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The Use of Human Factors Training to Improve the Quality of Decision--Making in Nurse Anesthesia Trainees

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Table of Contents

Abstract----4
Background
Introduction to the problem----5
Study Goal----6
Clinical Question----6
Literature Review
Search Method----7
Human Factors and Medical Errors----8
Theoretical Framework----13
Methods
Target Population----14
Project Description: Development of a Human Factors Seminar----16
Project Support: Departmental and Institutional Review Board Approval---17
Project Phase 1: Human Factors Seminar Development----19
Phase 1 Study Tool: Needs Assessment Survey----20
Phase 1 Needs Assessment Survey Implementation----23
Project Phase 2: Seminar Implementation and Evaluation----24
Phase 2 Study Tool: Acceptability Survey----29
Project Phase 3: Post-Seminar Evaluation----31
Phase 3 Study Tool: Usability Survey----31
Results
Phase 1: Needs Assessment Survey Results----32
Phase 2: Acceptability Survey Results----34
Phase 3: Usability Survey Results----34
Discussion
Phase 1 Needs Assessment Survey Discussion----35
Phase 2 Acceptability Survey Discussion----37
Phase 3 Usability Survey Discussion----38
Limitations----39
Ethical Considerations----40
Future Recommendations----41
Conclusion----43
References----45

Appendix A: Surveys----49
Phase 1 Needs Assessment Survey
Phase 2 Acceptability Survey
Phase 3 Usability Survey
Appendix B: Proof of Training----63
CITI training certificates of completion
FCOI certificate of completion
Appendix C: Supporting Documents----69
DNP Committee approval form

Departmental Vice Chair letter of support
Appendix D: Information sheet for participation in research study----------72
Appendix E: IRB Submissions----------74
NorthShore University HealthSystem IRB forms
DePaul University IRB Forms
Appendix F: IRB Approval Letters----------152
NorthShore University HealthSystem Nursing Research Council Approval
NorthShore University HealthSystem IRB approval
DePaul University LRB approval
DePaul University IRB approval
Appendix G: Results----------159
Survey 1 demographic and survey results
Survey 2 demographic and survey results
Survey 3 demographic and survey results
Appendix H: Seminar Content----------174
Human factors seminar power point
Human factors seminar case scenarios 1-4
Appendix I: Human Factors Defined (Table 1) ----------183

Abstract

In the U.S, an estimated 44,000-98,000 deaths occur annually due to medical errors. Adverse events can occur as anesthesia providers face a complex environment of high acuity patients undergoing interventions in a variety of locations. Production pressure, new equipment and medications, and constant turnover of personnel contribute to a hazardous working environment. Human factors educational training in cognitive errors, metacognition, and de-biasing strategies has been proposed as a solution to help prevent medical errors in anesthesia practice

The study of human factors has been integrated into safety culture industries such as aviation and nuclear power plants, but its incorporation into the medical field has been slow. Nurse anesthesia trainees are in the ideal position to receive human factors training because of their vulnerability to the demands and stressors involved in clinical residency.

In this project, a needs assessment survey was distributed to gain expert feedback on the most common and most dangerous human factors errors observed in nurse anesthesia trainees. A human factors seminar was developed that included information on how human factors contribute to errors, avoidance strategies for the human factors identified in the needs assessment survey, and a mental model to help improve decision-making. Post seminar evaluation demonstrated that nurse anesthesia trainees found the seminar content to be applicable to their practice, useful in the operating room environment, and effective in influencing their clinical decision-making.

Background

Introduction to the Problem

An estimated 44,000-98,000 deaths are due to medical errors annually in the United States (Stiegler, Neelankavil, Canales, & Dhillon, 2012). Total costs of preventable adverse events including lost income, lost household production, disability, and healthcare costs amount to between $17 billion and $29 billion (Kohn, Corrigan, & Donaldson, 2000). But the true cost of medical errors goes beyond the dollar figure and extends to a loss of trust in the healthcare system and diminished satisfaction by both patients and healthcare providers. Because of these staggering statistics, more attention is being focused on the prevention and management of medical errors.

