2007

Anesthesia Clinical Performance Outcomes: Does Teaching Methodology Make A Difference?

Nina E. McLain
Virginia Commonwealth University

Anesthesia Clinical Performance Outcomes: Does Teaching Methodology Make a Difference?

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Health Related Sciences at Virginia Commonwealth University

By

Nina E. McLain, MS, CRNA
Master of Science, Charity Hospital/Xavier University School of Nurse Anesthesiology, 1991
Certified Registered Nurse Anesthetist, 1991
Bachelor of Science, University of Southern Mississippi, 1989
Associate Degree in Nursing, Meridian Junior College, 1983

Chairman: Chuck Biddle, Ph.D., CRNA
Professor and Director of Research
VCU Department of Nurse Anesthesia

Virginia Commonwealth University
Richmond, Virginia
2007

ACKNOWLEDGEMENT

I would like to thank my committee, Dr. Diane Dodd-McCue, Dr. Jim Cotter, and Dr. Bill Hartland, for their guidance and direction. A most special thanks to Dr. Chuck Biddle, my dissertation chairman, who encouraged, supported, and illuminated the way for me throughout this process. Because of his belief in the merit of this study, his mentorship went above and beyond the requisite time most chairmen devote to their student's chosen topic. I also thank him for allowing me to build upon his previous work.

I thank the faculty and staff of the School of Allied Health Professions for their assistance and dedication to their students and the marvelous program they have built. A special thanks to the VCU nurse anesthesia department for providing encouragement, resources, and friendship along the way.

I thank my entire family for the sacrifices they made during this three year process. At times it seemed intolerable, yet, with their support, I was able to reach my goal and fulfill a dream. Without their support, this could never have happened.

I could not have completed this journey without the support from the 2004 Ph.D. cohort of the School of Allied Health Professions. Although we were from many different disciplines, they encouraged, helped, and supported me every step of the way. A whole hearted thanks to them all with a special thanks to Katie for everything.

At times, setbacks, or what I perceived as failures, taught me the most in this program. This was true even to the very end. Over the course of the program, I learned to extract what could be gleaned from these things and then set my sights on the next moment or step. A quote that is in part familiar to many, reflects the attitude I approached this program with and perhaps, it will inspire someone else to reach their goal.

Know the value of time.
Snatch, seize, and enjoy every moment of it.
No idleness, no laziness, no procrastination.
Never put off till tomorrow what you can do today.

Lord Chesterfield

TABLE OF CONTENTS

List of Tables

Table

List of Figures

Figure

Abstract

ANESTHESIA CLINICAL PERFORMANCE OUTCOMES: DOES TEACHING METHODOLOGY MAKE A DIFFERENCE?

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University.

Virginia Commonwealth University, 2007

Chuck Biddle, Ph.D., CRNA
Professor and Director of Research
VCU Department of Nurse Anesthesia

Researchers have studied memory recall of crisis-oriented or emotional events in non-educational settings. However, within the health care field, there has been a limited study of the the concept of recall of crisis oriented or emotional events in~~to~~ health care education. Crisis-oriented events such as natural disasters, acts of bioterroism, and industrial accidents, have been reported to impact memory.

Patient safety is a primary focus in anesthesia education, appropriate crisis management is imperative to quality anesthesia care. Due to the critical nature of anesthesia delivery, there is a strong, constant need to develop methods that will enhance, support, and improve current anesthesia practices that impact patient safety. Educational methodologies used by both clinical and didactic instructors that will improve teaching effectiveness need to be investigated to ensure that patient safety content is being delivered to nurse anesthesia students in a manner consistent with

the American Association of Nurse Anesthetists (AANAs) Council on Accreditation's (COAs) standards of care.

Utilizing a simulated anesthesia crisis situation, this study compared the differences in cognitive imprinting and application to practice between two content delivery methods, the written case study and patient safety vignettes, in nurse anesthesia students. The control group was given a written case study which is considered a traditional method of content delivery. The treatment groups studied vignettes, which are short, realistic, simulated audio-visual videos that demonstrate content to be relayed. The research hypothesis studied the use of anesthesia crisis oriented vignettes as an educational tool to impact memory recall, thus potentially improving application to clinical practice.

Hypotheses for the study were:

Hypothesis 1 (H1): Student anesthetists exposed to audio-visual vignettes will exhibit superior clinical performance during simulated apparatus-related crisis events, evidenced by higher group mean demonstration scores, when compared to a matched group exposed to written case studies.

Hypothesis 2 (H2): Student anesthetists exposed to audio-visual vignettes will exhibit superior recall of apparatus related material, evidenced by higher group mean post-test scores, when compared to a matched group exposed to written case studies.

Using the paired samples t-test and analysis of variance procedure (ANOVA), statistical findings were evaluated for significance. The different teaching methodologies were represented in the abbreviation of the variables studied. Two different crisis

oriented events were presented in vignette format, a malfunctioning unidirectional expiratory valve and a malfunctioning suctioning apparatus. Variables that were studied include: clinical performance during the anesthesia machine checkout process by recreating the stuck expiratory valve and malfunctioning suction apparatus scenarios.

Statistically, mixed results were obtained. The impact that the stuck expiratory valve vignette had on student recall and clinical performance was found to be insignificant. The impact resulting from exposure to the non-functioning suction apparatus vignette was found to be significant for both student recall and clinical performance. Other recall and clinical performance measures related to the non-functioning suction apparatus were also found to be significant.

Conclusions: In this research study, memory and clinical performance were impacted when the anesthesia provider incorporated the correct anesthesia apparatus checkout process and crisis management skills into their practice. This research demonstrated that under the conditions of this study, teaching methodology impacted some areas of clinical performance.

Due to the small sample size and because the clinical performance measurements tools were newly designed for this particular study, findings from this study cannot be generalized to any other group or population. However, the findings from this study merit further investigation into the potential use of vignettes as an educational methodology to impact clinical practice and improve patient safety.

CHAPTER 1: INTRODUCTION

Although vignettes have been used successfully to improve performance in disciplines outside of medicine, little research has been done to assess their efficacy in altering clinical practice when used as a teaching tool in nurse anesthesia. Current vignette related research has focused primarily on memory retention, the vicariousness of group learning, and use as an adjunct to traditional methodologies for teaching foundational anesthesia concepts. As focus on anesthesia patient safety intensifies, measures to improve clinical performance by anesthetists are needed.

In the 1950's, a publication by the motion picture industry addressed the scientific principles behind learning from audio-visual presentation (Miller, 1957). Miller discusses fundamental factors that typically result from the audio-visual format. These factors include: a) student motivation to learn, b) a cue or stimulus that is noticed, c) active participation, and d) reinforcement. Vignettes, when used in medical education, can meet these factors.

Nurse anesthesia students are typically adult, self-motivated learners that generally are highly motivated to learn. As anesthesia students move beyond the basic science portion of their education, the desire to acquire information regarding clinical scenarios intensifies. There is great interest in anecdotal accounts of anesthesia mishaps. These mishaps serve as a cue or stimulus which leads to the active participation factor for audio-visual learning. When presented in vignette format, both the audio and visual components can engage students and encourage involvement in the realistic scenario (Biddle, Hartland, & Fallacaro, 2005).

As the value of active participation and vicarious learning was recognized, vignettes, or patient safety vignettes (PSV), were instituted in the 1960's to teach concepts of patient safety. Over the years, and perhaps with the advent of anesthesia simulators, vignettes have begun to be utilized to engage students and stimulate discussion regarding an anesthetic mishap. This has been shown promote vicarious learning from group involvement (Cox, McKendree, Tobin, Lee, & Mayes, 1999). Simulation offers the capability to produce vignettes in a realistic, safe, believable environment, while being relatively inexpensive to create (Gaba, 2002). Nurse anesthesia education programs that lack financial resources to purchase a simulator, could potentially benefit from previously purchased vignettes to engage their students in a structured learning activity.

The proactive approach to evaluating and ensuring patient safety during the anesthesia delivery process is related to the potential for catastrophic outcomes. Thus, evaluation of methods that can potentially positively impact patient safety is worth examination. Vignettes can possibly be a venue by which this can be accomplished.

Vignettes are short, usually 3-10 minutes in length (Ber & Alroy, 2001), realistic, simulated audio-visual videos that show an evolving catastrophic scenario which includes the educational content to be relayed. Typically, the vignette will end without visually depicting corrective measures to avoid a poor outcome. This abrupt stop impacts the student's memory and engages them in learning vicariously through visual, auditory, and emotional involvement (Biddle et al., 2005).

A focus on patient safety in health care delivery is the basis for this study with special emphasis on patient safety as it relates to anesthesia. Continued improvement, evaluation, and creativity in educational programs may enhance patient safety by supplying educators with information that can influence curriculum changes. Learners in nurse anesthesia programs are expected meet high standards that potentially can be enhanced by audio-visual depiction of a negative cascade of events leading to catastrophic outcomes. The advantages of the vignette format may allow students to mentally absorb correct measures and skills to handle critical situations depicted in vignettes. However, this alone will not ensure a change in clinical practice.

The purpose of this study was to explore the feasibility of vignette use as a method to stimulate the application of learned knowledge to the clinical setting in comparison to a traditional method of instruction, the written case study. This may potentially improve patient safety by interrupting the cascade of events leading to a catastrophic outcome during anesthesia administration by nurse anesthesia students.

Background

The critical nature of anesthesia requires anesthetists to synthesize a wide, complex array of information in a short period of time. Appropriate critical thinking skills and a strong foundational knowledge of anesthesia are necessary to administer safe anesthesia. Patient safety outcomes are dependant upon the anesthetist's ability to think critically and apply knowledge clinically. When there is a failure in either of these abilities, anesthesia care related errors may be at particular risk of occurring.

Failure of the anesthetist to properly manage a crisis event during a surgical case can result in a cascade of events, leading to a catastrophic patient outcome. Anesthesia machine failure is representative of this type of event. Currently, equipment failure accounts for 4% of all anesthesia mishaps, down 14% from previous research (AHRQ, 2001). Of the 4% mishaps, 24% of these are due to inappropriate preoperative machine checkout. This percentage is significant considering there are over 71.3 million surgeries performed in the United States each year (UMMC, 2004). It is estimated that 2.86 million equipment failures comprise the 4%. Nearly one half million of these were due to inappropriate preoperative machine checkout (AHRQ, 2001). It is also likely that this number significantly underestimates the true rate of error and that many critical incidents involving anesthesia equipment go unreported. This could possibly be due to self-report processes used to disclose these errors.

In 1999, the Institute of Medicine (IOM) released To Err is Human: Building a Safer Health System . The report was issued to bring light to injury primarily related to incidence of medication errors (Kohn, Corrigan, & Donaldson, 2000). This study resulted in a greater national focus on all medical errors (Mazor, Fischer, Haley, Hatem, & Quirk, 2005). Medication administration, equipment use, differences in provider technique, provider stress response, and reaction time, are just a few of the areas where and error can occur during anesthesia delivery.

Reason's definition of error will be utilized as a basis for this investigation. He defines error as "failure of planned action to be completed as intended (ie: error of execution), or the use of the wrong plan to achieve an aim" (Reason, 1990).

Poor anesthesia clinical performance outcomes are in opposition to providing vigilant, safe, and quality anesthesia care. Training in crisis management, often referred to as crisis resource management (CRM), has been widely used in the aviation and nuclear power plant industries, and to a lesser degree in the military. Vignettes are used in these disciplines in CRM training.

Most present CRM models have been patterned after aviation's crew resource management programs and include crisis situations. In 1979, the National Aeronautics and Space Administration (NASA), conceptualized a framework for crisis management (Cooper, 1980). It was postulated that lessons learned from extensive research in the aviation industry related to safety issues, could be applied to medicine (Sexton, Thomas, & Helmreich, 2000). This framework will serve as a foundation for this research.

The CRM framework has been termed Error Trokia, named after a Russian term meaning, three horses abreast. Three components of Error Trokia, CRM training to avoid errors, "trapping" or stopping errors before they are committed, and error correction, can easily be translated to anesthesia CRM. The conceptual model modified for this study is presented in Figure 1.

Teaching Methodology Clinical Performance Outcome Framework

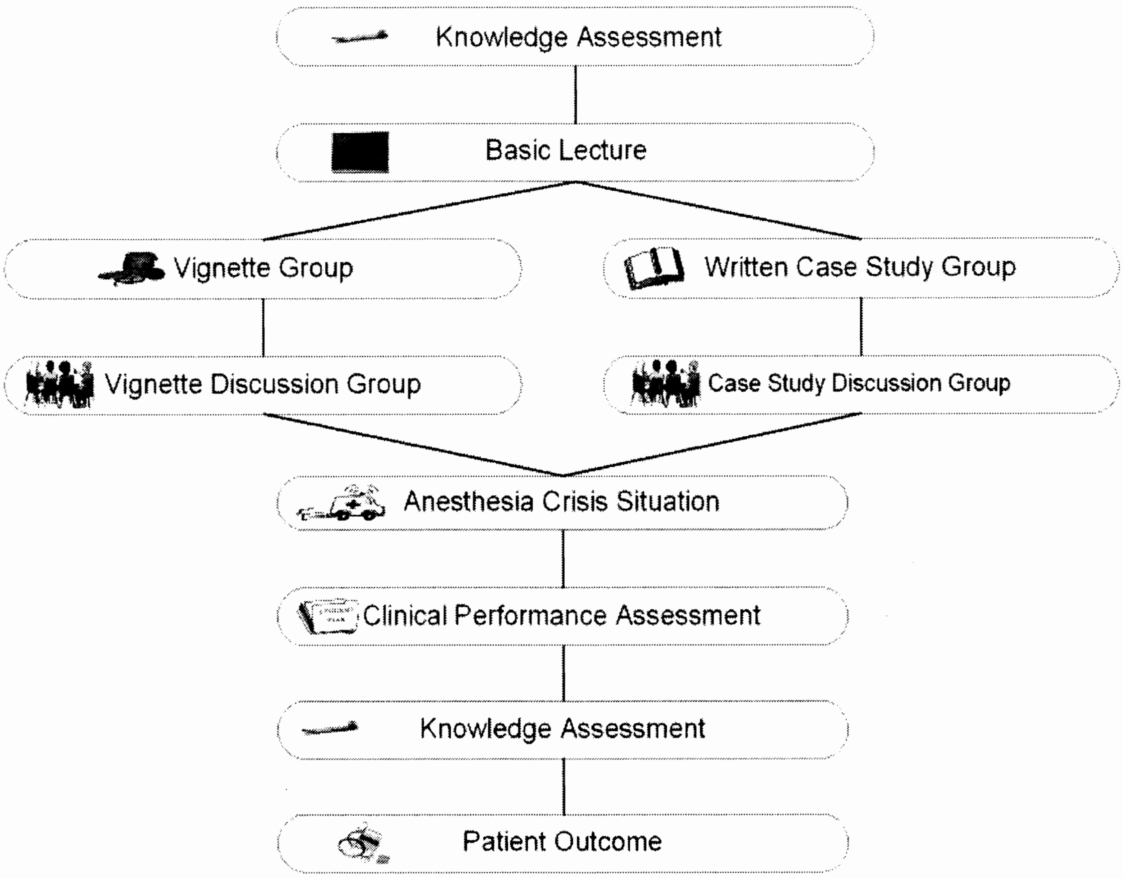


Figure 1. A conceptual framework depicting comparison of vignette and written case study teaching methodologies on anesthesia clinical performance.

Short audio-visual videos called trigger films or vignettes, are situational, scripted stories, and intended to convey information to an audience. They typically end abruptly after conveying a crisis oriented situation and offer no resolution to the evolving scenario (Biddle et al., 2005). Group discussion typically ensues that can provoke recall, allow examination of feelings toward the crisis situation and outcome, and stimulate thought as to corrective measures that could be taken to prevent the demonstrated error.

The second method to be employed as the comparison intervention, are written case studies. Case studies used in this research will be developed using the same objectives as the vignettes and will clearly describe the same crisis scenario as well as background information depicted in the vignettes.

Supporting the concept of vignette use as a method to improve recall, Renton-Harper et al. (1999), demonstrated improved recall in dental students with video instruction as compared to directions in written format (Renton-Harper, Addy, Warren, & Newcombe, 1999). Research in this area as it pertains to anesthesia education, is scarce. Traditional methods used in anesthesia education are lectures, written materials, and clinical rotations. Additionally, programs may include simulation, student presentations, and group discussion. Incorporating vignettes into curriculums may offer the additional benefit of improved recall for later application in clinical practice. Lag time between basic anesthesia and science courses, and beginning clinical rotations, prohibits students from correlating these foundational concepts with clinical experiences during the initial learning process. Incorporating learned concepts into clinical practice strengthens the student's ability to perform tasks properly, perhaps due to the repetition of knowledge learned in the classroom and then applied clinically (Rydman, Sonenthal, Tadimeti, Butki, & McDermott, 1999).

Historically, nurse anesthesia programs have been housed in hospital based programs. The need for nurse anesthetists spurned hospitals to institute training programs as a means to provide anesthesia staff. In this type program clinical practice began as soon as four weeks after admission. Didactic instruction was often scheduled around the hospital's clinical needs for anesthesia providers. As the programs have transitioned to university settings, front-loaded curriculums became commonplace. In this case, time lapse from didactic instruction to the student's clinical experience is often one full year. In programs that do not have access to, or financial resources for anesthesia simulation laboratories, students are not able to simultaneously correlate what knowledge learned from core science and anesthesia courses with realities of clinical experience and practice.

Vignettes could potentially help bridge the time gap of time delay between didactic education and clinical experience. High quality, realistic, simulated vignettes, offer active participation with both visual and auditory engagement (Biddle, 2005), just as if the student were in the operating suite.

Purpose and Research Questions

The very critical nature of anesthesia and the vast potential for disaster, has forced the profession to look for ways to improve patient outcomes and safety, therefore, research designed to assess methods to improve anesthesia education and learning is logical. The purpose of this study is to evaluate the efficacy of vignette use as a teaching method to improve anesthesia clinical performance outcomes. Anesthesia students with a strong ability to think critically recall learned material, and who appropriately apply knowledge in clinical crises, can potentially improve clinical performance. While it is reasonable to consider that improving knowledge will improve patient safety, knowledge retention alone does not ensure that change or improvement in clinical practice will occur. This study will address the following research questions:

1. Is there a significant difference between student anesthetist clinical performance during a simulated anesthetic apparatus related crisis when previously educated with either audio-visual vignettes or written case studies?
2. Is there significant difference in student anesthetist recall of apparatus related material between the use of either audio-visual vignettes or written case studies in anesthesia education?

Operational Definitions

Anesthesia crisis situation: a potentially life threatening situation that occurs during administration of anesthesia that may affect the patient's outcome if not handled appropriately.

Anesthesia education program: an accredited nurse anesthesia school or program housed in either a university or hospital setting, which trains student anesthetists the art and science of anesthesia administration.

Certified Registered Nurse Anesthetist (CRNA): A nurse anesthetist certified by the American Association of Nurse Anesthetists (AANA), licensed to practice by a state nursing board.

Clinical performance outcomes: evaluation of an anesthetist's performance which is measured against pre-determined criteria such as problem recognition, problem identification, troubleshooting mechanical failures, and corrective action.

Clinical practice: physically carrying out pre-operative evaluation, consultation, administration of anesthesia, post-operative and follow up care, in a clinical environment.

Equipment malfunction: failure of machinery to function appropriately.

Learning: knowledge retained from various teaching methodologies.

Patient safety outcomes: phenomena occurring after exposure to the anesthetic process, typically defined as the patients' resultant status as being either positive or negative.

Student Registered Nurse Anesthetist (SRNA): a licensed registered nurse functioning as a student, who is enrolled in a nurse anesthesia program accredited by the AANA.

Vicarious Learning: knowledge obtained from group discussion or interaction that otherwise may not have been retained.

Vignette: short 2-8 minute audio-visual film containing content mirroring that of a written case study, depicting a scenario yet, offers no resolution to the evolving problem.

Written case study: brief, written description of a specific case involving an anesthesia error or mishap.

Limitations and Weaknesses to the Study

Subject demographics could potentially be a limitation. Students begin anesthesia programs with very diverse backgrounds. To address this potential area of concern exclusion criteria have been developed. They include:

- Anesthesia technician experience
- Veterinarian assistant experience
- Operating room nurses

- Students previously enrolled in the Principles of Anesthesia I course

Professional behavior may be a limitation. Several efforts will be made to reduce this limitation. Subjects will choose to sign a confidentiality agreement or opt out. Students will be given explicit instructions regarding the importance of adherence to guidelines for this study. Specifically, instruction will be given not to discuss the content of the lecture, nor subsequent classroom work or discussion until completion of the research project. Machine checkout procedure demonstration will not be discussed for the 2 week period of data collection. Specific times for machine checkout demonstration will be assigned for each student. Once the demonstration has been completed, the subject will once again be reminded not to discuss the machine checkout process until appropriate notification has been given. The subjects are registered nurses from clinical settings, who will be familiar with privacy and confidentiality issues.

Another limitation is that learning is difficult to define. Some would argue that recalling information demonstrates learning, while others contend that application of recalled knowledge to a particular situation demonstrates learning. For this study learning will be defined as behavioral modification (Beard & Payack, 2006) or process change through experience, gained through formal education.

To eliminate researcher bias, data collection will be done by trained observers, two CRNAs highly versed in the national, standardized anesthesia machine checkout procedure. Assistants will be blinded as to members of subject groups. Both data collectors will have extensive knowledge of proper checkout procedures; will follow the

Food and Drug Administration (FDA) guidelines for this process, and shall have at least 10 years experience as a CRNA.

Scope of Study

Until the last decade, nurse anesthesia education has been steeped in the tradition of lectures and presentations as the primary method for content delivery. With the advent of simulation and the ability to produce high quality audio-visual material, such as vignettes, avenues to utilize these resources to produce quality, competent anesthesia providers can be explored. The possibility of improving patient safety outcomes by improving clinical performance by incorporating different teaching methodologies can potentially produce these competent providers. This study will investigate this possibility.

CHAPTER 2: LITERATURE REVIEW

Introduction and Background

This chapter reviews the literature regarding theoretical concepts relevant to this study. It will address crisis resource management and its application to anesthesia clinical practice as well as examine existing literature on the comparison of different educational methodologies, specifically, vignettes and written case studies. Research publications regarding patient safety, critical thinking, anesthesia educational program design, and anesthesia clinical performance outcomes will also be discussed.

The critical nature of anesthesia makes it fertile ground for investigating methods to improve patient safety. It seems beneficial to explore the augmentation of common teaching modalities with vignettes. This may offer opportunity to revise anesthesia program curriculums, thus possibly positively impacting the quality of anesthesia care provided. Patients and providers could only benefit from this adaptation with positive patient outcomes.

Evaluation of vignettes in curriculum design is essential. Although literature exists examining the influence vignettes have on memory, very little exists on the examination of the impact they have on clinical application of learned knowledge. The advent of anesthesia simulation laboratories has opened the door to produce high quality vignettes in an economical, safe, and realistic venue. As anesthesia educators are asked to look for economically sound, effective methods to educate students they will likely search for methodologies that will prove interesting to students in the hopes of impacting memory and improving patient safety by affecting clinical performance.

The primary purpose of this proposed study is to compare two teaching methodologies. This comparison is done to examine the feasibility of incorporating vignettes into anesthesia education to meet clinical performance and patient safety goals.

Framework and Theory

Within the body of anesthesia research, quantitative research investigating connections between theory, frameworks, and anesthesia clinical performance is limited. A review of the literature revealed several articles that focused on the qualitative aspects of clinical performance such as, attitudes and perceptions various anesthesia providers possess. While a common thread in many of the studies was patient safety, a gap appears to exist between robust theory and quantitative research regarding the impact that different educational methodologies may have on anesthesia provider clinical performance. Studies having a true experimental design are unfortunately missing.

Knowledge can be defined as having practical a understanding of a concept (Webster, 2003). In the 1960's, cognitive science emerged as researchers focused their attention on the composition of knowledge and how it functions (Paivio, 1986). From this field of study the Cognitive Information Processing (CIP) theory was developed. This offered plausible explanation of the organization of the mind's mechanisms used to process information, as well as how those mechanisms are activated (Pavio, 1986).

A theory that employs the CIP model is the cognitive load theory (CLT) credited to Sweller et al. in the late 1990's. CLT focuses on the human cognitive architecture and divides cognition into long term memory (LTM) and working or short term memory (Sweller, van Merrienboer, & Paas, 1998). Sweller equates working memory, which he termed cognitive load, with consciousness. His theory suggests that humans have only conscious control over working memory and thus, other memories such as LTM are stored. To bring LTMs to consciousness, the short term memory must first filter the information to be retrieved (Sweller et al., 1998). CLT suggests LTMs cannot be brought into consciousness via the working memory if the cognitive load has exceeded its capacity.

According to Sweller et al. human cognition can only process approximately seven items of information at one time. However, if processes such as organization, contrasting, and comparison are required to process the information, the working memory can then only process three or four items at one time (Sweller et al., 1998). In the context of anesthesia education this suggests that even if working memory capacity or cognitive load can be increased, it is evident that this places limitations on instructional design. Anesthesia delivery requires synthesizing information while processing multiple pieces of information simultaneously. As a result, this can significantly increase cognitive load.

Baddeley's determination that working memory can be increased in the face of mental multi-tasking suggests that other cognitive processes must in play when it comes to human cognition (Baddeley, 2000). This process or structure is believed to be long term memory (LTM).

LTM is an unconscious process. To bring it to consciousness, the working memory must first filter it and allow it to be brought forth as working knowledge (Sweller et al., 1998). Sweller investigated this phenomenon using the game of chess to examine and explain this phenomenon. The study compared grand masters to novice chess players by a five second exposure to differing chess board configurations that had actually occurred in previous matches. The players were then asked to replicate the configurations. The grand masters were able to replicate the configurations more accurately than the novices. Since both were exposed for the same length of time, the authors concluded that LTM was the difference in the two groups. The premise of this explanation was that the grand masters could pull the configurations from memory based on games from their past experience while the novices could only rely on the working memory to replicate the configuration. It was determined that many years of practice developed their LTM and potentially helped the masters attain their high level of expertise while increasing their knowledge capacity in this area.

In another novice-expert study, it is suggested that problem solving differences between the two groups were not the knowledge of sophisticated problem solving but rather, the number of exposures to problems (De Groot, 1966) . These studies also support the idea that intellectual abilities for problem solving comes from stored knowledge from LTM and not working memory (Sweller et al., 1998).

Based the 1998 study, Sweller et al. determined that LTMs were stored using schemas to categorize information. Schemas are frameworks within human cognitive processes that allow storage of diagrammatic represenations which may account for the ability to synthesize information. For example, a preschooler is taught that a vehicle with four wheels, a body, and a steering wheel is called a car. However, at this point, the child has no knowledge as to the make or model of the vehicle. With audio and visual reinforcement of a car's definition, the child stores this diagrammatic representation into LTM. This initial storage of information forms the start of a framework, or schema that can be augmented as new knowledge becomes available. Once the child learns the difference between, for example, a 1965 Mustang and a 2005 Volkswagen Beetle, he will then be able to add to the schema in LTM, building upon his previous knowledge base.

Using schemas, the chess masters categorized piece placement in patterns from past games. The schema allowed them to recall which moves would be most appropriate (Sweller et al., 1998). The authors felt that these processes could be either a conscious or unconscious effort. A chess configuration can clearly be considered an image. Images are more readily remembered than words (Kamin, O'Sullivan, Younger, & Deterding, 2001) as a result, it logically follows that images stored in schemas are more readily recalled.

The concept of schemas holds true for other domains such as reading-categorization of letters and words, for example. Another example which is more educationally related is that preschoolers construct schemas for letters, and then they form them into words, then later in sentences (Sweller et al., 1998). Ultimately, they will be able to quickly scan a page and be able to understand it. LTM is the storage site for schemas and allows for organization of knowledge. Schemas reduce the workload of working memory and appear to have no limit to the amount of information that can be processed from the LTM (Sweller et al., 1998).

It was also determined that practice, or automation, can be consciously or automatically processed, such as in the case of the chess players. The premise of this concept is that tasks can be carried out with minimal effort, whereas a child with little practice must consciously process each letter or symbol. Complex concept problem-solving has significant automation requirements and working memory capacity and seems to pull the desired information from the LTM schema into consciousness (Sweller et al.).

Cognitive Load Structure

Sweller et al. stated that a prime goal of instruction is the construction and automation of schemas. Another determination from the study indicated that synthesizing multiple concepts may be difficult, however, given many unrelated elements to be learned, it is not considered difficult and would require little cognitive load since the elements are not related. Learning vocabulary words from a list or symbols for the periodic table are examples of this. A greater level of difficulty is associated with the load required for complex problem solving where one step leads to another and the student must synthesize information from multiple schemas. This interrelation of the concepts stored in the schemas increases cognitive load. To relate this to anesthesia, under duress or stress, the student may have difficulty with complex problem solving during a crisis situation and thus an algorithmic approach could advantage the next step required to perform the appropriate intervention (Runciman, Kluger, Morris, Paix, Watterson, & Webb, 2005). Simple memorization of basic steps to take to resolve the problem would not be adequate as the elements of a deteriorating crisis event will likely interact, requiring higher cognitive processes to be utilized.

