of all nurse
anesthesia programs, but not generally designed to specifically focus on pharmacology content.
Similarly, there is no research that specifically explores the use of HFS to supplement didactic
pharmacology education in nurse anesthesia. Because of this, we designed a study to investigate
the impact that HFS has on the pharmacologic knowledge acquisition and retention of student
registered nurse anesthetists (SRNAs). This pilot study recruited fifteen SRNAs to participate in
a pharmacology curriculum that included a traditional didactic lecture supplemented with a
pharmacology focused HFS experience. Their baseline pharmacologic knowledge was assessed
with a pretest that indicated no significant difference in the scores ($P = .34$). After the
simulation, all participants scored 20% higher on knowledge assessment questions related to
pharmacology content that was supplemented with simulation and 1% lower on the content that
was taught via the traditional didactic lecture alone ($P < .001$). One month after the simulation,
participants were assessed for knowledge retention of the same pharmacologic content. All
participants scored 20% higher than the pretest on the questions pertaining to the content covered
in the simulation and 15% lower than the pretest on the questions that were assessing material
only taught via didactic lecture ($P < .001$). This pilot study strongly suggests that incorporating simulation into a nurse anesthesia pharmacology curriculum helps clinical trainees learn and retain new pharmacologic material. This educational method should be further explored as a potential means to promote safe practice in the hospital setting by increasing pharmacologic knowledge acquisition and long-term knowledge retention.
The research and writing of this thesis is dedicated to everyone who helped along the way. Thank you Dr. Bowman Dalley for your dedication to making this project a success. Thank you to the staff of the O’Neill Family Foundation Clinical Simulation Center for your assistance with the simulation implementation. Thank you to my dear friend Annie Camacho for your physical, emotional, and mental support throughout this entire process.

Many thanks,
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CHAPTER 1: INTRODUCTION

Introduction

Modern day medicine is constantly evolving and efforts to increase patient safety have become a common topic of discussion.\(^1\) Prior to practicing clinically, student registered nurse anesthetists (SRNAs) are expected to learn and retain a vast amount of new clinical information. Knowledge acquisition and knowledge retention are important skills for SRNAs to attain in order to promote safety in the clinical setting and to pass the National Certification Exam (NCE). It has been shown that newly acquired knowledge can decay in as little as one week\(^2\), and traditional learning styles often fail to engage students.\(^3\) Educators and students would both benefit from a curriculum that cultivates long term retention of the material presented.

Problem Statement

Experiential learning techniques, such as high-fidelity simulation (HFS), are useful means to teach SRNAs new clinical information without the risk of harming a live patient\(^4\). HFS is currently used in at least half of all nurse anesthesia programs\(^5\) but there are no studies that specifically explore the use of high fidelity simulation to supplement didactic pharmacologic education. Pharmacologic knowledge is a critical component of providing competent anesthesia care. However, some healthcare students have a hard time making connections between content learned in the classroom and practical application in the clinical setting\(^6\) and knowledge retention has been a long-standing problem in health science education.\(^7\) Simulation has been shown to
significantly increase the learners’ knowledge, competence, and confidence, and it also has been shown to promote knowledge retention. Therefore, a study focused on effectiveness of HFS in promoting pharmacologic knowledge acquisition in SRNAs is warranted.

*Purpose of Study*

The purpose of this study is to determine if supplementing didactic pharmacology lectures with high-fidelity simulation will improve the effectiveness of both short and long-term pharmacologic knowledge acquisition in student registered nurse anesthetists.

*Research Questions*

The research questions for this study are:

1. Does the addition of a high-fidelity simulation intervention using debriefing provide an advantage over didactic instruction alone in initial pharmacologic knowledge acquisition?
2. Does the addition of a high-fidelity simulation intervention using debriefing provide an advantage over didactic instruction alone in long-term pharmacologic knowledge retention?
Definitions

For the purpose of this study, the following terms and definitions were used:

Theoretical Definitions

1. Pharmacology: Pharmacology is defined as the study of the effects of drugs on the function of living systems.

2. Knowledge acquisition: Knowledge acquisition is defined as the process of identifying, understanding, and eliciting knowledge from existing sources.\(^9\)

3. Knowledge retention: Knowledge retention is the storage and organization of information into memory for later authentication and utilization.

4. Didactic: Didactic teaching is the traditional lecture-based educational strategy used to present new information to students.

5. Simulation: Simulation is an educational strategy in which a particular set of conditions are created or replicated to resemble authentic situations that are possible in real life. Simulation can incorporate one or more modalities to promote, improve, or validate a participant’s performance.\(^10\)

6. Fidelity: Fidelity is the degree to which a simulated experience approaches reality. As the simulation’s fidelity increases, the closer to reality it is. The level of fidelity is determined by the environment, the tools and resources used, and factors associated with the participants.\(^11\)
Operational Definitions

1. Pharmacology: The pharmacodynamics, pharmacokinetics, doses, contraindications and indications of antihypertensive agents and vasodilators that are used in the anesthesia clinical practice will be presented to participants.

2. Knowledge acquisition: Knowledge acquisition will be measured by comparing pre and post simulation performance on a multiple-choice test incorporating anesthesia pharmacology.

3. Knowledge retention: Knowledge retention will be measured by comparing performance on a multiple-choice test incorporating anesthesia pharmacology over time. This test will be administered pre-simulation, immediately after the simulation and one month after a simulation intervention to each of the study participants.

4. Didactic: A conventional lecture will be given to the SRNAs discussing the pharmacologic principles of the antihypertensive agents by a university faculty member. This is currently the standard teaching practice for this program.

5. Simulation: Four simulated clinical scenarios, which were created specifically for this study, will be implemented into the program’s didactic pharmacology curriculum. Simulations will be conducted in a small group setting and will require the application of knowledge and use of the pharmacologic agents in discussion. Debriefing sessions, led by a facilitator, will be conducted at the conclusion of each group’s simulation session.

6. Fidelity: High fidelity will be maintained during the simulation intervention by using CAE Healthcare’s HPS manikin that is capable of moving limbs, can physiologically
respond to pharmacologic agents in real time, has an imbedded microphone to simulate patient vocalization, has palpable pulses, and audible heart and lung sounds.
Student registered nurse anesthetists (SRNAs) are required to complete a rigorous academic program where retention of a vast amount of new information is vital to achieve clinical competency. A critical portion of content to be mastered is pharmacology. SRNAs must learn the pharmacodynamics, pharmacokinetics, dosages, adverse effects, and drug interactions for hundreds of medications during their training. Traditionally, pharmacology is taught to SRNAs through didactic lectures, but these lectures can often fail to engage students in active learning or critical thinking. Teachers commonly present drugs in individual sections and evaluate students at the completion of each section. This is optimal for short term evaluation of learning, but this strategy may not reflect the student’s ability to access pharmacologic knowledge at a later date in the clinical setting or during the national certification exam. New teaching strategies have begun to emerge in academia, all with a common goal of engaging students beyond tradition didactic lectures. In nurse anesthesia programs, the most frequently used innovative teaching strategy is the incorporation of simulation into the curriculum. Simulation plays an important role in many professions because it has the unique advantage of allowing experience to drive learning without exposing individual clients to potential harm or danger. Most simulation studies explore how simulation affects knowledge acquisition immediately after the task. However, very few look at long term knowledge retention. Furthermore, no studies were found evaluating the efficacy of simulation on knowledge acquisition and retention of pharmacologic material for SRNAs.
Pharmacologic knowledge retention is critical for SRNAs who must pass the National Certification Exam (NCE), and more importantly to provide safe, competent anesthesia care. The National Board of Certification and Recertifications for Nurse Anesthetists (NBCRNA) is the responsible party for administering the NCE to all SRNAs. This exam is a pre-requisite for licensure to practice as a Certified Registered Nurse Anesthetist (CRNA) in the United States. The NCE content is broken down into the following categories; basic sciences (25%), equipment, instrumentation and technology (15%), general principles of anesthesia (30%), and anesthesia for surgical procedures and special populations (30%). Pharmacology content appears in each of the four subdivisions on the NCE and is vital for the students to master prior to taking the exam.

Pharmacology is perhaps one of the most important fields of study for SRNAs and CRNAs due to their extensive use to keep patients hemodynamically stable, unconscious, and comfortable during procedures. Given the myriad of anesthetic agents and adjuncts, the potential exists for errors with disastrous consequences to patients if in-depth knowledge of pharmacology is not achieved. Medication errors are a major cause of patient morbidity and mortality and excessive costs, as outlined in the 1999 report “To Err is Human: Building a Safer Health System.” This report conducted by the National Academy of Sciences’ Institute of Medicine revealed a growing body of evidence demonstrating medical errors as the leading cause of death and injury in the US. An estimated 180,000 patients die each year in the US as a result of adverse medical events, with medication errors as a leading factor. Current research indicates these alarming trends have continued, revealing that 80% of anesthesia-specific medication
errors are preventable, and of those errors, 46% have the potential for causing patient harm.\textsuperscript{17}

Although, increasing pharmacologic knowledge retention will not eliminate anesthesia-specific medication errors entirely, it will provide a basis for optimal clinical decision making. In high reliability fields like anesthesia, every effort should be made to mitigate errors as much as possible, and to increase retention of pharmacologic knowledge may help mitigate medical errors.

\textit{Knowledge Retention and Knowledge Acquisition}

Loss of previously learned information is a universal human experience.\textsuperscript{2} The idea of fading knowledge was first written about in the early 1900s and continues to be studied throughout the modern age.\textsuperscript{7} Newly acquired knowledge can deteriorate during periods of nonuse in as little as a week.\textsuperscript{2} This is particularly problematic for SRNAs, as initial exposure to anesthesia pharmacology happens up to three years before they are required to take the NCE. SRNAs need not only to retain the pharmacologic knowledge to pass the NCE, but to practice safe and competently in the clinical setting. It is therefore important to determine what methods would minimize this knowledge deterioration.\textsuperscript{14} Early theories of knowledge acquisition can be separated into a model with three distinct stages: (1) obtaining declarative and procedural knowledge, (2) combining and solidifying the acquired knowledge and (3) fine-tuning knowledge through overlearning.\textsuperscript{18} During the first stage of learning, students are taught new information and concepts that support ways of using the new information; in the second stage, knowledge is consolidated into a procedure for applying the new information; and the third stage
involves practicing the procedures to enforce long term retention which is similar to procedural memory that is essentially immune to decay.\textsuperscript{18}

There are two other learning strategies that are commonly discussed in the knowledge retention literature: overlearning and distributed practice. In the overlearning strategy, a student first masters a skill and continues to practice the same skill beyond the point of initial mastery.\textsuperscript{19} Conversely, in the distributed learning strategy, a given amount of practice is divided amongst multiple short sessions over a long period of time.\textsuperscript{19} For example, after giving a lecture of drugs and their dosages to students, the students can attempt to master the material by either of these two strategies. In overlearning, the students would study the list until all drugs and dosages can be correctly recalled once and any immediate further study would be considered overlearning. In distributed practice, the students would study the list of drugs and dosages in shorter increments of time but for multiple consecutive days. A study completed by Rohrer and Taylor applied these two learning theories and determined their effects on learning outcomes. They separated 116 students into two groups and had each group attend three educational classes. The first group’s classes were spaced to fit the overlearning theory, while the second group’s classes were spaced to fit the distributed practice model. The researchers found that when the total amount of study time was equal in both groups, the overlearning strategy greatly favored immediate knowledge acquisition whereas distributed practice favored long-term knowledge retention.\textsuperscript{20} The results of their study were consistent with previous findings demonstrating spacing effects on learning outcomes. Students that do not need to recall the information learned after the exam would benefit most from overlearning, but if the material is needed to be recalled after a long retention interval, the optimal study technique is via the distributed strategy. It would benefit
anesthesia providers to retain the material learned throughout their education in order to provide the best care for their patients and promote a culture of safety.