Medical errors do not occur in a vacuum. They are often the result of a series of small mistakes that result from a combination of system failures and human error. Layers of defense should be put in place to provide multiple points of error interruption so that the chain of events that leads to an error can be avoided. This concept was first described by the sociologist James Reason, who developed the "Swiss cheese model of human error" (Reason, 1990). According to this model, efforts to avoid human error effectively reduce the number and size of the holes in the Swiss cheese, thereby making a mistake less likely. This model also elucidates the fact that humans are often not the main instigators of an accident, but rather inherit a system full of defects. Reason described the operator in an error as adding the final garnish to a lethal brew whose ingredients have already been long in the cooking (Reason, 1990, p 173). This model of human error helps to direct the focus

away from just the frontline operators and toward upstream conditions that influence and constrain their work (Dekker, 2011). Without proper training to recognize these potential pitfalls and recover from them, an error is more likely to occur.

Safety is a fundamental principle of patient care and a critical component of quality in healthcare (Dekker, 2011). A critical precursor to safety is properly trained healthcare providers who are not only technically competent but also critical thinkers and adept crisis managers (Wright & Fallarco, 2011). In order to practice safely, anesthesia educators have the difficult task of preparing nurse anesthesia trainees with not only didactic and procedural skills that allow them to be technically proficient, but also the mental and emotional skills that prepare them to meet the complex and rapidly changing demands that are required of the profession.

Study Goal

The goal of this capstone project was to develop, implement, and evaluate the use of a human factors seminar to improve the quality of decision-making in nurse anesthesia trainees. The project was conducted in three phases: needs assessment and seminar development, seminar implementation and evaluation, and post-seminar evaluation.

Clinical Question

In nurse anesthesia trainees, does the use of a human factors seminar improve the quality of decision-making once in the operating room?

Literature Review

Search Method

First, a broad search of the Cochrane Review database was performed to ensure that there were no previous meta-analysis publications on the topic of a human factors seminar for nurse anesthesia trainees. The search yielded no such paper. Then a search was conducted on PubMed, years 2004 to May 2014, using the medical subject headings (MeSH terms) *decision-making*, *mental processes, medical error, thinking, safety, health, and anesthesia*. This yielded over 1300 results. This search was narrowed down using the terms human factors and cognitive factors. Other criteria used to narrow the PubMed search included articles pertaining to humans and in the English language. 129 articles were available in full text. The abstracts were read and the most applicable articles were included. Related articles to relevant studies on PubMed were also reviewed and revealed several additional articles for inclusion.

An additional search was conducted via Ovid, from the years 2004-May 2014, to gain access to articles in CINAHL and Medline. Search terms included human factors, cognitive factors, anesthesia, decision-making, medical error, patient safety, and situation awareness. These results were further narrowed by the English language, human subjects, and the availability of full text. This yielded 27 papers, of which the abstracts were analyzed to determine their applicability. The main focus in the review of article abstracts was to find information on human factors that were applicable to the practice of anesthesia and dealt with improved decision-making processes. Background information on human factors and their contribution to

medical errors was also included to provide context. A combination of original research, quantitative as well as qualitative data, and systematic reviews were included.

During the second phase of the project, the literature was again searched for articles and information that would be useful for seminar content. PubMed and Ovid searches were conducted from the years 2004 to 2014. Search terms included human factors, anesthesia, team training, crisis management, mental model, cognitive model, cognitive processes, and dynamic decision-making. 9 articles were found to be most applicable, with four having content that ultimately was included in the seminar. A secondary search based off of relevant articles' references revealed several books that were of interest. Four books related to human error, patient safety, and situational awareness in anesthesia included information that was used as background as well as for seminar content.