"Understanding" exists only with higher cognitive loads; otherwise it simply may be regurgitation from working memory. No schema is required since the elements do not interact. From this concept Sweller et al. derived that once the schema is constructed, individual elements do not need to be considered individually in the working memory and are stored in the LTM.

SOI is an acronym for selecting relevant information, organizing selected information, and integrating the information with current knowledge (Wittrock & Farley, 1989). This framework termed SOI, has been used to explain these higher level cognitive processes. This describes more precisely the cognitive processes that Sweller et al, discuss. While the Dual Coding Theory (DCT) represents working memory as a single construct, Baddeley in 1974, described working memory as a construct with four parts (Baddeley, 1976). His theory suggests there is a "central executive" that moderates the visual-spatial, or visually based information, and the phonological loop, or the auditory and speech based information. These findings are relatively similar in that both agree that working memory serves to organize, select, contrast, and compare information.

Dual Coding Theory

There is yet another theory that has emerged as a result of DLT and CIP theory. Paivio developed the dual-code model using CIP theory to address how visual information is processed and stored as knowledge (Dabbagh, 2006). Over time, with research to support this concept, the model became accepted as theory. DCT suggests that the verbal and visual cognitive processing mechanisms are separate functions, yet are then interwoven to synthesize information (Paivio, 1971).

Paivio's early studies focused on imagery associative learning (Paivio, 1971). The findings from these studies prompted Paivio to develop a process that would objectively measure imagery's effect on memory. Paivio determined that visual imagery had a greater impact on memory and was more readily retrievable than information coded as verbal.

The visual component of DCT includes visual imagery and representations of words that can describe a picture, whereas, the verbal component consists of sounds or actions (Clark & Paivio, 1991; Dabbagh, 2006) and emotion evoking experiences (Clark & Paivio, 1991). These two elements intertwine are then are remodeled. An example of this is a student naming an object when shown a picture. Not only can an object be named by sight using the associated word, but emotional responses can be evoked by the image as well. When combined, these two processes demonstrate higher cognitive processes than simple memorization and that synthesis has occurred. It follows that Paivios's concept of schemas containing both words and pictures are presumably stored in the LTM, and are the basis of DCT.

Dabbagh suggests that it is much easier to retrieve and retain information that has been dually coded. Like Paivio, Dabbagh states that pictures are easier to recall than words. These suggestions are based on the premise that there are two pathways available for information storage and retrieval. Audio-visual material requires both the visual and verbal aspects of DCT.

Neurophysiologic Evidence Related to DCT

Crottaz & Ragot conducted a study to investigate neurophysiologic processes and responses in subjects as they were presented with both stimuli in visual and verbal formats (Crottaz & Ragot, 1998). Using functional magnetic resonance imaging (fMRI) they identified cerebral structures that were either stimulated or suppressed when subjects were exposed to both verbal (auditory), and visual (spatial) information. They concluded that for each presentation, different processes exist to generate, process, and route neural signals during short term memory, which is often referred to as verbal working memory (VWM). While similar studies have linked neural signal processing to the object model theory, it appears none have concluded that neurophysiologic evidence exists to support Paivio's DCT (Ganis, Schendan, & Kosslyn, 2006). Paivio's research related to coding of visual and verbal stimuli may potentially be supported in the neurophysiologic evidence presented in studies centered on memory and neural signal processing.

Researchers have studied neurophysiologic responses to memory coding and retrieval using both humans and rats as subjects (Crottaz & Ragot, 1998; Ganis et al., 2006; Henson, Burgess, & Frith, 2000; Moore, Cohen, & Ranganath, 2006; Otten &

Rugg, 2001; Paivio, 1986; Ross, 2006; Seeck, Mainwaring, Cosgrove, Blume, Dubuisson, Mesulam, & Schomer, 1997). In 1998 Crottaz et al. used identical stimuli in two different formats, visual and verbal, to examine potential differences in neurophysiologic activity processes and brain structures during memory retrieval. The researchers found that different cerebral structures were indeed stimulated when subjects were presented with either visual or verbal stimuli. This suggests that mechanisms within multiple structures are in place to process different types of information. The researchers also determined that information that is dually coded as both visual and verbal information is remembered more readily than stimuli that is singularly coded. This appears to suggest that synthesis of both the visual and verbal stimuli occurs after coding, aiding in memory retrieval, and thus supporting concepts in Paivio's DCT (Paivio, 1986). DCT proposes that coding for visual and verbal stimuli occurs separately, is processed differently, and then is recombined. Logically, it follows that verbal and visual stimuli processing may occur in separate brain regions and structures.

Crottaz et al. studied the neural basis for processing verbal working memory (VWM) utilizing fMRI. They investigated similarities and differences in brain structure activity during the presentation of each type of stimuli, using an identical stimulus. Both presentations demonstrated activity, however, more structures demonstrated an increase in activity when presented with the visual stimulus. Multiple structures appeared to be involved with both types of stimuli (see Table 1). The researchers concluded that there were differences between the auditory working memory (aud-VWM), and visual working memory (vis-VWM) with regard to neural signal generation and processing.

Table 1

Author	Year	Method	Structure	Action Within Structure
Crottaz-H, Anagnoson, and Menon	2003	fMRI	Dorsolateral prefrontal cortex, ventrolateral prefrontal cortex, intraparietal sulcus, basal ganglia, left posterior parietal cortex	Stimulation in response to visual stimuli. No appreciable stimulation with verbal stimuli.
Henson, Burgess, and Frith	2000	fMRI	Posterior temporal areas, left supramarignal gyrus.	Stimulation in response to verbal stimuli. No investigation of visual stimulus
Seeck, Mainwaring, Cosgrove, Blume, Dubuisson, Mesulam, and Schomer	1997	Evoked Potentials	Mid-and inferotemporal, neocortical areas of the temporal lobes.	Stimulation in response to visual stimuli. No investigation of verbal stimuli.
Ross and Eichenbaum	2006	fMRI	Medial temporal lobe, hippocampus, anterior cingulate region	Hippocampus plays a critical role in short term memory consolidation.anterior cingulate region plays critical role in LTM storage.

Neurophysiologic brain activity studies, year, type of testing. fMRI: functional magnetic resonance imaging.

A recent study by Ross and Eichenbaum (2006) demonstrated that damage to the hippocampal region of the brain affected memory consolidation. In conjunction with the

Crottaz et al. study conclusion, it is possible to extrapolate that the hippocampus may be the site of resynthesization once the aud-VWM and vis-VWM stimuli have been separately processed. Because Paivio's theory suggests that different cerebral or cortical sites are used for both vis-VWM and aud-VWM processing, storage and resynthesization, it is plausible that these studies present neurophysiologic evidence in favor of the DCT.

Registered Nurse Anesthetist Students

Student Registered Nurse anesthetists (SRNAs) are adult learners who have critical care backgrounds and varying clinical experiences. Typically, they are self-motivated and driven. Some aspects of Malcolm Knowles theory of andragogy, adult learning, are applicable. Connection can easily be made between andragogy and this proposed research. Knowles proposed the theory of andragogy in an attempt to explain the mechanism by which adults learn. He suggested that adults learn more efficiently when they are self motivated and involved in active learning as opposed to being instructor directed (National-Lewis, 2005). The principles of andragogy are centered on self directed study. Knowles theory proposes that this interactive approach is preferable to content oriented instruction, a traditional method of content delivery. Additionally, the theory suggests that learners should be able to relate the subject of study to their personal or professional experiences (National-Lewis, 2005). Problem based learning (PBL) centered on anesthesia content can draw from the student's past clinical experiences and may (Clark & Paivio, 1991) aid them in problem solving.

Problem Based Learning and Critical Thinking

PBL in a simulated environment involving a critical anesthesia incident sets the stage for both adult learning and active participation. This allows the SRNA to learn via a hands-on approach as well as through visual cueing. Both of these can potentially impact their critical thinking skills. Using PBL attempts to improve SRNAs critical thinking skills.

Improving critical thinking skills is an educational outcome objective for nurse anesthesia education programs. PBL may offer a means to accomplish this. Transition from traditional classroom didactic instruction, such as lecture, to PBL has been evident since early in the 1960's (Major, 2001). However, little research was done to evaluate PBLs efficacy in health care prior to being introduced (Balslev, de Grave, Muijtjens, & Scherpbier, 2005). Health care education began to focus on problem based learning as a means to improve student knowledge and skill (Hoffman, Hosokawa, Blake, Headrick, & Johnson, 2006) in the 1990's. PBL is often mistakenly used to assess concepts such as student improvement in understanding and skill proficiency (Major, 2001)).

Traditional assessment measures such as exams may give a more accurate representation of knowledge yet, not factually represent student improvements in task performance (Major, 2001). PBL was designed to stimulate active participation and ultimately, improve knowledge.

Some authors argue that PBL is actually correlated with a decrease in basic science knowledge and inhibits the use of higher cognitive processes (Albanese & Mitchell, 1993; Major, 2001). Opposing this view is research that supports improvement in student knowledge and skill when PBL is pervasive in the education curriculum (Schmidt, Dauphine, & Patell, 1987). A 22 year study was undertaken by Vernon and Blake (1993) to evaluate this concept. Their meta-analysis supported the idea that PBL was superior to traditional teaching methodologies (Vernon & Blake, 1993).

Crisis Resource Management

Crisis resource management is a concept that is interrelated with PBL. Considering that several studies do support the idea that PBL can improve student knowledge and skills, when faced with a problem based simulated crisis situation, students can potentially incorporate both to solve the problem at hand. This alternative evaluation processes can be utilized to determine if in fact there is any improvement (Major, 2001).

While not technically considered theory, a crisis resource management framework is the foundation for this proposed research. The primary underpinnings of the CRM framework is to establish a mechanism by which personnel can operate to maximize safety and minimize risk (Andreatta, Woodrum, Birkmeyer, Yellamanchilli, Doherty, Gauger, & Minter, 2006). When a CRM framework is incorporated into the anesthesia domain along with audio-visual, simulated crisis events, it is reasonable to expect that patient outcomes can be improved by impacting clinical performance.

Industries and organizations outside the medical realm utilize various methodologies in crisis resource management (CRM) personnel training to teach personnel skills that should enable them to manage critical, hazardous, or unexpected events (Biddle et al., 2005). Within the CRM training programs, industries such as aviation, nuclear power, public transportation, and the military all seek to accentuate safety and reduce risk (Ziv, Wolpe, Small, & Glick, 2003). Of these industries, aviation is most similar to the anesthesia profession in that their inherent nature has the potential for perilous situations to develop and quickly evolve into fatal, catastrophic events.

CRM, referred to in aviation as crew resource management, is a concept originating in the late 1970's to methodize a process aimed at achieving efficient, safe flight operations, and enhance a multi-disciplinary approach to error (Pizzi, Goldfarb, & Nash, 2001). This process led to a framework to provide countermeasures against human error and promote learning, not blame (AHRQ, 2001).

Anesthesia delivery is congruent with the aviation industry due to the similarities involving catastrophic outcomes when situations deteriorate. It logically followed that a crisis resource management framework for anesthesia would emerge from the aviation perspective, and thus, the term anesthesia crisis resource management (ACRM) evolved.

Anesthesia Crisis Resource Management

ACRM was developed to train anesthesia providers to develop skills for appropriate management of error commission in an attempt to improve patient outcomes (AHRQ, 2001). In 1992, Howard, Gaba, Fish, Yang, and Nash developed a course to meet this purpose. Subsequently, courses have been developed and expanded within the anesthesia profession. Basic principles used in development of an ACRM course by Blum et al. in 2004 were: a) role clarity and leadership, b) communication skills, c) management of personnel and resources, d) decision making. The course was designed to teach skills related to these principles.

Blum et al. found that one year following the ACRM course, 50% of the participants reported involvement in a critical event. A cardiac arrest, or code blue, scenario was used in the ACRM course as the critical event. One question in the one year post-course survey asked whether the participant had been involved in a critical event since completing the ACRM course. No definition for critical event was offered in the survey. Because life-threatening situations or crises happen very frequently in anesthesia, it seems likely that participants may have interpreted the question as asking if they had been involved, specifically, in a code blue situation since completion of the ACRM course. However, this was not noted by the authors. Overall, results from the study indicated that participants felt their ACRM skills had improved as a result of the educational program.

These studies, as well as the development of ACRM specific courses support the notion that different anesthesia education modalities can potentially foster appropriate crisis management skills. One method in which ACRM can be taught is using simulation.

Simulation

Anesthesia offers ample room for SRNAs to make errors related to both education and skill. There is significant pressure to perform mistake free while under scrutiny and time constraint. Anesthesia simulation replicates evolving clinical situations, typically challenging patient safety scenarios that allow for practice in learning from mistakes (Ziv et al., 2003). As a result, simulation can provide an opportunity to improve SRNA clinical performance by allowing the anesthetist to practice decision making in a safe and controlled venue (Sica, Barron, Blum, Frenna, & Raemer, 1999). CRNAs and patients could benefit from this by reducing education and skill based errors.

One study found that behavioral performance scores were significantly improved after simulating a radiologic crisis scenario (Sica et al., 1999). Similarly, another simulation study showed significant improvement in post-test scores when compared to pre-test scores after a simulated medical crisis using an operating room setting (Morgan, Cleave-Hogg, McIlroy, & Devitt, 2002). When considered in conjunction with the face validity of performance evaluation in simulation (Kim, Neilipovitz, Cardinal, Chiu, & Clinch), these studies suggest that in a non-threatening environment, SRNA skills could improve. Additionally, learning has the potential to occur when anesthesia providers are allowed to practice application of knowledge and commit errors based on their existing knowledge and skill. Although education with anesthesia simulation protects patients from safety issues (Biddle et al., 2005; Hartland, Biddle, & Fallacaro, 2003; Morgan et al., 2002), it is designed to improve real patient care outcomes and reduce anxiety by potentially enabling the anesthetist to draw upon knowledge gained in simulated crises when faced with a real life situation of critical nature.

In addition to the hands-on tasking afforded by simulation, visual feedback plays an integral part in learning from this modality. Visual feedback can then be used to develop schemas for cognitive processing. Improvement in clinical performance can potentially be achieved when visual feedback and schemas are present (Drews, Syroid, Agutter, Strayer, & Westenskow, 2006). Should SRNA clinical performance outcomes improve, it is feasible that patient safety outcomes could potentially improve as well.

Patient Safety

The Australian Incident Monitoring Study (AIMS) investigated 4000 incidents of bradycardia in patients undergoing anesthesia (Watterson, Morris, Westhorpe, & Williamson, 2005). Bradycardia was associated with hypotension in 51% of the cases. The authors concluded that ACRM skills could have potentially been of value if the developed ACRM algorithm had been applied. Twenty percent of these cases would have been diagnosed and 60% of these incidents would have been correctly managed (Watterson et al., 2005). This indicates that an anesthetist could possibly make a very brief scan of an ACRM algorithm that may refresh their memory as to the appropriate action to take. However, 40% of the problems in this study were associated with failure to appropriately utilize the entire algorithm (Watterson et al., 2005). Using the algorithm in its entirety can potentially facilitate a positive patient outcome. It stands to reason that the algorithm could be especially beneficial for the SRNA who has significant anxiety, difficulty thinking during a crisis situation, very little clinical experience, and needs prompting as to the appropriate corrective action to be taken (Runciman et al., 2005).

Algorithms are designed to augment, or at times substitute for, problem solving abilities when quick discernment of an evolving crisis is required and can serve as a memory stimulus. Additionally, algorithms are developed using evidence based principles of action that experts agree upon as the best intervention for the specific situation. From the conclusions stated in the AIMS report of the bradycardia incidences, it can be extrapolated that there is potential use for an algorithmic approach to most developing crisis situations in anesthesia delivery. This preplanned, evidence based approach could improve patient safety and arrest an evolving crisis situation caused by human error factors.

Human Error Factors

The complex environment in which anesthesia care is performed has the potential to engender human factor related errors. The IOMs seminal publication, To Err is Human, proposed that human factors were a prevalent cause of medical error (Kohn et al., 2000). A few of these factors include: (a) fatigue, (b) stress, (c) communication, and (d) decision making errors.

Stress responses are very individualized and set the stage for different reactions from SRNAs when facing the same situation. What typically is considered a routine or standardized task for one, can be perceived by another as very complex and difficult under emergent and extreme circumstances (Schull, Ferris, Tu, Hux, & Redelmeier, 2001). For example, one study found that some experienced anesthesia providers perceived urgent intubation as "very difficult" when preparatory time was reduced by 40%, and resulted in an increase in failed intubations (Xiao, Mackenzie, & Jefferies, 1996), while many others did not.

In addition to stress related errors, training can contribute to adverse patient outcomes (Schull et al., 2001). Two studies have shown that experience and exposure to critical incidences during training can enhance problem solving (DeAnda & Gaba, 1991;

Gaba & DeAnda, 1989). In 1984, it was demonstrated that 95% of the serious negative patient outcomes were attributable to errors (Cooper, Newbower, & Kitz, 1984). These studies suggest that regardless of the specific human factors involved in error, transforming knowledge into appropriate clinical performance is essential to improving patient safety outcomes.

Critical Thinking

Nurse anesthesia educators have established educational outcomes that include improving critical thinking skills in an attempt to decrease human errors that affect patient safety (Tiwari, Lai, So, & Yuen, 2006). Researchers have compared the effects of various teaching methodologies on the student's ability to think critically (Balslev et al., 2005; Tiwari et al., 2006). Tiwari et al found that PBL subjects, when compared to subjects who received the same content in the traditional lecture format, scored significantly higher on a critical thinking assessment tool. In another study, comparison was made between vignettes and written material to investigate relationships between the cognitive processes such as theory building, evaluation, and metareasoning. Metareasoning is defined as the decision to participate in evaluation or deliberation, taking into account what resources need to be allocated to solve the problem (Balslev et al., 2005). It involves multi-level cognitive processes that require critical thinking. Both of these studies suggest that PBL vignettes may improve critical thinking skills.

One of the goals of PBL is to positively impact and advantage critical thinking (Tiwari et al., 2006). Historically, healthcare providers relied on intuitive reasoning to make clinical care decisions. As research emerged evaluating patient safety outcomes, evidence based practice (EBP) compelled providers and educators to pursue a more scientific approach to decision making. This is a reasonable course since as in aviation, healthcare providers are often expected to function without error (Sexton et al., 2000). The intuition approach to patient care has led to dissimilarities in provider practices (Lamond & Thompson, 2000). According to Lamond et al. this has impacted patient outcomes. However, some would argue that EBP has restricted the autonomy of healthcare providers (Rolfe, 2005). One can surmise this may actually limit the provider's ability to utilize learning from past situations, as CRNAs with valuable clinical experience may have the capability to handle adverse situations.

SRNAs have little clinical experience and must rely on good problem solving skills to manage difficult situations. During their anesthesia education, SRNAs are closely supervised by experienced anesthesia clinicians. However, upon completion of their education program, they will work independently and will not have supervision on the same level. Decisions must be quickly made that determine the course of action the SRNA will take to interrupt or resolve a developing anesthetic crisis. Limited experiences dealing with crisis situations can inhibit the student since they may not have a clear concept as to how to resolve the situation (Mayer, 1999).

The magnitude of importance of a SRNAs practice decision during a crisis situation cannot be over emphasized. The decisions made are interrelated with the other activities occurring simultaneously which may serve to distract or diminish the ability of the SRNA to make an appropriate clinical decision regarding the critical event.

Judicious processes are required to appropriately manage simultaneous events resulting from critical situations in anesthesia. If this fails to happen, a snowball effect, or cascade, of a negative chain of events is set in motion when corrective measures are not taken during an anesthetic crisis. When this type of error occurs, patient safety can be compromised and can lead to poor patient outcomes.

Equipment Related Errors

Patient safety is jeopardized if human error leads to equipment misuse or when anesthesia equipment malfunctions occur. Due to patient safety issues, guidelines for the anesthesia machine checkout procedure have been established by the FDA (see Appendix A).

The FDA guidelines have been developed to verify proper anesthesia machine functioning before each anesthetic is delivered. The FDA updated the anesthesia apparatus checkout recommendations in 1994. The checkout includes assessment for; leak detection in the system, malfunctioning valves, faulty ventilator and vaporizer function, proper oxygen and gas supplies, and functioning scavenging systems, as just a few examples (FDA, 1993). A complete preoperative machine check is required each day to test the delivery system. Any change in the breathing system, such as replacement of the patient circuit between cases, requires the system to be retested to verify the ability to administer positive pressure ventilation. Failure to perform a procedurally correct and thorough machine checkout could be a stimulus for a catastrophic patient outcome. A stuck expiratory valve is just such a stimulus.

In one study done in 2005, researchers evaluated 18 anesthesia machines for incompetent or sticking unidirectional expiratory valves (Weigel & Murray, 2005). The researchers found that 3% of the machines expiratory valves were malfunctioning or sticking. While this does not seem like a large percentage, it must be considered that a single hospital can easily utilize 18 anesthesia machines. As no national equipment malfunction database exists, it is virtually impossible to estimate the number of anesthesia machines in use across the United States, and thus, the number of machines with malfunctioning valves. This gives one pause when considering that 3% of the limited number of machines in this one study had expiratory valve malfunctions and that the magnitude of valve malfunctions nationally is not known.

There is provision in the checkout procedure to verify visually appropriate expiratory valve function (FDA, 1993). The check is a quick, easy, safe, and effective way to assess the functional status of the valve. Omission of this one simple step in the checkout process could potentially have a significant impact on patient outcomes.

Normal functioning of the anesthetic delivery system is primarily dependent upon correct functioning of the inspiratory and expiratory unidirectional valves (Han, Ho, Jin, & Liu, 2003). Researchers suggested in a review of anesthesia morbidity and mortality the literature indicates that the most common causes of death or serious injury were due to failure to ventilate the patient (Caplan, Posner, Ward, & Cheney, 1990; Sigurdsson & McAteer, 1996; UMMC, 2004). Expiratory valve malfunction can certainly impede patient ventilation.

A primary component of safe anesthesia delivery is the performance of the FDA standardized checkout procedure which includes the inspection of the unidirectional valves. While sticking valves are not a common occurrence in closed claims reports (Petty, Kremer, & Biddle, 2002), injuries associated with a malfunctioning valves have enormous potential for catastrophic outcomes. The unidirectional expiratory valve allows escape of exhaled gasses from the patient breathing circuit and a malfunction such as sticking, can rapidly cause a buildup of positive pressure in the lungs. Although reported expiratory valve malfunctions are relatively low in comparison to other machine related issues, malfunction of this nature has potential for a severe level of injury to the patient (Caplan et al., 1990). Visual inspection and manual testing of the unidirectional valves takes less than one minute. If the SRNA neglects to perform this step in the machine checkout process it can be considered misuse of equipment or human fault (Eisenkraft, 2004). The patient's safety is compromised when a valve malfunction occurs (Caplan et al., 1990) and the user is either unaware (Eisenkraft, 2004), unable to determine the source of the problem, or fails to utilize a back up system for ventilation.

User complacency may occur with the newer anesthesia machines with self-check systems being introduced into the marketplace. Often, this system does not resemble the FDA checkout procedure (Eisenkraft, 2004). Although these machines have self-check capability with electronic checklists, a visual and manual inspection of the valves is certainly possible and implicitly necessary. Eisenkraft maintains that the self-check system alone is inadequate and should be performed in combination with the FDA standardized process.

A 2000 study supports this position and additionally suggests that the FDA checkout procedure has ample room for improvement (Blike & Biddle, 2000). The researchers performed a critical analysis of the FDA versus electronic checklist with regard to human factors. They determined that while the electronic version was expensive to implement, it was more beneficial than the FDA checklist alone in that there was a significant difference in detection of faults that are difficult to uncover (Blike & Biddle, 2000). Just as algorithms serve as a memory stimulus, the electronic checklist is designed to do the same for the preoperative machine check (Blike & Biddle, 2000) in an attempt improve detection of malfunctioning components of the anesthesia machine by emphasizing each step to be performed.

Failure to detect a sticking expiratory valve in the preoperative machine checkout, along with an inappropriate user response to an ensuing critical situation, can lead to significant pulmonary barotrauma, alveolar rupture, mediastinal emphysema, and pneumothorax (Newton & Adams, 1978), any of which can lead to death.

Just as a stuck expiratory valve can cause serious harm or death, the absence or malfunction of necessary equipment can be just as detrimental to patient safety. Step 14e of the FDA Anesthesia Apparatus Checkout Recommendations (see Appendix A) is to verify that the patient suction level is adequate (FDA, 1993) meaning, suction is available and functioning properly. Aspiration of gastric contents is a noteworthy cause of anesthetic morbidity (Kluger & Short, 1999) which may largely be preventable with suction availability and SRNA diligence.

Aspiration can occur before, during, or after anesthetic administration. In an AIMS report regarding aspiration during anesthesia delivery, at least 56% of the reported cases occurred during induction (Kluger & Short, 1999). In light of this, suction capability prior to starting anesthesia administration is crucial. A critical corrective measure is unavailable if the suction device is missing or malfunctioning and the patient aspirates gastric contents. A 12.5% mortality rate was reported in one study involving 32 aspiration cases (Suraseranivongse, Valairucha, Chanchayanon, Mankong, Veerawatakanon, & Rungreungvanich, 2005). This high aspiration related mortality rate and high percentage of aspirations during induction emphasizes the absolute need for suction capability during anesthesia administration. Vigilant anesthetists will ensure that suction is available as part of the FDA checkout procedure.

It is widely accepted that failure to comply with the FDA machine checkout compromises patient safety. Standards mandated by both the American Society of Anesthesiologists (ASA) and the American Association of Nurse Anesthetists (AANA) require monitoring of all patients undergoing anesthesia. Trainees such as SRNAs as well as licensed providers, CRNAs and Medical Doctor Anesthesiologists (MDAs), use anesthesia machines for delivery of anesthetic gasses. Additionally, equipment monitoring allows continuous assessment of the patient's physiologic responses and status. Failure of any machine component could potentially be disastrous if inappropriately handled and as a result, deterioration of the patient's physiologic status can rapidly occur. The anesthetist can avert disaster by properly performing the standardized preoperative anesthesia machine checkout which can alert the anesthetist to malfunctioning or missing components, thus potentially reducing patient injury while improving patient safety.

Anesthesia Educational Program Design

Many nurse anesthesia graduate programs are comprised of two components, the clinical and the didactic portions. Some programs are designed with a front-loaded didactic component which includes the basic sciences and foundational concepts of anesthesia. The clinical component of hands-on learning takes place in clinical sites and in some cases via anesthesia simulation. There is often a significant time lapse between the didactic instruction and its actual application to patient care. As much as one year may elapse before the SRNA enters the clinical setting after beginning an anesthesia education program.

Programs that are financially able to purchase anesthesia simulators bridge the time gap between didactic and clinical instruction. The simulator can be used to prepare students to enter the clinical setting, evaluate performance during anesthesia delivery, or simply be used for the SRNA to "practice" in a realistic setting. This allows the SRNA to administer anesthesia in the safe, effective learning environment of a simulator without compromising patient safety (Morgan et al., 2002). This is one method that can potentially improve SRNA clinical performance outcomes by allowing learned concepts to more readily be applied clinically.

Another method that can offset the time lapse between didactic and clinical instruction is the use of vignettes. While they do not substitute for clinical experience, they complement class room learning (Ber & Alroy, 2001). Simulation in a realistic setting can offer repetition and the ability to learn from one's own mistakes (Biddle et al., 2005) while vignettes are exportable and can be recycled. They can be used in multiple class sites, or in multiple programs. This makes vignettes attractive to the educational program that cannot financially support simulation. Teaching methods, such as vignettes, that can be utilized to enhance knowledge retention and retrieval, and potentially aid the SRNA when crisis situations arise.

Teaching Methodologies

Traditional teaching methods such as lecture, reading assignments, written case studies, group work, discussion, student presentations, and written materials are used in combination or as primary modes of content delivery to facilitate learning. Each method is not without its benefit or limitation. Comparisons in this study are drawn between written case studies and vignettes while including both lecture and active discussion.

Written Case Studies

Written case studies are useful in promoting development of critical thinking skills necessary for synthesis and analysis of knowledge (Thomas, O'Connor, Albert, Boutain, & Brandt, 2001). They should be evidence based, founded in a strong theoretical framework, meet the objectives for the content to be taught, and clearly direct the SRNA toward the important concepts contained within. Case scenarios presented in text format offer the SRNA the ability to organize, analyze, and synthesize knowledge

(Thomas et al., 2001). These actions exhibit high-level learning and cognitive processing. Case studies are often utilized to bring the clinical setting to the classroom.