David Kolb, an educational theorist, developed the experiential learning theory, which offers insight into the process by which SRNAs could learn new information in a more interactive environment. The experiential learning theory places emphasis on clinical experience as a central role in human learning and development. It also highlights the importance of a learning cycle inspired by four stages; concrete experience, reflective observation, abstract conceptualization, and active experimentation. Kolb proposed his theory to combat the issue of knowledge decay. The combination of Kolb’s experiential learning theory with the overlearning/distributed learning strategies was tested in a study conducted by Madani et al between 2013-2016 when 60 electrosurgical trainees were taught the practice of safe electrosurgery. Researchers were exploring the effect that simulation had on trainees’ long term knowledge retention. The trainees were tested prior to being exposed to an educational session where baseline knowledge was proven to be the same. The participants were split into a control group and a testing group. Each group was exposed to their respective training sessions and tested three separate times; the first time was immediately following their sessions where the group exposed to a high-fidelity simulation lesson scored 6% higher than the control group that attended an unstructured hands-on session. The second testing was completed 3 months after the education sessions where the simulation group scored 10% higher than the control group. The third testing came 1 year following the exposure, where the simulation group scored 21% higher than the control group. The results concluded that the trainees who were exposed to simulation after their didactic lecture retained the information much longer than those not participating in the simulation. This research study demonstrates that combining the overlearning and
distributed learning strategies with Kolb’s experiential learning theory, SRNAs should show greater immediate knowledge acquisition and longer knowledge retention when HFS is used in their curriculum.

Most studies specific to clinical knowledge retention are focused on medical students who completed their clinical education approximately two years after their initial exposure to the didactic material. Because of this, there is a widespread concern that a large portion of information learned in the didactic phase of medical programs is lost during the final clinical years. Many experts suggest that students forget what they learned in school within a short period of time after the examination. It has been hypothesized that when students shift focus from previously retained information to new information, previous knowledge deteriorates after periods of nonuse. This concern is why more research studies need to be conducted about long-term knowledge retention, especially for healthcare workers, who may go many years before needing to recall previously learned information.

*Teaching Strategies to Improve Pharmacologic Knowledge Retention*

Teaching pharmacology effectively to students is paramount for safe medication administration. Medication errors can be caused by lack of knowledge, routine failure, insufficient practical skills, or as a result of human error. After conducting an 8 year retrospective analysis of nearly 250 incident reports related to medication errors, Yamamoto et al reported that the most common medication errors were overdosing, substitution of drug, and omission of drugs; all content that is included in anesthesia pharmacology curriculums. SRNAs are required to quickly draw on pharmacologic information in order to make appropriate
clinical decisions in a timely manner; choosing an inappropriate medication or dose in a given clinical situation can have morbid consequences. Traditionally, pharmacology is taught to SRNAs in a format revolving around lectures and memorization. However, this method often fails to engage students in active learning or critical thinking. The Learning Pyramid, developed in the 1960s by the NTL Institute, summarizes that learners only retain 5% of the information they receive in didactic lectures compared to 75% when active learning was involved. This has led to the emergence of new and innovative teaching strategies in an effort to increase pharmacologic knowledge retention in medical and nursing curriculums. A 2016 study evaluated the educational outcomes of undergraduate nursing students after integrating an interactive activity that required active learning into a pharmacology curriculum. Thomas and Schuessler adapted popular games like “Go Fish” and “Bingo” and turned them into pharmacology games which were implemented into their pharmacology course curriculum. Prior to implementation of these games, 40% of their students achieved less than the benchmark on the pharmacology section of the registered nurse board exam. After implementation, less than three percent failed to attain the required score on the board exam, and the overall class average increased by 10%. There have been many other innovate teaching strategies crafted with the overall goal of engaging students beyond traditional lecture based education. HFS is another teaching strategy aimed at engaging students, that is currently being used in many different high-fidelity fields, such as healthcare, space, aviation, and the military. HFS can evoke an intense emotional arousal, which has been shown to play a role in students’ enhanced knowledge retention. During events that elicit emotional arousal, the release of stress hormones play an important role in modulating memory. In particular the arousal-mediated enhancement of memory occurs when the amygdala interacts with other regions of the brain,
including the hippocampus, that are important for sensory and mnemonic processing. There is evidence showing that emotion influences the accuracy of memory, with negative emotional arousal, such as fear and stress, being the most effective. Simulations cause a self-reported heightened stress response in participants, as well as an increased cortisol production which could help to explain the correlation between participation in high fidelity simulations and enhanced memory formation. Kensinger et al conducted a study where 48 subjects were tested in order to determine the extent a negative emotional response is linked to memory enhancement. The subjects were told to memorize neutral objects and negative objects, which were later shown to them on a computer. Some pictures had been slightly modified and the participants were asked to identify which ones had been changed. The subjects were more likely to identify the altered images that contained negative objects over the neutral objects. The results of this study support the many previous studies claiming that negative emotional arousal can enhance memory formation.

In a systematic review, examining over 75 studies regarding simulation-based training in anesthesiology, the use of simulation to teach anesthesia trainees was shown to be more effective in acquiring clinicals skills and knowledge than non-simulation instruction. In a specific clinical study investigating the effect that simulation-based training had on medication errors, 24 nurses who worked in an ICU were required to attend either a simulation based training or a didactic lecture on medication administration. Before the intervention, researchers observed the nurses administering medications during their daily shifts for a total of 200 hours. Medication errors were defined as incorrect dose, incorrect administration technique, or incorrect administration time. After the respective educational intervention, the nurses who attended the simulation-based training had less medication errors than those who attended the didactic lecture.
during multiple 4-hour sessions during the 12 weeks after the intervention. During the observation period, 31% of medications administered were flagged as errors prior to intervention implementation whereas after implementation, medication errors declined to only 4%.\textsuperscript{13} Although this was a relatively small study at a single site, it does suggest that implementing HFS into clinical education curriculums can significantly decrease errors in performance that could influence patient safety.\textsuperscript{13,36}

Not only has it been suggested that participating in simulation can increase knowledge acquisition and retention, but what happens after the simulation can also affect knowledge outcomes. A central component to HFS education is the incorporation of debriefing after the completion of the simulation. Debriefing leads students through a reflection on the events that happened during a simulation intervention, with a goal of developing knowledge, skills, and improvements to clinical practice.\textsuperscript{37} Simulations that include a debriefing following the HFS have been compared to simulations that do not include debriefings and found that when included, debriefings are more effective for knowledge transfer to the trainees. For example, Shinnick et al conducted a study including 162 participants where researchers investigated knowledge gains at different points during a simulation experience. Tests were given to the participants at baseline, after the hands-on simulation experience, and then once more after the debriefing. They found the greatest improvements in test scores occurred after the debriefing session. Investigators concluded that the most significant knowledge gains occurred after the debriefing session compared to after the simulation itself.\textsuperscript{38}
High Fidelity Simulation

The history of simulation in education dates back centuries. Currently, simulation has been extensively integrated into military, aviation, space, nuclear power, and medical curriculums. Simulation became popular in these industries to avoid the cost and inherent risk of testing in the real world. The medical and nursing professions specifically adopted simulation in education to minimize risks to patients and provide opportunities for students to experience rare clinical events they might not encounter in their individual training. The rise of clinical simulation is often credited to Åsmund Lærdal, a toy maker who worked with anesthetists to create a life-like manikin, named Resusciti-Anne. Resusciti-Anne was used to train the general public and emergency workers in cardiopulmonary resuscitation. Two anesthesiologists, Abrahamson and Denson, then expanded on the idea of Resusciti-Anne and created Sim One, a more lifelike manikin. Sim One had the capability of synchronized breathing, palpable heart beats, and could physiologically respond to four different intravenous drugs and two gases in real time, allowing for more accurate simulated training. Following Sim One, simulation education became increasingly sophisticated with an enhanced emphasis on ‘fidelity’. Fidelity denotes how close the simulation mimics reality. Fidelity is influenced by the type of equipment used and perhaps more importantly, how the equipment is used. Modern day mannikins are more complex and now can behave more lifelike compared with earlier models and include physiological responses to a wide variety of drugs, limb movement, exhaled carbon dioxide, pupillary changes, and include embedded microphones allowing for simulated patient vocalization. HFS is used widely in medical and nursing education to teach students new information, technical skills, and communication skills prior to entering clinical practice.
is also being considered for use during the recertification process of CRNAs, particularly for the training of high-risk, low-frequency events, pending the outcome of ongoing research. More recently, HFS is being considered as a substitution for direct clinical patient contact hours for practitioners reentering the field of nurse anesthesia after an extended leave of absence.

The major challenges associated with implementation of HFS are centered around financial burdens. HFS manikins are a capital purchase for an institution and can cost up to $125,000. In addition to the upfront cost, maintenance of the equipment is also necessary. Audiovisual software must also be purchased and maintained; adding an additional $10,000-$50,000. Another hurdle to overcome in the implementation of HFS is simply the complexity of operating such intricate technology, which may require partnering with simulation vendors to train faculty on how to successfully operate the mannikin. However, there are many funding options and grants that are available for educators and many health professional programs mandate simulation lab fees that may assist with overcoming the financial burden. Patient safety is a high priority, so the challenge of cost associated with HFS is offset if there is evidence to prove it increases clinical competency.

*Simulation Standards of Best Practice*

As the use of HFS began to increase throughout nursing curriculums, a group of professionals identified the need of an organization to serve the growing demands of the nursing simulation community. This group formed the International Nursing Association for Clinical Simulation and Learning (INACSL). After surveying its members and examining the literature for best practices in simulation, they published a list of Standards of Best Practice of Simulation
for use across all health care professions. The standards they created are used as a resource for simulation rationale, outcomes, criteria, and guidelines. The standards were founded on evidenced based research to guide simulation design, implementation, debriefing, evaluation, and research. They are reviewed and revised on a regular basis as technology and research continue to inform the practice. When creating a new simulation intervention, the INACSL’s list of evidence based standards are useful to consider during the design process in order to maximize simulation-based instruction, enhance skill acquisition, and further the science of simulation. The first standard emphasizes the importance of using standardized medical terminology to provide a framework for effective communication. The second standard focuses on the importance of mutual respect, maintaining confidentiality, and promoting professional behavior. This standard has been validated by research indicating that a simulation environment lacking these values can negatively impact willingness of the participants to fully participate. The third standard states a need for clear objectives and expectations for participants which has been shown to be an essential step in the setting the tone of the simulation. Educational and psychological research both provide evidence that when participants have a sense of control and clarity about what is expected from them, they are more likely to engage. Because it may be a novel environment to the student, simulation etiquette, norms, and roles may be unfamiliar, so it is mandatory for the instructors to clarify them. Doing so will provide a foundation for the simulation by identifying the appropriate scenario, level of fidelity, type of facilitating, and the environment. Pre-simulation exercises can be used to orient the students to the simulation environment and outline the learning objectives intended. Pre-simulation briefing can be used to help evaluate participants after the task has been completed.
The fourth standard discusses the aspect of facilitation throughout the simulation task. During the simulation, facilitation involves the use of physiological, environmental, and verbal cues that assist participants to interpret the simulated reality. Traditionally, training in most skill-based professions has been dominated by skill transfer from instructors to trainees, but research shows that individuals learn far more as active participants responsible for their own learning process, rather than passive recipients of wisdom from instructors. Facilitation can be done differently for each student due to participants’ variation in cultural and individual differences, but should always be congruent with the goals and objectives outlined in the pre-simulation briefing.