Human Factors and Medical Errors

Adverse events can easily occur as anesthesia providers face a complex environment of high acuity patients undergoing interventions in a variety of locations. Production pressure, new equipment and medications, and constant turnover of personnel contribute to a hazardous environment (Trentman, 2013). One study found that 49% of anesthesiologists reported that they had observed or felt pressured to conduct anesthesia in a fashion that they considered unsafe given the level of urgency of the situation (Kirsner & Biddle, 2012). The safe administration of anesthesia requires vigilance, multitasking, and the ability to rapidly make decisions and take appropriate actions amongst a highly interactive

system composed of the patient, equipment, surgeons, operating room personnel, and the broader operating room environment (Weinger & Slagle, 2001). Lapses in judgment that lead to error are usually the result of an attempt to achieve a goal that is incompatible with safe practice (Ruskin, 2013). It is obvious that the administration of anesthesia is filled with opportunities to commit an error just by its complex nature. Furthermore, humans working in environments in which they are uncomfortable are more likely to experience unintentional errors in both judgment and performance.

Human factors involve subconscious bias, faulty decision-making, and erroneous thought processes. Real-world medical decision-making is frequently driven by the use of cognitive shortcuts, individual preferences, emotions, and an experience base that may be distorted by imperfect recall and inaccurate estimates of likelihood (Stiegler & Tung, 2014, p 214). Human factors errors are the most frequently identified root cause of healthcare sentinel events (Jericho, 2012).

Cognitive errors, a subset of medical errors, are important contributors to missed diagnoses and patient injury (Stiegler, Neelankavil, Canales, & Dhillon, 2012). Examples include feedback bias, in which the absence of feedback is subconsciously noted as positive feedback, and confirmation bias, in which a practitioner tries to force data to fit a desired or suspected diagnosis (Stiegler, et al., 2012, p 231). Several studies have catalogued the human factors specific to anesthesia practice, with the most common errors including premature closure (seen in 80% of simulations), confirmation bias (77%), sunk costs (67%), commission bias (67%), omission bias (62%), and anchoring (62%) (Trentman,

2013). Overconfidence is another human factor that can be particularly dangerous when coupled with the naturally autonomous nature of anesthesia practice. An anesthesia provider with a great deal of experience may be considered by to have an expertise in the field. But there is a dual face to error and expertise in that the very thing that may make someone good at delivering care may also make them vulnerable to failure (Dekker, 2011). Human factors may contribute to errors involving medications, communication, leadership, and accuracy, which are repeatedly listed in the annually reported National Patient Safety Goals (Gravenstein, 2013). A full list of human factors and their definitions can be found in Appendix I, Table 1: Human Factors Defined.

The study of human factors has previously been common in safety culture industries such as aviation and nuclear power plants, but its integration into the medical field is relatively new. In the 1980s, the aviation industry integrated safety practices such as checklists, crew resource management, and human factors training and, by the 1990s, effectively reduced the risk of being in a fatal crash to 1 in 8 million, a 4-fold decrease (Miller, 2003). In 2004, 195,000 patients died due to medical errors, which is equivalent to at least two airliners crashing in the United States every day (Gravenstein, 2013). After a two-day program for pilots on situation awareness and error management, 99% of the participants reported the training to be very useful (Schultz, Endsley, Kochs, Gelb, & Wagner, 2013). In the Institute of Medicine's final report, they concluded that "healthcare is decades behind other industries in terms of creating safer systems" (Miller, 2003, p 128).

Although no formal human factors training is currently included as part of anesthesia education, it is clear that the need exists and that its inclusion could improve the quality of trainee decision-making. Both the Anesthesia Patient Safety Foundation and the Joint Commission have recommended the use of strategies to improve decision-making and have advocated for human factors training to be included in anesthesia education. Stiegler and colleagues (2012) recommended that anesthesia providers have insight into their own decision-making processes and deliberately abandon intuitive reasoning for an analytic approach when necessary. They note that to achieve this, educational training in cognitive errors, metacognition, and de-biasing strategies is needed (Stiegler, Neelankavil, Canales, & Dhillon, 2012). Another study by Schultz et al. (2013) suggested that situation awareness training is a promising approach for increasing healthcare providers' ability to form individual and team situation awareness and thus to promote better performance and improved patient care. The existing literature supports that the integration of human factors training into the mindset of a trainee will improve their decision-making processes in the operating room and result in safer patient care.