Problem Based Learning

The backbone for written case studies is PBL which was developed over 30 years ago and is still used in health sciences today as a foundation for teaching (Ryan & Marlow, 2004). While the case study can clearly articulate the relevant material to be learned, prior research strongly supports the idea that visualization is important in the learning process (Paivio, 1986). If discussion does not take place after reading the case study without visualization, there is no additional information to be gleaned from the text (Renton-Harper et al., 1999) which limits the student's level of critical thinking.

A coding system was used to evaluate critical thinking in PBL discourse using high level cognitive indicators coded from group discussions (Kamin, O'Sullivan, Deterding, & Younger, 2003; Kamin et al., 2001). This system allowed evaluation of the effectiveness of using PBL as a means to stimulate critical thinking in various content presentations. The authors reported that when case studies are presented in text format, the assessment capability of the student is limited as there is no opportunity for visual cueing. The use of PBL utilizing case presentations was found to be useful when presented in verbal, face to face, or video format. These two studies were limited by the fact that no foundational knowledge assessment was done for comparison to post-treatment testing or coding. Without controlling for baseline knowledge it is possible that the group discussion may have been driven by a participant with expertise in the case study content. In the 2003 study, the authors concluded that case studies presented in video format enhanced critical thinking skills.

Lecture

Traditional learning methods are less effective in promoting learning (Deyer & Bongero, 1981). It has been suggested that lecture may be less effective than video or other means of instruction because the pace of content delivery and sequencing of information is determined by the lecturer (Beard, Bligh, & Harding, 1978). Effectiveness can also be impacted by the quality of lecture delivery (University, 2006). Even though these concerns exist, the lecture method remains one of the cornerstones in content delivery for higher education (Pittsburgh, 2006). Newer methods of instruction have been investigated and implemented over the last few decades but often times lecture is still used as an adjunct.

Some advantages to lecture are (Pittsburgh, 2006; University, 2006) they:

- provide elaboration on complex subject matter
- can present the most current, reliable content
- are economical and efficient
- can deliver content to large numbers of students
- advantage synthesis and summation of studied concepts
- allows the lecturer to add emotion and emphasis where needed
- are easily updated.

Some disadvantages of lecture (Pittsburgh, 2006; University, 2006) are:

- too much information can be presented so that the student feels overwhelmed

- encouragement of passive learning and non-participation
- differences in lecturers abilities
- students may not receive individual feedback
- individual learning styles are difficult to accommodate

Lectures can capture the student's attention and guide the student through the important aspects of the subject matter but are considered less effective in demonstrating technical procedures or skills (Chen, Horrocks, & Evans, 1998) necessary in nurse anesthesia education. Vignettes or video may be better suited to accomplish this task.

Learning via Group Discussion

Written materials without interaction do not allow for cooperative or vicarious learning (Yoder & Hochevar, 2005). Yoder and Hochevar at the University of Akron demonstrated that psychology students exposed to active learning techniques scored higher on multiple choice tests than students exposed to traditional learning methods. An example of an active learning technique used in their study is group discussion which helped the group focus on the more important aspects of the content. Vicarious learning is discussed later in this study.

Vignettes

Deciding which content is most important can be difficult (Yoder & Hochevar, 2005) for the self directed student. Content delivery method can help clarify the important concepts. While written format materials can narrow the direction, crisis oriented vignettes can distinctly highlight the importance of a specific topic or concept by affecting multiple senses and sensations. Like a vignette, written material such as a case study, can be designed to include an emotional event but can lack the powerful emotive impact. Vignettes can be designed to include emotional content, such as the death of a child, in an effort to have greater cognitive impact (Biddle et al., 2005) by personalizing the event. Conceptually, discussion that ensues from the vignettes utilizes the learner's perspectives and experiences to connect the concrete ideas within the video to the more abstract. It can be extrapolated that this, in conjunction with enhanced involvement due to the personalization of a negative patient outcome, may facilitate LTM by improving cognitive imprinting. Vignettes may promote student learning by advantaging the quality of vicariousness (Biddle et al., 2005).

Vicarious Learning

Vicarious learning can be defined as the potential benefit gained by learners being able to observe and "listen in" on discussion between their peers or experts (Cox et al., 1999). Discussions are considered a form of active learning because cognitive processes are required to organize, understand, and synthesize (Clark & Paivio, 1991) the content being examined. Yoder & Hochevar (2005) reported significant support for active learning techniques when compared to traditional lecture formats. This seems to validate vignettes as a method to stimulate cognitive processes more effectively than traditional education modalities due to their inherent vicarious nature.

Similar support for the use of vignettes has been offered in comparison to traditional education methods such as written text (Balslev et al., 2005). In a study involving pediatric residents, Balsev et al. utilize a vignette with a specific patient case and group discussion. Using a five step evaluation process, the subjects analyzed the presented case. They were then divided into two groups, one being exposed to a 2.5 minute vignette and the other a written description of that same scenario. Discussions ensued in both groups. The groups were then asked to reanalyze the case. Results indicated a statistically significant improvement in data exploration and theory application in post-vignette evaluations. As suggested in previous studies (Clark & Paivio, 1991; Yoder & Hochevar, 2005), cognitive processes were stimulated effectively by the vicarious nature of the vignettes.

The post-vignette discussion portion of this teaching methodology is an important part of cognitive imprinting and learning. Vicarious learning via active participation rather than passive viewing, was preferred by medical students when shown vignettes to teach the fine points of interviewing a child with mental health issues (Parkin & Dogra, 2000). Training in a specific skill such as this (Kamin et al., 2001) can be accomplished using a set of criterion-based objectives which are adhered to when producing a vignette (Parkin & Dogra, 2000). This may be especially useful when attempting to educate SRNAs in crisis management regarding infrequently occurring events. Experiences that may otherwise be unavailable to SRNAs not directly involved, such as a malignant hyperthermia crisis or an operating room fire, can be replayed to deliver the content to all students equitably (Parkin & Dogra, 2000).

Students exposed to vignettes that are audio-visual representations of a developing anesthesia crisis scenario, may benefit from vicarious learning by seeing the mistakes of others without committing the error themselves (Cox et al., 1999; Lee, Dineen, McKendree, & Mayes, 1999). This is a concept founded in social learning theory whereby subjects observing negative consequences or punishment, produced a behavior change (Bandura, 1977). Bandura notes that in 1977, re-usable educational resources and observational learning have been studied very little. While not singularly addressed, but certainly encompassed within, this study investigates vicarious learning through the use of re-usable vignettes.

Crisis oriented vignettes that end before the problem resolution occurs offers opportunity for group discussion. SRNAs can benefit from discourse centered on complex anesthetic issues by exposure to the discussions between their peers and instructors. Vicarious learning and utilization of higher cognitive processes (McKendree, Stenning, Mayes, Lee, & Cox, 1998) allows the SRNA to formulate a plan of action that includes corrective measures that could be taken. The exploitation of knowledge from other SRNAs can contribute to the body of knowledge to one who has a lesser understanding of the content (Naughton, 2006). Additionally, the discourse can potentially improve cognitive imprinting which may facilitate the application of the knowledge to clinical practice. Regardless of how the content is imprinted cognitively, if it is accurate, it follows that this could improve the likelihood that the anesthetist would take the correct action during an anesthetic crisis, thus improving patient safety.

The Vicarious Leaner project assessed the "fundamental role of dialogue for learning" (Lee et al., 1999; McKendree et al., 1998). One study that has been produced from the project investigated the use of vicarious learning techniques in a Master's level computing course using 36 students. Half were exposed to vicarious learning strategies and the other half served as a control group. Results showed positive changes in favor of vicarious learning methodologies suggesting that active participation in discussion influenced knowledge acquirement. Both visual exposure and discussion of the content of a vignette encourages vicarious learning (Biddle et al., 2005).

Additional support for vicarious learning or active participation comes from the unlikely source of television and Hollywood productions. Otherwise bland or dry content can be made to "come alive" when presented in audio-visual format (Masters, 2005). In a study to determine how visualization contributes to learning from television, researchers found a significant number of participants recalled concepts and themes from news stories shown in visual format versus audio presentation (Graber, 1990) presumably because the content was not perceived as dry and involved visual cuing. The same study also determined that if news stories were personalized with visuals such as unusual sights or human figures, recall was increased. These observations or visual cues can provide subtle information and demonstrate relationships otherwise not recognized (Miller, 1957).

Observed experiences in the news and Hollywood productions can potentially impact schematic processing. This is supportive of the CIP theory discussed previously. Visual and auditory exposure to "memorable" events, especially when combined with an emotive component, are readily stored in the schemas of LTM and may help the SRNA to cognitively process the information and think more critically (Sweller et al., 1998). A vignette that demonstrates an evolving error related crisis and a catastrophic patient outcome is designed to be cognitively processed as a memorable event.

Miller (1957) suggests that motivation for learning should be built into a film. Within a vignette, motivation for an SRNA might be a catastrophic or poor patient outcome, which may allow the SRNA to personalize the situation based on emotional components and observation of subtle visual cues gleaned from the vignette.

One study found that participants recalled specific details of a dramatic, emotional event more significantly than that of a human interest story (Valkenburg, Semetko, & De Vreese, 1999). The authors concluded that how information is packaged or framed can affect recall in their population. Vignettes can convey the concept to be presented and be designed to include an emotional event, which may potentially impact recall if they are produced with creativity.

Creativity and realism are sought after in the filming of a motion picture to entice audience participation thereby increasing financial gain. In an attempt to avoid dry or bland content delivery, vignette producers seek realism and creativity (Biddle et al., 2005) as well, which is essential for the SRNA of today's society.

Today's SRNAs have grown up in a media saturated society with abundant exposure to television, film, and video as undergraduates. They may perceive that returning to the traditional lecture format of their earlier primary education as boorish or uninteresting. Because the content that must be learned in anesthesia education is vital to patient safety and of critical nature, educators need to strive to find innovative and interesting ways to present the material. This should be done in an effort to make a strong cognitive impact, allow the SRNA to synthesize and organize information, and ultimately apply it to their clinical practice. Vignettes offer the ability to make a strong cognitive impact, provide a forum for vicarious learning, present the material in an innovative and interesting manner, and when used in anesthesia education, can potentially be used to produce a high-quality, safe, anesthesia practitioner (Biddle et al., 2005).

Comparison of Teaching Methodologies

Renton-Harper et al. conducted a study comparing the effectiveness of video and written instructions for plaque removal using an electric toothbrush. After controlling for baseline plaque formation via dental cleaning by a hygienist, a group of recruited subjects from dental and medical hospitals were randomized into two groups. One group received instruction in video format while the other received instruction via a leaflet. Results showed overall improvement in plaque removal in the video instruction group yet, at the lingual area surfaces which are typically much harder to reach there was no difference. These results suggested that the video could have been more specific and focus on the more difficult areas to clean by spending more time instructing on the lingual areas (Renton-Harper et al., 1999). The study tested differences in plaque removal scores between two teaching methodologies, using volunteers from a medical and dental hospital.

Generalization to any other group outside a similar dental and medical hospital cannot be considered valid. Employees of a facility such as a dental hospital will likely be more cognizant of dental hygiene and be potentially more likely to follow teeth cleaning instruction. Little demographic information regarding the subjects was offered. Overall, this study supports the use of video as a more effective method of instruction on the proper use of a toothbrush than if presented in a written format. It can be postulated that vignettes may have a similar positive effect on SRNA clinical performance.

Another study also compared video instruction to leaflet or written format yet used an interactive visual presentation methodology (Addy, Renton-Harper, Warren, & Newcombe, 1999). Using two randomized groups and controlling for baseline plaque, the researches compared plaque formation after use of an electric toothbrush for two weeks. The data showed the video instruction group had marginally significant less plaque than the written text group. An admitted limitation to this study's crossover design is that the subjects were exposed to the same information in the second phase as they were in the first. The alternative instructional method for each group could be considered as reinforcement of the instructions and confounds results from data collected from the two methods. The authors concluded that instruction via video is more effective than when presented in written format. It is worthy of noting the video used in this study promoted significant active participation by including a "watch and follow" technique whereby the participants actually mimicked the actions of appropriate use by the actress in the video (Addy et al., 1999).

An additional study offering support for video instruction over text was conducted by Balslev et al. in 2005. The study compared the two teaching methodologies for impact on cognitive and metacognitive processes in pediatric residents using a PBL foundation. PBL is frequently used in medical education for adult learners to foster independent thinking and develop their problem solving skills (Schmidt, 1993). The clinical scenario depicted a child diagnosed with Sturge-Webber syndrome, a rare disease. A visual cue in the video was a continuous, unilateral seizure augmented with audible respiratory wheezing. Both sample groups analyzed the written vignette and then split into their respective randomized groups. One group was shown a 2.5 minute vignette of the patient and the other read a written description of the video. Within group discussions took place. The video group was allowed to watch the vignette twice. It was noted that the vignette group spent eight minutes longer analyzing the video case suggesting that cognitive processes were more stimulated than with the text delivery method. However, the frequency of metareasoning was actually lower after the video when compared to the text group.

The authors suggested that cognitive processes and metareasoning are intertwined and cannot be considered as independent variables. A plausible explanation offered to support this concept is the working memory capacity as described in the CLT, whereby cognitive processes consumed more time disallowing equal opportunity for metareasoning. The conclusion reached in the study was that the use of video may be a valuable supplement to medical training, specifically for visual and auditory cueing of movement disorders (Balslev et al., 2005).

In the Balslev et al. 2005 study, specific quantitative variables were used, such as the length of time of case review and discussion, as well as qualitative measurements such as coding for the verbal interactions of the resident groups. Gaba, in 2002, determined that the difficulty in assessing patient safety lies in that it is difficult to measure performance with objectivity. Measurement tools typically are not designed to encompass individual variability in performance due to the complexities of real patient care (Gaba, 2002). Because of individual differences, multiple raters may be necessary and may increase the costs of training via simulation (Gaba, 2002). However, this brings about inter-rater reliability issues.

One study agrees with the notion that one of the difficulties in comparing two teaching methodologies is due to problems related to the subjectivity, reliability, and validity of measuring resident clinical performance (Morgan, Cleave-Hogg, Guest, & Herold, 2001). Rydman et al. avoided this dilemma in a study, not in clinician performance, but in patient performance of appropriate asthma inhaler use. Asthma patients were randomized into two groups, one of which received verbal instructions and a demonstration, the other, written instructions. Patients then demonstrated their ability to use the inhalers. Rydman et al. developed a coding system which was used to score the participants on an "all or none" basis. If all five predetermined steps were demonstrated the patient received a one. If only one step was missed, the subject received a zero. In comparison with the Morgan et al. study (1991), this seems to condense the variability associated with measuring the complex nature of clinical performance, specifically, reducing the margin of error related to subjectivity. However, it seems that this approach would yield minimal data and fail to reliably evaluate the degree to which each clinical action was performed correctly.

It can be extrapolated from the Rydman et al. study (1999) that predetermined guidelines for clinical actions in anesthesia can help to reduce subjectivity. It can further be suggested that it may be possible to develop a reliable, valid tool to measure certain

SRNA task performance and decision making. This could advantage objectivity in assessing SRNA cognitive processes related to clinical application of knowledge.

Vignette Production Process

Vignette production is time consuming (Biddle et al., 2005) yet, with proper planning one can feasibly be filmed in a relatively short period of time. This is one advantage of self-produced vignettes. Additional time is needed for adding the audio component or voice over for the film.

Patient safety vignettes are commercially available. Vignettes that are self-produced can be more beneficial (Ber & Alroy, 2001) since they can be made to include local problems and colloquialisms. There may be implication for judiciary concern as a result of regional differences not addressed in commercially prepared films. While commercially available vignettes are attractive to educational programs without filming capabilities, institutions with the financial resources and access to anesthesia simulation, may be able to produce vignettes specific to the content they desire to be delivered to SRNAs.

Vignettes are considered relatively simple to produce and are a cost-effective means to convey content (Alroy & Ber, 1982). Authors agree (Alroy & Ber, 1982; Biddle et al., 2005) that a highly skilled production crew and editing capabilities are necessary to produce a quality film capable of conveying a realistic crisis situation. In addition to the crew and editing capability, a well written script, willing participants or actors, and a realistic environment are essential to producing a quality vignette. Professional camera zoom and the ability to film using multiple camera angles may be necessary to focus the viewer's attention to a specific gesture, action, concept, or component (Alroy & Ber, 1982; Ber & Alroy, 2001). While film crew and editing costs may initially seem high, when considering that vignettes are recyclable and can be used in many formats, the cost advantage becomes clearer. Practice sessions may be utilized and can conceivably cut filming costs while adding to the quality of the vignette (Biddle et al., 2005). This allows for adjustments and corrections to be made before the actual filming begins. Meticulous coordination must be done to ensure a cost-effective product.

In addition to film crew, cast, setting, and equipment, time constraints are can be a production issue. Additional time should be allotted for re-takes. Ideally, filming would be completed in one day; however, ample resources may alter this. Should a cast member be absent on the second day of filming, the previous day's video may be unusable. Another consideration to avoid production delay is to schedule substitute personnel in the event a participant cannot fulfill their obligation. Again, the financial ramifications are clear if production is taking place with a minimal cast size and one member must leave for unforeseen reasons.

As discussed earlier, low production costs make vignettes attractive to educational programs. Another attraction is that vignettes may be produced in multiple formats. These include video home system (VHS), compact disc (CD), digital video devices (DVDs), and audio-video streaming for publication to a website (Biddle et al., 2005). These different formats afford exportability and expand their usability into different domains.

Clinical Application and Outcomes

Potential patient outcomes can be demonstrated using vignettes that convey the appropriate machine safety checkout procedure. Catastrophic anesthesia events can be shown to emphasize the negative results of human error which, when cognitively processed may facilitate clinical application of appropriate processes and actions to avoid poor outcomes.

When faced with a deteriorating intra-operative crisis, the SRNA could potentially improve the patient outcome by applying knowledge learned from exposure to a vignette. This knowledge application due to cognitive imprinting derived from a vignette can potentially be measured. However, a single clinical performance measurement tool is not available and while some exist, none is accepted as a gold standard (Robb, Fleming, & Dieter, 2002). Most are considered too subjective. Criterion-referenced standards can be used to develop a tool to assess competency, improve observer objectivity, as well as ensuring fairness for the student (Searle, 2000).

Considering that anesthesia as a profession is one with great accountability, SRNAs must be able to demonstrate competency to transition into the clinical setting as a CRNA. Appropriate ACRM skills and the ability to clinically apply learned knowledge are paramount to success as an anesthesia provider. Social and litigious expectations for positive patient outcomes abound (Boursicot, 2006). Thus, SRNA and CRNA performance is under scrutiny, in particular when a poor patient outcome occurs.

One study recognizes process measures as an indicator of quality of care which can affect patient and performance outcomes (Crombie & Davies, 1998). The authors suggest that process measures are easily measured, interpretable, and can be an indication of areas of deficiency in clinical performance. It is also suggested that process indicators be linked to patient outcomes. It follows that clinical application of error prevention or appropriate corrective measures by SRNAs could be easily linked to patient outcomes.

Patient Safety Outcomes

Patient safety encompasses error prevention and avoidance (Flanagan, Nestel, & Joseph, 2004). Another focus of patient safety is to protect the patient from further or continued harm once a human error has occurred. A positive safety outcome exists if the patient has been protected.

SRNAs can have direct impact on patient safety by first, learning appropriate crisis management skills, and second, applying them correctly in the clinical setting. Much emphasis has been placed on providing conceptual knowledge in anesthesia curricula yet, this does little good if the SRNA cannot apply the knowledge clinically (Flanagan et al., 2004) .

Quality anesthesia care is at the core of patient safety and thus, nurse anesthesia educators should strive to present material in a format that advantages learning and affords motivation to use learned knowledge in clinical practice. Vignettes are one method of content presentation that potentially can impact clinical practice. Many authors (Alroy & Ber, 1982; Ber & Alroy, 2002; Biddle et al., 2005; Deyer & Bongero, 1981; Eshed & Epstein, 1991; Hartland et al., 2003; Rabinowitz, Melzer-Geva, & Ber, 2002) have investigated the use of vignettes, or trigger films, as a means to present content to students. All found positive implications for using the audio-visual format to present concepts and material. It logically follows that patient safety vignettes can improve patient safety should it elicit appropriate crisis intervention in the process of application to clinical performance.

Summary

Within the developed ACRM framework and the premise of the DCT, differences in the cognitive imprinting of two teaching methodologies and application to SRNA clinical performance will be quantified. It is proposed that this research will add to the scientific body of knowledge by bridging the gap between strong, well accepted theory and SRNA clinical performance, as well as provide quantitative data related to teaching methodologies and SRNA clinical performance outcomes.

This review integrated multiple concepts outlined in the literature regarding issues related to human error based anesthesia critical events and SRNA clinical performance. It is designed to evaluate the role of vignettes as a means of improving cognitive imprinting and clinical performance in SRNAs.

Overall, review of literature supports the use of vignettes as a means to improve cognitive imprinting, stimulate vicarious learning, deliver content in an interesting and innovative format, and provide visual cuing to facilitate content storage into LTM schemas. Additionally, it supports the concept that improved clinical performance outcomes positively impact patient safety. With strong theory support and an existing gap in the scientific body of knowledge, this study will fulfill the need for quantitative data to evaluate the efficacy of vignettes as a teaching methodology to improve SRNA clinical performance outcomes.

Hypotheses

Anesthesia education is intended to deliver content in a manner such that SRNAs can store and retrieve knowledge from their LTM. Within memory systems, verbal and visual information is managed separately by different cognitive processes (Sweller et al., 1998). Remodeling or cognitive synthesis takes place after this has been accomplished according to the DCT (Paivio, 2006).

Anesthesia requires synthesizing concepts previously learned with real-time crisis events then taking action based on the remodeled information. As a result, hypotheses for this proposed study have been developed using DCT as a foundational concept. The hypotheses are:

- Student anesthetists exposed to audio-visual vignettes will exhibit superior clinical performance during simulated apparatus-related crisis events, evidenced by higher group mean demonstration scores, when compared to a matched group exposed to written case studies.
- Student anesthetists exposed to audio-visual vignettes will exhibit superior recall of apparatus related material, evidenced by higher group mean post-test scores, when compared to a matched group exposed to written case studies.

CHAPTER 3: METHDOLOGY

Introduction

This chapter presents the research design used in the study. Population and sample descriptions as well as instrumentation were discussed. Data collection processes were described. Validity issues, assumptions and limitations, and plans for statistical analysis of data were considered as were the strengths and weaknesses of the study design.

This study addressed the profession's charge to improve nurse anesthesia educational and clinical performance. This study suggested it may be possible to accomplish this goal by using a non-traditional teaching methodology. It is possible that improved clinical performance reduced anesthesia error and subsequently might improve patient safety in future practice.

The Institution Review Boards (IRB) at both Virginia Commonwealth University and Samford University approved the proposed study. The proposal was successfully defended to the dissertation committee, prior to data collection.

Research Design

The study design was a randomized control trial (RCT). A pre-test/post-test, cross-over design was utilized. Pre-test/post-test methods offer ample opportunity for threats to internal validity and if not used in conjunction with other study designs, offer little experimental control. This RCT, pre-test/post-test, crossover design combination was chosen to significantly reduce these potential threats (Cook & Campbell, 1979; Isaac & Michael, 1995; Polit & Beck, 2004).

Equivalent subject groups are necessary to lend strength to the study. With this in mind, a crossover design was chosen to ensure the "highest possible" equivalence among subjects to reduce threats to external validity (Polit & Beck, 2004). Study participants met the stringent requirements for admission to the Samford University nurse anesthesia program. Criteria evaluated for admission to the nurse anesthesia graduate program included undergraduate grade point average (GPA), graduate record examination (GRE) scores, intensive care work experience, multiple reference letters, and five face-to-face interviews, among other requirements. These criteria were chosen to enable selection of the most qualified, highest quality students for admission to the program. Subject equivalency is enhanced as a result of participants meeting these initial requirements, thereby strengthening this study.

Additional strength is added to the crossover design by incorporating the pre-test/post-test component. Pre-intervention data was collected to establish the pre-study knowledge level for the participants. Establishing this knowledge level reduced the variability between sample groups related to previous experiences by accounting for baseline knowledge differences. In addition to this, the pre-test/post-test design also offers the ability to measure and examine changes that occur as a result of treatments to which the subjects are exposed. Changes that occurred in knowledge retention after exposure to different treatments were measured quantitatively.

Another strength of a crossover trial is that it allows each set of participants to be used as their own control group (Redelmeier & Tibshirani, 1997; Reed, 2004). This was beneficial as expenses are reduced and a smaller sample size was utilized. Randomization, equivalency of subject groups, and the addition of the pre-test/post-test component, all served to strengthen the power of this study.

Data collected can be used in future research. The study was designed to be replicable under the same or similar conditions. Additionally, it is expected that a multi-cohort longitudinal study can be easily developed using the design of this research.

Diagrammatic Representation

Cook and Campbell's (1977) diagrammatic depiction is displayed in Figure 2.

O_1 O_2 R X_1 X_3 O_3 O_4 X_2 X_4

O_1 O_2 R X_2 X_4 O_3 O_4 X_1 X_3

R Randomization

X_1 Stuck expiratory valve vignette	X_3 Suction malfunction case study
X_2 Suction malfunction vignette	X_4 Stuck expiratory case study
O_1 Pre-study questionnaire	O_2 Written pre-test
O_3 Hands-on demonstration	O_4 Written post-test

Figure 2. Cook and Campbell's Diagrammatic Representation of the Study Methodology.

Population, Sample, and Justification

According to Issac and Michael's Handbook in Research and Evaluation, a small sample size is appropriate for assessing behaviors involving complex, in-depth studies. Issac et al. (1995) describes benefits of using samples containing 10-30 subjects. Stated benefits include cost effectiveness, simpler statistical monitoring, fewer input errors, economic advantages, and convenience. It is noted that an N between 10 and 30 can be large enough to test hypotheses and yield significant results (Isaac & Michael, 1995). In this proposed research, the entire population to be studied is the sample.

The population was identified as the entire SRNA class of 2008 at Samford University, in Birmingham, Alabama. The group began core science courses in June 2006, and had no exposure to anesthetic principles or equipment of yet in their education. Due to logistic issues and complexities in course scheduling, a single educational site was chosen. Scheduling of treatments and lectures required reorganization of existing class times and content, classroom reservation rearrangements, and reserving multiple blocks of time in the nurse anesthesia laboratory. Using a single research site allowed greater control of study conditions by limiting the complicating factors related to curriculum changes and scheduling that may have occurred in a multi-site study.

The population and sample consisted of 24 SRNAs. The study content was material that is typically covered in Principles of Anesthesia I, a required course in the nurse anesthesia curriculum. As such, each SRNA was required to attend lectures, view the vignettes, read the case studies, participate in group discussions, and perform a hands-on demonstration of the FDA anesthesia apparatus checkout. All subjects were properly informed regarding methods that were taken to ensure anonymity. A pre-study questionnaire was done to identify SRNAs who met the exclusionary criteria previously discussed in Chapter 2.

Confidentiality

Processes were implemented within this study to protect subject confidentiality. These processes were meant to avoid any adverse consequences a student may have encountered as a result of participation in this study. All Samford University and Virginia Commonwealth University confidentiality requirements were met. Pre-study questionnaires were shredded and disposed of according to Samford University's policy regarding confidential documents. Another method utilized to ensure subject confidentiality was to randomize the SRNAs to treatment groups using a simple numbering system using the Statistical Procedures for Social Sciences (SPSS) 12.0 software. Study identification information was unrelated to personal data such as social security numbers or birthdates. This numerical system was used for the data collection process. The randomization process is discussed later in this chapter.

A Promise of Confidentiality statement was distributed to each SRNA at the beginning of the study (see appendix B). This included the recognition of the subject's right to anonymity by removing any identifying information and destroying documentation containing personal data, once the study has been completed. SRNAs were instructed as to the need for confidentiality of their experiences in the study. Subjects were instructed to refrain from discussing the vignettes or case studies to which they were exposed. Policies regarding professional conduct, academic integrity, and the honor code, were strictly enforced. The policies and honor code were reviewed with the subjects on the first day of the study.

Variables

The proposed study is centered on five major variables. These variables are outlined in Table 2.

Table 2

Description of Variables

Independent Variable	Type	Measurement
Vignettes	Independent Qualitative	Not Applicable
Written Case Studies	Independent Qualitative	Not Applicable
Clinical Performance	Dependent Quantitative	Total time from initiation of FDA Anesthesia Related Apparatus Checkout Procedure steps 12 & 14 to equipment related problem identification
Knowledge Gain	Dependent Quantitative	Pre-test/Post-test score differences
Baseline Knowledge	Control Quantitative	Pre-test scores

Pre-study Questionnaire

Prior to the start of the lecture series, the pre-study questionnaire was administered to all subjects (see appendix C). Results were evaluated to determine if subjects met the exclusionary criteria. To avoid response alternatives, questions were presented such that yes/no answers were required. This improved the clarity of the respondents answers and the ability of the participants to give specific, accurate information (Polit & Beck, 2004). In addition to this, each question was designed to be mutually exclusive to avoid any crossover contamination as a result of previous queries. Questions were designed to specifically address the work experiences of the participants while avoiding response alternatives. These measures strengthened the reliability of this questionnaire.