Standard five outlines the requirements a facilitator should be compliant with while leading a simulation task, and how they can optimize learning outcomes. The facilitator should help the participants explore the case and their thought processes in decision making. They are an imperative part of the simulation to make sure students remain engaged in order to draw upon previously learned knowledge, foster skill development, and develop sound clinical judgment and reasoning. It is the job of the facilitator to communicate objectives and expected outcomes, create a safe learning environment (as discussed in the second standard), promote and maintain fidelity, use individualized facilitation methods appropriate to the participants level of learning and experience, assess level of knowledge acquisition, foster student learning with appropriate support, and provide constructive feedback. By placing the students’ at the center of the educational experience, the term “student-centered learning” was created in order to describe this style of teaching. Student centered learning shifts the responsibility of learning from the instructor to the student, and gives them the control over what and how they learn. When this
shift of responsibility occurs, students often view it as a positive change and report a better learning environment.\textsuperscript{51}

The sixth standard discusses the importance of debriefing after the task is over. As previously mentioned, the process of debriefing is equally or more important to foster student learning as the task itself.\textsuperscript{52} Learning without guidance could lead the student to negatively transfer a mistake into their practice without realizing it is poor practice.\textsuperscript{52} The debriefing facilitator should aim to create a trusting environment where participants are comfortable in exploring their thinking processes, the actions taken or not taken, gaps in their knowledge and skills, reflecting on events of the simulation experience, and how they relate to their future clinical practice.\textsuperscript{52} When debriefing is conducted after the simulation task is over, participants are at an advantage for knowledge acquisition. They achieve a proficiency level quicker than those simulations that do not utilize debriefing.\textsuperscript{53} Many types of debriefing strategies have been employed, as outlined in a literature review completed by Dufrene and Young.\textsuperscript{54} The researchers compared 9 research studies that occurred between 2004-2011, and each used a unique debriefing strategy. In all 9 research studies, student performance and learning outcomes were not shown to affected by which method used, rather if debriefing occurred or not.\textsuperscript{54}

The last standard of best practice the INACSL outlines is the assessment and evaluation of the participants which discusses the learners’ outcomes.\textsuperscript{11} The INACSL recommends the use of either summative evaluation or formative assessment following the simulation task. Formative assessment fosters personal and professional development and helps students progress towards achieving objectives.\textsuperscript{55} It provides information for the purpose of improving performance and behaviors associated with the three domains of learning; cognitive, affective, and psychomotor.\textsuperscript{55} Summative evaluation focuses on measurement of outcomes or achievement
of objectives.\textsuperscript{55} Observer bias is a factor that can play into the assessment of students learning, so all previous knowledge of students should be avoided whenever possible, and using an evaluation tool that breeds interrater reliability is necessary.\textsuperscript{55}

High fidelity simulation is already a mainstay in nurse anesthesia curriculums throughout the country to teach anesthetic management in general.\textsuperscript{5} However, there is a lack of research focusing on the effect of including high fidelity simulation to specifically meet the objectives of the pharmacology curriculum. The impact of HFS on pharmacologic knowledge acquisition and knowledge retention is also unknown. Each anesthetic patient presents with unique comorbidities and physiologic responses that require the CRNA to have extensive knowledge of the pharmacokinetics, pharmacodynamics, and doses of anesthetic and adjunct medications. Research into increasing pharmacologic knowledge retention would be beneficial to SRNAs in order to increase the likelihood of passing the NCE, but more importantly to promote patient safety through well informed clinical decision making.
CHAPTER 3: METHODOLOGY, INSTRUMENTATION, AND PROCEDURE

Methodology

This chapter describes the methodology that was used to answer the research questions outlined in the first chapter: (1) Does the addition of high-fidelity simulation provide an advantage over didactic instruction alone in initial pharmacologic knowledge acquisition? (2) Does the addition of high-fidelity simulation provide an advantage over didactic instruction alone in long-term pharmacologic knowledge retention? The research design, sample, instrumentation, procedure, data analysis and protection of human rights are outlined.

Research Design

This study was conducted using a quasi-experimental design to compare short- and long-term knowledge outcomes after the implementation of an educational simulation intervention into an anesthesia pharmacology curriculum.

Sample

A convenience sample of 24 first year SRNAs enrolled in a front-loaded nurse anesthesia program in the Mid-Atlantic region were recruited to voluntarily participate in this research study. The Raosoft Sample Size Calculator was used to determine a recommended sample size from a population of 24 ensuring a 90% confidence interval with a 5% margin of error and a
50% response distribution (Appendix A). The sample size or ‘n’ was found to be 23. Every first year SRNA from this Mid-Atlantic nurse anesthesia program that is enrolled in the didactic pharmacology course was offered the opportunity to participate in this research study. Any SRNAs not currently in the first year of this Mid-Atlantic nurse anesthesia program were not included in the sample.

**Instrumentation**

Data was collected from a written test named Pharmacology Experiential Learning Tool and was administered to the SRNAs. It was developed by the investigator of this study and reviewed by five experts from the field of anesthesia and simulation education. The test was reviewed by two doctorally prepared CRNAs with experience as educators involved in simulation and pharmacology, one anesthesiologist with experience in simulation education, a doctorally prepared CRNA who is the director of a simulation center, and a doctorally prepared CRNA with experience in simulation education who serves as a program director.

The Pharmacology Experiential Learning Tool consisted of 25 questions. The first five questions were aimed at collecting demographic data of each participant; age, sex, years of experience as a nurse, years of experience as a nurse specifically in the intensive care unit (ICU), and which type of ICU the SRNA worked in prior to entering the program. There were ten questions regarding the material presented during the antihypertensive and vasodilator lecture (AV questions) that was emphasized during the simulation intervention, and ten control questions incorporating material that was taught within the same 4-week span during the subjects’ standard pharmacology course but was not integrated into the simulations (NS
questions). The SRNAs received this test prior to and after an educational intervention, and then one month after completion of the educational simulation session. The demographic data collection questions were only asked on the initial test and were not included on any subsequent test after the simulation. The test took no longer than 15 minutes to complete at each sitting. The subject’s performance on each test was scored based on the number of questions correct. These scores were then reported and analyzed.

Procedure

After approval from the Georgetown University IRB, the study took place in a university simulation skills lab and an adjacent conference room. Privacy was maintained in both rooms by ensuring all doors were closed during the simulation and debriefing periods. No cameras or recordings were used during the educational simulation intervention. The investigator of this study took notes on a modified lab evaluation form (see appendix C) for the debrief session that was used to provide feedback on each student’s performance, clinical judgment, application of pharmacologic knowledge, and essential attributes. At the conclusion of the research study, the notes were shredded and destroyed. The simulation skills lab was equipped with an anesthesia machine, a high-fidelity manikin lying on an operating room table, and an anesthesia cart stocked with medications and intubation equipment. The investigator of this study reserved this simulation suite for five total hours, allowing one hour for each simulation and corresponding debriefing session.

All students in the convenience sample initially attended the same two-hour didactic lecture presented by a doctorally prepared CRNA regarding antihypertensive agents and
vasodilators. This didactic lecture, which is the normal practice of the anesthesia program, was not changed or modified for the purpose of this research study. After the lecture was completed, the investigator of this study offered the SRNAs an opportunity to participate, explaining that there was no association with the didactic curriculum. This recruiting session took place at an administrative meeting within three weeks of the lecture. Any SRNA who expressed interest in volunteering to participate was then asked to sign an informed consent document prior to proceeding. The SRNAs who chose to participate in this study were able to sign up for a simulation time slot of their preference. Once groups of four had chosen their preferred time slots, randomization of simulation scenarios were distributed. There were four cards labeled A-D in an envelope. Each student in the group blindly selected a card which corresponded to the simulation that they acted as the primary anesthesia provider. The four unique simulations that were created for the purpose of this research study were created and programmed using the MUSE software and was operated by a university affiliated operation specialist. A trial run of the simulations was executed prior to initiation of this study to minimize operational errors and interruptions during the educational intervention. While one student at a time acted as the primary provider in each simulation, the other three in the group observed and were able to assist their peers if asked for help.

Upon arrival to their simulation session, the SRNAs selected a piece of paper out of an envelope that had the number 1-24 on it signifying each student’s personal identifier number. A third-party participant kept a roster of participants and associated number that was kept in a locked cabinet and destroyed after the post tests have were distributed. They were then given 15 minutes to take a written pre-test (Appendix B) in the conference room and then had five minutes to orient to the simulation setting. The randomized number that the students selected was written
on the test so that results could be evaluated at the end of the procedure. The SRNAs participated in the four simulations in order from A-D. The first simulation (Appendix D) was created with the intention of teaching SRNAs the uses and adverse effects of calcium channel blockers. The first SRNA who selected the letter ‘A’ during randomization acted as the primary anesthesia provider and was given pertinent information about the patient, see Appendix D. They were given ten minutes to complete the simulation. After the scenario was completed, the facilitator reset the room for the next simulation to begin. The second simulation (Appendix E) was created with the purpose of highlighting the importance of understanding the hemodynamic instability of a patient on ACE-inhibitor therapy for chronic hypertension. The SRNA who selected the letter ‘B’ during randomization was the primary anesthesia provider of this simulation. This SRNA was also given all of the pertinent information about the simulated patient that would guide them in their anesthetic management choices. The individual then had ten minutes to complete this simulation. Again, the facilitator reset the room before beginning the third simulation. The third simulation (Appendix F) was created with the purpose of helping the SRNAs to improve their understanding of the pharmacodynamics of nitroglycerin. The SRNA who selected the letter ‘C’ during randomization acted as the primary anesthesia provider of this scenario and had ten minutes to complete the scenario. The final simulation (Appendix G) was created to help the SRNAs gain a better understanding of the pharmacokinetics and pharmacodynamics of sodium nitroprusside. The SRNA who selected the letter ‘D’ during randomization was the primary anesthesia provider in this simulation and had ten minutes to complete the scenario.

At the conclusion of the simulations, the subjects and the facilitator moved to the conference room attached to the simulation suite to debrief. Prior to initiation of this study, the
facilitator underwent a training created by a simulation training and education laboratory designed to ensure debriefings are appropriate and of quality. The debriefing session involved a discussion of the events that occurred during the simulations and serve to reinforce the objectives of each simulation. The material discussed during the debriefing sessions is outlined in Appendices D, E, F, and G. After the debriefing had concluded and prior to leaving, the SRNAs then took the written post-test (Appendix B) to measure if their understanding of the material was enhanced by participation in the simulation. The randomized number that the students selected prior to the educational intervention was again written on the test so that results can be evaluated at the end of the procedure. The participants were encouraged not to look up any of the answers to the questions on the test after leaving the simulation suite and were assured that at the end of the research study, the correct answers would be provided.