The reduction of cognitive errors can be approached from three angles; self-awareness, metacognition, and de-biasing strategies. Studies of metacognitive training have demonstrated improved decision-making processes and decision outcomes (Stiegler et al., 2012). An anesthesia provider's attention must be shared between many cognitive functions, many tasks, and possibly, many problems (Gaba, 1992). A trainee's attention to secondary tasks may be reduced while they are still learning to multitask effectively. Metacognitive abilities such as allocation of

attention and supervisory control are major components of the expertise of an anesthesia provider and are learned over time. Megacognitive training includes techniques such as "recovery strategies" which are taught to anesthesia providers to help them recognize and recover in real time from cognitive errors (Trentman, 2013, p 145). De-biasing strategies are aimed at reducing one's subconscious tendencies on decision-making and can be as simple as consulting a colleague for a second opinion (Stiegler, 2012).

Crew resource management has been integrated into the aviation industry's required training for its ability to optimize not only the person-machine interface and the acquisition of timely, appropriate information, but also interpersonal activities such as leadership, effective team formation and maintenance, problem-solving, decision-making, and maintaining situational awareness (Jericho, 2012, p 66). The Institute of Medicine recommended the use of crew resource management in medical training in the year 2000 and the Joint Commission followed with its own recommendation soon after, but its integration has been slow to nonexistent.

Due to the complex, fast-paced nature of anesthesia, a dynamic decision making approach is recommended. Gaba, Fish, Howard, and Burden (2015) advocate for a dynamic decision making model that involves a repeated loop of observation, decision, action, and reevaluation. This model encompasses the use of vigilance to observe incoming data, verification and cross-checking to come to a diagnosis, a prediction of future states to help determine the best course of action, and the use of situational awareness to continuously reassess the situation. The practice of anesthesia is unique in that one decision-maker is responsible for

detecting, diagnosing, and acting upon a situation. Because of this, the integration of an effective dynamic-decision making model into one's practice is a hallmark of metacognitive training. Increasing the awareness of decision processes and of statistically driven approaches may improve both the accuracy and consistency of good medical decisions (Stiegler & Tung, 2014).

Theoretical Framework

The theoretical approach used for this project was that of a constructivist paradigm. The goal of a constructivist approach is to gain a better understanding of a program and those it serves (Fitzpatrick, Sanders, & Worthen, 2011). The human factors seminar was primarily meant to serve nurse anesthesia trainees, but other stakeholders included practicing nurse anesthetists and anesthesiologists, former students, and patients. Each of these individuals carries with them previous experiences and a set of values that may influence how they viewed the success of the seminar. The constructivist paradigm recognizes the many differing "realities," conditions, or life experiences of those that the seminar was intended to serve (Fitzpatrick, Sanders, & Worthen, 2011, p 116). One of the goals of the seminar development phase was to gain an understanding of the differing realities of every stakeholder and determine how their values fit with a successful human factors seminar.

The constructivist paradigm also brings into focus how the information gained during the evaluation process was to be used. In the case of the human factors seminar development, the knowledge gained directly affected the students, but its implementation ultimately reached all of the other stakeholders. Despite this

extrapolation of knowledge to many people, the focus of the seminar ultimately was in the operating room environment. The lessons provided during the seminar were specific to the nurse anesthesia trainee and the operating room environment. This focused approach was fitting with the constructivist paradigm because the process was intended to provide understanding of a particular program (human factors seminar) and its context (nurse anesthesia trainees in the operating room) and was less concerned with generalizability to other settings (Fitzpatrick, Sanders, & Worthen, 2011).