Because the sample size is limited, it was determined that if two students are eliminated, the study will continue. In crossover designs, significant results have been found using as few as 8 subjects. An acceptable number of excluded students were set at 3 subjects so that at least 90% of the population was be able to be utilized. The sample size studied was 23.

Pre-Test

Both subject groups were given a short multiple choice pre-test to determine their baseline knowledge of the anesthesia apparatus check-out process (see Appendix D). The questions were of a basic nature related to proper anesthesia machine functioning and the FDA apparatus checkout procedure. Pre and post-test scores were analyzed for differences between group means. The pre-test was validated prior to use. This was accomplished by administering the test to 10 CRNAs with at least five years experience in the clinical setting, who are familiar with the FDA anesthesia apparatus checkout procedure. Pre-test validation is supported by review using a "panel of experts". Three CRNAs, each having more than two decades of anesthesia education experience, have reviewed the pre-test and found it to be appropriate for this research. It was determined that if the CRNAs score highly on the pretest, it stands to reason the test is a valid representation of knowledge related to the anesthesia machine checkout procedure.

Additionally, concepts in healthcare and anesthesia are often abstract and therefore require indirect measurement. Clinical performance is such an example. Once determination was made as to which aspect of clinical performance was to be measured, a tool was developed that measured in the most exact manner.

Each question on the pre-test was equally weighted and the test was scored using a 100 point scale. The pre-test was to be considered validated if the composite score for the experienced CRNAs was 80% or higher.

Randomization

After pre-testing, the subjects included in the study were assigned a random number using their last name, in alphabetical order. They were randomized into two groups using their assigned numbers by the 12.0 (SPSS) software. Randomizing after the pre-test aids in controlled for researcher bias that may have existed from knowledge of group assignments (Polit & Beck, 2004). In this study, randomization served to distribute any variance related to different learning styles among students. Once randomized, no further identifying information was available. Records containing randomization information were protected in a locked drawer of a secured office until completion of the study, upon which, the information was appropriately destroyed.

Lecture

Subjects attended two lectures. A portion of the first lecture included description of the AANA standards of practice related to the use of anesthesia equipment and monitors. The second portion introduced the anesthesia machine's function and design. The second lecture involved detailed explanations of the route of gas flow through the anesthesia machine and potential areas for malfunction. Group participation was encouraged, as is typical of the program's class lectures. Preparation for anesthetic delivery regarding the anesthesia machine checkout process, availability of suction, necessary monitors, and appropriate back up ventilation sources was discussed within the lecture material.

Vignette and Case Study Treatments

In the week following the lecture series, the two randomized groups were separated into different classrooms. Written case studies and vignettes were presented to both groups. Each case study had a corresponding vignette depicting the same crisis oriented scenario. The same content was represented between each scenario and its matching vignette. For example, Group 1 was given vignette scenario A (expiratory valve malfunction) and written case study B (suction device malfunction). Both methods depicted different anesthetic mishaps. Group 2 was given vignette scenario B (suction device malfunction) and written case study A (expiratory valve malfunction). Therefore, each group was exposed to two different mishaps, in different formats. To satisfy IRB requirements and ensure equivalent educational experiences for enrolled students, once the post-test data was been collected, each group received the content in the format they were not exposed to in the initial portion of the study.

Group discussion took place after each treatment was administered. This was done to stimulate the use of scientific thought processes and promote vicarious learning.

One moderator was present in each group but did not participate. Moderators facilitated the discussion by inviting conversation regarding any thoughts or questions students had. The two moderators were CRNAs with clinical experience of more than ten years. Additionally, they had at least five years experience as a nurse anesthesia educator. The moderators were given instruction regarding their limited role as a facilitator and were given specific questions to be used to encourage group discussion (see appendix E). Facilitator instructions were based on common teaching tools using open ended discussion guidance (Davis, 1993). During this portion of the study, no data collection took place. Ten minutes were allotted for group discussion after each treatment. Both groups then merged and the entire cohort attended a lecture containing content unrelated to the crisis scenarios.

Hands-on Demonstration

Depicted in both the vignettes and the case studies was a breach in an AANA standard of practice. This breech set the stage for an anesthetic crisis that rapidly deteriorated into a catastrophic event with a poor patient outcome. Two such scenarios were depicted. These crisis oriented events, a stuck expiratory valve and a broken suction canister, were replicated through simulation during each subject's hands-on demonstration of the anesthesia apparatus checkout procedure.

A non-biased, observer collected data during the demonstration portion of this study. The observer was blinded as to which vignette or case study the subject received. A CRNA educator with ten years clinical experience and intricate knowledge of the check out process served as the observer.

Prior to beginning the hands-on demonstrations, a sticking expiratory valve was simulated using double-sided tape. In addition to this, a canister was fractured in an obscure place to simulate a malfunctioning suction device. Both the valve and the suction canister appeared as normal upon routine visual inspection.

Students were instructed to verbalize the number of each step in the FDA anesthesia apparatus checkout procedure prior to starting. For example, the first step in the checkout process was to verify that backup ventilation is available and functioning. The SRNA said "step one" and proceeded to verify that backup ventilation was present and in working order. For this proposed study, the crises that were replicated involved steps number 12 and 14.

Step 12 included a manual check and inspection of the unidirectional valves. This is the point at which the sticking expiratory valve should have been detected. Using a stopwatch, the observer recorded the time when the student called out "step 12" (see Appendix F). Timing ceased at the point at which either the student removed the dome ring surrounding the expiratory valve to correct the problem or verbalized that the valve was malfunctioning. Both actions are indicative that the student recognized that the unidirectional valve was not functioning properly. The total number of seconds was recorded. If neither of these events occurred, timing was to continue until the student calls out "step 13".

The last step of the checkout procedure was step 14. This step requires checking the final status of the machine which included ensuring that patient suction is available and functioning. As done in the previous step, the observer began timing when the student called out "step 14". Timing for this step concluded once the student verbalized that the suction level was inadequate or when the student stated they have completed the checkout processes. The total number of seconds taken to complete step 14 was recorded.

Total Checkout Time

The time taken for each subject to complete the entire anesthesia checkout machine process was recorded. Timing started when the subject called out "step one" and stopped when the subject completed step 14.

Post-Test

The post-test portion of the study had two components (see Appendix G). The first portion was a repeat of the pre-test to evaluate knowledge gain. To test recall differences between treatments, the second portion of the post-test consisted of eight multiple choice questions focusing on specific clinical details contained within the vignettes and case studies. Multiple authors have utilized non-standardized tests or questionnaires developed specifically for their study, to test recall of material presented in different presentation methods (Gray, 1996; Langdon, Hardin, & Learmonth, 2002; Moseley, Wiggins, & O'Sullivan, 2006; Turner & Williams, 2002; Weston, Hannah, & Downes, 1997). In these studies, six to eleven questions were presented to the subjects who were exposed to various multimedia presentations of the same content. The post-test questions posed in this study were applicable to both the case study and its matching vignette. Questions were presented so that neither methodology will give a subject recall advantage over the other. The post-test was administered once all subjects had completed the hands-on demonstration of the machine checkout process. Results were calculated and analyzed. Within one week of the study completion, the design and findings were disclosed to all participants. Questions were answered and feedback was encouraged.

Data collection points are designated in the timeline outlined in Table 3.

Table 3

Timeline and Data Collection Points

Day 1*	Questionnaire
Day 2*	Pre-testing
Week 1	Lectures 1 & 2
Week 2	Treatments Administered
Week 3*	Hands-on Demonstration
Week 4*	Post-testing
Week 5	Content Delivery in Alternative Format
Week 6	Disclosure

Note: * Data collection points

Face and Content Validity

Face validity in conjunction with the other validities presented in this study, supported the quality of the research (Polit & Beck, 2004). Content validity of the study further reinforced this concept as the pre-test, post-test, and hands-on demonstration measures appearred representative of knowledge gain and clinical performance. While these two instrument validities alone certainly did not validate this research, they did enhance and strengthen the overall validity of this study. Other instrument or measurement validities that impacted this study are criterion and construct validity.

Criterion Validity

The relationship between the data collection instruments and their associated criterion could be fully established. This study was very unique in design and therefore, no existing instrument was found that was adequate to assess clinical performance under the conditions of this research. Many instruments existed for use in pre-test/post-test designs but questions specific to this study had to be developed to appropriately address the research questions. The pre-test/post-test questions themselves were validated by experienced, practicing CRNAs. However, because the instrument was untested, it cannot be assured with certainty that the tests were useful predictors of baseline anesthesia apparatus knowledge.

Construct Validity

Construct validity of instruments in this research was supported within the concept of achievement testing (Isaac & Michael, 1995). Establishing participant baseline knowledge and subsequently measuring post treatment knowledge, demonstrated test performance improvement. Likewise, though less clear cut, clinical performance was assessed by exposing subjects to different teaching methodologies and subsequently testing their ability to handle crisis situations depicted within the two teaching techniques. Both of these measures allowed inferences to be drawn from the collected data.

Internal Validity

Post-testing allowed for the comparison of group means to evaluate recall between groups. A positive change from pre-test to post-test scores indicated that knowledge was gained.

In this study, threats to internal validity included: (a) interaction effects of pre-testing, and (b) the reactive effects of experimentation. Interaction effects between variables cause confounding or mixing of variances. This occurs when there is loose control within a study and forces outside of the research exert influence on the independent variable (Isaac & Michael, 1995). There is the possibility that effects between the dependent and independent variables were hidden. The effects may have counteracted each other and study findings may have been obscured (Isaac & Michael, 1995; Polit & Beck, 2004).

Reactive effects of participation were a concern subject as a result of awareness of involvement in a research project (Isaac & Michael, 1995). These reactive effects included:

- The Hawthorne effect
- Role selection
- Practice effects or carryover
- Acquiescence response
- Social desirability response
- Interviewer effects
- Change in research instrument

Of these potential effects, practice effects were the most likely to have influenced this study. Practice effects were labeled as confounding because pre-testing could have affected knowledge gain on the post-test (Isaac & Michael, 1995). This may have occurred because a highly-motivated student could have researched the answers to questions posed in the pre-test, which may have influenced post-test scores.

Other internal validity threats associated with pre-test/post-test designs that had potential to affect this study included maturation, and experimental mortality (Polit & Beck, 2004). Maturation effects such as the loss of subjects during the proposed study or subject fatigue as the demonstration day wears on could have potentially altered research findings. Because the length of time between data collection points was relatively short, it was anticipated that mortality, or loss of subjects, in the graduate nurse anesthesia program would be a personal crisis or academic related factor such as a non-progressing grade. Of course, it was possible to lose participants for other reasons that were outside the control of this proposed study.

External Validity

Crossover designs have been shown to reduce threats to external validity as well as advantaging equivalence among subjects (Isaac & Michael, 1995; Polit & Beck, 2004). One disadvantage of a crossover design is the potential for multiple treatment interference. Each group received two treatments which may influence the results. In an attempt to avoid this interference, both groups received the treatments in the same order. The written case studies were administered first, followed by the vignettes for each group.

Participant communication was considered a reactive effect of the experiment and therefore threatened external validity. Once the treatments began, subject contamination could have occurred as a result of communication between participants in the randomized groups, thus may have affected behaviors of the subjects. Within the confines of this study, there was no feasible option for controlling communication between subjects. Total isolation of participant groups was not possible. Prior to the start of the study, and again before treatment administration, measures were taken to reduce this threat by reinforcing the need for ethical and professional behavior as well as assigning hands-on demonstration appointments so as to prevent student time overlap and contact during the pre-demonstration waiting period.

Generalizability

While the goal of most research is to generalize the findings to other subject groups, most initial or smaller studies typically can only be generalized to the studied subjects (Polit & Beck, 2004). Studies using small sample sizes raise the issue of sampling adequacy. In this proposed study, the entire population of one graduate class of anesthesia students was used, thus allowing for results to be generalized to the entire group as well as other similar cohorts at other institutions.

Assumptions

Both positivist and statistical assumptions were made for this proposed study. It was assumed that graduate SRNA students would adhere to the instructions. As adults and registered nurses, it was expected that SRNA behavior and conduct would be ethical and professional. It was further assumed that the whole population of SRNAs would have the same capacity to learn and could exhibit learning via testing, as well as through hands-on demonstration. Other positivist assumptions were:

1. Simulated crisis oriented videos were realistic and had a vicarious emotive component.
2. Participants responded with honesty to the pre-study questionnaire, pre-test, and post-test.
3. The observer/data collector and discussion facilitators were impartial and unbiased.
4. Patient safety was improved when anesthesia clinical performance was appropriate.

Statistical assumptions made were:

1. A normal distribution was achieved by using the entire population to be studied.
2. The dependent variables, clinical performance and knowledge gain, were normally distributed.
3. A linear relationship existed between the dependent and control variables; knowledge gain, clinical performance, and baseline knowledge.
4. This linear relationship existed in both sample groups.
5. Equal variance existed between groups.

Limitations and Weaknesses

State of the art simulator technology has been utilized to produce vignettes with great realism. Yet, there was still potential for the vignettes to incompletely represent true life scenarios. An operating room environment can be created with relative ease but an actor's performance can affect realism.

Another limitation was found in the instrumentation. There is no existing standardized data collection tool for determining knowledge related to the anesthesia apparatus checkout process. Although face validity for this tool was acceptable, instrumentation for this study remains untested.

Other limitations to this proposed study were related to human factors. SRNAs may have not honored the request for confidentiality during the testing period and may have discussed experiences and treatments among themselves. Additionally, study participants were enrolled in two other rigorous courses. This may have affected their ability to study, perform, or get adequate rest prior to testing.

Statistical analysis

Statistical analyses were used to test the null hypotheses. The unit of analysis for the study was the SRNA. Using SPSS 12.0, quantitative variables were converted to z scores to identify outliers. A scatter plot was used. Any data with a z score greater or less than 3 was considered an outlier. The outliers were excluded. This will helped assess for incorrect data entries and determine if an unusual number of extreme cases were present. Data analysis included descriptive statistics using SPSS 12.0 software. Location of data was assessed using measures of central tendency. The mean, median, and mode were determined. The standard deviation and standard error were calculated as measures of variation. These statistics were used to evaluate what was actually observed and measured with regard to the quantitative variables, a) time to problem identification, b) pre-test scores, c) pre-test/post-test score differences.

Knowledge Gain

The two-sample t-test was used for examining group differences. The dependent variable measurement, post-test scores, was continuous. This statistical method was used to test the null hypothesis that there is no difference in recall between the two sample groups. One of the assumptions of the t-test is that a normal distribution exists and this assumption was made. The sample was randomized into two groups which met the additional criteria for use of the t-test.

Clinical Performance

The time to problem identification, measured in seconds, was evaluated using the statistical method of analysis of variance (ANOVA). This study investigated differences between group means while controlling for individual differences in baseline knowledge between subjects. ANOVA provided a more sensitive test of differences between groups than a t-test (Polit, 1996). ANOVA offerred advantages over other statistical methods to analyze data because it functions to combine t-tests with multiple regression while reducing error variance in the outcome measures (Munro, 2005; Polit, 1996).

Removing variance related to baseline knowledge should increase the power of the analysis (Munro, 2005). This is especially true when a small sample size is used (Stevens, 2002). A small sample size increases the opportunity for chance differences to affect the study results. Considering that this study's sample size was 24, ANOVA was an appropriate method to analyze the data to allow accurate interpretation of the results while reducing error variance.

Power and Sample Size

Relationships between independent variables and dependent variables are defined within the context of statistical power (Polit & Beck, 2004). Although small sample sizes typically produce results with low statistical power, it is possible that relationships could be demonstrated when N is < 30 and a crossover design is utilized.

Three studies are identified having sample sizes less than 30. These three studies comparing multiple teaching techniques support the argument that small sample sizes can indeed reveal relationships between variables (Addy et al., 1999; Balslev et al., 2005; Parkin & Dogra, 2000; Renton-Harper et al., 1999). These studies, using sample sizes of

8 -26 subjects, reported statistically significant results that showed a relationship between the independent and dependant variables.

Balslev et al. utilized a pediatric residency cohort of 16, 11 of which participated. This was justified as being adequate since most medical residency programs accept only a small number of students, as is the case for the cohort in this proposed study.

Studies similar to this research have been reported but differ enough in their design that their effect sizes cannot be used as an estimate for this study. Without effect size estimates a power analysis cannot be conducted at this time (Addy et al., 1999; Balslev et al., 2005; Polit & Beck, 2004; Renton-Harper et al., 1999). Power analysis was done after data collection was complete.

Summary

This chapter has presented the methodological approach used for this research. Data collection and statistical analyses are reported in Chapter 4.

CHAPTER 4: RESULTS

This chapter presents the quantitative results from this research. The findings are reported relative to the research questions posed in chapter one as well as the different steps in the data collection. There is a brief discussion of the population and sample as it was necessary for one subject to withdraw from the study. Table 3 defines the relevant variable abbreviations used throughout this study.

Prior to data collection, institution review board (IRB) approval was requested and obtained from both Virginia Commonwealth University (VCU) and Samford University (SU). The actual data collection was done at SU in Birmingham, Alabama.

The convenience sample used was the entire population of a freshman nurse anesthesia cohort from Samford University in Birmingham, Alabama, consisting of 23 subjects. Prior to the start of the study, it was anticipated that 24 students would participate. Just prior to beginning the study, one student withdrew from the nurse anesthesia program for personal reasons. Data collection procedures were carried out as discussed in chapter three of this study. Data collection proceeded without any apparent breech in the pre-designed processes.

Table 4
Relevant Variable Abbreviations Used Throughout Study

DCT	Dual coding theory
CRM	Crisis resource management
ACRM	Anesthesia crisis resource management
LTM	Long-term memory
PBL	Problem based learning
SPSS	Statistical procedures for the social sciences (software)
FDA	Food and Drug Administration
CPVal	Clinical performance for valve vignette group
CPSuc	Clinical performance for suction vignette group
IDVal	Correct identification of malfunctioning valve during clinical performance in the hands-on demonstration of the FDA checkout procedure.
IDSuc	Correct identification of malfunctioning suction apparatus during clinical performance in the hands-on demonstration of the FDA checkout procedure.
CPTotalsec	Sum of seconds taken to complete step 12 (expiratory valve step) and step 14 (malfunctioning suction apparatus).
CPTotaltime	Total time taken to complete the entire FDA anesthesia apparatus checkout procedure.
Recall (Post-test 1-5)	Questions numbered 1-5 (same as presented in the prê-test) on the post-test.
Recall (Post-test 6-11)	Questions numbered 6-11, focusing specifically on direct information contained in the valve vignette and written case study.

Table 4 Continued

PTVal(#)	Post-test questions related to the valve scenario (Example PTV7 = Post-test Valve question 7). Valve questions: PTVal7, PTVal 9, PTVal10).
PTSuc(#)	Post-test questions related to the suction scenario (Example PTSuc6, PTSuc8, PTSuc11).

Questionnaire

A six question work history questionnaire was administered as the first step in the data collection process (See Appendix H). Queries were designed to provide information regarding the subjects work histories. This information was used to determine if the subject met the exclusionary criteria.

After review of the questionnaire data, three subjects were questioned in greater detail regarding their actual work experiences. Two participants witnessed equipment failures in an operating room environment; however, neither occurrence involved anesthesia equipment. One subject admitted to one year of experience as a respiratory therapist technician. Upon further investigation, the work experience was limited to assisting patients with respiratory treatments and incentive spirometery procedures. When presented with this additional information, a panel comprised of four anesthesia educators qualified to evaluate work history as it relates to anesthesia care, determined that the three subjects' work experience would not interfere in the study's validity. As a result of this decision, it was determined that no subject would be excluded from the study as it was deemed that none had work histories that provided an unfair advantage resulting in skewed or contaminated data. Twenty-three participants were considered an appropriate number of subjects and data collection proceeded as planned.

Hypotheses

Two hypotheses were tested in this research. The first focused on clinical performance, while the second, focused on knowledge recall. The hypotheses tested were:

- Student anesthetists exposed to audio-visual vignettes will exhibit superior clinical performance during simulated apparatus-related crisis events, evidenced by higher group mean demonstration scores, when compared to a matched group exposed to written case studies.
- Student anesthetists exposed to audio-visual vignettes will exhibit superior recall of apparatus related material, evidenced by higher group mean post-test scores, when compared to a matched group exposed to written case studies.

To test hypothesis one, data was collected at eight points in the hands-on demonstration process. Time, measured in seconds, was used to represent clinical performance during the demonstrations. The first measure used was the total time to taken to perform step 12 of the anesthesia apparatus machine checkout process. The clinical performance variable measured in this step, SRNA clinical performance for the malfunctioning expiratory valve scenario, was given the designation CPVal. Data for step 14 performance was then collected and reported for SRNA clinical performance for the non-functioning suction device (CPSuc) in the same manner. The third performance measure was the total time, in minutes and seconds represented by the variable CPTotaltime. This variable was the time taken by the SRNA to perform the entire anesthesia apparatus checkout process.

Time was also used to represent clinical performance regarding identification of a malfunctioning expiratory valve in step 12 (IDVal). Data for step 14 was collected and reported in the same manner. The variable for this measure was designated IDSuc. In each of these measures, the subject was timed from the beginning of each step until the subject suggested the component was functioning improperly. In the cases where the malfunctioning component went unrecognized, the time for completion of the entire step was recorded.

Hypothesis 2 referred to recall differences between groups. Recall was measured by using post-test scores to evaluate differences between content presented via vignettes and the written case study format. As with the pre-test, scores were reported using a 100 point scale. Each of the five post test questions had a 20 point value.

Pre-Test

Prior to the start of the study, the pre-test was evaluated by the four experienced anesthesia educators and was found to be acceptable. The pre-test was considered an appropriate test of knowledge relating to the basic anesthesia apparatus checkout processes and was considered an essential part of determining the validity of the instrument.

The pre-test was then administered to 10 CRNAs with five or more years of clinical experience. The CRNAs were employed at Samford University in Birmingham, Alabama, Jeff Anderson Regional Medical Center and Meridian Surgery Center, both located in Meridian, Mississippi. The mean score for the CRNA pre-test participants was 84%. Descriptive statistics were performed on the pre-test data. The minimum reported score was 60% and the maximum was 100%. Descriptive statistics are presented in Table 5.

Table 5.

Pre-test Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
PreTestScore	10	60.00	100.00	84.0000	15.77621
Valid N	10				

The group means of the CRNA validation scores exceeded the pre-determined acceptable 80% value, supporting validity of the pre-test. CRNA "validators" did not have opportunity to review or study the FDA Anesthesia Apparatus Checkout Procedure Guidelines; however, the group mean was still greater than the anticipated 80% limit. The CRNA validation scores are displayed in Figure 4.

Prior to pre-testing, subjects were once again reminded to refrain from discussing any portion of the research with each other. All agreed to abide by this request and expressed understanding as to the purpose of the blinded process. The entire study population was given the pre-test as one group during the Principles I course. All 23 subjects completed the pre-test within 11 minutes. Each subject's last name was used as identification for the purposes of scoring.

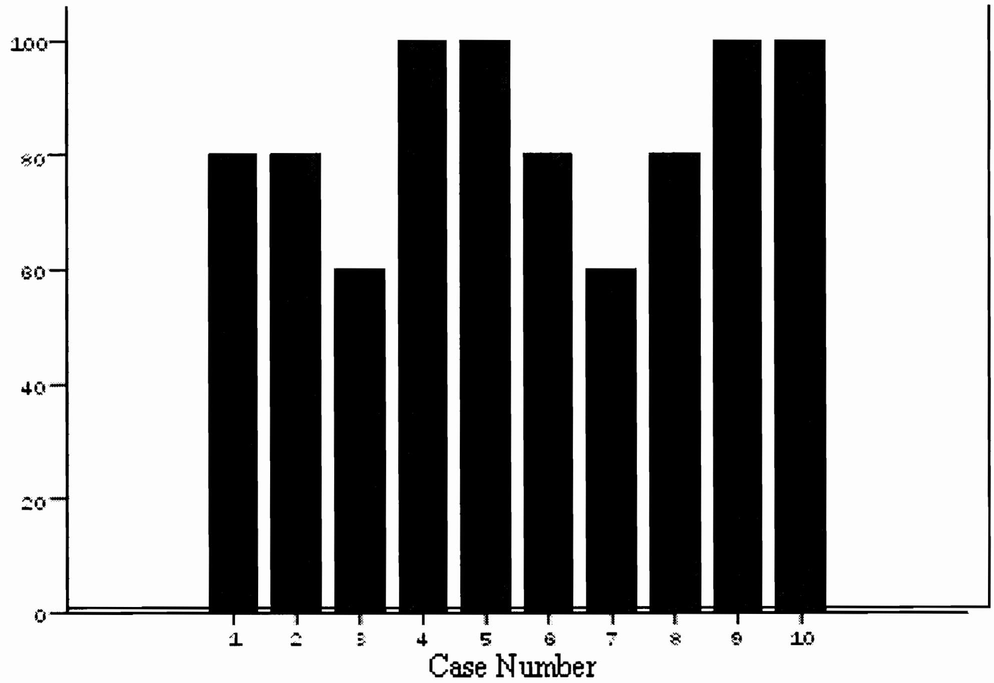


Figure 4. CRNA pre-test validation scores.

Once the pre-test was completed, the pre-tests were kept within a locked office. After the study concluded, the pre-test documents were shredded in accordance to Samford University policy, as discussed in Chapter Three.

Content of the pre-test focused on the basics of the anesthesia machine apparatus checkout procedure suggested by the FDA in 1993. Scores were low as the subjects had no previous exposure or reading assignments related to the machine checkout process content. Subject pre-test scores are displayed in Figure 5.

The equality of pre-test group means between the different vignette/case study groups was evaluated using the two-tailed independent samples T-test. This test was chosen because the two groups were independent and had the same variable of interest.

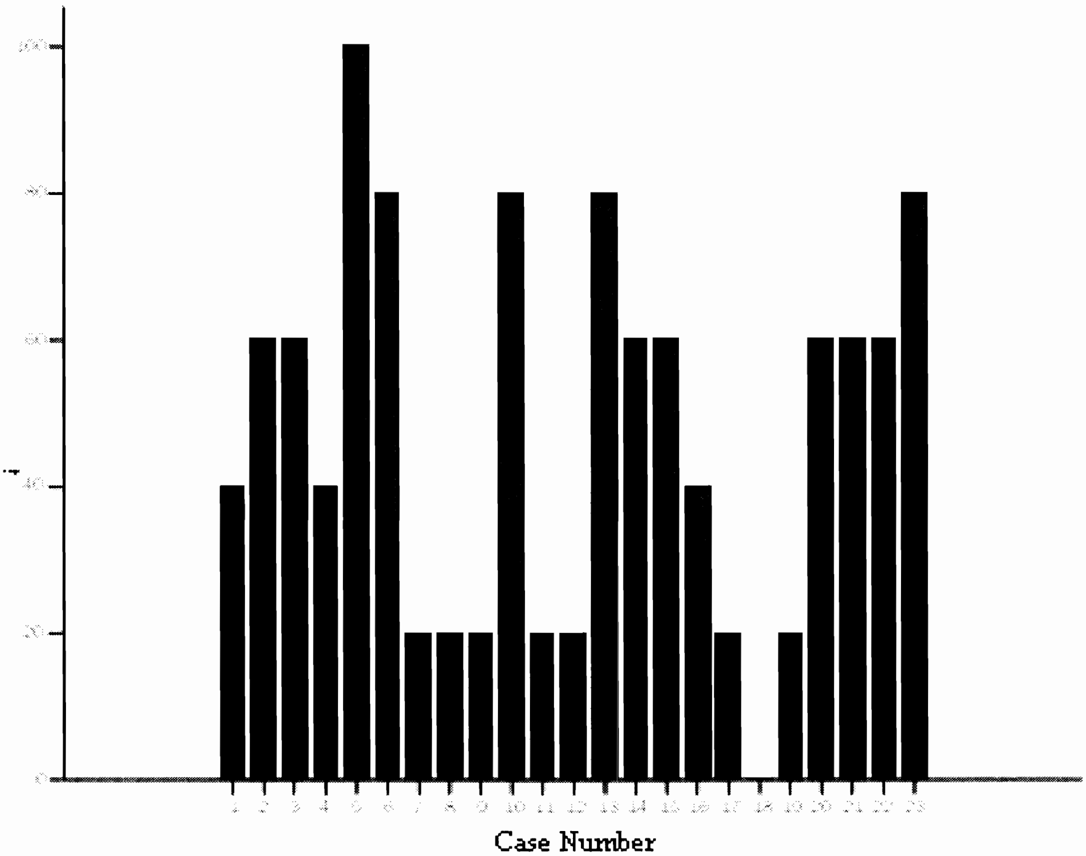


Figure 5. Subject pre-test scores.