One month after completion of the simulations, the investigator of this study came to the subjects’ classroom and asked participants to fill out the written 1-month post-test (Appendix B). The randomized number that the students selected prior to the simulation intervention was written on the test so that results can be evaluated at the end of the procedure. The third party that had kept the roster of participants and associated numbers was present to inform participants of their number. After the 1-month post test was distributed and numbers were written on the test, this third-party participant destroyed and discarded the roster. These results were then uploaded into a spreadsheet on a password protected personal computer and performance on the test was analyzed to assess for knowledge acquisition, retention, and decay. No personal identifying information was retained or recorded on this computer.
Data Analysis

The data collected from the Pharmacology Experiential Learning Tool was compiled into an Excel document and was analyzed both qualitatively and quantitatively. Demographic data was analyzed at a nominal and ordinal level. Descriptive and inferential statistics were completed by exporting the data into the R statistical software. To help answer the two research questions, paired two tailed t-tests were performed to assess for knowledge acquisition and knowledge retention. Due to the small sample size, the margin of error may interfere with appropriate inferential analysis. With a sample size of 15 SRNAs, out of the possible 24 enrolled in the program, the margin of error would be 13%.

Protection of Human Rights

This research study was reviewed by Georgetown’s Institutional Review Board prior to initiation. All researchers involved completed a course approved by the National Institute of Health regarding protection of human subjects (see Appendix H). Before recruiting volunteers to participate, the SRNAs were provided information regarding the purpose of the study and how confidentiality would be maintained throughout. The SRNAs were also guaranteed that their performance in the simulation was confidential and would in no way influence their standing in the Doctor of Nurse Anesthesia Program. All informed consent documents, pretests, and post-tests were secured by password protected computer and/or via a locked cabinet which was only accessible by researchers involved in this study. The tests that the students completed contained no personal identifiers. The notes taken by the facilitator of this educational intervention for the
purpose of the debriefing conversation was destroyed at the completion of the simulation sessions. The roster connecting subject names with their identification number was also destroyed and discarded immediately after completion of the post test.
CHAPTER 4: RESULTS

Introduction to Findings

This chapter summarizes the results from the study which help answer the two research questions identified in chapter 1. The first research question asked if the addition of a high-fidelity simulation intervention would provide an advantage over didactic instruction alone in initial pharmacologic knowledge acquisition. The second research question asked if the addition of a high-fidelity simulation intervention would provide an advantage over didactic instruction alone in long-term pharmacologic knowledge retention. There are three sections; the first will discuss the demographic characteristics of the convenience sample that participated in the study, the second will discuss the results relevant to answer the first research question, and the third will discuss the results relevant to answer the second research question.

Sample

Of the 24 first year SRNAs in the Mid-Atlantic nurse anesthesia program, 15 volunteered to participate in this study. The previously calculated recommended sample size to ensure a 90% confidence interval and 5% margin of error (Appendix A) was 23 SRNAs. All 15 SRNAs that volunteered to participate completed all phases of the study. Demographic questions collected from each participant included gender, age, years of nursing experience, years of critical care nursing experience, and the type of critical care unit worked prior to entering the nurse anesthesia program. Results from these demographic questions are listed in Table 1 below.
Eleven female SRNAs and four male SRNAs participated. Participants ranged in age from 25 to 33 years old with the average being 28.7 years (+2.6 years). The participants had an average 4.5 years of nursing experience and 3.5 years of critical care nursing experience. Prior to entering the nurse-anesthesia program, 33% (n=5) SRNAs worked in a Cardiothoracic ICU, 20% (n=3) SRNAs worked in a Surgical ICU, 20% (n=3) SRNAs worked in an ICU other than listed in the questionnaire, 13% (n=2) SRNAs worked in a Medical ICU, 7% (n=1) SRNA worked in a Neurosurgical ICU, and 7% (n=1) SRNA worked in a Trauma ICU.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sample (n=15)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gender</strong></td>
<td></td>
</tr>
<tr>
<td>Male (n)</td>
<td>4 (27%)</td>
</tr>
<tr>
<td>Female (n)</td>
<td>11 (73%)</td>
</tr>
<tr>
<td><strong>Age (mean ± SD)</strong></td>
<td>28.7 ± 2.6 years</td>
</tr>
<tr>
<td><strong>RN Experience (mean ± SD)</strong></td>
<td>4.5 ± 1.8 years</td>
</tr>
<tr>
<td><strong>ICU Experience (mean ± SD)</strong></td>
<td>3.5 ± 1.6 years</td>
</tr>
<tr>
<td><strong>Previous ICU Experience</strong></td>
<td></td>
</tr>
<tr>
<td>Neurosurgical ICU (n)</td>
<td>1 (7%)</td>
</tr>
<tr>
<td>Surgical ICU (n)</td>
<td>3 (20%)</td>
</tr>
<tr>
<td>Medical ICU (n)</td>
<td>2 (13%)</td>
</tr>
<tr>
<td>Cardiothoracic ICU (n)</td>
<td>5 (33%)</td>
</tr>
<tr>
<td>Trauma ICU (n)</td>
<td>1 (7%)</td>
</tr>
<tr>
<td>Other ICU (n)</td>
<td>3 (20%)</td>
</tr>
</tbody>
</table>

*Results Research Question 1*

The first research question asked, “Does the addition of a high-fidelity simulation intervention using debriefing provide an advantage over didactic instruction alone in initial pharmacologic knowledge acquisition?” To investigate this question, a simulation-based
learning experience was added to the formal didactic pharmacology course. Its effect on SRNA’s knowledge acquisition was then assessed by the comparison of scores from a pretest and post-test.

The SRNAs baseline pharmacologic knowledge was assessed by a pretest prior to the initiation of the simulation-based learning experience. Ten questions of other topics in pharmacology that were taught in the same time period served as control questions. The subject matter of these questions was not covered in the simulation and therefore are called non-simulation questions (NS questions). The other 10 questions were designed to assess knowledge of antihypertensives and vasodilators (AV questions); the subject matter of these questions corresponded to events in the simulation. The average score on the pretest for the 10 NS questions was 79% (standard deviation [$SD$] = 7.4%). The average score on the pretest for the 10 AV questions was 81% ($SD = 5.9\%$) (see Figure 1). A paired t-test showed no significant difference in the scores on the pretest between the AV and NS questions ($P = .34$).

![Figure 1: Pretest Scores.](image)

**Figure 1: Pretest Scores.**
SRNAs scores on the pretest for the non-simulation (NS) questions and the antihypertensive/vasodilator (AV) questions. Averages were 79% and 81% respectively.
Immediately after the simulation was implemented, the SRNAs took the post-test which included 20 questions total. The average for the NS questions on the post-test was similar to the pretest, at 78% ($SD = 6.8\%$). All 15 SRNAs that participated in the research study scored 100% on the post-test AV questions (see Figure 2). A paired t-test showed that the difference in improvement of -1% and 19% on the NS and AV questions, respectively, was significant ($P < .001$).

![Figure 2: Post-test Scores](image)

SRNAs score on the first post-test. The average score on non-simulation (NS) questions was 78%. All fifteen participants scored 100% on the antihypertensive/vasodilator (AV) questions.

**Results Research Question 2**

The second question asked, “Does the addition of a high-fidelity simulation intervention using debriefing provide an advantage over didactic instruction alone in long-term pharmacologic knowledge retention?” To investigate this, a post-test was distributed to the SRNAs participating in this research study one month after the simulation-based learning experience was executed. The effect of this addition on SRNA’s long term knowledge retention
was assessed by comparing the scores from the pretest, post-test and 1-month post-test. The average score on the pretest for the NS questions was 79% ($SD = 7.4\%$), and 81% ($SD = 5.9\%$) for the AV questions. One month later, the average score on the NS questions on the 1-month post-test was 64% ($SD = 8.3\%$). Like the initial post-test, all participants scored 100% on the AV questions on the 1-month post-test (see Figure 3).

**Figure 3: 1-Month Post-test Scores**
SRNAs score on the 1-month post-test. The average score on non-simulation (NS) questions was 64%. All fifteen participants scored 100% on the antihypertensive/vasodilator (AV) questions.

A paired t-test showed that the difference in improvement of -15% and 20% from the means of the NS and AV questions respectively was significant ($P < .001$).
Figure 4: Averages on all Tests
Average scores for the non-simulation (NS) and antihypertensive/vasodilator (AV) questions on all tests throughout research project.
CHAPTER 5: DISCUSSION OF RESULTS

Discussion

This pilot study was designed to determine if supplementing didactic pharmacology lectures with a simulation-based learning experience would improve the short-term pharmacologic knowledge acquisition and long-term pharmacologic knowledge retention in SRNAs. During their training, SRNAs are introduced to new pharmacologic information that they will need to recall for the entirety of their career. For this reason, methods to minimize the pharmacologic knowledge deterioration have been investigated,\(^{29}\) including experiential learning using HFS.\(^{10,22,24}\) Experiential learning has previously been successful in increasing knowledge retention in many different clinical disciplines.\(^{13,36}\) The results of this study serve to further validate these findings and suggest HFS may be a valuable educational adjunct when teaching pharmacology to advanced practice nurses.

This study found that supplementing a didactic nurse anesthesia pharmacology course with a simulation-based learning experience improved both knowledge acquisition and long-term retention. Knowledge acquisition was shown to be improved after completion of the simulation-based learning experience by comparing the scores from the pretest to the post-test on the non-simulation (NS) and the antihypertensive and vasodilator (AV) questions. Scores on the pretest suggested that after attending only the didactic pharmacology lectures, the SRNAs participating in this study displayed an equal baseline knowledge between the NS material (79%) and the AV material (81%). Following the implementation of the simulation-based learning experience regarding antihypertensives and vasodilators, the SRNAs’ average score on the post-test NS
questions remained equivalent to the pretest (78%). However, on the same post-test, all 15 participants improved their score on the AV questions to 100%. These results reveal that the simulation experience was successful to increase the SRNA’s acquisition of pharmacologic knowledge. Our results are similar to those published by other researchers including Lorello et al. and Ortner et al., supporting the evidence that simulation instruction is more effective for acquiring knowledge than non-simulation instruction. Lorello et al conducted a systematic review synthesizing evidence for the effectiveness of simulation-based anesthesiology training. They included 77 studies in their meta-analysis and found that compared with no intervention, simulation was associated with moderate to large pooled effect sizes for all outcomes.\textsuperscript{35} Ortner et al conducted a study that aimed to evaluate the impact that simulation-based training had on anesthesia resident’s long-term knowledge retention.\textsuperscript{36} Their results indicate that lectures enhanced with simulation-based training produced superior performance and competency.\textsuperscript{36}

Knowledge retention was also shown to be improved by comparing the scores of the NS and AV questions on the post-test to those on the 1-month post-test. The average score on the NS questions deteriorated from 78% to 64%, showing that knowledge gained during the pharmacology didactic lectures had begun to decay. In contrast, on the same 1-month post-test, all 15 SRNAs again scored 100% on the AV questions. The scores of the NS questions demonstrate that knowledge decayed after exposure to the simulation while the scores of the AV questions reflect simulation protected knowledge from decay. Since all questions on the post-tests were derived from pharmacology lectures taught at the same time, one would expect equal knowledge deterioration of all pharmacology topics.