Methods

Target Population

Student nurse anesthetists are particularly vulnerable to human factors that may contribute to medical errors. They are expected to transition from their known professional practice as a registered nurse, to a new role in which they must learn to work with a great deal of autonomy, must refine their decision-making ability, logical reasoning, and ability to reach a conclusion under what may be life or death circumstances (Phillips, 2010). One study suggested that the most important errors might be more likely to occur amongst trainees (Stiegler, Neelankavil, Canales, & Dhillon, 2012). Observation of medical residents in the simulation setting has demonstrated that common thought-process errors occur frequently and are likely to contribute to actual error behaviors and ultimately, adverse outcomes (Stiegler, Neelankavil, Canales, & Dhillon, 2012).

A study of military nurse anesthesia trainees found that clinical awareness and personality characteristics such as the ability to analyze data and apply to the

situation at hand, quick decision making ability, situational awareness, and practical thinking are the most important qualities of clinical success (Wong & Li, 2011). These characteristics are imperative to the effective management of life-threatening crises arising in the operating room. Cognitive processes allow a learner to reconcile the current problem with the preexisting mental model in order to come to a solution. Wright & Fallacaro (2012) found that once these mental models are established, nurse anesthesia faculty can incorporate cognitive exercises into hands-on training to improve and promote situational awareness.

In an observational study of anesthesia residents undergoing emergency simulation management, seven out of nine types of cognitive errors occurred in over 50% of observed emergencies (Stiegler, Neelankavil, Canales, & Dhillon, 2012). But cognitive errors can occur even in experienced hands. Stiegler and Dhillon (2014) conducted a survey of over 500 anesthesiologists to determine whether a list of 14 cognitive errors had occurred to them personally, or to someone else, and to estimate the frequency they perceived each error to occur. At least 20% of participants admitted that all of the cognitive errors have affected them personally (Stiegler & Dhillon, 2014). When considering the impact of cognitive errors on a colleague's practice, greater than 50% of respondents reported that every cognitive error had occurred (Stiegler & Dhillon, 2014, p 90). It is clear that more experienced practitioners are also vulnerable to human factors errors. With these experienced anesthesia providers offering mentorship to nurse anesthesia trainees, it is that much more important that the trainee enter the operating room with a skill set to deal with human factors that may lead to a medical error.

Identification of the most common cognitive errors and human factors that trainees commit is crucial in developing appropriate training strategies for management and prevention (Stiegler, Neelankavil, Canales, & Dhillon, 2012). Harvard and Stanford were the first to introduce the discussion of fixation errors (also called anchoring or tunnel-vision) into their medical curricula in the 1990s (Stiegler, Neelankavil, Canales, & Dhillon, 2012). Further research into the impact of human factors on errors that are made by anesthesia trainees is needed and appropriate avoidance strategies must be fully integrated into anesthesia education.

Project Description: Development of a Human Factor Seminar

As a faculty member of the NorthShore University HealthSystem School of Nurse Anesthesia (NSUHSNA), the study investigator is intimately involved in the daily evaluation of student clinical performance. The investigator is also responsible for taking the feedback received on these evaluations and using it to mentor the students towards improved clinical performance. Repeated feedback has highlighted that students are lacking situational awareness and what are considered good clinical judgments by their preceptors. Cognitive errors are considerably less tangible than procedural errors and are distinct from knowledge gaps (Stiegler, Neelankavil, Canales, & Dhillon, 2012). Therefore, students can be prepared with book knowledge prior to their clinical residency, but they may not be adequately prepared with appropriate decision-making or coping skills.

Although the NSUHSNA adequately prepares its students for the operating room by offering 15 months of didactic clinical information, there is currently no information or training on human factors. It is often not until students are

struggling in their residency that concepts included in human factors training are identified. At that point, the students are often so far into their residency that a complete overhaul of their thought-processes is unrealistic. Instead, these students are guided towards improved decision-making through intensive remediation. There clearly exists a gap between book knowledge and cognitive reasoning. If students were educated about cognitive errors prior to their exposure to the stressful operating room environment, they might be better prepared to handle the human factors that could ultimately lead to medical mistakes. Studies of unconscious mental influences demonstrate that increased self-awareness of human factors leads to better management of these cognitive distortions (Stiegler, 2012). The goal of this project was to improve the quality of trainee decision-making by educating them on human factors.