There was no significant difference in mean scores between the malfunctioning valve vignette (group 1) and the suction canister failure (group 2) groups as revealed in the independent samples T-test. SPSS 12.0 output is displayed in Table 6.

Table 6.

Independent Samples T-test of Group Statistics for Identification of Malfunctioning Machine Component.

	VigAll	N	Mean	Std. Deviation	Std. Error Mean
PreTest	1	11	49.09	28.794	8.682
	2	12	46.67	26.054	7.521

The Levene test was used determine pre-test mean score equivalence between groups. The two-tailed significance level of the Levene test was large (>0.8). Thus, the null hypothesis was accepted. SPSS 12.0 output is shown in Table 7.

Lecture

All participants attended two mandatory, three hour lectures, required for the Principles of Anesthesia I course. The lectures were given on two consecutive days. The first lecture in the series centered on the American Association of Nurse Anesthetists Standards of Practice Guidelines. Each standard was discussed in detail as well as each standard's application to clinical practice. Class discussion took place regarding potential patient and provider outcomes when standards are breeched. After these discussions, a 15 minute break was allowed.

The next portion centered on the function and components of the anesthesia machine. Detailed component slides were shown in a PowerPoint presentation. Major anesthesia machine concepts were presented and discussed.

The second lecture focused on gas flow through the anesthesia machine and potential areas of malfunction. A group discussion took place regarding potential

Table 7.

Pre-test Mean Score Equivalence Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
PreTest	Equal variances assumed	.186	.670	.212	21	.834	2.424	11.434	-21.355	26.203
	Equal variances not assumed			.211	20.266	.835	2.424	11.486	-21.516	26.364

outcomes when mechanical component malfunction occurs. No data was collected during the lecture portions of the study.

Randomization

Using SPSS 12.0, the subjects were randomized into two groups. Each subject was assigned a random number and given a copy of the number to keep for later reference. The master randomized subject number list was kept within a locked office. As with the pre-tests, the master list was shredded at the end of the study in accordance to the Samford University policy for sensitive and confidential documents.

Treatments

One week following the pre-test, subjects were divided into randomized groups. The groups were placed in nearly identical classrooms. Each room was the same design, size, temperature, and contained the same type of audio-visual equipment. Neither group was advantaged in any way as a result of randomization or room assignment.

In the separate rooms, Group 1 received the non-functioning suction apparatus case study in written format and Group 2 received the malfunctioning expiratory unidirectional valve scenario in written format. Once all subjects had finished reading the case studies, the moderators allowed 10 minutes for group discussion. Both moderators reported good interaction and that no prompting was required to stimulate involvement.

Each group was then shown a vignette. Group 1 received the malfunctioning expiratory unidirectional valve vignette that also demonstrated correct performance of the machine checkout procedure, while group 2 received the non-functioning suction canister scenario that also described in detail the American Association of Nurse Anesthetists (AANA) Standards of Practice. Included in the discussion of standards of the standards was Standard VIII that requires the anesthesia machine checkout process be performed to minimize risks to the patient. Once the vignettes were viewed, the moderators allowed 10 minutes of group discussion. Moderators reported similar discussion content in the group conversations. The guided discussion outline was used to facilitate conversation. The outline is presented in Appendix E. Both moderators commented that while there was active participation after the written case studies, there was greater participation after the vignettes. Discussions were closed and students were dismissed after being reminded not to discuss the written studies or the vignettes further.

Clinical Performance

Prior to beginning the hands-on demonstrations, faulty machine components were replicated. The malfunctioning expiratory unidirectional valve was created by using industrial strength, double sided tape. Several tests were done to ensure the ability to reproduce the malfunctioning valve. Additionally, between each subject's demonstrations, "sabotage" was confirmed to be sure a faulty valve was realistically represented.

Prior to the demonstrations, the suction canister was rendered useless. The canister was punctured in two places in a place not easily seen on cursory inspection. Suction adequacy or strength was checked several times and found to be non-existent, yet, a sound typical of a correctly functioning apparatus was clearly audible.

Clinical Performance was measured using five specific data collection points. Total time (CPTotalsec) in seconds, used per subject to complete each of the two identified steps in the FDA anesthesia machine apparatus checkout procedure, was recorded. The subject was timed from the start of step 12 until either the subject identified the malfunctioning unidirectional expiratory valve (CPVal), or completed the entire step. This method was repeated for step 14, the non-functioning non-functioning apparatus (CPSuc). For the purposes of data reporting, the terms "total time" and "identification" were chosen to distinguish the two data points.

With regard to the first data point, the total time taken by the SRNA to complete each step was considered the assessment outcome of application of learned knowledge to the machine checkout process. Longer times represented subject difficulty in applying the learned concepts, while shorter times suggested superior application of knowledge to clinical performance. For analysis, performance times were measured to a hundredth of a second using a digital stop watch and data was recorded.

The third data point used was the total time the subject took to complete the entire anesthesia checkout process (CPTotaltime). This data was measured in minutes and hundredths of a second, also by a digital stopwatch.

The fourth and fifth data points, identification of the malfunctioning components, were considered the assessment outcome of the subject's application of learned knowledge to clinical practice. This was demonstrated in step 12 and step 14 of the hands-on checkout demonstration. The time from the start of step 12, the malfunctioning unidirectional expiratory valve, until the SRNA suggested that they had identified the problem (IDVal) was recorded. The time from the start of step 14, the non-functioning suction apparatus, until the SRNA suggested that they had identified the problem (IDSuc) was recorded. Failure to identify a device malfunction while performing the machine checkout process suggested an absence of application of knowledge to clinical practice. Proper identification of the non-functioning component demonstrated that the subject could positively apply learned knowledge to the FDA machine procedure. Descriptive statistics for the SRNA identification analyses are displayed in SPSS 12.0 output as Table 8.

Table 8.

Descriptive Statistics of SRNA Identification Analyses of Malfunctioning Machine Component.

	N	Minimum	Maximum	Mean	Std. Deviation
CPVal	23	85.10	183.60	125.7057	25.49115
CPSuc	23	12.69	183.60	82.6648	58.22458
Valid N (listwise)	23				

Note: CPVal = SRNA clinical performance time for step 12 of the FDA anesthesia apparatus checkout procedure (malfunctioning unidirectional valve). CPSuc = SRNA clinical performance time for step 14 of the FDA anesthesia apparatus checkout procedure (non-functioning suction device).

Total Time

To assess the differences in Step 12 clinical performance times (CPVal) between groups, a one-way ANOVA was performed. In this step, the application of learned knowledge was measured as total time from initiation of step 12 until recognition of the malfunctioning unidirectional expiratory valve. Analysis revealed a p-value of 0.454 ($\alpha = 0.05$). There was no significant difference in clinical performance times for the malfunctioning unidirectional valve step (step 12) between the groups (F = 0.582, df =22). There was no difference between clinical performance times for step between groups, thus, the null hypothesis was accepted. SPSS 12.0. Output is shown in Table 9.

Table 9.

One-way ANOVA for Step 12 Clinical Performance Time: Malfunctioning Unidirectional Valve.

CPVal

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	385.757	1	385.757	.582	.454
Within Groups	13909.821	21	662.372		
Total	14295.578	22			

Note: CPVal = SRNA clinical performance time for step 12 of the FDA anesthesia apparatus checkout procedure (malfunctioning unidirectional valve).

To assess the differences in Step 14 clinical performance times (CPSuc) between groups, a one-way ANOVA was performed. In this step, the application of learned knowledge was measured as total time from initiation of step 14 until recognition of the non-functioning suction device. Analysis revealed a p-value of 0.000 (α =0.05). A significant difference between groups was observed in clinical performance times for the non-functioning suction apparatus in step 14 (F = 54.277, df =22). The difference in clinical performance times for step 14 was clearly significant; therefore, the null hypothesis was rejected. SPSS Output is shown in Table 10.

Table 10.

One-way ANOVA for Step 14 Clinical Performance Time: Non-functioning Suction Device.

CPSuc

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	53776.019	1	53776.019	54.277	.000
Within Groups	20806.208	21	990.772		
Total	74582.227	22			

Note: CPSuc = SRNA clinical performance time for step 14 of the FDA anesthesia apparatus checkout procedure (non-functioning suction device).

Complete Anesthesia Apparatus Checkout Process Performance Time

The time taken by the subjects to complete the entire anesthesia checkout procedure (CPTotaltime) was recorded using a digital stopwatch. This was measured using minutes and hundredths of a second. Analysis revealed a p-value of 0.009 (α =0.05). A significant difference between groups was observed in total anesthesia apparatus checkout clinical performance times (F = 8.3, df =22). The difference in total clinical performance times was significant; therefore, the null hypothesis was rejected. Results of group comparisons are displayed in Table 11.

Combined Step 12 and Step 14 Clinical Performance Time

The time taken by the subjects to complete step 12 and step 14 of the anesthesia checkout procedure (CPTotalsec) was recorded using a digital stopwatch. This was measured in seconds. Analysis revealed a p-value of 0.000 (α =0.05). A significant

Table 11.

One-way ANOVA Complete Anesthesia Apparatus Checkout Performance Time

CPTotaltime

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	46.961	1	46.961	8.300	.009
Within Groups	118.819	21	5.658		
Total	165.781	22			

Note: CPTotaltime: SRNA clinical performance time taken to complete the entire FDA anesthesia apparatus checkout procedure.

difference between groups was observed in SRNA performances times for the anesthesia apparatus checkout procedure for the combined times. The combined times were data from clinical performances of step 12, the malfunctioning unidirectional valve and step 14, the non-functioning suction apparatus ($F = 8.3$, $df = 22$). The difference was found to be was significant; therefore, the null hypothesis was rejected. Results of group comparisons are displayed in Table 12.

Malfunctioning Device

Of the twenty-three participants, seven subjects failed to identify the non-functioning component of the anesthesia machine during the hands-on demonstration portion of data collection. Three subjects failed to identify the malfunctioning expiratory valve and four subjects failed to detect the non-functioning suction apparatus.

Table 12

One-way ANOVA Total Combined Clinical Performance Times for Step 12 and Step 14 of the FDA Anesthesia Apparatus Checkout Procedure SRNA Demonstration

CPTotalsec

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	63270.991	1	63270.991	25.532	.000
Within Groups	52040.352	21	2478.112		
Total	115311.343	22			

Note: CPTotalsec: SRNA clinical performance combined total seconds taken to complete Step 12 (malfunctioning unidirectional expiratory valve) and Step 14 (non-functioning suction device), of the FDA anesthesia apparatus checkout procedure.

To assess differences in Step 12 (IDVal) clinical performance times between groups, a one-way ANOVA was performed. Analysis revealed a p-value of .056 ($\alpha =$ 0.05). There was no significant difference in clinical performance times for identification of the malfunctioning expiratory valve (step 12) between the groups ($F = 4.109$, $df = 22$). The p-value was considered to be of interest due to the F value nearing 5; however, the analysis suggested an insignificant finding for step 12 clinical performances between groups. The null hypothesis was accepted. Table 13 displays SPSS 12.0 output for the analysis.

To assess the differences in Step 14 (IDSuc) clinical performance times between groups, a one-way ANOVA was performed. Analysis revealed a p-value of 0.036 ($\alpha =$ 0.05). There was a significant difference in clinical performance times for the non-functioning suction apparatus step (step 14) between the groups ($F = 5.02$, $df = 22$). The null hypothesis was rejected. SPSS 12.0 output for the data is displayed in Table 14.

Table 13

One-way Clinical Performance Step 12 Malfunctioning Component Identification: Malfunctioning Unidirectional Valve.

IDVal

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.427	1	.427	4.109	.056
Within Groups	2.182	21	.104		
Total	2.609	22			

Note: IDVal = SRNA clinical performance times for step 12 of the FDA anesthesia apparatus checkout procedure (correct identification of the malfunctioning unidirectional valve).

Table 14

One-way ANOVA

Clinical Performance Step 14 Malfunctioning Component Identification: Non-functioning Suction Device.

IDSuc

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.638	1	.638	5.022	.036
Within Groups	2.667	21	.127		
Total	3.304	22			

Note: CPSuc = SRNA clinical performance times for step 14 of the FDA anesthesia apparatus checkout procedure (correct identification of the non-functioning suction device).

Data for one participant was used but it was noted that the physical action of checking the suction was not performed. However, the subject verbalized that suction strength would be checked by enclosing the Yankauer suction a gloved hand. The observer then instructed the subject to demonstrate. The subject noted that the suction strength was non-functioning and appropriately determined the cause of the apparatus malfunction.

Post-test

One week following the hands-on anesthesia apparatus machine checkout procedure demonstration, a post-test consisting of 11 questions was given to all subjects as one group. Twenty minutes were allowed for subjects to complete the test. Post-test questions 1-5 were identical to the pre-test questions. All subjects' scores improved from pre to post-testing with the exception of one. The subject scored a zero on the pre-test, as well as scoring zero on the post test. Data is presented in Figure 6.

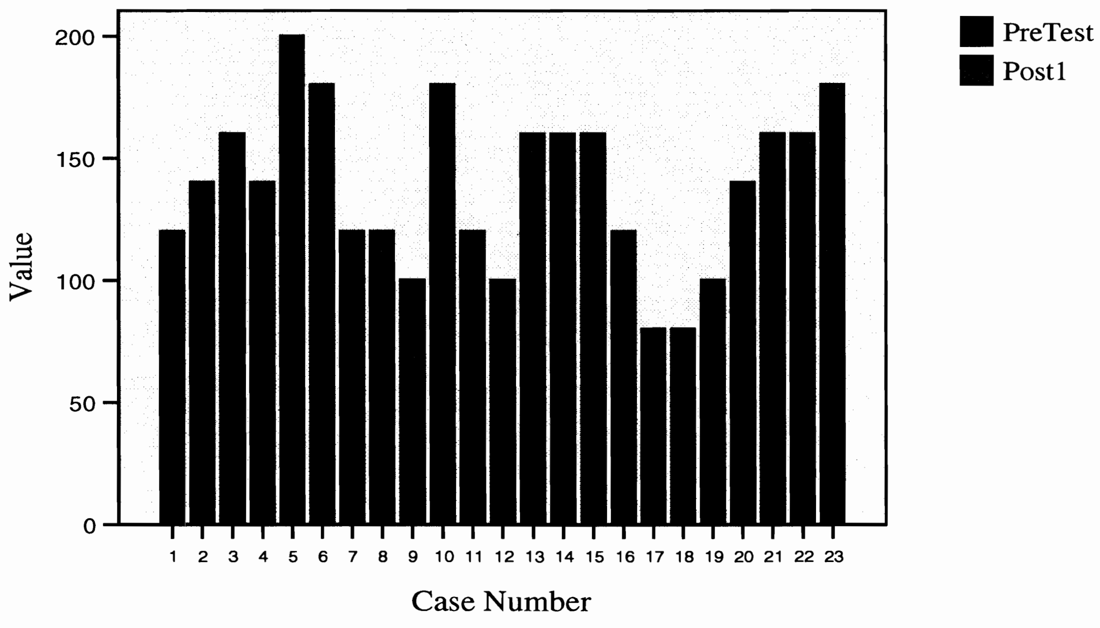


Figure 6. SRNA Pre-test/post-test score comparisons.

To assess the difference between group pre-test scores, a one-way ANOVA was performed. Analysis revealed no significant difference (F= 0.045, df=22) between group pre-test scores suggested by a p-value of 0.834 ($\alpha = 0.05$). The null hypothesis was accepted. SPSS output is displayed in Table 14.

To assess differences between group post-test scores (Pretest), a one-way ANOVA was performed. Analysis revealed no significant difference (F = 2.731, df = 22) between group post-test scores suggested by a p-value of 0.113 ($\alpha = 0.05$). The null hypothesis was accepted. SPSS 12.0 output is displayed in Table 15.

Table 15

One-way ANOVA Results for Group of Pre-test and Post-test Scores

		Sum of Squares	df	Mean Square	F	Sig.
PreTest	Between Groups	33.729	1	33.729	.045	.834
	Within Groups	15757.576	21	750.361		
	Total	15791.304	22			
Post1	Between Groups	356.258	1	356.258	2.731	.113
	Within Groups	2739.394	21	130.447		
	Total	3095.652	22			

Note: Post1 = Post-test scores from repeat of pre-test questions 1-5.

Post-test questions number 6-11 were designed to elicit subject recall of specifics contained within the two scenarios. The questions were posed such that neither the vignette group nor the case study group would have an unfair advantage. Content for the queries were contained within both the vignette and case study treatments. Three separate questions were asked for each of the two scenarios, the malfunctioning expiratory valve and the non-functioning suction device.

Hypothesis 2 predicted that recall would be improved as evidenced by higher group mean post-test scores. A two-tailed paired samples t-test was performed to test the difference between the group means of the two variables. The results supported the hypothesis suggested by a p-value of .000 ($\alpha = 0.05$).The F value was greater than 5.00 (F = 5.022, df = 22). The null hypothesis was rejected. SPSS 12.0 output is presented in Table 16.

Recall (hypothesis 2) was also evaluated using a one-way ANOVA procedure to examine between group performances on individual post-test questions. Questions 6-11 were labeled to indicate post-testing (PT), malfunctioning expiratory valve (V), non-functioning suction device (S), and the question number. For example, PTS6 represents post-test question six and suggests that it pertains to the non-functioning suction device.

ANOVA procedure results showed no significant difference between group performance on post-test questions 6, 9, and 11. For questions 6, 9, and 11, the p-values were 0.708, 0.573, 0.160, respectively ($\alpha = 0.05$). The null hypothesis was accepted for each of these questions. The ANOVA procedure revealed a significant difference between group performance on post-test questions 7, 8, and 10. For these questions the p-values were 0.003, 0.015, and 0.003, respectively ($\alpha = 0.05$).

Table 16

Paired Samples Test of Group Comparison of Pre-test to Post-test Scores

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	PreTest - Post1	-42.609	24.349	5.077	-53.138	-32.079	-8.392	22	.000

Note: PreTest-Post1 = Differences in group scores between pre-testing and post-testing of identical questions.

Recall (hypothesis 2) was also evaluated using a one-way ANOVA procedure to examine between group performances on individual post-test questions. Questions 6-11 were labeled to indicate post-testing (PT), malfunctioning expiratory valve (V), non-functioning suction device (S), and the question number. For example, PTS6 represents post-test question six and suggests that it pertains to the non-functioning suction device.

ANOVA procedure results showed no significant difference between group performance on post-test questions 6, 9, and 11. For questions 6, 9, and 11, the p-values were 0.708, 0.573, 0.160, respectively ($\alpha = 0.05$). The null hypothesis was accepted for each of these questions.

The ANOVA procedure revealed a significant difference between group performance on post-test questions 7, 8, and 10. For these questions the p-values were 0.003, 0.015, and 0.003, respectively ($\alpha = 0.05$). The null hypothesis was rejected for each of these questions. SPSS 12.0 output post-test analyses are shown in Table 17.

Power

The power of a statistical test is the probability of rejecting the null hypothesis when the alternative hypothesis is true. It is viewed as a very descriptive and concise measure of the sensitivity of a statistical test (Montgomery & Runger, 1999). Using SPSS 12.0, power was calculated for the primary variables in this study. A summary table was developed using this data (see Table 18). The ability of the analyses to detect differences within the factors was tested by using the calculated power of each variable. For example, the mean of the variable CPSuc was 82.6648.

Table 17

One-way ANOVA for Post-test Questions 6-11 Group Differences

One-Way ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
PTS6	Between Groups	.027	1	.027	.144	.708
	Within Groups	3.886	21	.185		
	Total	3.913	22			
PTV7	Between Groups	1.903	1	1.903	11.173	.003
	Within Groups	3.576	21	.170		
	Total	5.478	22			
PTS8	Between Groups	1.226	1	1.226	7.063	.015
	Within Groups	3.644	21	.174		
	Total	4.870	22			
PTV9	Between Groups	.084	1	.084	.328	.573
	Within Groups	5.394	21	.257		
	Total	5.478	22			
PTV10	Between Groups	1.903	1	1.903	11.173	.003
	Within Groups	3.576	21	.170		
	Total	5.478	22			
PTS11	Between Groups	.527	1	.527	2.123	.160
	Within Groups	5.212	21	.248		
	Total	5.739	22			

1. Note: PTS6, PTS8, PTS11 = Post-test questions related to recall of the non-functioning suction device. PTV7, PTV9, PTV10 = Post-test questions related to recall of the malfunctioning unidirectional expiratory valve.

Table 18

Primary Variable Summary Table

Result	Variable	Mean	F Value	Significance	Observed Power
Significant	CPSuc	82.664	54.277	0.000	1.00
	IDSuc	1.17	5.022	0.036	0.571
	CPTotalsec	208.3704	25.532	0.000	0.998
	PostSuc	50.7096	7.763	0.011	0.757
	CPTotaltime	22.4261	8.300	0.009	0.784
Marginally Significant	IDVal	1.13	4.109	0.056	0.490
Insignificant	CPVal	125.7057	0.582	0.454	0.113
	PostVal	53.6609	0.188	0.669	0.070

CPVal = SRNA clinical performance of step 12 of the FDA anesthesia apparatus checkout procedure (malfunctioning unidirectional valve). CPSuc = SRNA clinical performance of step 14 of the FDA anesthesia apparatus checkout procedure (non-functioning suction device). CPTotaltime: SRNA clinical performance time taken to complete the entire FDA anesthesia apparatus checkout procedure. Note: IDVal = SRNA clinical performance of step 12 of the FDA anesthesia apparatus checkout procedure (correct identification unidirectional valve). IDSuc = SRNA clinical performance of step 14 of the FDA anesthesia apparatus checkout procedure (correct identification of the non-functioning suction device). PostVal = post-test questions related to the malfunctioning unidirectional valve scenario. PostSuc = post-test questions related to the non-functioning suction device. CPTotalsec = SRNA clinical performance time in seconds to complete step 12 (malfunctioning unidirectional expiratory valve) and step 14 (non-functioning suction device) combined.

The power calculated using this mean test will correctly detect differences 100 percent of the time. The significance level for the study was set at $\alpha = 0.05$.

Rejecting the null hypothesis when it is true is defined as a Type I error (Montgomery & Runger, 1999). The possibility of a Type I error is minimized when the power is high. The possibility of committing a type II error, failing to reject the null hypothesis when it is in fact false, is low when the power is high (Montgomery & Runger, 1999).

Chapter Summary

This chapter has presented the results of the investigation of audio-visual, patient safety vignettes as a method to improve anesthesia clinical performance outcomes in SRNAs. Relationships between knowledge application to practice, clinical performance times, accuracy, and recall have been discussed. Statistical analyses, ANOVAs and t-tests, have been reported.

CHAPTER 5: SUMMARY

This chapter summarizes the results of this research, analyzes the statistical findings reported in Chapter 4, and discusses its findings in the context of DCT. The relationship of the study's findings to the theoretical framework is presented first. A review of literature as well as the research methodology employed is presented, followed by a discussion of the quantitative statistical results. The relationship of the research findings to the existing literature, the limitations, the potential application of the study's findings to other disciplines, the contribution of this research to the anesthesia scientific body of knowledge, and suggestions for future research are presented.

Discussion

Patient safety has is a primary focus of anesthesia. As such, it is also one of the foremost concepts in the minds of nurse anesthesia educators. The profession continually strives to improve patient safety and employ teaching methodologies to educate students in appropriate anesthesia crisis management. Both concepts are necessary in anesthesia education to teach quality anesthesia care.

It has been shown that audio-visual presentations of emotional or crisis oriented events improve recall (Miller, 1957). Anesthesia educators have been slow to embrace this concept and incorporate it into their programs and courses. There is little quantitative research in the literature that evaluates the impact audio-visual presentations of emotional or crisis oriented events have on anesthesia clinical performance.

Based on the DCT it can be surmised that recall of content alone is not enough to improve clinical performance. Recalled content must be synthesized to incorporate multiple concepts and transform them into useable information and then must apply that knowledge to clinical situations. An assumption of this study is that positively affecting both content recall and clinical performance impacts patient safety.

Utilizing a crisis resource management (CRM) framework represented by two emotionally provoking inter-operative scenarios, a) a stuck expiratory unidirectional valve, and b) a malfunctioning patient suction device, this research investigated the application of the DCT to evaluate the impact that different educational methodologies had on content recall and clinical performance. DCT was shown to be the appropriate, applicable theory for this study.

This study investigated this phenomenon by utilizing a cohort of 23 freshman nurse anesthesia students from Samford University in Birmingham, Alabama, as the population for this study. The differences between groups receiving vignettes versus written case studies were analyzed and evaluated using these teaching methodologies to positively impact student nurse anesthesia clinical performance during a simulated crisis oriented events. Statistically significant results were obtained from comparisons made between the two teaching methodologies, supporting previous studies that audio-visual presentations positively impact recall, clinical performance and behavior, and that DCT is the applicable theory on which to found this research.

A comprehensive survey of the seminal articles related to this study was performed. DCT, audio-visual presentations, CRM, short and long term memory, vicarious learning, problem based learning, and anesthesia simulation concepts were explored by evaluating prior research in these areas.

The literature survey revealed work by many authors that support audio-visual representations as a means to convey information and impact recall (Miller, 1957; Paivaio, 1971; Sweller, 1998). Previous research also revealed that neurophysiologic studies in the late 1990's demonstrated that multiple cerebral components were involved in the storage of memory (Croattz et al., 2006; Ross, 2006). These studies specifically demonstrated that audio and visual information was processed in separate cerebral locations. Additionally, other authors have demonstrated that using higher cognitive processes, memories from emotionally evoking events are consciously retrieved and synthesized for use (Clark & Paivio, 1991; Sweller et al., 1998). Studies suggest that personalization of the event occurs within the subject when an emotive component is present in an audio-visual presentation advantaging vicarious learning and improving content recall (Biddle et al., 1995; Balslev et al., 2005; Clark & Paivio, 1991; Cox et al., 1999; Sweller et al., 1998).

Considering the problem based critical nature of anesthesia delivery, presenting educational content via a problem based format can enhance recall, stimulate discussion, encourage active participation, promotes critical thinking skills during crisis oriented events, and offers opportunity for vicarious learning. Vignettes have the potential to combine these crucial components that may be necessary to improve knowledge and thus, promote the application of learned concepts into student nurse anesthesia clinical practice. When this occurs, students may facilitate patient safety by appropriately performing clinical procedures rather than ignoring or overlooking key components of the anesthesia machine checkout procedure designed to prevent poor patient outcomes from equipment malfunctions or anesthetist negligence.

Utilizing a randomized control trial, pre-test/post-test, dual cross-over methodological approach, the study compared differences between group means when the two groups were exposed to different teaching methodologies. The 23 person sample was the entire population of a freshman nurse anesthesia cohort with no prior exposure to anesthesia coursework or experience. Questionnaires, pre-tests, lectures, hands-on demonstrations, and post-tests were used to analyze group mean differences. This methodology proved to be an appropriate design to test the study's hypotheses.

Quantitative Statistical Results

The quantitative statistical results reported in Chapter 4 of this study were used as the basis for discussion of the research findings. Table 19 outlines the variables examined in the study and their associated significance levels of the hypothesis testing. The alpha level for the study was set at 0.05 ($\alpha = 0.05$).

Statistical findings for the pre-test portion of this study indicated that randomization processes utilized in the research were appropriate. As expected, upon analysis, the pre-test data yielded insignificant findings.

To meet the assumptions for the ANOVA procedure there must be equal variance between groups. Changes that occurred within groups were assessed by

Table 19

Nine Study Variables

Research Step	Statistical Test	F-Value	Significance
Pretest	Independent samples T-test	0.186	0.670
Clinical Performance Total Time Step 12 (CPVal)	One-way ANOVA	0.582	0.454
Clinical Performance Total Time Step 14 (CPSuc)	One-way ANOVA	54.277	0.000
Clinical Performance Malfunctioning Component Step 12 (IDVal)	One-way ANOVA	4.109	0.056
Clinical Performance Malfunctioning Component Step 14 (IDSuc)	One-way ANOVA	5.022	0.036
Clinical Performance Total Seconds Step 12 and 14 (CPTotalsec)	One-way ANOVA	25.532	0.000
Clinical Performance Total Anesthesia Apparatus Checkout Time (CPTotaltime)	One-way ANOVA	8.300	0.009
Recall (Post-test1)	One-way ANOVA	2.731	0.113
Recall (Pretest-Post 1)	Paired Samples T-test	- -	0.001
Recall (PostVal)	One-way ANOVA	0.118	0.669
Recall (PostSuc)	One-way ANOVA	7.763	0.011

CPVal = SRNA clinical performance of step 12 of the FDA anesthesia apparatus checkout procedure (stuck unidirectional valve). CPSuc = SRNA clinical performance of step 14 of the FDA anesthesia apparatus checkout procedure (malfunctioning suction device). IDVal = SRNA clinical performance of step 12 of the FDA anesthesia apparatus checkout procedure (correct identification unidirectional valve). IDSuc = SRNA clinical performance of step 14 of the FDA anesthesia apparatus checkout procedure (correct identification of the malfunctioning suction device). CPTotalsec = SRNA clinical performance time in seconds to complete step 12 (stuck unidirectional expiratory valve) and step 14 (malfunctioning suction device) combined. CPTotaltime: SRNA clinical performance time taken to complete the entire FDA anesthesia apparatus checkout procedure. Post1 = Post1 = Post-test scores from repeat of pre-test questions 1-5. PreTest-Post1 = Differences in group scores between pre-testing and post-testing of identical questions. PostVal = post-test questions related to the stuck unidirectional valve scenario. PostSuc = post-test questions related to the malfunctioning suction device.