One limitation to the internal validity of this study is the potential for testing bias. For example, a possible explanation to the sustained improvement that is seen on the AV questions
after taking the pretest could be explained by the participants “learning to take the test,” rather than learning the material. However, if testing bias was a major factor in the results, one would expect the averages of both the AV and NS questions on the 1-month post-test to be similar. These results indicate that the knowledge gained through the addition of an HFS experience was more resistant to decaying than the knowledge gained through didactic lectures alone. This result is consistent with other research that has shown simulation and other experiential learning trainings to be effective methods to improve clinical knowledge retention. For example, Madani et al. performed a randomized control trial on medical trainees analyzing long-term knowledge retention following a simulation based training on electrosurgical safety. Just like the results of this study, despite equal baseline test scores, the simulation group demonstrated higher scores compared to the control group immediately, at three months, and one year later.23 Another example demonstrating the effects that simulation has on long term knowledge retention and supporting the results of this paper was performed by Silverstein et al. They used a tele-immersive simulation experience to teach surgical residents hepatic surgical principles. The simulation experience demonstrated significant improvement in mean scores from pretest to post-test, and displayed complete knowledge retention at a six-month delayed test.56

The addition of simulation and other innovative teaching strategies into clinical curriculums has been researched to better understand their effects on students’ learning outcomes. Although there is not a significant amount of research regarding the addition of experiential learning into pharmacology curriculums, Thomas et al recently evaluated the implementation of experiential learning in an undergraduate pharmacology class.29 The study examined the changes in standardized test scores and student evaluations after implementation of games and other activities that required active learning into a pharmacology curriculum. With
traditional didactic pharmacology lectures, 40% of their class achieved less than the benchmark score on the pharmacology specialty exam. After implementing innovative teaching strategies that engaged the students in active learning, fewer than 3% achieved less than the benchmark score.29 The results from this study showed similar marked improvement of pharmacologic knowledge acquisition in students after implementing a teaching strategy that engages students beyond traditional didactic lectures.

Limitations and Future Recommendations

To develop stronger research on this topic in the future, some potential limitations of research study should be noted. This pilot study measured the effect that HFS had on pharmacologic knowledge acquisition and long-term knowledge retention at one DNAP program and suggested a highly favorable effect. The recommended sample size that was calculated to ensure a 90% confidence interval and 5% margin of error prior to beginning this study was 23. Only 15 SRNAs voluntarily participated in this research study, leaving a margin of error of 13% and increasing the risk of a Type II error. However, despite the small sample size, we found a significant difference in knowledge acquisition and retention following this intervention. Because all study participants were enrolled in the same program, it will be important to validate these encouraging findings in a larger, multi-site study to rule out the influence of potential unknown confounding factors. The gender demographics of this study were not consistent with the national trends. Men make up approximately 40% of the CRNA population,57 and in this study, account for only 27%. An ideal follow-up study would be designed to incorporate a sample that is representative of the profession as a whole.
Ideally, this study would have been completed by dividing the convenience sample into two separate groups and only exposing half of the volunteers to the simulation-based learning intervention and then testing all SRNAs with the two post-tests. A follow-up study should include a control group to improve internal validity by further controlling for the influence of testing bias between the pre and post-tests. Then, the results from the two separate groups would be compared and analyzed for knowledge acquisition and retention.

This study demonstrated that after only one month, knowledge acquired through didactic lecture alone showed deterioration. Therefore, another recommendation for future studies would be to expand the window of measurement for long-term knowledge retention by retesting participants a year after the simulation intervention to investigate if differences still exist between retention of the didactic information and the information that was supplemented with a simulation-based learning intervention. This could help determine if refresher simulation sessions would be valuable prior to program completion.

As previously mentioned, the results of this study are not only relevant to the nurse anesthesia community, but to all students of clinical pharmacology including nursing, advanced practice nursing, and medical programs. Therefore, educational researchers in these disciplines should consider these results and develop studies that implement HFS into their curriculums and publish their results.

To our knowledge, this is the first study to evaluate the efficacy of incorporating simulation to specifically teach pharmacology in nurse anesthesia programs. While further research is needed to support the results of this pilot study, this investigation could influence faculty to begin incorporating HFS during pharmacology curriculum planning in order to improve educational efficacy for SRNAs enrolled in doctoral programs. If this study inspires
researchers to investigate this topic further, and additional evidence is found that supports these results, pharmacology curriculums could move beyond didactic only teaching and incorporate active learning methods, including HFS with favorable outcomes to students.

**Implications**

0The results from this pilot study suggest that adding HFS into the pharmacology curriculum of a nurse anesthesia program enhances the memory formation of pharmacologic agents, increasing long-term knowledge retention. The results may also be applicable to other disciplines including medicine, nursing, and advanced practice nursing as these curriculums all require clinical pharmacology. Faculty that are responsible for creating the pharmacology curriculum for each of the clinical programs would benefit from the incorporation of simulations into the curriculum, or the addition of a pharmacology simulation lab to supplement the traditional didactic lectures. Uniquely for SRNAs, the Council on Accreditation of Nurse Anesthesia Educational Programs has announced a change in degree requirements. They stated that “all accredited programs must offer a doctoral degree for entry practice by January 1, 2022.” Transforming the currently required master’s degree into a doctoral degree will subsequently lengthen the nurse anesthesia curriculums. SRNAs will now be required to retain the knowledge they learned up to three years prior to taking the NCE in order to successfully pass. Increasing pharmacologic knowledge retention, a key component of the NCE, may increase the SRNAs likelihood of passing on the first attempt. More importantly, increasing pharmacologic knowledge retention will provide a strong basis for optimal clinical decision making, mitigating the potential for medication errors and improving patient safety. Because
pharmacology is an essential component to nursing and medical education in general, these results may have implications beyond nurse anesthesia curriculums. Therefore, the benefits of HFS as a pedagogical strategy in pharmacology education should be further explored not only nurse anesthesia programs, but other nursing and medical school programs as well.
## APPENDIX A: RAOSOFT SAMPLE SIZE CALCULATOR

<table>
<thead>
<tr>
<th>Sample size calculator</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What margin of error can you accept?</strong></td>
<td>5 %</td>
</tr>
<tr>
<td>5% is a common choice</td>
<td></td>
</tr>
<tr>
<td><strong>What confidence level do you need?</strong></td>
<td>90 %</td>
</tr>
<tr>
<td>Typical choices are 90%, 95%, or 99%</td>
<td></td>
</tr>
<tr>
<td><strong>What is the population size?</strong></td>
<td>24</td>
</tr>
<tr>
<td>If you don't know, use 20000</td>
<td></td>
</tr>
<tr>
<td><strong>What is the response distribution?</strong></td>
<td>50 %</td>
</tr>
<tr>
<td>Leave this as 50%</td>
<td></td>
</tr>
<tr>
<td><strong>Your recommended sample size is</strong></td>
<td>23</td>
</tr>
<tr>
<td>This is the minimum recommended size of your survey. If you create a sample of this many people and get responses from everyone, you're more likely to get a correct answer than you would from a large sample where only a small percentage of the sample responds to your survey.</td>
<td></td>
</tr>
</tbody>
</table>

- The margin of error is the amount of error that you can tolerate. If 90% of respondents answer yes, while 10% say no, you may be able to tolerate a larger amount of error than if the respondents are split 50-50 or 45-55. Lower margin of error requires a larger sample size.
- The confidence level is the amount of uncertainty you can tolerate. Suppose that you have 20 yes-no questions in your survey. With a confidence level of 95%, you would expect that for one of the questions (1 in 20), the percentage of people who answer yes would be more than the margin of error away from the true answer. The true answer is the percentage you would get if you exhaustively interviewed everyone.
- Higher confidence level requires a larger sample size.
- How many people are there to choose your random sample from? The sample size doesn't change much for populations larger than 20,000.
- For each question, what do you expect the results will be? If the sample is skewed highly one way or the other, the population probably is, too. If you don't know, use 50%, which gives the largest sample size. See below under More Information if this is confusing.
APPENDIX B: PHARMACOLOGY EXPERIENTIAL LEARNING TOOL

Pharmacology Experiential Learning Tool

*Please answer the following by selecting the most appropriate answer. Please choose only one option for each question.*

**Identification Number:** __________

**Demographic Questions:**
1. What is your gender?
   a. Male
   b. Female
   c. Prefer not to answer
   d. Other: _________________

2. What is your age in years?
   __________

3. How long did you work as an RN prior to entering the Doctoral of Nurse Anesthesia Program?
   ______ years (*please round to the nearest ½ year*)

4. Of those years, how many were spent working in an ICU?
   ______ years (*please round to the nearest ½ year*)

5. What type of intensive care unit did you work in prior to entering the Doctoral of Nurse Anesthesia Program?
   a. Neurosurgical ICU
   b. Surgical ICU
   c. Medical ICU
   d. Cardiothoracic ICU
   e. Trauma ICU
   f. Pediatric ICU
   g. Neonatal ICU
   h. Other: _________________

**Application of Knowledge Questions:**
6. Which antiarrhythmic medication has properties of all 4 classes of antiarrhythmics according to Vaughan Williams Classification of Antiarrhythmic Drugs?
   a. Lidocaine
   b. Amiodarone
   c. Procainamide
   d. Flecainide
7. Doses of atropine less than _______ can evoke a paradoxical response?
   a. 0.1 mg  
   b. 0.2 mg  
   c. 0.3 mg  
   d. 0.4 mg

8. A patient is prescribed Lisinopril daily to manage their hypertension. What do you tell them during their pre-operative visit and evaluation?
   a. Continue Lisinopril through the morning of surgery  
   b. Do not take the Lisinopril the day of surgery  
   c. Stop taking the Lisinopril 5 days before surgery  
   d. None of the above

9. Which opioid receptor specifically causes hypoventilation when stimulated?
   a. Mu1 receptor  
   b. Mu2 receptor  
   c. Kappa receptor  
   d. Delta receptor

10. During a case, you notice the patient’s blood pressure reads 195/100 mmHg. You scan the EKG and see a >1mm change in the ST depression. What is the best option to treat this?
    a. Sodium Nitroprusside  
    b. Hydralazine  
    c. Nitroglycerin  
    d. Nicardipine

11. A patient with chronic pain has been receiving 10mg of PO Methadone at home. What is the equipotent IV dose?
    a. 1 mg  
    b. 10 mg  
    c. 5 mg  
    d. 100mcg

12. You just gave a patient 5mg IV Hydralazine. When do you expect to see the peak effect?
    a. 1.5 minutes  
    b. 5 minutes  
    c. 15 minutes  
    d. 30 minutes

13. What is the elimination half-life of morphine?
    a. 1-2 hours  
    b. 3-4 hours  
    c. 5-6 hours  
    d. 10-12 hours
14. Which antihypertensive agent is the most appropriate in counteracting the physiologic effects of a pheochromocytoma?
   a. Nifedipine
   b. Sodium Nitroprusside
   c. Nitroglycerin
   d. Hydralazine

15. A patient receives metoprolol IV immediately before surgery. What vasodilator should you avoid intraoperatively?
   a. Nitroglycerin
   b. Verapamil
   c. Hydralazine
   d. Sodium Nitroprusside

16. What is a therapeutic plasma concentration of Digoxin?
   a. 2.1-3.5 ng/mL
   b. 5.1-6.7 ng/mL
   c. 0.5-1.2 ng/mL
   d. 0.1-0.4 ng/mL