Project Support: Departmental and Institutional Review Board Approval

It was essential for the success of the seminar that its content be appropriate and useful for nurse anesthesia trainees. The support of stakeholders at the NorthShore University HealthSystem, the NorthShore University HealthSystem School of Nurse Anesthesia, and DePaul University was required. Letters of support from DNP committee members as well as the Vice Chair of the Department of Anesthesia at NorthShore University HealthSystem can be found in Appendix C.

Prior to submission to the NorthShore University HealthSystem Institutional Review Board (IRB), all research conduced by nurses must be discussed and approved by the Nursing Research Council. This council was established to help nurses conduct and disseminate research, to empower them with both information

and resources, and to reflect upon the organization's commitment to nurses. Advanced Practice Nurses sit on the council and meet with nurses within NorthShore who plan on conducting research.

The principle investigator of this project electronically submitted IRB paperwork to NorthShore University HealthSystem on August 25th, 2014. On September 4th, it was recommended by the NorthShore IRB that this project be reviewed and approved by the Nursing Research Council (NRC). A meeting was arranged and the principle investigator presented to the NRC on September 17th, 2014. Two doctorally prepared and one masters prepared Advanced Practice Nurse offered feedback regarding the IRB submission. No amendments were recommended but several clarifications were suggested. A letter from the NRC offering their approval can be found in Appendix C.

As part of the NRC final approval, a meeting with the NorthShore University HealthSystem Chief Nursing Officer was also required. This meeting between the principle investigator and Nancy Semerdjian, RN, CNO took place on September 23rd, 2014 and her approval for this project was granted. Her signature can be found in the IRB submission forms found in Appendix E. All clarifications that had been suggested by the NRC were completed, and with the approval of the CNO and the NRC, final IRB forms were submitted to NorthShore on September 23rd, 2014.

Concurrent to IRB submission at NorthShore was submission to DePaul University's Local Review Board (LRB). Review board paperwork was submitted electronically on September 10th, 2014. Final LRB approval was received from DePaul without any required amendments on October 1st, 2014. The proposal was

sent to the IRB at DePaul University that same day and a copy can be found in Appendix E. On October 17th, 2014, the DePaul IRB contacted the principle investigator stating there were concerns that the proposed project did not meet qualifications for exempt status. Since NorthShore was the primary site of the study, DePaul stated that they would defer final approval until NorthShore had approved the project as exempt. On October 24th, 2014, final IRB approval was granted with exempt status for this project from NorthShore. DePaul University followed suit and granted final IRB approval with exempt status for this project on October 30th, 2014. Copies of IRB approval letters can be found in Appendix F.

Project Phase 1: Human Factors Seminar Development

The first step in the development of a successful human factors seminar was to gain all relevant information. The methodology for this phase of the project was approached from two angles: a review of relevant literature and a formative cross-sectional investigator-developed needs assessment survey. The objectives for phase one of the project were to:

1. Determine which human factors influenced decision-making processes.
2. Determine which human factors were most applicable to the nurse anesthesia trainee population.
3. Determine which human factors contributed to good and bad decision-making processes.
4. Use expert feedback to narrow down the most applicable human factors that contribute to good nurse anesthesia trainee decision-making processes.

To begin evidence gathering, a literature review was conducted to gain insight into the most relevant human factors to anesthesia practice. Five articles including reviews of current literature and original research were used to make a comprehensive list of anesthesia-specific human factors. This list included anchoring, availability bias, premature closure, feedback bias, confirmation bias, framing effect, commission bias, overconfidence bias, omission bias, sunk costs, visceral bias, zebra retreat, unpacking principle, psych-out error, situation awareness, retrospective bias, bias blind spot, and memory shifting. A table describing each of these factors can be found in Appendix I, Table 1: Human Factors Defined.

This list contained human factors that are known to influence the quality of decision-making in anesthesia practice, but they were not specific to the nurse anesthesia trainee. In order to better qualify which human factors influence the decision making processes of the nurse anesthesia trainee, expert opinion was sought from those who worked closely with students. These experts included stakeholders such as nurse anesthetists and anesthesiologists who mentor students during their clinical residency.