Results from the analyses of the primary study variables identified above are displayed in Figure 7 as a Venn diagram.

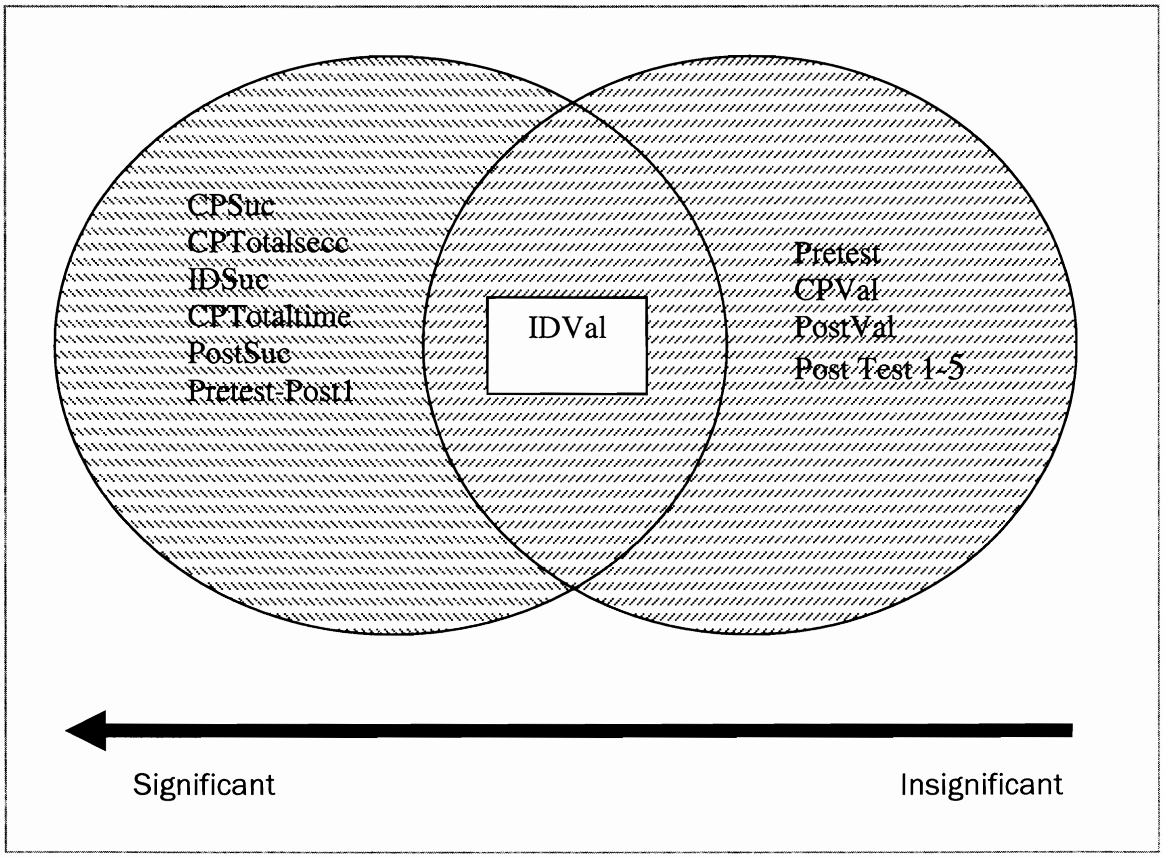


Figure 7. Venn diagram summary of significant results, marginal results, and insignificant results within this study. CPSuc = SRNA clinical performance of step 14 of the FDA anesthesia apparatus checkout procedure (malfunctioning suction device). CPTotalsec = SRNA clinical performance time in seconds to complete step 12

(stuck unidirectional expiratory valve) and step 14 (malfunctioning suction device) combined. Post1 = Post1 = Post-test scores from repeat of pre-test questions 1-5. CPTotaltime: SRNA clinical performance time taken to complete the entire FDA anesthesia apparatus checkout procedure. PostSuc = post-test questions related to the malfunctioning suction device. PreTest-Post1 = Differences in group scores between pre-testing and post-testing of identical questions. IDVal = SRNA clinical performance of step 12 of the FDA anesthesia apparatus checkout procedure (correct identification unidirectional valve). Pretest = pretest score mean between the malfunctioning unidirectional vignette group and the inadequate suction vignette. CPVal = SRNA clinical performance between groups for step 12 malfunctioning suction device. PostVal = post-test questions related to the stuck unidirectional valve scenario. Post1-5 = Post1 = Post-test scores from repeat of pre-test questions 1-5.

---

comparison of scores from pre-testing to post-testing. When compared to pre-test results, post test questions 1-5 allowed assessment of content recall and changes or improvements in baseline knowledge, demonstrating that learning occurred. This suggested that treatments in the study affected learning by promoting memory retention.

Differences in recall and learning existed between the groups, evidenced by the significance levels reported from the pre-test to post-test (Pre-test, Pretest-Post 1) data. The two methods of content delivery, vignettes and written case studies, appeared to impact memory differently, as demonstrated in the significant results in the pre-test/post-test analysis (Pretest-Post 1). The first hypothesis (H1) tested was:

> H1) Student anesthetists exposed to audio-visual vignettes will exhibit superior clinical performance during simulated apparatus-related crisis events, as evidenced by higher group mean demonstration scores, when compared to a matched group exposed to written case studies.

Information regarding content recall was also evident from the identification of the malfunctioning anesthesia machine component portion of the study. Hypothesis 2 (H2) was related to recall. The hypothesis was:

H2) Student anesthetists exposed to audio-visual vignettes will exhibit superior recall of apparatus related material, evidenced by higher group mean post-test scores, when compared to a matched group exposed to written case studies.

Significant differences existed between the two groups in the identification of the non-functioning suction apparatus (IDSuc). No significant difference existed in identification of the stuck expiratory valve component (IDVal). The p-value (0.056) and F-value (4.109) of the IDVal variable analysis was considered to be "a finding of interest" as it approached the pre-analysis alpha level of 0.05. These two analyses (IDSuc, IDVal), indicate that vignettes made a stronger impact on the subjects' memories that did the written case study presentations. Differences in memory impact between the two different vignettes are discussed in the limitations section of this chapter.

For discussion, to easily differentiate between the two steps of the FDA Anesthesia Apparatus Machine Checkout Procedure, a table has been developed. This is displayed as Figure 8.

The anaylsis of data collected from the simulated malfunctioning suction device in 14, (CPSuc) yielded strong significant support for vignettes as a method of content delivery to impact anesthesia clinical performance.

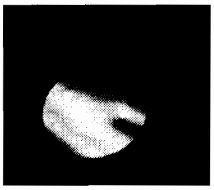
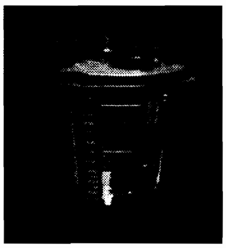
 Step 12	Visual example of the damaged, stuck unidirectional expiratory valve.
 Step 14	Visual example of the malfunctioning suction device.

Figure 8. Static Display of Sabotaged Anesthesia Machine Components utilized Step 12 and 14 of the FDA Anesthesia Apparatus Checkout Procedure.
Picture source: www.medicalzone.com

Differences existing in both recall (IDSuc) and clinical performance (CPSuc) in the group that received the malfunctioning suction apparatus vignette scenario versus the written case study presentation are clear. Under the conditions of this study, findings for both of these analyses are significant, indicating that vignettes are an efficient content delivery method to present information that can effect a change in clinical performance.

The analysis relative to the amount of time needed to perform clinical step 12 comparing the two groups (CPVal) yielded insignificant differences. This suggests that the vignette presentation of the stuck expiratory valve component had no impact on mechanical performance of the step.

The post-test portion of this study yielded significant results in 50 percent of the queries. Superior recall appeared to have occurred in students given the stuck valve scenario, as measured by post-test valve questions (PTV7, PTV9, PTV10). This finding seemed to be an outlier when compared to other results found in this study. Prior to review of this analysis, data indicated that the malfunctioning suction related vignette impacted student clinical performance greater than that presented in the stuck unidirectional valve clip. Based on the concepts of the DCT, recall should have been greater in subjects who demonstrated superior clinical performance. It was determined that the question posed in the post-test related to the valve scenario may have been constructed so as to elicit recall better than the suction related questions. Researchers replicating this study should evaluate this determination and consider altering the post-test questions in an effort to ensure their ability to clearly measure recall.

As discussed later in the limitations section of this chapter, differences between the two vignettes, such as video quality, emotional content, scenario development, and realism, may have had an influence on the outcome of this portion of the study. Although the production quality of each vignette was excellent, at times, different visual angles and effects were utilized between the two videos. Zooming in on objects as well as the length of time the camera was focused on static displays of equipment was more prevalent in one of the videos. A voiceover technique was utilized in one vignette to convey the anesthetist's thought processes as the crisis situation was unfolding. The other vignette solely utilized the actors' verbal abilities to convey the content as the patient's status was deteriorating.

Differences existed between the groups for both the CPSuc and CPTotaltime analysis. The group that received the non-functioning suction apparatus vignette demonstrated superior clinical performance in the hands-on checkout step (step 14) related to the suction scenario. Additionally, this same group demonstrated superior total clinical performance time in all steps of the entire anesthesia apparatus checkout process. This further supported the notion that vignettes had a positive impact on anesthesia clinical performance, more so than did written case study formats.

In the post-test portion of the study measuring clinical performance, data from post-test questions related to the suction scenario yielded significant results between groups (PostSuc). This also suggested the vignette format presentation impacts memory greater than the written case study formats.

When comparisons were made between the PostSuc and PostVal analyses, post-test questions related to the suction and valve scenarios, there is a large difference in the significance of the findings between groups. On the post-test, the group exposed to the suction vignette demonstrated superior performance over the group exposed to the stuck expiratory valve video. However, findings also indicate that the stuck expiratory valve vignette group did not perform superiorly to those subjects exposed to the suction video. It would be logical to assume that if video presentations were the sole cause of differences in memory impact and clinical performance, then both of these analyses would have been significant. However, it is suspected that enough content development and presentation differences existed between the two vignettes to explain these findings.

Application to Theory

DCT provides a theoretical infrastructure upon which to interpret the findings of this investigation. The applicability of DCT is supported by the observations relative to the recall and clinical performance components of this study. The differences in clinical performance can be related to the vignette presentations with confidence. Differences in recall can be related but with less confidence. Verbal and audio-visual information appeared to have been dually coded, allowing for synthesis of the information upon retrieval for later use. The two types of information gleaned from the vignettes, verbal and visual, were apparently utilized and recombined in the application to the subject's clinical performance. This is evidenced by the fact that the vignettes (visual information) had greater impact than did the written case studies (verbal information).

Subjects received the same necessary information in the two formats, and data analysis suggested stronger clinical performances from the visual (vignette) presentations. This suggested that clinical performance was affected by differences in information processing and retrieval, supporting the relationship between the clinical performance aspect of this study and the DCT.

Group performances were weaker when presented with information in a verbal presentation format (written case studies), as compared to performances after exposure to content delivered by an audio-visual vignette. In comparing these findings, in appears that a less substantial synthesis of knowledge or information occurred from the written case studies than from the vignettes. The synthesis of the audio and visual information after retrieval from memory is the factor that most likely resulted in better group clinical performances. Again, this is supported by the data presented from the clinical performance measures.

Major Limitations

The greatest limitation to this study was the size of the convenience sample. Although an entire freshman cohort was used (N = 23), a larger N using multiple educational programs (multi-site) would have been preferred.

A second limitation to this study may have been differences that existed between the two vignette scenarios. While an emotive component was present in the stuck valve scenario, the suction vignette was deemed more emotionally charged. This may have affected the impact on the subjects' memories. As alluded to earlier, evidence of this limitation may be present in the differences in clinical performance (CPVal, CPSuc, IDVal, IDSuc) measures between the two vignette groups. The differences in emotive content between the two vignettes are a potentially limiting factor; however, a strong emotional component such as the one present in the suction scenario can serve to cognitively impress upon the student the severity of the consequences of their clinical performance actions while maintaining patient safety.

As discussed in Chapter 3, the quality of vignettes can affect memory impact. Vignettes used in this study were consistent in quality, produced by the same writers and professional technicians, in the same simulated anesthesia environment. Additionally, both vignettes were narrated by the same person, allowing for the same verbal emphasis on critical points. PowerPoint presentations accompanying the vignettes were also produced by the same professor, keeping the styles similar between the two presentations.

Greater "Hollywood factors", or higher fidelity values, could be introduced into the vignette production process, including more dramatic acting and special effects. These factors could be incorporated in an effort to produce a more emotionally charged product. The environment in which the vignettes were produced, as well as the quality of realism in each video was independently rated as being very realistic (Hotchkiss, Biddle, and Fallacaro, 2002). This supported the notion that a realistic emotive component was reproducible in a simulated environment.

However, as with any simulated scenario, realism may have been suppressed by nuances only subtly evident. This limitation is difficult to address as real life anesthesia critical events are rarely videotaped. By continually improving scripts, acting, and video production quality, the barrier between realism and simulation can be diminished.

A fourth limitation to the study is related to human interaction, such as interpersonal discussions between the subjects. While the subjects were professional, mature, adult, graduate students, it is possible that there were human qualities that may have interfered with the study cannot be ignored. The tendency of a cohort to discuss course work and content among themselves was addressed. The researcher reinforced the need for confidentiality multiple times. It appeared that the request for confidentiality was honored as subjects in both randomized groups left out or "missed" steps in the checkout process. As later subjects demonstrated the checkout process, there was no improvement in detection of the intentionally sabotaged components during the hands-on demonstration. This indicated that discussion between subjects had not taken place with regard to the sabotaged or faulty machine components, thus interactions between students regarding the study appeared to not take place.

It was not determined if failure to detect the non-functioning anesthesia machine components was a result of poor recall, knowledge or learning, and anxiety. This limitation is one that will likely exist in future replications of this study as well. Collection of qualitative data post-demonstration may help determine the possible rationales for poor performance. For example, the students could be given an open ended questionnaire asking why they felt they incorrectly performed the identification steps.

Another limitation to the study is the instrumentation. Both the pre-test and post-test were developed specifically for this study and the reliability of these data collection instruments cannot be assured, although both were administered to practicing CRNAs. The expert panel utilized in this research deemed the pre-test as a reliable, valid tool to test basic anesthesia machine checkout procedure knowledge. Future administration of the pre-test will provide a more concrete evaluation of the validity and reliability.

The second portion of the post-test (Post 6-11) was untested as well. The questions should be written to more accurately reflect differences gained from the vignettes as opposed to the written case studies. Differences in group performances were demonstrated in the PostVal and PostSuc analyses. Because both case studies were essentially transcripts of the vignettes, it was anticipated that data analyses for the two variables would be similar, yet this was not the case. This indicated that post-test questions needed to have a greater degree of specificity with regard to each variable tested.

Another limitation to the study was the simplicity of the simulated machine component malfunction depicted in the vignettes. Developing and using scenarios that are based on more complex anesthesia machine malfunctions would have allowed for more between subject variations in performance times, potentially altering the statistical findings of this study. The relatively simple machine checkout steps, valve function and suction strength, required little time to perform. Thus, clinical performance evaluation was limited to identification of the stuck expiratory valve and suction apparatus. Whereas, increasing the complexity of the crisis-oriented scenario by selecting a checkout step that would require a greater degree of critical thinking to resolve or troubleshoot the presenting machine component malfunction would allow for a more specific evaluation of clinical performance.

Critical thinking required by using a more complex machine checkout step would also better demonstrate the applicability of the DCT to this study. This higher level thinking would potentially better differentiate between the subject's ability to re-synthesize learned knowledge and their ability to recall then perform simple tasks. The premise of DCT is that verbal and audio-visual information is stored in the memory using separate processes and retrieved information is then later synthesized for use. Selecting a more complex task would better demonstrate cognitive processes proposed within DCT. For example, one step, also a part of the checkout procedure, that is more complex than the steps used in this study is the assessment of appropriate functioning of the low pressure system of the anesthesia machine. This step requires multiple checks of several different components and also requires complex thinking concepts to determine the causative factor for the malfunction, demonstrating higher level cognitive processing.

Replicating this study may serve to address another limitation of this research. A multi-institutional study, preferably using programs across the nation, could provide researchers with information regarding regional or dialectal differences.

Application of Findings

Anesthesia

Results of this study indicate that vignettes have the potential to impact nurse anesthesia education. Traditional lecture and written case study formats cannot offer the emotional impact that vignettes are capable of presenting. The potential impact that vignettes have on clinical performance cannot be ignored.

Concepts found in DCT are evident in this process. To impact clinical performance positively, anesthesia educators must first impact content recall in their students. An audio-visual presentation, such as a vignette, will accomplish this, if DCT is applicable to the domain of nurse anesthesia clinical practice. Once information is retrieved, the students must synthesize multiple pieces of information into a usable composite for application to their clinical practice. Re-synthesis of the stored information is demonstrated when the recalled knowledge is applied to clinical practice, just as the DCT suggests that intertwining of stored content occurs after retrieval from the LTM to the conscious mind.

Using vignettes, anesthesia education programs can potentially improve student clinical performance that would likely carry over into their professional careers as nurse anesthetists. However, the availability of problem-based learning vignettes is somewhat limited.

Researchers should consider that programs that have simulation capability are advantaged and may be able to produce vignettes that can be reused from year to year at a reasonable cost. Programs without simulation availability could purchase reusable vignettes for a one-time fee that yields a cost-effect method to improve their educational program. As more information and research becomes available regarding vignettes, more programs may incorporate them into their courses, in light of the fact that findings indicate that the concepts found within the DCT have applicability to anesthesia education.

The relatively inexpensive process of vignette production is a positive enticement to adopt them as a means to deliver content that may improve patient safety. The reusability of the vignettes is potentially another positive aspect for purchasing the videos. It is apparent that the reusability of the videos presents a cost-effective means to educate anesthesia students in an effort to impact clinical performance and patient safety.

Governmental budget cuts are taking place may affect anesthesia educational programs, inventive cost-effective methodologies that improve patient safety will likely be sought.

The potential ability to impact over 2500 nurse anesthesia students across the nation is staggering. Improving content recall and clinical performance this large number of students clearly can impact patient safety. It is fathomable that that over time the ability to deliver content in a vignette format could tremendously improve patient safety across the nation. While this is but an estimate of the potential impact vignettes could have on patient safety, the possibility that this format could positively effect a change in clinical performance in a large number of future CRNAs cannot be ignored.

Anesthesia patient safety vignettes can potentially be used to affect clinical performance outcomes for seasoned, experienced CRNAs. As part of continuing education courses, vignettes offer the same benefits to CRNAs as they would the student subjects in this study. The Council on Recertification of Nurse Anesthetists requires all CRNAs are required to obtain 40 contact hours of continuing education to be eligible for recertification.

Other Disciplines

Disciplines other than anesthesia may benefit from this research. The concepts presented in this study could be used as foundational support for research related to vignette use in other fields. For example, pharmacists could develop patient safety vignettes that present tragic outcomes resulting from erroneous prescription filling. One such scenario might be the death of a child as a result of taking a medication to which the child had an extreme allergy. The content emphasis in the vignette might be violation of the procedural checks and balance systems required by pharmacists when filling patient prescriptions.

Likewise, respiratory therapists may benefit from vignettes depicting the erroneous use of nebulized medications. Radiology and clinical laboratory employees could potentially benefit from patient safety vignettes depicting erroneous equipment calibration. It is not difficult to imagine any medical discipline using vignettes to improve clinical performance and patient safety.

Nurse practitioner programs may benefit from using vignettes to educate students. A vignette that presents the misdiagnosis of a child's condition, depicting a subsequent fatal outcome, could be utilized. Another scenario that could be utilized in nurse practitioner education might be visual images of severe eye damage resulting from the clinician accidentally flushing the eye with a non-opthalmic solution. Yet another scenario might involve inappropriate triage in an emergency room setting. For instance, a patient complaining with anginal symptoms is kept waiting while patients with minor ailments are seen. The patient's angina worsens and ultimately, the patient has a myocardial infarction.

Primary nurse educators may also benefit from using vignettes as an educational tool. Professors could educate nursing students using a vignette that presents content regarding administration of an intravenous antibiotic infusion over a specified period of time. A negative patient outcome resulting from rapid incorrect rapid infusion could be demonstrated. This is just one of very many examples where vignettes could play a role in nursing education.

Some examples of disciplines potentially benefiting from the use of vignettes in their educational programs, as well as possible scenarios that could be used to portray crisis events affecting patient safety are presented in Table 20.

Table 20

Examples of Disciplines Potentially Benefiting from Vignettes as an Educational Modality.

Discipline	Scenario
Nurse Practitioners	Misdiagnosis of a child's condition
Respiratory Therapists	Ventilator malfunction
Laboratory Technicians	Blood cross-matching error

There is potential benefit for disciplines outside of medicine to improve human performance. The military has effectively utilized vignettes to train pilots to avert aviation disasters. Given that positive results have been reported in aviation, as well as the results obtained from this study, it is feasible that vignettes can be used to alter human performance in certain scenarios.

For example, hurricane Katrina, a recent natural disaster, devastated much of the Mississippi gulf coast and a large part of New Orleans, Louisiana. Federal emergency management systems did not meet public expectations. Because of the magnitude of this disaster, the Federal Emergency Management Administration (FEMA) was not able to handle the overwhelming need for even the most basic of necessities, such as water. Procedural vignettes could be produced that depict a breakdown in either communication or supply delivery that results in a catastrophic outcome for a citizen.

Another procedural breakdown occurred in the search and rescue attempts by the coast guard and other military organizations. Initially, too few helicopters and boats were deployed for the rescue efforts. Yet another breakdown occurred in the early stages of the flooding that resulted in the loss of many lives. Over one hundred school and public buses sat unused in a city parking lot. These buses could have utilized for the evacuation of home bound, disabled, critically ill hospitalized patients, and nursing home patients unable to leave of their own accord. Again, this demonstrates a tragic breakdown in communication between officials and the leadership involved in the daily operation of the buses. A vignette could be used for training purposes in an effort to avert similar performance errors in future natural disasters.

Today's technologic capabilities, such as the internet, could potentially be used to alter performance. The internet could easily be used as a method to deliver vignettes to a large population. The reusability, cost-effectiveness, and ease of production that vignettes offer, make them a viable method to convey information aimed at altering performance in many industries and common crisis situations. Virtually, vignettes could potentially be used to improve performance outcomes in most any discipline when they are well made, realistic, and promote dual coding in subjects.

Contribution to the Scientific Body of Anesthesia Knowledge

The study offers results that add to the body of knowledge related to three major components of the anesthesia discipline, anesthesia education methods, patient safety, and clinical performance. These are three of the major components in the anesthesia discipline. Using more effective educational methods, clinical performance can potentially be impacted, thus making anesthesia safer for patients. Data analyses from this study indicated that patient safety vignettes positively impacted clinical performance in four of the six measures. This suggests that patient safety can potentially be improved when vignettes are incorporated into anesthesia educational programs. These findings support H1 of this study.

Findings from this study open the door to future research in the areas of anesthesia patient safety education, CRM, and clinical performance. Furthermore, it raises questions regarding the potential use for vignettes as educational tools in medical and non-medical disciplines.

Suggestions for Future Research

As with most studies, this one also opens doors to other avenues of research. The sample size in this study was appropriate, as demonstrated by the observed power for most of the analyses. However, increasing the sample size or combining data from multiple studies replicated from this research, would produce a larger population for examination. Ideally in the future, a meta-analysis could be compiled.

Previous research demonstrates that neurophysiologic responses to verbal and visual stimuli can be evaluated using MRI. Recent technologic advances, such as the

PET scanner, will allow researchers to investigate the relationship between visual and verbal stimuli and the DCT, more effective using this neurophysiologic evidence.

The researcher suggests that two or three additional future cohorts be used to replicate this study to provide a larger sample size. Replication of this study would also provide information regarding the reliability of the research project's instrumentation. The study could be replicated annually with different cohorts to determine annual differences and allow for differences in learning styles of the subsequent classes. A

Another area that needs to be explored relates to a qualitative aspect of vignette use. As with any change, resistance by educators to switch from traditional methods of content delivery to problem-based patient safety vignettes may be present. Investigations into this phenomenon and potential ways to alter educator resistance to vignettes as a content delivery method need to be explored.

An avenue for distribution needs to be developed for anesthesia patient safety vignettes. Educational programs without simulation or filming capabilities are disadvantaged if their goal is to educate students in a manner that will most greatly impact student clinical performance and patient safety in a positive manner. Programs could pool their resources (vignettes), possibly creating a national database, in order to maximize cost-effectiveness and access.

Research aimed at investigating potential business partnerships and educational cooperatives would be beneficial. Similarly, the AANA, ASA, or the Anesthesia Patient Safety Foundation (APSF) could be designated as a "clearing house" and anesthesia patient safety vignettes could be purchased or rented by educational programs for repeated use.

Vignette use as a method for continuing education (CE) is another area for potential inquiry. Traditional methods used now for this include seminars, lectures, case studies, and reading assignments. Case study reports and reading assignments typically have short multiple choice tests associated with them, however, seminars and lectures usually do not. There is no gauge to determine if the exposure to the content provided impacts or alters clinical performance. Potentially, vignettes could be used as a CE method and simulation could optionally be used to gauge application to clinical performance. The interest in using vignettes for CE would need to be investigated from a consumer, educator, and CE provider perspective.

Determining what scenarios are best to base anesthesia patient safety vignettes on is another area for investigation. Given that emotionally charged, realistic situations impact memory and clinical performance, selecting scenarios that will have the greatest impact and need is essential. While vignettes are often used to bring rarely occurring catastrophic events to life, there is great potential to improve clinical performance in more commonly occurring negative events leading to poor patient outcomes.

Conclusion

This study replicated scenarios that demonstrated rapid deterioration in a patient's physiologic status which was directly related to negligent nurse anesthesia clinical performances. Supporting the premise of the DCT developed by Paivio in 1971, the results from this research yielded support that verbal and audio-visual information was processed differently. Results from this study indicate that students retrieved information from memory and synthesized it for application to their clinical performance. This supported the primary hypothesis (H1). Hypothesis number 2 (H2) was not strongly supported, but it is possible this was due to the small number of subjects. The mixed results related to hypothesis 2 suggest that further clarifying studies will be needed. Although vignettes did seem to make a difference in some aspects of this study, it was not determined that global use of them is not strongly indicated. However, they are not strongly contraindicated. The suggestion of a possible cost-effective retention suggested further merit in this field.

Although various factors that may have affected clinical performance were present, knowledge gleaned from the exposure to the vignettes, as opposed to the written case studies, did appear to be more readily utilized during the simulated anesthesia crisis events. Personalization of the critical event through a brief introduction to the patient, could have been the catalyst for a greater allowed for a greater emotional impact resulting in content retrieval for later use. Yet, cautious interpretation of this concept due to the potential that other factors were in play that may have allowed for greater emotional impact and that these factors were not measured. When the same crisis scenario depicted in the vignette arose in the subject's hands-on demonstration of the anesthesia apparatus checkout procedure, in most instances, corrective measures were appropriately taken, possible due to the content being more readily retrievable to be applied to the presenting situation. This was evidenced by the application of corrective measures and identification of malfunctioning machine components by the vignette groups.

Incorrect or negligent actions were performed after subjects were presented with the same scenarios in a traditional, written case study format evidenced by significant differences between groups in the statistical analyses.

Under the conditions of this research, these findings support the hypothesis that vignettes have the potential capability to impact anesthesia clinical performance (H1) in a simulated anesthetic crisis. However, insignificant findings do not allow for support of hypothesis 2 (H2), superior performance of the vignette groups related to recall.

The evidence demonstrated that under the simulated conditions of this study, interesting results were obtained but statistical analyses demonstrated mixed results.

Clinical performance measures indicated that teaching methodologies made a difference in student nurse anesthesia scores for the hands on demonstration and identification of one of the malfunctioning components, the suction device. SRNA recall was impacted to a lesser degree. It was demonstrated that under the conditions of this study, crisis oriented, anesthesia educational vignettes have the potential to impact clinical performance in a simulated environment. Due to the small sample size and because the clinical performance measurements tools were newly designed for this particular study, findings from this study cannot be generalized to any other group or population. However, the findings from this study merit further investigation into the potential use of vignettes as an educational methodology to impact clinical practice and improve patient safety.