17. What is the mechanism of action of aspirin?
   a. Irreversibly inhibits pro-aggregate TxA₂
   b. Reversibly inhibits pro-aggregate TxA₂
   c. Irreversible ADP receptor antagonist
   d. GPIIb/IIIa inhibitor

18. During a preoperative interview on the day of surgery, a patient reveals that he/she took Enalapril this morning. What is the most appropriate action?
   a. Cancel/postpone the case
   b. Proceed with case and be prepared for intraoperative hypotension
   c. Proceed with case and be prepared for intraoperative hypertension
   d. Proceed with case, it will not affect intraoperative management

19. According to Vaughan Williams Classification of Antiarrhythmic Drugs, which class works by blocking beta adrenergic receptors?
   a. Class I
   b. Class II
   c. Class III
   d. Class IV
   e. Class V

20. Infusing Sodium Nitroprusside greater than ________ for more than 10 minutes increases the patient’s risk of developing cyanide toxicity.
   a. 1mcg/kg/min
   b. 2mcg/kg/min
c. 4mcg/kg/min
d. 6mcg/kg/min

21. Which of the following is a drug interaction that should be recognized when the patient’s medication reconciliation reveals they are on nonsteroidal anti-inflammatory drugs (NSAIDs)?
   a. Decreased lithium levels
   b. Decreased risk of GI bleed when combined with anticoagulants
   c. Decreased levels of highly protein bound drugs like warfarin, digoxin, and phenytoin
   d. Reduced effect of beta-adrenergic antagonists

22. The elimination half time of Nitroglycerin is:
   a. 1.5 minutes
   b. 5 minutes
   c. 15 minutes
   d. 30 minutes

23. Which calcium channel blocker is associated with reflex tachycardia?
   a. Nifedipine
   b. Diltiazem
   c. Verapamil
   d. All of the above

24. Which antiarrhythmic medication can cause a systemic lupus erythematosus like syndrome?
   a. Lidocaine
   b. Flecainide
   c. Procainamide
   d. Ibutilide

25. During a surgery a patient receives high doses of Nitroglycerin and you suspect she has developed methemoglobinemia. What is the treatment of methemoglobinemia?
   a. Intralipid 20% 1.5ml/kg bolus, followed by 0.25ml/kg/min infusion for 10 minutes
   b. Methylene blue 1-2mg/kg over 5minutes
   c. Sodium thiosulfate 150mg/kg over 15 minutes
   d. Discontinue the use of nitroglycerin
### Performance
(skills and execution of plan)
- pre-op management
- intra-op management
- standard monitoring
- airway management

### Clinical Judgment
- knowledge of coexisting disease, anesthesia considerations
- identifying options
- vigilance and appropriate response

### Essential Attributes
- professionalism
- effective communication
- patient safety

### Application of Pharm Knowledge
- proper use of medication
- dosage of medication
- contraindications

### Overall Comments
APPENDIX D: SIMULATION 1

Simulation 1: Calcium Channel Blockers

Purpose: The purpose of this scenario is for the SRNA to have a better understanding of calcium channel blockers and their potential risks associated with use perioperative use.

Background: (information for facilitator) The student will be taking care of a patient with a history of hypertension (HTN) that is managed at home with metoprolol. The patient did not take their metoprolol within the past 24hrs and is therefore given 1mg IV in the pre-operative holding area. The student will induce general anesthesia and intubate under the guidance of a facilitator who will act as the student’s clinical preceptor. This preceptor will tell the student to give a calcium channel blocker that is contraindicated because of a dangerous interaction with beta blockers.

Learning Objectives:
During this scenario, participants will:
- Recognize the risks of administering verapamil to a patient who has taken a beta-adrenergic antagonist
- Learn the optimal pharmacologic management for hypertensive patients who are chronically treated with beta blocker therapy.
- Provide appropriate and timely interventions in response to patient’s hemodynamic changes.
- Integrate didactic education about calcium channel and beta blockers

Facilitator Notes:
There should be another facilitator not involved with the research study to act as the SRNA’s preceptor and to direct the SRNA through induction of general anesthesia and intubation. The patient will have a sustained increased blood pressure during and following endotracheal intubation. The preceptor will then direct to the SRNA to give 5mg of Verapamil. The student should realize that the patient had been given a beta blocker pre-operatively and recognize the risks of combining these medications. If not, then the patient will develop complete heart block intraoperatively.

Supplies:
- OR bed
- HFS manikin
- Monitor providing EKG, SpO₂, EtCO₂, BP, temperature
- Surgical hat and mask
- ETT, laryngoscope
- Anesthesia machine
- Induction medications in syringes
  - Propofol, ketamine, etomidate
- IV fluid, tubing, and IV (placed in manikin)
- Full anesthesia cart, ensuring there are nitroglycerin, sodium nitroprusside, hydralazine, labetalol, metoprolol, esmolol, diltiazem, nifedipine, verapamil, available
Premade infusions: nitroglycerin, sodium nitroprusside, fentanyl, remifentanil, dopamine, phenylephrine, esmolol

**Scenario Commencement:**
The student will be given a sheet of paper explaining the patient’s history:
- **Patient:** Rebecca Smith, 45y/o Female, 80kg, 160cm
- **Procedure:** tibial open reduction and internal fixation (ORIF)
- **Past medical history:** Rebecca Smith presented to the hospital for a tibial ORIF after falling downstairs. Her only other medical history includes hypertension which she is treated with the beta-adrenergic antagonist metoprolol.
- **Medications:** Metoprolol 25mg – last dose 36 hours ago
- **Hand-off:** The patient misunderstood her preoperative instructions did not take her metoprolol within the past 24 hours. The preoperative RN gave 1mg IV metoprolol before rolling the patient back to the operating room. This patient will need general anesthesia

**Pre-op Vital Signs:**

<table>
<thead>
<tr>
<th>EKG</th>
<th>Normal sinus rhythm (NSR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate</td>
<td>70</td>
</tr>
</tbody>
</table>

| SpO₂               | 99% on room air           |

| Blood Pressure     | SBP:120                   |
|--------------------| DBP:76                     |

<table>
<thead>
<tr>
<th>Temperature</th>
<th>36.5</th>
</tr>
</thead>
</table>

| Respiratory rate   | 15                         |

**Note:** Please verbalize all actions, as well as medication names and doses you plan to administer to the patient.

**Scenario Steps**

1. SRNA enters simulated operating room where patient is already on the table with monitors on. The SRNA will be instructed to induce general anesthesia and intubate with an endotracheal tube by his/her preceptor. The following information should be displayed on the monitor after the student assesses vital signs:

<table>
<thead>
<tr>
<th>EKG</th>
<th>Normal sinus rhythm (NSR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart rate</td>
<td>Between 70-75</td>
</tr>
</tbody>
</table>

| SpO₂               | 100%                      |

| Blood Pressure     | Cycling every minute     |
|--------------------| DBP:60-70                |

| EtCO₂              | Normal waveform          |
|--------------------| 31-35mmHg                |

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Between 36-36.5</th>
</tr>
</thead>
</table>

| Respiratory Rate   | 14-16                     |

2. After the preceptor assists the student with induction and intubation of the patient, the following vital signs will appear on the monitor:

| EKG                | Normal sinus rhythm (NSR) |
Heart rate between 70-75

<table>
<thead>
<tr>
<th>SpO₂</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blood Pressure</strong></td>
<td>Cycling every minute</td>
</tr>
<tr>
<td></td>
<td>SBP:180-190</td>
</tr>
<tr>
<td></td>
<td>DBP: 60-70</td>
</tr>
<tr>
<td><strong>EtCO₂</strong></td>
<td>Normal waveform</td>
</tr>
<tr>
<td></td>
<td>31-35mmHg</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td>Between 36-36.5</td>
</tr>
<tr>
<td><strong>Volatile Anesthetic</strong></td>
<td>2% Sevoflurane</td>
</tr>
</tbody>
</table>

3. The patient’s vital signs will show a sympathetic response to the recent intubation and remains hypertensive.
   a. SRNA should treat with any drug of choice (opioid, beta blocker, calcium channel blocker, vasodilator, deepen the volatile agent) and vital signs will remain close to the above values

4. After initial treatment by the SRNA shows no efficacy, the student’s preceptor will recommend the SRNA give 5mg Verapamil to the patient: “You know, I have been using 5mg of Verapamil lately in situations like this, and it has been working well for me. Let’s try that.”
   a. The student should voice concern that patient was treated with beta blocker preoperatively and that that combination of drugs is contraindicated. If this occurs, student should suggest a different pharmacologic treatment such as an opioid, beta blocker, calcium channel blocker, vasodilator, deepen the volatile agent (a different treatment than was attempted in step 3)

5. If SRNA gives verapamil, then have the patient go into complete heart block and the simulation would end here

<table>
<thead>
<tr>
<th>EKG</th>
<th>Third degree heart block</th>
</tr>
</thead>
<tbody>
<tr>
<td>SpO₂</td>
<td>99%</td>
</tr>
<tr>
<td><strong>Blood Pressure</strong></td>
<td>Cycling every minute</td>
</tr>
<tr>
<td></td>
<td>SBP:80-90</td>
</tr>
<tr>
<td></td>
<td>DBP: 45-50</td>
</tr>
<tr>
<td><strong>EtCO₂</strong></td>
<td>flattened waveform</td>
</tr>
<tr>
<td></td>
<td>27-30mmHg</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td>Between 36-36.5</td>
</tr>
<tr>
<td><strong>Volatile Anesthetic</strong></td>
<td>2% Sevoflurane</td>
</tr>
</tbody>
</table>

6. Simulation will end after 5 minutes, or if the patient ends up in heart block after Calcium channel blocker is administered.

**Debriefing Session Main Talking Points**
- What do you think happened here?
  o Beta blocker combined with calcium channel blocker sent the patient into heart block
- How could this situation have been handled better?
SRNA should not always blindly trust what the preceptor suggests. Student should be empowered to challenge unsafe practice. Important to understand drug interactions that are likely in anesthetic practice.

- What are some other pharmacologic options that the anesthesia team could have used in this scenario?
  - Note that calcium channel blockers selective for vascular calcium channels would be acceptable (nifedipine, diltiazem)
- Which calcium channel blockers cause reflex tachycardia? Which do not and why?
- What would you do if your patient did go into heart block?
  - Transcutaneous pacing
  - Maybe atropine if hemodynamically unstable
Simulation 2: ACE Inhibitors

**Purpose:** The purpose of this scenario is to better understand the hemodynamic instability of a patient on ACE inhibitor therapy.

**Background:** (information for facilitator) A patient is having a laparoscopic procedure to treat cholelithiasis. Other significant medical history includes hypertension, hyperlipidemia, obesity, and obstructive sleep apnea. Patient is on Lisinopril for treatment of hypertension and took dose the morning of surgery. SRNAs should treat pressure with a goal to maintain BP within 20% of baseline blood pressure (BP). BP will continue to trend down, then after treatment, return to an appropriate level.

**Learning Objectives:**
During this scenario, participants will:
- Recognize hemodynamic changes associated with general anesthesia on a patient on ACE inhibitors
- Provide appropriate and timely interventions in response to patient’s hemodynamic changes
- Integrate didactic education about antihypertensives and vasodilators into clinical practice

**Facilitator Notes:**
Throughout this scenario, the SRNA will be required to treat a fluctuating blood pressure. The facilitator should be prompt in providing real time vital signs of the patient for the participant to respond. At the end of this scenario, the debriefing should focus on the anticipation of hypotension for a patient on ACE-inhibitors, and the proper management of this type of patient. The total length of this scenario should last about 5 minutes.