Phase 1 Study Tool: Needs Assessment Survey

To gain information related to the applicability of human factors to nurse anesthesia trainees, a formative, cross-sectional needs assessment survey utilizing purposive sampling was performed. A copy of this survey can be found in appendix A: Phase 1 Needs Assessment Survey. The main goals of the survey were to determine which human factors the experts felt were most common as well as

which factors were felt to be most dangerous in nurse anesthesia trainee decision-making processes. Information gained from the survey was used in the development of the content of the human factors seminar.

A formative evaluation was chosen because it is very useful at the beginning of a program to help it succeed in achieving its intended outcomes. And because formative evaluations are designed to improve programs, it is critical that the primary audience (practicing nurse anesthetists and anesthesiologists) be familiar with the program's day-to-day operations or in a position to make changes if necessary (Fitzpatrick, Sanders, & Worthen, 2011).

Needs assessment questions are concerned with establishing whether a problem or need exists, describing that problem, and making recommendations for ways to reduce the problem (Fitzpatrick, Sanders, & Worthen, 2011). The feedback of very specific individuals is needed, namely practicing nurse anesthetists and anesthesiologists, and the program director. The goals of this needs assessment survey were to determine whether sufficient need for a student human factors seminar existed as well as to assist in program development and meeting the program's goals.

The design of the survey was cross-sectional in nature and included mostly Likert-scale items, with an option for narrative or informal feedback. This design was chosen because surveys that are cross-sectional are intended to collect information on attitudes, behavior, and opinions (Fitzpatrick, Sanders, & Worthen, 2011). Questions about student performance were designed to help assess clinical behaviors. Student preceptors such as anesthesiologists and nurse anesthetists

were able to offer their opinions about how students are currently prepared for the complex decision-making that is expected in the operating room. The Likert scale was chosen because it allowed respondents to answer standardized questions on a scale ranging from agree to disagree. It also allowed for systematic analysis following collection of the data. Having an open-ended question at the conclusion of the survey allowed a respondent to offer free-text information that may not have been covered in the other questions.

Purposive sampling was utilized to gain the most appropriate feedback. The goal of purposive sampling is to select people who are either informed on an issue or who represent a particular group that is important to answering an evaluation question (Fitzpatrick, Sanders, & Worthen, 2011). Furthermore, purposive sampling ensures that those who have an interest in the opinions or performance of the program are involved in the evaluation process. Since students were the audience members of the seminar and practicing nurse anesthetists and anesthesiologists were mentoring these students during their clinical residency, their opinions and feedback were most valuable.

Nurse anesthetists and anesthesiologists are the individuals tasked with mentoring and evaluating student performance in the operating room setting. Their evaluation feedback was included in the program development process to ensure that program components rated as very important by this group were emphasized in the seminar and properly integrated into the students' clinical practice. Involving the stakeholders in the evaluation process and sharing the results can also

demystify the data and actively involve those individuals who may ultimately have a say in the implementation of the program.

Phase 1 Needs Assessment Survey Implementation

The target population for this survey was nurse anesthetists and anesthesiologists who work with nurse anesthesia trainees at NorthShore University HealthSystem. Demographic information was collected from the survey participants including job title, gender, years in practice, age, ethnicity, work status, and frequency of work with nurse anesthesia trainees. The 15 human factors errors that were included in this survey were based on a review of the literature as described earlier. A copy of the Phase 1 Needs Assessment Survey can be found in Appendix A.

The needs assessment survey was designed and distributed online via Survey Monkey. It was required by the IRB that the principle investigator not have access to email addresses of potential study participants. To manage this, the principle investigator set up a link to the survey. The link was then distributed via email by the NSUHSNA administrative assistant to all NorthShore faculty members on file. The Survey Monkey link was delivered on November 4th, 2014 to a total of 85 faculty members. It was estimated that completion of the survey by approximately 30% of the faculty members would return meaningful results to move forward. Approval from the IRB was for 30 responses. The survey responses were monitored daily and the majority of surveys were completed in the first four days. On November 11th, 2014, the principle investigator closed the survey after a total of 29 responses had been received.