References

AANA. (2003). Professional practice manual for the certified registered nurse. *American Association of Nurse Anesthetists Journal, 71*(5), 347-352.

Addy, M., Renton-Harper, P., Warren, P., & Newcombe, R. G. (1999). An evaluation of video instruction for an electric toothbrush. Comparative single-brushing cross-over study. *Journal of Clinical Periodontology, 26*, 289-293.

AHRQ. (2001). Making health care safer: A critical analysis of patient safety practices (pp. 501-508): Agency for Healthcare Research and Quality.

Albanese, M. A., & Mitchell, S. (1993). Problem-based learning: A review of literature on its outcomes and implementation issues. *Academic Medicine, 68*(1), 52-81.

Alroy, G., & Ber, R. (1982). Doctor-patient relationship and the medical student: The use of trigger films. *Journal of Medical Education, 57*(4), 334-336.

Andreatta, P. B. E., Woodrum, D. T. M., Birkmeyer, J. D. M., Yellamanchilli, R. K. M. S., Doherty, G. M. M., Gauger, P. G. M., & Minter, R. M. (2006). Laparoscopic skills are improved with lapmentor[tm] training: Results of a randomized, double-blinded study. *Annals of Surgery, 243*(6), 854-863.

Arbous, M. S., Meursing, A. E., van Kleef, J. W., de Lange, J. J., Spoormans, H. H., Touw, P., Werner, F. M., & Grobbee, D. E. (2005). Impact of anesthesia management characteristics on severe morbidity and mortality. *Anesthesiology, 102*(2), 257-268; quiz 491-252.

Baddeley, A. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Science, 4*(11), 417-423.

Baddeley, A. D. (1976). *The psychology of memory*.New York: Basic Books.

Balslev, T., de Grave, W. S., Muijtjens, A. M., & Scherpbier, A. J. (2005). Comparison of text and video cases in a postgraduate problem-based learning format. *Medical Education, 39*(11), 1086-1092.

Bandura, A. (1977). *Social learning theory*.Englewood Cliffs, N.J.: Prentice Hall.

Beard, R., & Payack, P. J. J. (2006). Yourdictionary.Com. from Online access: http://bibpurl.oclc.org/web/2032 http://www.yourdictionary.com

Beard, R. M., Bligh, D. A., & Harding, A. G. (1978). *Research into teaching methods in higher education, mainly in british universities* (4th ed.). Guildford: Society for Research into Higher Education.

Ber, R., & Alroy, G. (2001). Twenty years of experience using trigger films as a teaching tool. *Academic Medicine, 76*(6), 656-658.

Ber, R., & Alroy, G. (2002). Teaching professionalism with the aid of trigger films. *Medical Teacher, 24*(5), 528-531.

Biddle, C. J., Hartland, W., & Fallacaro, M. (2005). Patient safety vignettes: Preliminary observations on a novel use of an old methodology. *The Internet Journal of Allied Health Sciences and Practice., 3*(1).

Blike, G., & Biddle, C. (2000). Preanesthesia detection of equipment faults by anesthesia providers at an academic hospital: Comparison of standard practice and a new electronic checklist. *American Association of Nurse Anesthetists Journal, 68*(6), 497-505.

Boursicot, K. (2006). Setting standards in a professional higher education course: Defining the concept of the minimally competent student in performance-based assessment at the level of graduation from medical school. *Higher Education Quarterly, 60*(1 %R doi:10.1111/j.1468-2273.2006.00308.x), 74-90.

Caplan, R. A., Posner, K. L., Ward, R. J., & Cheney, F. W. (1990). Adverse respiratory events in anesthesia: A closed claims analysis. *Anesthesiology, 72*(5), 828-833.

Chen, M. S., Horrocks, E. N., & Evans, R. D. (1998). Video versus lecture: Effective alternatives for orthodontic auxiliary training. *British Journal of Orthodontics, 25*(3), 191-195.

Clark, J., & Paivio, A. (1991). Dual coding theory and education. *Educational Psychology Review, 3*(3), 149.

Cook, T. D., & Campbell, D. T. (1979). *Quasi-experimentation: Design & analysis issues for field settings.*Chicago: Rand McNally College Pub. Co.

Cooper, G. E., White, M.D., Lauber, J.K. (1980). Resource management on the flightdeck: Proceedings of a nasa/industry workshop.Moffett Field, CA: NASA-Ames Research Center. NASA Conference Publication No. CP-2120.

Cooper, J., Newbower, R., & Kitz, R. (1984). An analysis of major errors and equimpment failures in anaesthesia mangment: Considerations for prevention and detection. *Anesthesiology, 60*, 34-42.

Cox, R., McKendree, J., Tobin, R., Lee, J., & Mayes, T. (1999). Vicarious learning from dialogue and discourse. *Instructional Science, 27*(6), 431-458.

Crombie, I. K., & Davies, H. T. O. (1998). Beyond health outcomes: The advantages of measuring process. *Journal of Evaluation in Clinical Practice, 4*(1 %R doi:10.1046/j.1365-2753.1998.t01-1-00003.x), 31-38.

Crottaz, S., & Ragot, R. (1998). A dual mechanism for sound pitch perception: New evidence from brain electrophysiology. *Neuroreport, 9*(14), 3123-3127.

Dabbagh, N. (2006). Dual coding theory: A theoretical foundation of learning with graphics.

Davis, B. G. (1993). *Tools for teaching* (1st ed.). San Francisco: Jossey-Bass Publishers.

De Groot, A. (1966). Perception and memory versus thought: Some old ideas and recent findings. In B. Kleinmuntz (Ed.), *Problem Solving*.New York: Wiley.

DeAnda, A., & Gaba, D. M. (1991). Role of experience in the response to simulated critical incidents. *Anesthesia and Analgesia, 72*(3), 308-315.

Deyer, C. A., & Bongero, A. A. (1981). Trigger films for teaching in the affective domain. *American Journal of Medical Technology, 47*(4), 255-258.

Drews, F. A., Syroid, N., Agutter, J., Strayer, D. L., & Westenskow, D. R. (2006). Drug delivery as control task: Improving performance in a common anesthetic task. *Human factors: the journal of the Human Factors Society, 48*(1), 85(10).

Eisenkraft, J. (2004). Hazards of anesthesia gas delivery systems. *Canadian Journal of Anesthesia, 51*(suppl_1), R7-.

Eshed, H., & Epstein, L. (1991). Assessment of primary care nursing in relation to adolescent health behaviour by means of trigger films. *Journal of Advanced Nursing, 16*(1), 24-29.

FDA. (1993). Anesthesia apparatus checkout recommendations. In C. f. D. a. R. Health (Ed.):US Government.

FDA. (1993, 05/12/97). Anesthesia apparatus checkout recommendations. Retrieved 05/15/06, from http://www.fda.gov/cdrh/humfac/anesckot.html

Flanagan, B., Nestel, D., & Joseph, M. (2004). Making patient safety the focus: Crisis resource management in the undergraduate curriculum. *Medical Education, 38*(1), 56-66.

Gaba, D. M. (2002). Two examples of how to evaluate the impact of new approaches to teaching. *Anesthesiology, 96*(1), 1-2.

Gaba, D. M., & DeAnda, A. (1989). The response of anesthesia trainees to simulated critical incidents. *Anesthesia and Analgesia, 68*(4), 444-451.

Ganis, G., Schendan, H. E., & Kosslyn, S. M. (2006). Neuroimaging evidence for object model verification theory: Role of prefrontal control in visual object categorization. *Neuroimage*. Graber, D. (1990). Seeing is remembering: How visuals contribute to learning from television news. *Journal of Communication, 40*(3), 134-155.

Gray, D. (1996). Disaster plan education: How we made and tested a video. *Journal of Accident Emergeny Medicine, 13*(1), 21-22.

Han, S. R., Ho, C. S., Jin, C. H., & Liu, C. C. (2003). Unexpected intraoperative hypercapnia due to undetected expiratory valve dysfunction--a case report. *Acta Anaesthesiol Sin, 41*(4), 215-218.

Hartland, W., Biddle, C., & Fallacaro, M. (2003). Accessing the living laboratory: Trigger films as an aid to developing, enabling, and assessing anesthesia clinical instructors. *American Association of Nurse Anesthetists Journal, 71*(4), 287-291.

Henson, R. N. A., Burgess, N., & Frith, C. D. (2000). Recoding, storage, rehearsal and grouping in verbal short-term memory: An fmri study. *Neurophsycologia, 38*, 426-440.

Hoffman, K., Hosokawa, M., Blake, R., Jr., Headrick, L., & Johnson, G. (2006). Problem-based learning outcomes: Ten years of experience at the university of missouri-columbia school of medicine. *Academic Medicine, 81*(7), 617-625.

Hotchkiss, M.A, Biddle C, Fallacaro M. Assessing the authenticity of the human simulation experience in anesthesiology. *American Association of Nurse Anesthetists Journal*. 2002;70:470-47

Isaac, S., & Michael, W. B. (1995). *Handbook in research and evaluation: A collection of principles, methods, and strategies useful in the planning, design, and evaluation of studies in education and the behavioral sciences* (3rd ed.). San Diego, Calif.

Kamin, C., O'Sullivan, P. S., Younger, M., & Deterding, R. (2001). Measuring critical thinking in problem-based learning discourse. *Teaching and Learning in Medicine, 13*(1), 27-35.

Kim, J. M., Neilipovitz, D., Cardinal, P., Chiu, M., & Clinch, J. *A pilot study using high-fidelity simulation to formally evaluate performance in the resuscitation of critically ill patients: The university of ottawa critical care medicine, high-fidelity simulation, and crisis resource management i study. [article]*:Critical Care Medicine.

Kluger, M. T., & Short, T. G. (1999). Aspiration during anaesthesia: A review of 133 cases from the australian anaesthetic incident monitoring study (aims). *Anaesthesia, 54*(1 %R doi:10.1046/j.1365-2044.1999.00642.x), 19-26.

Kohn, L. T., Corrigan, J., & Donaldson, M. S. (2000). *To err is human: Building a safer health system.*Washington, D.C.: National Academy Press.

Lamond, D., & Thompson, C. (2000). Intuition and analysis in decision making and choice. *Journal of Nursing Scholarship, 32*(4), 411-414.

Lampotang, S., Moon, S., Lizdas, D., Feldman, J.M., Zhang, R.V. (2006). Virtual anesthesia machine. Retrieved 09/14/2006, 2006, from http://vam.anest.ufl.edu/reviewpubs.html

Langdon, I. J., Hardin, R., & Learmonth, I. D. (2002). Informed consent for total hip arthroplasty: Does a written information sheet improve recall by patients? *Annual Review of the College of Surgery England, 84*(6), 404-408.

Lee, J., Dineen, F., McKendree, J., & Mayes, T. (1999). *Vicarious learning: Cognitive and linguistic effects of observing peer discussion.* Paper presented at the Annual Meeting of the American Educational Research Association, United Kingdom, Scotland.

Major, C. H., Palmer, B. (2001). Assessing the effectiveness of problem-based learning in higher education: Lessons from the literature. *Academic Exchange Quarterly, 5*(1).

Masters, J. C. (2005). Hollywood in the classroom: Using feature films to teach. *Nurse Educ, 30*(3), 113-116.

Mayer, R. E. (1999). Multimedia aids to problem-solving transfer. *31*(7), 611.

Mazor, K. M., Fischer, M. A., Haley, H. L., Hatem, D., & Quirk, M. E. (2005). Teaching and medical errors: Primary care preceptors' views. *Medical Education, 39*(10), 982-990.

McKendree, J., Stenning, K., Mayes, T., Lee, J., & Cox, R. (1998). Why observing a dialogue may benefit learning. *Journal of Computer Assisted Learning, 14*(2 %R doi:10.1046/j.1365-2729.1998.1420110.x), 110-119.

Miller, N. M. (1957). Scientific priniciples for maximum learning from motion pictures. *Audio-Visual Communication Review, 5*, 61-113.

Montgomery, D. C., & Runger, G. C. (1999). *Applied statistics and probability for engineers* (2nd ed.). New York: John Wiley Sons.

Moore, C. D., Cohen, M. X., & Ranganath, C. (2006). Neural mechanisms of expert skills in visual working memory. *Journal of Neuroscience, 26*(43), 11187-11196.

Morgan, P. J., Cleave-Hogg, D., McIlroy, J., & Devitt, J. H. (2002). Simulation technology: A comparison of experiential and visual learning for undergraduate medical students. *Anesthesiology, 96*(1), 10-16.

Morgan, P. J., Cleave-Hogg, D. M., Guest, C. B., & Herold, J. (2001). Validity and reliability of undergraduate performance assessments in an anesthesia simulator. *Can J Anaesth, 48*(3), 225-233.

Moseley, T. H., Wiggins, M. N., & O'Sullivan, P. (2006). Effects of presentation method on the understanding of informed consent. *Br J Ophthalmol, 90*(8), 990-993.

Munro, B. H. (2005). *Statistical methods for health care research* (5th ed.). Philadelphia: Lippincott Williams & Wilkins.

National-Lewis, U. (2005, 05/01/2005). Malcom knowles: Apostle of androgogy. 10/15/2005, from http://www.nl.edu/academics/cas/ace/resources/malcolmknowles.cfm

Naughton, D. (2006). Cooperative strategy training and oral interaction: Enhancing small group communication in the language classroom. *The Modern Language Journal, 90*(2 %R doi:10.1111/j.1540-4781.2006.00391.x), 169-184.

Newton, N. I., & Adams, A. P. (1978). Excessive airway pressure during anaesthesia. Hazards, effects and prevention. *Anaesthesia, 33*(8), 689-699.

Otten, L. J., & Rugg, M. D. (2001). Task-dependency of the neural correlates of episodic encoding as measured by fmri. *Cerebral Cortex, 11*(12), 1150-1160.

Paivio, A. (1971). *Imagery and verbal processes.*New York: Holt.

Paivio, A. (1986). *Mental representations: A dual coding approach.*New York. Oxford [Oxfordshire]: Oxford University Press; Clarendon Press.

Paivio, A. (1986). *Mental representations: A dual coding approach.*New York. Oxford [Oxfordshire]: Oxford University Press; Clarendon Press.

Paivio, A. (2006). *Mind and its evolution: A dual coding theoretical approach.*Mahwah, N.J.: L. Erlbaum Associates.

Parkin, A., & Dogra, N. (2000). Making videos for medical undergraduate teaching in child psychiatry: The development, use and perceived effectiveness of structured videotapes of clinical material for use by medical students in child psychiatry. *Medical Teacher, 22*(6), 568.

Petty, W. C., Kremer, M., & Biddle, C. (2002). A synthesis of the australian patient safety foundation anesthesia incident monitoring study, the american society of anesthesiologists closed claims project, and the american association of nurse anesthetists closed claims study. *American Association of Nurse Anesthetists Journal, 70*(3), 193-202.

Pittsburgh, U. o. (2006). Developing and teaching a course: The lecture method. Retrieved June 03, 2006, from http://www.pitt.edu/~ciddeweb/FACULTY-DEVELOPMENT/FDS/lectmeth.html

Pizzi, L., Goldfarb, N., & Nash, D. (2001). Crew resource managment and its applications in medicine:AHRQ.

Polit, D. F. (1996). *Data analysis & statistics for nursing research.*Stamford, Conn.: Appleton & Lange.

Polit, D. F., & Beck, C. T. (2004). *Nursing research: Principles and methods* (7th ed.). Philadelphia: Lippincott Williams & Wilkins.

Rabinowitz, D., Melzer-Geva, M., & Ber, R. (2002). Teaching the cultural dimensions of the patient-physician relationship: A novel approach using didactic trigger films. *Medical Teacher, 24*(2), 181-185.

Reason, J. T. (1990). *Human error.*Cambridge [England]; New York: Cambridge University Press.

Redelmeier, D. A., & Tibshirani, R. J. (1997). Interpretation and bias in case-crossover studies. *J Clin Epidemiol, 50*(11), 1281-1287.

Reed, J. F. (2004). Analysis of two-treatment, two-period crossover trials in emergency medicine. *Annals of Emergency Medicine, 43*(1), 54-60.

Renton-Harper, P., Addy, M., Warren, P., & Newcombe, R. G. (1999). Comparison of video and written instructions for plaque removal by an oscillating/rotating/reciprocating electric toothbrush. *J Clin Periodontol, 26*(11), 752-756.

Robb, Y., Fleming, V., & Dieter, C. (2002). Measurement of clinical performance of nurses: A literature review. *Nurse Education Today, 22*, 293-300.

Rolfe, G. (2005). The deconstructing angel: Nursing, reflection and evidence-based practice. *Nursing Inquiry, 12*(2), 78-86.

Ross, R. S., Eichenbaum, H. (2006). Dynamics of hippocampal and cortical activation during consolidation of a nonspatial memory. *The Journal of Neuroscience, 3*(26), 4852-4859.

Runciman, W. B., Kluger, M. T., Morris, R. W., Paix, A. D., Watterson, L. M., & Webb, R. K. (2005). Crisis management during anaesthesia: The development of an anaesthetic crisis management manual. *Qual Saf Health Care %R 10.1136/qshc.2002.004101, 14*(3), e1-.

Ryan, D. P., & Marlow, B. (2004). Build-a-case: A brand new continuing medical education technique that is peculiarly familiar. *Journal of Continuing Education for Health Proffessions, 24*(2), 112-118.

Rydman, R. J., Sonenthal, K., Tadimeti, L., Butki, N., & McDermott, M. F. (1999). Evaluating the outcome of two teaching methods of breath actuated inhaler in an inner city asthma clinic. *Journal of Medical Systems, 23*(5), 349-356.

Schmidt, H. G. (1993). Foundations of problem-based learning: Some explanatory notes. *Medical Education, 27*(5), 422-432.

Schull, M. J., Ferris, L. E., Tu, J. V., Hux, J. E., & Redelmeier, D. A. (2001). Problems for clinical judgement: 3. Thinking clearly in an emergency. *CMAJ, 164*(8), 1170-1175.

Searle, J. (2000). Defining competency - the role of standard setting. *Medical Education, 34*(5 %R doi:10.1046/j.1365-2923.2000.00690.x), 363-366.

Seeck, M., Mainwaring, N., Cosgrove, R., Blume, H., Dubuisson, D., Mesulam, M. M., & Schomer, D. L. (1997). Neurophysiologic correlates of implicit face memory in intracranial visual evoked potentials. *Neurology, 49*(5), 1312-1316.

Sexton, J. B., Thomas, E. J., & Helmreich, R. L. (2000). Error, stress, and teamwork in medicine and aviation: Cross sectional surveys. *British Medical Journal, 320*(7237), 745-749.

Sica, G. T., Barron, D. M., Blum, R., Frenna, T. H., & Raemer, D. B. (1999). Computerized realistic simulation: A teaching module for crisis management in radiology. *AJR :American Journal Roentgenology, 172*(2), 301-304.

Sigurdsson, G. H., & McAteer, E. (1996). Morbidity and mortality associated with anaesthesia. *Acta Anaesthesiology Scandanavia, 40*(8 Pt 2), 1057-1063.

Stevens, J. (2002). *Applied multivariate statistics for the social sciences* (4th ed.). Mahwah, N.J.: Lawrence Erlbaum Associates.

Suraseranivongse, S., Valairucha, S., Chanchayanon, T., Mankong, N., Veerawatakanon, T., & Rungreungvanich, M. (2005). The thai anesthesia incidents study (thai study) of pulmonary aspiration: A qualitative analysis. *Journal of Medical Association Thailand, 88 Suppl 7*, S76-83.

Sweller, J., van Merrienboer, J., & Paas, F. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10*(3), 251.

Thomas, M. D., O'Connor, F. W., Albert, M. L., Boutain, D., & Brandt, P. A. (2001). Case-based teaching and learning experiences. *Issues in Mental Health Nursing, 22*(5), 517-531.

Tiwari, A., Lai, P., So, M., & Yuen, K. (2006). A comparison of the effects of problem-based learning and lecturing on the development of students' critical thinking. *Medical Education, 40*(6), 547-554.

Turner, P., & Williams, C. (2002). Informed consent: Patients listen and read, but what information do they retain? *N Z Med J, 115*(1164), U218.

UMMC. (2004). Surgical care, surgery statistics (Vol. 2005).

University, F. S. (2006). Instruction at fsu: A guide to teaching & learning practices. Retrieved May 05, 2006, from http://online.fsu.edu/learningresources/handbook/instructionatfsu/PDF-Chptr7.pdf

Valkenburg, P. M., Semetko, H. A., & De Vreese, C. H. (1999). The effects of news frames on readers' thoughts and recall. *26*(5), 550-569.

Vernon, D. T., & Blake, R. L. (1993). Does problem-based learning work? A meta-analysis of evaluative research. *Academic Medicine, 68*(7), 550-563.

Watterson, L. M., Morris, R. W., Westhorpe, R. N., & Williamson, J. A. (2005). Crisis management during anaesthesia: Bradycardia. *Quality and Safety in Health Care, 14*(3), e9.

Webster. (2003). Webster's new millennium™ dictionary of english, *Preview Edition* (Vol. v 0.9.6): Lexico Publishing.

Weigel, W. A., & Murray, W. B. (2005). Detecting unidirectional valve incompetence by the modified pressure decline method. *Anesthesia and Analgesia, 100*(6), 1723-1727.

Weston, J., Hannah, M., & Downes, J. (1997). Evaluating the benefits of a patient information video during the informed consent process. *Patient Educational Counseling, 30*(3), 239-245.

Wittrock, M. C., & Farley, F. (1989). *The future of educational psychology*.Hillsdale, N.J.: L. Erlbaum Associates.

Xiao, Y., Mackenzie, C., & Jefferies, N. (1996). Task complexity in emergency medical care and it's implications for team coordination. *Human Factors, 38*, 636-645.

Yoder, J. D., & Hochevar, C. M. (2005). Encouraging active learning can improve students' performance on examinations. *Teaching of Psychology, 32*(2), 91-95.

Ziv, A., Wolpe, P. R., Small, S. D., & Glick, S. (2003). Simulation-based medical education: An ethical imperative. *Academic Medicine, 78*(8), 783-788.

Appendix A

Anesthesia Apparatus Checkout Recommendations, 1993

This checkout, or a reasonable equivalent, should be conducted before administration of anesthesia. These recommendations are only valid for an anesthesia system that conforms to current and relevant standards and includes an ascending bellows ventilator and at least the following monitors: capnograph, pulse oximeter, oxygen analyzer, respiratory volume monitor (spirometer) and breathing system pressure monitor with high and low pressure alarms. This is a guideline which users are encouraged to modify to accommodate differences in equipment design and variations in local clinical practice. Such local modifications should have appropriate peer review. Users should refer to the operator's manual for the manufacturer's specific procedures and precautions, especially the manufacturer's low pressure leak test (step #5).

Emergency Ventilation Equipment

***1. Verify Backup Ventilation Equipment is Available & Functioning**

High Pressure System

***2. Check Oxygen Cylinder Supply**

a. Open O_2 cylinder and verify at least half full (about 1000 psi).
b. Close cylinder.

***3. Check Central Pipeline Supplies**

a. Check that hoses are connected and pipeline gauges read about 50 psi.

Low Pressure System

***4. Check Initial Status of Low Pressure System**

a. Close flow control valves and turn vaporizers off.
b. Check fill level and tighten vaporizers' filler caps.

***5. Perform Leak Check of Machine Low Pressure System**

a. Verify that the machine master switch and flow control valves are OFF.
b. Attach "Suction Bulb" to common (fresh) gas outlet.
c. Squeeze bulb repeatedly until fully collapsed.
d. Verify bulb stays fully collapsed for at least 10 seconds.
e. Open one vaporizer at a time and repeat 'c' and 'd' as above.
f. Remove suction bulb, and reconnect fresh gas hose.

***6. Turn On Machine Master Switch**

and all other necessary electrical equipment.

***7. Test Flowmeters**

a. Adjust flow of all gases through their full range, checking for smooth operation of floats and undamaged flowtubes.
b. Attempt to create a hypoxic O_2/N_2O mixture and verify correct changes in flow and/or alarm.

Scavenging System

***8. Adjust and Check Scavenging System**

a. Ensure proper connections between the scavenging system and both APL (pop-off) valve and ventilator relief valve.
b. Adjust waste gas vacuum (if possible).
c. Fully open APL valve and occlude Y-piece.
d. With minimum O_2 flow, allow scavenger reservoir bag to collapse completely and verify that absorber pressure gauge reads about zero.
e. With the O_2 flush activated allow the scavenger reservoir bag to distend fully, and then verify that absorber pressure gauge reads < 10 cm H_2O.

Breathing System

***9. Calibrate O_2 Monitor**

a. Ensure monitor reads 21% in room air.
b. Verify low O_2 alarm is enabled and functioning.
c. Reinstall sensor in circuit and flush breathing system with O_2.
d. Verify that monitor now reads greater than 90%.

10. Check Initial Status of Breathing System

a. Set selector switch to "Bag" mode.
b. Check that breathing circuit is complete, undamaged and unobstructed.
c. Verify that CO_2 absorbent is adequate.
d. Install breathing circuit accessory equipment (e.g. humidifier, PEEP valve) to be used during the case.

11. Perform Leak Check of the Breathing System

a. Set all gas flows to zero (or minimum).
b. Close APL (pop-off) valve and occlude Y-piece.
c. Pressurize breathing system to about 30 cm H_2O with O_2 flush.
d. Ensure that pressure remains fixed for at least 10 seconds.
e. Open APL (Pop-off) valve and ensure that pressure decreases.

Manual and Automatic Ventilation System

12. Test Ventilation Systems and Unidirectional Valves

a. Place a second breathing bag on Y-piece.
b. Set appropriate ventilator parameters for next patient.
c. Switch to automatic ventilation (Ventilator) mode.
d. Fill bellows and breathing bag with O_2 flush and then turn ventilator ON.
e. Set O_2 flow to minimum, other gas flows to zero.
f. Verify that during inspiration bellows delivers appropriate tidal volume and that during expiration bellows fills completely.
g. Set fresh gas flow to about 5 L/min.
h. Verify that the ventilator bellows and simulated lungs fill and empty appropriately without sustained pressure at end expiration.
i. Check for proper action of unidirectional valves.
j. Exercise breathing circuit accessories to ensure proper function.
k. Turn ventilator OFF and switch to manual ventilation (Bag/APL) mode.
l. Ventilate manually and assure inflation and deflation of artificial lungs and appropriate feel of system resistance and compliance.
m. Remove second breathing bag from Y-piece.

Monitors

13. Check, Calibrate and/or Set Alarm Limits of all Monitors

Capnometer — Pulse Oximeter
Oxygen Analyzer — Respiratory Volume Monitor (Spirometer)
Pressure Monitor with High and Low Airway Alarms

Final Position

14. Check Final Status of Machine

a. Vaporizers off
b. APL valve open
c. Selector switch to "Bag"
d. All flowmeters to zero
e. Patient suction level adequate
f. Breathing system ready to use

* If an anesthesia provider uses the same machine in successive cases, these steps need not be repeated or may be abbreviated after the initial checkout.

Appendix B

Promise of Confidentiality Statement

Participants in this research study will have every effort made on their behalf to protect their privacy. The pre-study questionnaire which provides the researcher with background information and student names will be the only documentation linking data to a specific student. These documents will be protected during the study and once the research is completed they will be destroyed by shredding in accordance with Samford University's policy for confidential document disposal. Students will be randomized into two groups and each student will be assigned a subject number and other than name, will have no correlation with any personal information such as birth date, or social security number, etc. Data will be collected and documented by subject number only. The researcher will respect and observe the confidentiality rights of each student participating in this study.

Appendix C

Pre-Study Questionnaire

Name: ______________________________

Work Experience:

	Yes	No
• Have you ever been employed as anesthesia technician or assistant?	☐	☐
• Do you have veterinarian assistant experience?	☐	☐
• Have you witnessed an inter-operative equipment failure crisis?	☐	☐
• Do you have experience as an operating room circulator nurse?	☐	☐
• Do you have experience as a respiratory therapist or assistant?	☐	☐
• Is this the first time you have been enrolled in MSNA 571 Principles of Anesthesia I?	☐	☐

Appendix D

Pre-Test

1. What agency provides guidelines for the anesthesia apparatus pre-operative checkout process?
   a. Occupational Safety and Health Administration (OSHA)
   b. Anesthesia Patient Safety Foundation (APSF)
   c. Food and Drug Administration (FDA)
   d. National Institute for Occupational Safety and Health (NIOSH)

2. How much oxygen should be available in an e-cylinder prior to administering an anesthetic?
   a. 500 psi
   b. 1000 psi
   c. 1500 psi
   d. 2000 psi

3. A suction bulb is used to test which anesthesia machine system?
   a. Backup ventilation system
   b. Breathing system
   c. High pressure system
   d. Low pressure system

4. To what liter flow should the gas flows be set to perform a leak check of the breathing system?
   a. 0
   b. 1
   c. 3
   d. 5

5. What is the prudent anesthetist evaluating by closing the adjustable pressure limiting valve (APL), pressurizing the breathing system to 30 cm H20 pressure using the oxygen flush valve, and ensuring a fixed pressure for at least 10 seconds?
   a. Potential leaks in the ventilator bellows
   b. E-cylinder supply disruptions
   c. Positive pressure capability
   d. Smooth operation of floats in Thorpe tubes

Appendix E

Facilitator Discussion Guidance

1. Allow no more than 10 minutes for group discussion.
2. Invite all students to participate.
3. Open the discussion.
    - What was interesting about this case study/vignette?
    - What were some things you noticed?
4. Draw more subjects into the discussion.
    - Does everyone agree with what has just been said?
    - How do the rest of you feel about that?
    - Does anyone disagree?
5. It may be necessary to repeat example questions from # 3 & 4 during the course of the discussion.
6. Close the discussion.
    - Thank you everyone for participating.
    - That was an interesting discussion.