**Supplies:**
- OR bed
- HFS manikin
- Monitor providing EKG, SpO₂, EtCO₂, BP, temperature
- Surgical hat and mask
- ETT
- Anesthesia machine
- Induction medications in syringes
  - Propofol, ketamine, etomidate
- IV fluid, tubing, and IV (placed in manikin)
- Fully stocked anesthesia cart with all medications
- Premade infusions: nitroglycerin, sodium nitroprusside, fentanyl, remifentanil, dopamine, phenylephrine, esmolol

**Scenario Commencement:**
SRNA provided with a sheet that includes these pertinent details of the patient:
- **Patient:** Matt Smith, 46y/o Male, 98kg, 168cm, BMI 35
- **Procedure**: laparoscopic cholecystectomy
- **Past medical history**: Matt Smith presented to the hospital for a laparoscopic cholecystectomy to treat cholelithiasis. Other pertinent medical history includes hypertension, hyperlipidemia, obesity, and obstructive sleep apnea.
- **Medications**: Lisinopril 20mg QID, Atorvastatin 15mg QID - taken this morning with sip of water
- **Hand-off**: The patient has been intubated with a 7.5 endotracheal tube and surgery began about 15 minutes ago. The CRNA that you are relieving tells you that she had been having trouble with fluctuating blood pressures and has had to treat low blood pressure a few times.
  - **Pre-op vital signs**:
    | EKG                      | Normal sinus rhythm (NSR) |
    |                          | Heart rate: 70bpm         |
    | SpO₂                     | 99% on room air           |
    | Blood Pressure           | SBP: 140mmHg              |
    |                          | DBP: 86mmHg               |
    | Temperature              | 36.5°C                    |
    | Respiratory rate         | 15 per minute             |

**Note**: Please verbalize all actions, as well as medication names and doses you plan to administer to the patient.

**Scenario Steps**
1. SRNA enters simulated operating room where patient is already induced and intubated with an endotracheal tube in proper position under general anesthesia, and receives the information listed above. The following information should be displayed on the monitor:
   | EKG                      | Normal sinus rhythm (NSR) |
   |                          | Heart rate between 60-70bpm |
   | SpO₂                     | 99%                        |
   | Blood Pressure           | Cycling every minute      |
   |                          | SBP: 100-120mmHg           |
   |                          | DBP: 60-70mmHg             |
   | EtCO₂                    | Normal waveform            |
   |                          | 31-35mmHg                  |
   | Temperature              | Between 36-36.5°C          |
   | Respiratory Rate         | 15 per minute              |
   | Volatile Anesthetic      | 2% Sevoflurane             |

2. New vital signs updated shortly after SRNA finishes receiving background information on the patient
<p>| EKG                      | NSR, Heart rate between 90-100bpm |
| SpO₂                     | 99%                                 |
| Blood Pressure           | SBP: 70-75mmHg                     |
|                          | DBP: 35-40mmHg                     |
| EtCO₂                    | flattened waveform, 24-27mmHg      |
| Temperature              | Between 36-36.5°C                  |</p>
<table>
<thead>
<tr>
<th><strong>Respiratory Rate</strong></th>
<th>15 per minute</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Volatile Anesthetic</strong></td>
<td>2% Sevoflurane</td>
</tr>
</tbody>
</table>

3. SRNA should actively respond to blood pressure by verbalizing actions
   a. If student does not respond to this blood pressure within a minute, remind them to “look at their vital signs”
   b. If student responds and does not verbalize, facilitator should remind student to verbalize all actions
   c. If student gives a vasopressor, update vital signs as indicated by student’s drug of choice
      i. If ephedrine is given:
         | **EKG** | NSR, Heart rate between 110-120 |
         | **SpO₂** | 99% |
         | **Blood Pressure** | SBP:100-110, DBP: 60-70 |
         | **EtCO₂** | Normal waveform, 31-35mmHg |
         | **Temperature** | Between 36-36.5 |
         | **Respiratory Rate** | 15 per minute |
         | **Volatile Anesthetic** | 2% Sevoflurane |
      ii. If phenylephrine is given:
         | **EKG** | NSR, Heart rate between 60-65 |
         | **SpO₂** | 99% |
         | **Blood Pressure** | SBP:100-110, DBP: 60-65 |
         | **EtCO₂** | Normal waveform, 31-35mmHg |
         | **Temperature** | Between 36-36.5 |
         | **Respiratory Rate** | 15 per minute |
         | **Volatile Anesthetic** | 2% Sevoflurane |

d. If student decides to decrease volatile anesthetic, vital signs would remain unchanged
e. If student decides to increase IV fluid rate, vital signs would remain unchanged
f. If student administers a pharmacologic intervention other than those listed above, use the associated medication on the simulation software to determine the outcome.

4. After action is taken, next set of vital signs would appear on monitor
   | **EKG** | NSR, Heart rate between 80-85 |
   | **SpO₂** | 99% |
   | **Blood Pressure** | SBP:80-85, DBP: 50-55 |
   | **EtCO₂** | Flattened waveform, 27-30mmHg |
   | **Temperature** | Between 36-36.5 |
   | **Respiratory Rate** | 15 per minute |
   | **Volatile Anesthetic** | 2% Sevoflurane |
5. SRNA should again treat this blood pressure or cycle another pressure – if this is done, the same set of vital signs would appear
   a. Same responses as step #3 above
6. This process should repeat until the simulation lasts about 5 minutes in entirety.

**Debriefing Session Main Talking Points**

- What do you think was happening here?
  o Patients on ACE inhibitors and ARBs can have refractory hypotension in conjunction with general anesthesia. The anesthesia provider should be prepared for intraoperative hypotension

- How do you recognize ACEi and ARBs on a patient’s medicine reconciliation?
  o ACEi= -pril, ARBs= -sartan

- How long before surgery is it recommended for patients on ACEi to hold their dose
  o 24-48 hours prior, depending on the ACEi and the pharmacokinetics
    ▪ Captopril = DOA: 6-10hrs, but Enalapril=24-60hrs

- What could we do as providers to prepare for this situation and take better care of this type of patient?
  o In pre-op, ask the patient when’s the last time they took their medicine, and if they respond with anytime in the last 24hrs, have a phenylephrine drip ready

- What is the target blood pressure for this patient? (w/in 20% of baseline= ~140/75mmHg)
Simulation 3: Microlaryngoscopy Stimulation

Purpose: The purpose of this scenario is to have a better understanding the pharmacodynamics of antihypertensives, and apply previous learned knowledge to a clinical scenario.

Background: The patient is having a microlaryngoscopy to treat a laryngeal papilloma. Other history significant for hyperlipidemia, HTN. The patient will be induced and intubated with an endotracheal tube, and the ENT surgeon will place patient in suspension, causing extreme sympathetic stimulation with corresponding response in the patient’s vital signs. After a moment of extreme tachycardia and hypertension, the patient will begin to have ST changes displayed on the monitor.

Learning Objectives:
During this scenario, participants will:
- Recognize hemodynamic changes associated with microlaryngoscopy procedures
- Provide appropriate and timely interventions in response to patient’s hemodynamic changes
- Integrate didactic education about nitroglycerin and other vasodilators into clinical practice

Facilitator Notes:
Throughout this scenario, the SRNA will be required to treat an extreme sympathetic response to a surgical stimulation during microlaryngoscopy. Long acting medications (opioids and some beta blockers) would not be the best choice for this procedure, as there is not much, if any, pain after the procedure is over. The student should recognize that when stimulation ends, the sympathetic response will also discontinue.

Supplies:
- OR bed
- HFS manikin
- Monitor providing EKG, SpO2, EtCO2, BP, temperature
- Surgical hat and mask
- ETT
- Anesthesia machine
- Induction medications in syringes
  - Propofol, ketamine, etomidate
- IV fluid, tubing, and IV (placed in manikin)
- Syringes labelled nitroglycerin, nitroprusside, hydralazine, labetalol, metoprolol, esmolol
- Premade infusions: nitroglycerin, sodium nitroprusside, fentanyl, remifentanil, dopamine, phenylephrine, esmolol

Scenario Commencement:
Prior to the start of this simulation, the student will receive written information about the patient and their past medical history:
- Patient: Ben Childs, 49y/o Male, 100kg, 165cm
- **Procedure:** microlaryngoscopy  
- **Past medical history:** Ben Childs presented to the hospital for a microlaryngoscopy to treat a laryngeal papilloma that has resulted in recent changes in voice quality. Other pertinent history includes hypertension, hyperlipidemia, obesity, and obstructive sleep apnea.  
- **Medications:** HCTZ 10mg QID, Atorvastatin 15mg QID - both taken this morning with sip of water  

**Note:** Please verbalize all actions, as well as medication names and doses you plan to administer to the patient.

The facilitator should inform the SRNA that a microlaryngoscopy is a procedure where the patient is suspended in a direct laryngoscopy for the entire procedure. They should also be reminded that direct laryngoscopy is associated with a similar level of stimulation as surgical incision. The SRNA should be told this is a temporary stimulation and that there is not much, if any, pain associated in the postoperative phase.

**Scenario Steps:**

1. SRNA enters simulated operating room where patient is already induced and intubated with an endotracheal tube in proper position under general anesthesia, and receives the information listed above. The following information should be displayed on the monitor:

| EKG     | Normal sinus rhythm (NSR)  
|         | Heart rate between 60-70bpm  
| SpO₂    | 99%  
| Blood Pressure | Cycling every minute  
|         | SBP: 100-120mmHg  
|         | DBP: 60-70mmHg  
| EtCO₂   | Normal waveform  
|         | 31-35mmHg  
| Temperature | Between 36-36.5°C  
| Respiratory Rate | 15 per minute  
| Volatile Anesthetic | 2% Sevoflurane  

*Facilitator asks SRNA “the surgeon is asking if they can begin. Is the patient ready?”*

2. After the surgeon (a third-party participant acting as a surgeon for this scenario) places patient in suspension, patient develops extreme sympathetic response and next set of vitals displayed on the monitor:

| EKG     | Sinus Tachycardia  
|         | Heart rate between 120-125bpm  
| SpO₂    | 99%  
| Blood Pressure | Cycling every minute  
|         | SBP: 200-205mmHg  
|         | DBP: 110-115mmHg  
| EtCO₂   | Normal waveform  
|         | 31-35mmHg  
| Temperature | Between 36-36.5°C  
| Respiratory Rate | 15 per minute  
| Volatile Anesthetic | 2% Sevoflurane  

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3. SRNA should attempt to treat sympathetic response with a medication that would help blunt sympathetic response
   a. Due to the procedure’s short duration, a medication with a rapid onset and elimination is preferred. Although if student gives a medication with an extensive elimination, discuss this in the debriefing session.
4. After a few cycles of the blood pressure cuff, the vital signs remain as above, and the patient’s EKG will start to show ST depression

<table>
<thead>
<tr>
<th>EKG</th>
<th>Sinus Tachycardia, with ST depression (-1.2mm) in two leads</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SpO₂</strong></td>
<td>99%</td>
</tr>
<tr>
<td>Blood Pressure</td>
<td>Cycling every minute</td>
</tr>
<tr>
<td></td>
<td>SBP: 200-205mmHg</td>
</tr>
<tr>
<td></td>
<td>DBP: 110-115mmHg</td>
</tr>
<tr>
<td>EtCO₂</td>
<td>Normal waveform</td>
</tr>
<tr>
<td></td>
<td>31-35mmHg</td>
</tr>
<tr>
<td>Temperature</td>
<td>Between 36-36.5°C</td>
</tr>
<tr>
<td>Respiratory Rate</td>
<td>15 per minute</td>
</tr>
<tr>
<td>Volatile Anesthetic</td>
<td>2% Sevoflurane</td>
</tr>
</tbody>
</table>

a. If the student does not notice ST changes after 1 minute, the facilitator should ask SRNA if they notice anything different with the EKG rhythm

5. The SRNA should now recognize that the patient has developed active cardiac ischemia due to the continuous sympathetic response. The SRNA can either treat with nitroglycerin and/or have a conversation with surgeon. If the SRNA decides to have a conversation with surgeon, they should emphasize change in patient condition/status and discuss pharmacologic management of cardiac changes versus suspension/termination of procedure.
   a. If sodium nitroprusside is used, the ST changes should still be evident
   b. If student tries to deepen the volatile anesthetic, vital signs would remain the same
   c. If nitroglycerin is used:

<table>
<thead>
<tr>
<th>EKG</th>
<th>Normal sinus rhythm (NSR)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heart rate between 60-70bpm</td>
</tr>
<tr>
<td><strong>SpO₂</strong></td>
<td>99%</td>
</tr>
<tr>
<td>Blood Pressure</td>
<td>Cycling every minute</td>
</tr>
<tr>
<td></td>
<td>SBP: 100-120mmHg</td>
</tr>
<tr>
<td></td>
<td>DBP: 60-70mmHg</td>
</tr>
<tr>
<td>EtCO₂</td>
<td>Normal waveform</td>
</tr>
<tr>
<td></td>
<td>31-35mmHg</td>
</tr>
<tr>
<td>Temperature</td>
<td>Between 36-36.5°C</td>
</tr>
<tr>
<td>Respiratory Rate</td>
<td>15 per minute</td>
</tr>
<tr>
<td>Volatile Anesthetic</td>
<td>2% Sevoflurane</td>
</tr>
</tbody>
</table>

d. If SRNA initiates conversation with surgeon and requests suspension, surgeon should respond and say that is not an option, and insist that there are medications
that can treat the sympathetic surge that previous anesthesia providers have used in situations like these.

6. If SRNA treats with nitroglycerin or nitroprusside, vitals should only respond for 1 cycle of the BP cuff (as elimination ½ life is 1.5 minutes) and should return to the elevated values that they were after initial suspension
   a. SRNA may decide to start an infusion of either, and vital signs should return to baseline values

7. Simulation should end after 5 minutes

**Debriefing Session Main Talking Points**

- What do you think was going on here?
  o Sustained sympathetic stimulation causing ischemia to the heart
    ▪ Supply versus demand imbalance

- Let’s talk about the surgery
  o Microlaryngoscopy is relatively short procedure associated with minimal postoperative pain. Long acting medications would not be the optimal choice in this scenario because the medications will remain at therapeutic plasma concentrations despite termination of the stimulus and corresponding sympathetic nervous system response.

- What are the short acting vasodilators/antihypertensives that would be best to use in this scenario?
  o Esmolol, nitroglycerin, nitroprusside
    ▪ Remifentanil would be a great medication to use in this scenario as well; it has an immediate onset and a short elimination half-life and would help blunt the sympathetic stimulation from the suspension.

- What medications would not be ideal for this situation? Why not?
  o Hydralazine – decreases BP with little change in heart rate, onset is 15 minutes
  o Long acting Opioids - will last longer than the stimulation.
  o Labetalol – will last longer than stimulation

- When the patient starts to experience ST changes, which agent that we just listed is the best option to use?
  o Nitroglycerin (NTG) – this increases coronary blood flow to ischemic subendocardial areas. Sodium nitroprusside does the opposite- it dilates all coronary vessels, which means it has the potential to cause blood from to shunt from the ischemic areas of the heart and send it to the well perfused areas/
  o Esmolol affects heart rate more than blood pressure (as it is beta-1 adrenergic selective), improving oxygen supply and demand
  o Remifentanil – potent opioid that has a rapid onset and rapid elimination

- What is the half-life of nitroglycerin and why is that important?
  o 1.5 minutes. The clinical effect will be short-lived, so if the stimulus is necessary, an infusion may need to be started

- Major complication of using NTG?
  o At high doses, methemoglobinemia. (What is the treatment?)
    ▪ Methylene blue 1-2mg/kg given over 5 minutes
Simulation 4: Pheochromocytoma Resection

*Purpose:* The purpose of this scenario is to develop a greater understanding of the pharmacokinetics and pharmacodynamics of the medications used to treat pheochromocytoma and its associated complications.

*Background:* (information for facilitator) The patient has a history of pheochromocytoma and is having the tumor resected. The medical history should alert the SRNA to expect extreme variability in hemodynamics throughout the case, especially during tumor manipulation. The major takeaway from this scenario is for the student to have a better understanding of how, and when to use sodium nitroprusside.

*Learning Objectives:* During this scenario, participants will:
- Recognize hemodynamic changes associated with patients that have a history of pheochromocytoma
- Learn the optimal pharmacologic management for patients with pheochromocytoma
- Provide appropriate and timely interventions in response to patient’s hemodynamic changes
- Integrate didactic education about sodium nitroprusside into clinical practice

*Facilitator Notes:* Throughout this scenario, the SRNA will be required to continuously monitor blood pressure and heart rate of a patient that is expected to have hemodynamic instability during the resection of a pheochromocytoma. Sodium nitroprusside (SNP) is a potent venous and arterial dilator and is the best choice for treatment of hypertension associated with pheochromocytoma. SNP’s short half-life makes a continuous infusion the optimal drug-delivery approach. Students should be able to recognize and treat hypertension due to the unpredictable release of catecholamines from the adrenal tumor.

*Supplies:*
- OR bed
- HFS manikin
- Monitor providing EKG, SpO₂, EtCO₂, BP, temperature
- Surgical hat and mask
- ETT
- Anesthesia machine
- Induction medications in syringes
  - Propofol, ketamine, etomidate
- IV fluid, tubing, and IV (placed in manikin)
- Syringes labelled nitroglycerin, nitroprusside, hydralazine, labetalol, metoprolol, esmolol, diltiazem, nifedipine, phentolamine
- Premade infusions: nitroglycerin, sodium nitroprusside, fentanyl, remifentanil, dopamine, phenylephrine, esmolol
**Scenario Commencement:**

Prior to the start of this simulation, the SRNA acting as the primary anesthesia provider will be given written information about the patient.

- **Patient:** Kathleen Baker, 31y/o Female, 68kg, 159cm
- **Procedure:** adrenal tumor resection
- **Past medical history:** Kathleen Baker presented to the hospital for an adrenal tumor resection. She has no other significant history
- **Medications:** Phenoxybenzamine 10mg - taken this morning with sip of water
- **Hand-off:** The patient has just been intubated with a 7.0 endotracheal tube and is ready for surgery to begin. 100mg Lidocaine, 150mg propofol, 100mcg fentanyl, and 50mg rocuronium were used to facilitate intubation. The patient is now receiving 2% (1 MAC) sevoflurane

**Note:** Please verbalize all actions, as well as medication names and doses you plan to administer to the patient.

**Scenario Steps**

1. SRNA enters simulated operating room where patient is has just been induced and intubated with an endotracheal tube in proper position under general anesthesia, and receives the information listed above. The following information should be displayed on the monitor:

<table>
<thead>
<tr>
<th>EKG</th>
<th>Sinus Tachycardia</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Heart rate between 120-125bpm</td>
</tr>
</tbody>
</table>

| SpO2        | 100% |

<table>
<thead>
<tr>
<th>Blood Pressure</th>
<th>Cycling every minute</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SBP:200-210mmHg</td>
</tr>
<tr>
<td></td>
<td>DBP: 115-120mmHg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EtCO₂</th>
<th>Normal waveform</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>31-35mmHg</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Between 36.5-37°C</th>
</tr>
</thead>
</table>

| Volatile Anesthetic | 2% Sevoflurane |

2. Student should recognize increased blood pressure and heart rate and treat stimulation with a vasodilator, beta adrenergic antagonist or calcium channel blocker (Nitroglycerin, Sodium Nitroprusside, Hydralazine, Diltiazem, Nicardipine)

   a. If treating with hydralazine – should note to student that this takes 10-15min to reach peak effect
   b. If student tries to deepen the patient with the volatile anesthetic or administer an opioid, vital signs would remain the same.
   c. If student tries to treat with beta adrenergic antagonist, just the heart rate would change. New heart rate would be 100-115bpm
   d. If student tries to treat with labetalol, new heart rate would be 100-115bpm, new blood pressure would be 190-200mmHg systolic over 110-115mmHg diastolic.
   e. After treatment with pharmacologic intervention, monitor should display the following:

| EKG            | Normal sinus rhythm (NSR) |
Heart rate between 60-70bpm

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
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<tr>
<td><strong>Blood Pressure</strong></td>
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</tr>
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<td></td>
<td>SBP:100-120mmHg</td>
</tr>
<tr>
<td></td>
<td>DBP: 60-70mmHg</td>
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</tr>
<tr>
<td><strong>Temperature</strong></td>
<td>Between 36-36.5°C</td>
</tr>
<tr>
<td><strong>Volatile Anesthetic</strong></td>
<td>2% Sevoflurane</td>
</tr>
</tbody>
</table>

3. Facilitator should tell SRNA that they are about to resect tumor and to expect catecholamine surge
   a. Vital signs should reflect this surge:

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</thead>
<tbody>
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</table>

   b. Sodium nitroprusside would be the drug of choice around tumor manipulation. Remember that elimination half-life is about 2 minutes; effects will not last long and a continuous infusion should be prepared.

4. The vital signs will repeat as above, showing a sympathetic surge, then being treated by SRNA until it has lasted about 5 minutes.

**Debriefing Session Main Talking Points**

- What was happening in this scenario?
  - Pheochromocytoma was causing excessive catecholamine surges and sympathetic responses appeared in vital signs.
- What is the difference in how nitroglycerin and sodium nitroprusside work?
  - Nitroglycerin vasodilates more venous capacitance vessels decreasing preload whereas SNP dilates both arteries and venous capacitance vessels.
- What are the major risks with using SNP?
  - Cyanide toxicity, extreme hypotension, coronary steal
- What puts the patient at a greater risk of developing cyanide toxicity?
  - Running rates >2mcg/kg/min for longer than 10 minutes
- How do you treat this?
  - Initially treat with sodium thiosulfate 150mg/kg over 15 min. this will act as a sulfur donor, converting cyanide into thiocyanate
APPENDIX H: CITI COMPLETION FORM

This is to certify that:

Carter Gisriel

Has completed the following Citi Program course:

**Human Research**

Group 2. Social and behavioral research investigators and key personnel.

1 - Basic Course

Under requirements set by:

Georgetown University

Completion Date: 08-Sep-2018
Expiration Date: 07-Sep-2021
Record ID: 28573407

Verify at www.citiprogram.org/verify/?wd827dbbc-8a19-4c64-b6ea-79fe5bad4c4e-28573407
REFERENCES