Appendix F
Hands-On Demonstration Data Collection Form

Subject Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Step 12												
Start Time												
Stop Time												
Total Seconds												
Step 14												
Start Time												
Stop Time												
Total Seconds												

Subject Number	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**
Step 12												
Start Time												
Stop Time												
Total Seconds												
Step 14												
Start Time												
Stop Time												
Total Seconds												

Appendix G

Post-Test

1. What agency provides guidelines for the anesthesia apparatus pre-operative checkout process?
    a. Occupational Safety and Health Administration (OSHA)
    b. Anesthesia Patient Safety Foundation (APSF)
    c. Food and Drug Administration (FDA)
    d. National Institute for Occupational Safety and Health (NIOSH)

2. How much oxygen should be available in an e-cylinder prior to administering an anesthetic?
    a. 500 psi
    b. 1000 psi
    c. 1500 psi
    d. 2000 psi

3. A suction bulb is used to test which anesthesia machine system?
    a. Backup ventilation system
    b. Breathing system
    c. High pressure system
    d. Low pressure system

4. To what liter flow should the gas flows be set to perform a leak check of the breathing system?
    a. 0
    b. 2
    c. 4
    d. 6

5. What is the prudent anesthetist evaluating by closing the adjustable pressure limiting valve (APL), pressurizing the breathing system to 30 cm H20 pressure using the oxygen flush valve, and ensuring a fixed pressure for at least 10 seconds?
    a. Potential leaks in the ventilator bellows
    b. E-cylinder supply disruptions
    c. Positive pressure capability
    d. Smooth operation of floats in Thorpe tubes

6. In the case study/scenario involving the malfunctioning suction apparatus, after the initial crisis:
    a. The patient's head was turned to the left
    b. The patient's head was turned to the right
    c. The patient's head was positioned neutrally
    d. The patient's head position was not depicted

7. In the case study/scenario involving the parent of two small children, the surgical case to be performed was:
    a. An appendectomy
    b. Repair of an inguinal hernia
    c. Repair of a fractured calcaneous
    d. A tubal ligation

8. With regard to the case study/scenario involving the suction apparatus, which piece of equipment was used just after the anesthesia induction drugs were given?
    a. Stethoscope
    b. Laryngoscope
    c. Nerve stimulator
    d. Oral airway

9. In the case study/scenario involving a male patient, what piece of equipment was malfunctioning?
    a. Artificial mechanical breathing unit AMBU (AMBU)
    b. The machine's adjustable pressure limiting (APL) valve
    c. The anesthesia machine's unidirectional expiratory valve
    d. The Nurse anesthetist's available suction apparatus

10. With regard to the case study/scenario involving the surgeon, what was the surgeon's chief complaint?
    a. The anesthesiologist was not present
    b. He was unable to visualize the gallbladder
    c. More muscle relaxant was needed
    d. There was movement on incision

11. In the case study/scenario involving the male patient and a surgeon, what was found to be the root cause of crisis situation and poor patient outcome?
    a. Nurse anesthetist negligence
    b. Equipment manufacturer or shipping defect
    c. Anesthesia machine malfunction
    d. ACLS improperly performed

Appendix H

Anesthesia Case Study: Malfunctioning Unidirectional Valve and the FDA Anesthesia Apparatus Checkout Procedure

Introduction

Given that aviation has great success with safety checklists, pre-anesthetic checklists represent plausible safety tools. With this in mind, an anesthesia apparatus checkout procedure was developed by the Food and Drug Administration (FDA) in 1987. This procedure was updated in 1993 and is presently under review for revision (Lampotang, 2006).

Case Scenario

A 37 year old healthy woman, mother of two, received a 50mg Lidocaine spinal anesthetic with a T-10 sensory loss with light sedation for an open reduction, internal fixation (ORIF) of a fractured calcaneous as a result of a fall from a ladder. The patient was breathing room air. Near the end of the procedure, it appeared that the spinal was wearing off and the patient became agitated. The pulse oximeter had been removed due to patient movement and to stop the alarms occurring from signal loss. Morphine 5mg and Midazolam (Versed) 5mg were administered IV with subsequent apnea observed within 60 seconds. Application of oxygen via circle system and face mask failed due to inability to pressurize the circuit. No alternative oxygen source was immediately available and mouth to mouth ventilation ensued until an artificial mask bag unit (AMBU) was secured approximately 2 minutes later. Cardiac arrest followed. Advanced Cardiac Life Support (ACLS) was initiated but significant damage to the central nervous system resulted. Subsequent examination of the anesthesia machine revealed a dime size perforation in the circle system tubing attributed to manufacturer error and that no back up positive pressure ventilation apparatus was available. The provider indicated that they did not perform an apparatus pre-use checkout due to the nature of the case, spinal anesthesia.

Patient Safety and the Anesthesia Apparatus

Optimizing patient safety is paramount. This includes:

- Ensuring equipment functionality
- Understanding and using available safety devices
- Clinical vigilance during a case
- Knowing how to respond and react if a failure occurs

Major Functions of Anesthesia Machine

- Precise and adjustable delivery of gasses
- Ability to deliver positive pressure 100% O2
- Electronic monitoring interface - - a centralized workstation
- Sources for patient suction and waste gas management
- Back-up for critical functionality

The traditional anesthetic machine has evolved over the years to incorporate more than simply a gas delivery system. Anesthesia delivery machines are now modern workstations equipped with ventilators, rotometers, automated recording, a variety of safety features, and soft-ware that allows a machine “self-check” procedure for leaks and faults.

Checkout Procedure

The pre-use checkout procedure involves 4 fundamental areas:

1. Verify back-up ventilation source & oxygen supply
2. Inspect equipment configuration (eg. circuit)
3. Inspect equipment functionality (eg. valves, suction)
4. Preparation of monitors (eg. calibrate & activate)

In 1987 the Food and Drug Administration first published a recommended anesthesia apparatus checkout procedure. This allowed anesthesia providers a standardized approach to the checkout process. The checkout procedure was revised in 1993 and included the following concepts:

- The average time to completion < 5 minutes.
- There are 14 major processes involved in the checkout.
- Nine of these processes can be removed from the checkout procedure if the same practitioner is staying in the same room for subsequent cases, with the same machine.
- Modification of guidelines to accommodate differences in equipment design.

A number of safety features to avoid hypoxic mixtures are built into modern anesthesia delivery systems. Some include:

- Oxygen concentration monitor.
- Low oxygen pressure nitrous cutoff (“fail safe”).
- Oxygen supply pressure failure alarm.

- Single oxygen flow control knob ("touch coded").
- Oxygen flow control knob at the extreme right.
- Central and tank gas supply pressure gauges.
- Color coded flow meters and control knobs.
- Oxygen/Nitrous oxide ratio monitoring/controller.
- Locking common gas outlet.
- Pin index/diameter index/coupling system.

Failure to check the anesthesia delivery system can lead to patient injury or near misses. The most common near misses or patient injuries are respiratory-related events (Caplan, Posner, Ward, & Cheney, 1990; Caplan, Vistica, Posner, & Cheney, 1997; Cooper, Newbower, & Kitz, 1984) The checkout procedure is designed to reduce the risk of injury or death (Arbous, Meursing, van Kleef, de Lange, Spoormans, Touw, Werner, & Grobbee, 2005). However, the checkout procedure is neither well understood nor used reliably by anesthesia providers.

Checkout Evlauation

An ongoing American Society of Anesthesiologists (ASA) formal study of the checkout procedure, anesthesia providers report (Lampotang, 2006):

- All CRNAs do not perform a pre-use check
- 29% of the subjects demonstrated "poor" competency
- 33% rated as "satisfactory"
- 38% rated as "good/excellent"

Based on this data, there is obvious room for improvement.

Applicability of Checkout Process

It is important to realized that fixed guidelines are not universally applicable to all anesthesia machines, there is an increasing complexity of modern delivery systems, it is important to appreciate the value a pre-use check, education and training in the checkout process is vital, and guidelines need to be user friendly. Currently, the checkout guidelines are under revision in an effort to make them applicable to all anesthesia systems by not simply outlining the exact step or precise action for each process involved, but rather offer general guidelines that can be used with every anesthesia delivery system.

Case Scenario

A 45 year old healthy, athletic male was brought to the operating room (OR) for an emergency appendectomy. The anesthetist started an 18 gauge intravenous catheter and 1000cc of Lactated Ringer's Solution was begun. During the following monitors were available and ready for use:

- EKG.
- Non-invasive blood pressure cuff.
- Pulse oximetry.
- Temperature strip.

A fully stocked anesthesia cart with the appropriate emergency drugs was available. A suction source was available and making the usual distinctive noise. Once the patient was properly positioned and adequately sedated, the face mask was applied and the patient began breathing 100% oxygen. Induction drugs were given per the attending anesthesiologist. Cricoid pressure was applied. An oral airway was inserted to improve airway control. After appropriately pre-oxygenating the patient, the anesthetist placed the endotracheal tube on top of the patient's chest and opened the laryngoscope for intubation. The patient's head was positioned properly and the anesthetist used her fingers to open the mouth. As she opened the mouth the patient began vomiting copious amounts of undigested food. Instinctively, she turned the patient's head to the right to allow drainage of the vomitus. As the anesthetist was reaching for the suction, anesthesiologist excitedly told her to suction the patient. The reaction time for suctioning was prompt and appropriate for the situation; however, the device was not working properly. During this time, the patient aspirated stomach contents into his lungs and his status began to rapidly deteriorate. A quick check of the suction device revealed that there was suction from the source to the canister, but not from the canister to the patient. The anesthesiologist asked the CRNA, "didn't you set this up?" Cardiac arrest followed. Advanced Cardiac Life Support (ACLS) was initiated but there was significant damage to the central nervous system. A catastrophic patient outcome resulted.

Anesthesia Equipment

Subsequent examination of the anesthesia equipment revealed a small hole in the bottom edge of the suction canister that possibly occurred due to damage during shipping or as a result of being dropped prior to its use. The CRNA admitted that she had prepared the suction device but only listened for the distinctive noise.

Patient Safety and the Anesthesia Equipment

Completing a proper anesthesia machine pre-use checkout cannot be emphasized heavily enough. A general review of the steps recommended by the FDA for the anesthesia apparatus checkout procedure is listed as follows (FDA, 1993).

FDA Checkout Procedure

Emergency Ventilation Equipment

1. Verify backup ventilation equipment is available and functioning (AMBU and oxygen).*

High Pressure System Check (with anesthesia equipment off).

2. Check oxygen cylinder supply.*
   a. Open oxygen cylinder and verify that it is at least half full (1000 psi)+.
   b. Close cylinder and flush system to 0 psi+.
3. Check central pipeline supplies.*
   a. Check that hoses are connected and pipeline gauges read approximately 50 psi.

Low Pressure System Check

4. Check initial status of the low pressure system.*
   a. Close flow control valves and turn vaporizers off.
   b. Check fill level and tighten vaporizer filler caps.
5. Perform Leak Check of Machine Low Pressure System.*
   a. Verify that the machine master switch and flow control valves are off.

b. Attach suction bulb to common (fresh) gas outlet.

c. Squeeze bulb repeatedly until fully collapsed.

d. Verify bulb stays fully collapsed for at least 10 seconds.

e. Open one vaporizer at a time and repeat the two previous steps.

f. Remove suction bulb and reconnect fresh gas hose.

6. Turn on the machine master switch and all other necessary electrical equipment.*

7. Test flowmeters.*

a. Adjust flow of all gasses through their full range checking for smooth. operation of floats and undamaged flow tube.

b. Attempt to create a hypoxic oxygen/nitrous oxide mixture and verify correct. changes in flow and/or alarm.

Scavenging System

8. Adjust and check scavenging system.*

a. Ensure proper connections between the scavenging system and both the adjustable pressure limiting valve (APL) or "pop off" valve and the ventilator relief valve.

b. Adjust waste gas vacuum if possible.

c. Fully open the APL valve and occlude the Y-piece.

d. With minimum oxygen flow, allow scavenger reservoir bag to collapse. completely and verify that absorber pressure gauge reads about zero.

e. With the oxygen flush activated allow the scavenger reservoir bag to distend fully and then verify that the absorber pressure gauge reads less than 10 cm H_2O.

Breathing System

9. Calibrate oxygen monitor.*
    a. Ensure monitor reads 21% room air.
    b. Verify low oxygen alarm is enabled and functioning, with an initial setting of at least 30%.
    c. Reinstall sensor in the circuit and flush the breathing system with 100% oxygen.
    d. Verify that monitor now reads greater than 90%.
10. Check initial status of breathing system.
    a. Set selector switch to bag mode.
    b. Check that breathing circuit is complete, undamaged and unobstructed.
    c. Verify that the carbon dioxide (CO_2) absorbent is adequate.
    d. Install breathing circuit accessory equipment (e.g. humidifier, positive end expiratory valve) to be used during the case.
11. Perform a leak check of the breathing system.
    a. Set all gas flows to zero (or minimum).
    b. Close APL valve and occlude Y-piece.
    c. Pressure breathing system to about 30 cm H_2O with O_2 flush.
    d. Ensure that pressure remains fixed for at least 10 seconds.

e. Open APL valve and ensure that pressure decreases.

Manual and Automatic Ventilation Systems

12. Test ventilation systems and unidirectional valves.

    a. Place a second breathing bag on the Y-Piece.

    b. Set appropriate ventilator parameters for the next patient.

    c. Switch to automatic ventilation (ventilator) mode.

    d. Fill bellows and breathing bag with O_2 flush and then turn on ventilator on.

    e. Set O_2 flow to minimum and other gas flows to zero.

    f. Verify that during inspiration the bellows deliver appropriate tidal volume and that during expiration bellows fill completely.

    g. Set fresh gas flow to about 5 liters per minute (5L/min).

    h. Verify that the ventilator bellows and simulated lungs fill and empty appropriately without sustained pressure at end expiration.

    i. Check for proper action of unidirectional valves.

    j. Exercise breathing circuit accessories to ensure proper function.

    k. Turn ventilator off and switch to manual ventilation (bag/APL) mode

    l. Ventilate manually and assure inflation and deflation of the artificial lung, and appropriate feel of the system resistance and compliance.

    m. Remove second bag from Y-Piece.

Monitors

13. Check, calibrate, and/or set alarm limits of all monitors

    a. Capnometer.

b. Pulse oximeter.

c. Oxygen analyzer.

d. Respiratory volume monitors (spirometer).

e. Pressure monitors with high and low settings.

f. Airway alarms.

14. Check final status of machine

a. Vaporizers off.

b. APL valve open.

c. Selector switch is turned to bag mode.

d. Patient suction level adequate.

e. Breathing system ready for use.

f. All flow meters to zero.

*If an anesthesia provider uses the same machine in successive cases, these steps need not be repeated or may be abbreviated after the initial checkout.

+ = pounds per square inch.

Appendix I

Anesthesia Case Study: Non-functioning Suction Apparatus and the FDA Anesthesia Apparatus Checkout Procedure

Adherence to the Standards of Practice will promote patient safety, enhance professional competence, and support the CRNA in the event that a medicolegal issue arises.

Humans often learn best from their own mistakes. However, humans also learn vicariously from the mistakes of others. Errors or negative outcomes are opportunities for anesthesia providers to learn and develop robust systems to prevent similar errors from befalling others.

An enlightened view of errors recognizes that punishing those involved or simply reassigning them to other tasks does not prevent mistakes. Educating providers and building better systems represents a superior approach to error prevention and error absorption.

Patient safety vignettes (PSVs) have been developed to demonstrate the AANA Standards for Nurse Anesthesia Practice for use as a continuing education modality. There are three shared themes to the PSVs:

1. The crises are documented to have occurred frequently.
2. They involve a catastrophic patient outcome.
3. The crises are completely preventable if the standards of practice are adhered to by the Certified Registered Nurse Anesthetists (CRNA).

There is strong research indicating that agencies and organizations that most successful in managing potentially hazardous processes are those that actively create safety by anticipating and planning for unexpected events and future surprises.

Because of the complexity of the healthcare landscape, it is essential for each healthcare provider to be cognizant of the responsibilities inherent to anesthesia. Each task, even those of an ancillary nature, must be accorded the appropriate attention. Strategies directed at improving safety and performance are most effective when they are grounded in an organizational culture that effectively communicates the need for change while embracing and sustaining appropriate change.

Story telling is an effective tool in the quality and risk management disciplines. A well told story with emotional impact can provide powerful vicariousness and make a strong cognitive impression. A story behind the content or data is the most important factor contributing to change. It is possible that virtually all common anesthetic errors can be eliminated using PSVs as an educational tool.

The AANA standards are designed to:

- Assist the profession in evaluating the quality of care provided by the CRNA.
- Provide a common foundation for the CRNA to use in developing and maintaining a quality practice.
- Assist the public in understanding what to expect from the CRNA.
- Support and preserve the patient's basic rights.

Although these standards apply to all anesthetizing locations and are intended to encourage high quality patient care, they cannot assure specific outcomes. Key issues related to the standards are:

- Know the standard.
- Be able to explain the standard.
- Base clinical practice on the standard.
- Be able to actively evaluate the standard in the practice setting.

PSVs are designed to increase awareness of errors with regard to patient safety, ground safety interventions on the framework of the AANA Practice Standards, create an effective educational program that promotes patient safety, and develop an effective continuing educational program that promotes patient safety.

CRNAs are responsible for the quality of services they render. These responsibilities and services include rendering a patient insensible to pain by the administration of anesthetic agents and related drugs, consultation for management of pain associated with labor and delivery, and management of acute and chronic ventilatory support. Other areas in which CRNAs may be consulted are for diagnostic and therapeutic management of chronic pain, and post-operative pain relief. CRNAs practice under state statutes, clinical abilities, and institutional regulations and policy.

The AANA Standards of Practice and their interpretations are (AANA, 2003):

1. Perform a thorough and complete preanesthesia assessment.

   Interpretation: The responsibility for the care of the patient begins with the preanesthetic assessment. Except in emergency situations, the CRNA has an obligation to complete a thorough evaluation and determine that relevant tests have been obtained and reviewed.

2. Obtain informed consent for the planned anesthetic intervention from the patient or legal guardian.

   Interpretation: The CRNA shall obtain or verify that an informed consent has been obtained by a qualified provider. Discuss anesthetic options and risks with the patient and/or legal guardian in language the patient and/or legal guardian can understand. Document in the patient's medical record that informed consent was obtained.

3. Formulate a patient-specific plan for anesthesia care

   Interpretation: The plan of care developed by the CRNA is based upon a comprehensive patient assessment, problem analysis, anticipated surgical or therapeutic procedure, patient and surgeon preferences, and current anesthesia principles.

4. Implement and adjust the anesthesia care plan based on the patient's physiological response.

   Interpretation: The CRNA shall induce and maintain anesthesia at required levels. The CRNA shall continuously assess the patient's response to the anesthetic and/or surgical intervention, and intervene as required to maintain the patient in a satisfactory physiologic condition.

5. Monitor the patient's physiologic condition as appropriate for the type of anesthesia and specific patient needs.

A. Monitor ventilation continuously. Verify intubation of the trachea by auscultation, chest excursion and confirmation of carbon dioxide in the expired gas. Continuously monitor end-tidal carbon dioxide during controlled or assisted ventilation, including any anesthesia or sedation technique requiring artificial airway support. Use spirometry and ventilatory pressure monitors as indicated.

B. Monitor oxygenation continuously by clinical observation, pulse oximetry, and if indicated, arterial blood gas analysis.

C. Monitor cardiovascular status continuously via electrocardiogram and heart sounds. Record blood pressure and heart rate at least every five minutes.

D. Monitor body temperature continuously on all pediatric patients receiving general anesthesia and, when indicated, on all other patients.

E. Monitor neuromuscular function and status when neuromuscular blocking agents are administered.

F. Monitor and assess patient positioning and protective measures at frequent intervals.

Interpretation: Continuous clinical observation and vigilance are the basis of safe anesthesia care. The standard applies to all patients receiving anesthesia care and may be exceeded at any time at the discretion of the CRNA. Unless otherwise stipulated in the standards, a means to monitor and evaluate the patient's status shall be immediately available for all patients. As new patient safety technologies evolve, integration into the current anesthesia practice shall be considered. The omission of any monitoring standards shall be documented and the reason stated on the patient's anesthesia record. The CRNA shall be in constant attendance of the patient until the responsibility for care has been until the responsibility of care has been accepted by another healthcare provider.

6. There shall be complete, accurate, and timely documentation of pertinent information on the patient's medical record.

   Interpretation: Document all anesthetic interventions and patient responses. Accurate documentation facilitates comprehensive patient care, provides information for retrospective review and research data, and establishes a medical-legal record.

7. Transfer the responsibility for care of the patient to other qualified providers in a manner that assures continuity of care and patient safety.

   Interpretation: The CRNA shall assess the patient's status and determine when it is safe to transfer the responsibility of care to other qualified providers. The CRNA shall accurately report the patient's condition and all essential information to the provider assuming responsibility for the patient.

8. Adhere to appropriate safety precautions, as established within the institution, to minimize the risks of fire, explosion, electrical shock and equipment malfunction. Document on the patient's medical record that the anesthesia machine and equipment were checked.

Interpretation: Prior to use, the CRNA shall inspect the anesthesia machine and monitors according to established guidelines. The CRNA shall check the readiness, availability, cleanliness, and working condition of all equipment to be utilized in the administration of the anesthesia care. When the patient is ventilated by an automatic mechanical ventilator, monitor the integrity of the breathing system with a device capable of detecting a disconnection by emitting an audible alarm. Monitor oxygen concentration continuously with an oxygen supply failure alarm system.

9. Precautions shall be taken to minimize the risk of infection to the patient, the CRNA, and other healthcare providers.

   Interpretation: Written policies and procedures in infection control shall be developed for personnel and equipment.

10. Anesthesia care shall be assessed to assure its quality and contribution to positive patient outcomes.

    Interpretation: The CRNA shall participate in the ongoing review and evaluation of the quality and appropriateness of anesthesia care. Evaluation shall be performed based upon appropriate outcome criteria and reviewed on an ongoing basis. The CRNA shall participate in a continual process of self evaluation and strive to incorporate new techniques and knowledge into practice

11. The CRNA shall respect and maintain the basic rights of patients.

Interpretation: The CRNA shall support and preserve the rights of patients to personal dignity and ethical norms of practice.

The following scenario is a report from an actual case. The error depicted is a violation of AANA Standard of Practice VIII.

Case Scenario

A 45 year old male presented to the operating room for an exploratory laporotomy. Other than some persistent vague abdominal pain, no other symptoms were present. A complete gastro-intestinal work up revealed no pathology. Midway through the case, the surgeon complained that the patient was not relaxed, that he was "tight", and that the intestines were obstructing his field. He was unable to visualize the organs due to this. The CRNA informed the surgeon that her monitor revealed an adequate level or relaxation. At this point the surgeon became frustrated and voiced that he did not care what the monitor showed, that the patient was not relaxed. The CRNA checked the patient's breath sounds and confirmed that the endotracheal tube was properly placed. She noted that the peak inspiratory pressures (PIP) were high. At this point she paged the anesthesiologists to the room and he arrived promptly. The CRNA continued to assess the potential cause for the patient's lack of relaxation and PIPs. The endotracheal tube was disconnected from the circuit and the patient was suctioned to ensure patency of the endotracheal tube. The ETT was then reconnected to the anesthesia circuit. The end tidal carbon dioxide wave form flattened, indicating that that the patient was not being ventilated. PIPs continued to rise. Once again, the endotracheal tube position was verified and breath sounds were audible via auscultation, with manual lung inflation. Cardiac arrest ensued. The surgical drapes were lowered and the crash cart was brought into the room. Despite best efforts, the patient died.

Post Crisis Evaluation

The CRNA admitted to bypassing the test for unidirectional valve function prior to use of the anesthesia machine. Additionally it was noted that both the CRNA and the anesthesiologist failed to diagnose a rising PIP as the cause of the patient's "tightness" and that a malfunction of a unidirectional valve could be the culprit. It was noted that no back up ventilatory device was available. Disconnecting the patient from the circuit and utilizing the back up device would have been a fast, simple, and appropriate action that would have likely prevented the patient's demise.

Anesthesia Equipment

If an anesthesia equipment malfunction is suspected, the back up source of ventilation should be utilized. The patient should be completely disconnected from the anesthesia circuit and machine. Retrospectively, it was discovered that there was a malfunction of the unidirectional expiratory valve not allowing for lung deflation. In fact, the lung volume continued to rise as the anesthesia ventilator continued to inflate the lungs despite rising inspiratory pressures.

A major responsibility of the CRNA is to ensure the safe application of technology for the patient. To avoid error and improve patient safety it is imperative that as technology develops, the CRNA stays current with equipment requirements and indications that an malfunction is occurring.

Peak Inspiratory Pressures

There are many possible causes of rising inspiratory pressures. A few include:

- A kinked, plugged, or defective endotracheal tube.
- Circuit factors including a malfunctioning expiratory valve.
- An inadequate anesthestic depth.
- Endobronchial intubation.
- Tidal volume is set too high.
- Bronchospasm.
- Airway pathology, such as a mass.
- Surgical compression or patient positioning.
- Ventilator malfunction or a leak in the bellows.
- Pneumothorax or hemothorax.
- Pulmonary edema.
- Aspiration.

Interventions

If elevated airway pressure occurs, rapid diagnosis and intervention are essential. If unchecked, elevated PIPs can quickly lead to pulmonary and cardiovascular complications. Should the CRNA be unable to immediately correct the equipment malfunction, a backup source of ventilation should be implemented.

Food and Drug Administration (FDA) Pre-Use Checkout (FDA, 1993).

Specific steps to check anesthesia equipment prior to use are outlined in the FDA Anesthesia Apparatus Checkout Procedure, often referred to as the pre-use checkout or the anesthesia machine checkout process. The primary components of the checkout procedure are:

- Verification of a backup source of ventilation.
- Checking the oxygen cylinder supply.
- Checking the central pipeline supply.
- Performing an initial status and leak test of the low and high pressure systems.
- Testing the flowmeters.
- Checking the scavenging system for appropriate functioning.
- Calibrating the oxygen analyzer.
- Checking the initial status and leak test of the breathing system.
- Testing ventilation systems and the functionality of the unidirectional valves.
- Check, calibrate, and set all alarm limits.
- Check the final status of the machine.

Failure to check proper functioning of the expiratory unidirectional valve can lead to a catastrophic patient outcome if a malfunction occurs and the system has not be appropriately tested.

Intraoperative Crisis

A factor frequently noted to be associated with intraoperative critical incidents is failure by the CRNA is failure to perform a proper pre-use check of anesthesia equipment (Arbous, M. S., Meursing, A. E., van Kleef, J. W., de Lange, J. J., Spoormans, H. H., Touw, P., 2005; Cooper, J., Newbower, R., & Kitz, R., 1984).

Study Results

An ongoing American Society of Anesthesiologist's (ASA) survey suggests that <30% of respondents rate their understanding of the existing checklist as "poor". Only 20% indicated that they perform the recommended pre-use check before every case, with only about 50% performing a pre-use check for the first case of the day only.

FDA Checkout Procedure

The FDA checkout procedure is often misunderstood and is viewed by many as unclear. Because newer delivery systems have evolved, the current FDA procedure is being evaluated for potential change. Newer systems have automated checkouts which may allow for undetected machine faults and thereby contribute to clinician error.

Vita

Nina E. McLain was born in Philadelphia, Mississippi on November 3, 1962. She graduated from Meridian Junior College in Meridian, Mississippi in 1983 with an Associate Degree in Nursing. She continued her education, earning a Bachelor of Science Degree from the University of Southern Mississippi in 1989. Nina earned her Master of Science Degree from Charity Hospital/Xavier University School of Nurse Anesthesiology in 1991. She began her practice as a Certified Registered Nurse Anesthetist (CRNA).

Nina has worked as a staff CRNA, anesthesia quality improvement coordinator, and department chief, during the course of her 16 year anesthesia career. During her doctoral study, Nina was employed as an assistant professor in the nurse anesthesia program at Samford University in Birmingham, Alabama. She practiced clinically part-time at the Meridian Surgery Center in Meridian, Mississippi. Her doctoral study has enriched her as an educator, clinician, and researcher.