The quantitative data obtained from the Likert-style survey was compiled and entered into the Statistical Package for the Social Sciences (SPSS) software, version 22. The value of certain questions was determined by using descriptive statistics such as frequency and weighted mean to analyze which questions received the most extreme responses.

The open-ended questions at the end of the survey allowed for informal feedback. Informal feedback is deficient in systematic structure, which can make it more difficult to analyze, and can also contain erroneous judgments (Fitzpatrick, Sanders, & Worthen, 2011). But it also lends itself to potentially valuable information that was missed in the more formal Likert-scale survey. Interpretation of this qualitative data was used to bring to the surface common themes and issue-relevant information to which meaning can be applied (Fitzpatrick, Sanders, & Worthen, 2011). In this case, an interpretation of the data was used to determine which human factors were deemed by the experts to be most common and most dangerous, and therefore included in the seminar.

Project Phase 2: Seminar Implementation and Evaluation

Although the field of human factors is relatively new to the medical field, a great deal of valuable information has been published in other fields such as aviation. A successful seminar cannot be developed without a full understanding of which human factors errors are most harmful and applicable to the decision-making processes of anesthesia providers.

The literature review provided the majority of the information used as seminar content. A process called metacognition is at the forefront of human factors

training and was therefore the basis of the seminar. Metacognition is defined as the self-awareness of human cognitive processes, their potential pitfalls, and the use of deliberate thinking strategies to avoid such pitfalls (Stiegler & Tung, 2014). It is sometimes described as thinking about how one thinks.

The human factors seminar was offered in the students' final semester leading up to their clinical residency. At this point the students were making final preparations to enter the operating room including simulations of actual anesthesia-related procedures and events. These simulations can elicit some of the stress of the operating room and forces students to start making independent decisions. This was the ideal time to introduce human factors into their thought processes. The students could use that final semester, which is intensive in simulations and residency preparation, to become aware of cognitive errors, and to practice using coping strategies to improve their decision-making.

It was important that the seminar enhance the knowledge that the nurse anesthesia trainees received while being trained at the NSUHSNA, however its content and this study's implementation could not place any additional burden on this vulnerable population. To achieve this, the seminar was limited to one hour in length and was presented on a day that the students were already at Evanston Hospital for other classes. This was to avoid making the students travel in for the seminar on a day that they otherwise could have had free to work or study.

Per DePaul University IRB policy, the students were required to receive an information sheet for participation in a research study. On November 11th, 2014,

the students received the following email with the information sheet attached (information sheet can be found in Appendix D).

> "Hello students. Tomorrow you may choose to attend a human factors seminar presented as part of my DNP scholarly leadership project. The goal of the seminar and surveys is to determine if a human factors seminar will improve your decision-making processes. Your participation is voluntary and anonymous. If at any time during the seminar or survey you decide not to participate, simply exit. Once you submit a survey, however, I will be unable to remove your data later from the study because all data is anonymous and I will not know which data belongs to you. Attached you will find an information sheet for participation in a research study. Please review prior to your participation in the human factors seminar and completion of any surveys. Thank you in advance for your participation."

The seminar was presented on Wednesday, November 12, 2014. Twenty students attended the seminar. The basic format of the seminar was a classroom-based didactic presentation of the most important and dangerous human factors as identified in the needs assessment survey, then mock situation evaluations in groups. Schultz, et al. (2013), found that when a combination of classroom-based instruction along with individual or team exercises was used, a situational awareness course for pilots was rated by 99% of the participants to be useful (Schultz et al., 2013). Since it was important that the seminar content be viewed as useful by the nurse anesthesia trainees, this format of instruction was used. A copy

of the seminar power point presentation as well as case scenarios can be found in Appendix H.

Background information into the incidence and severity of medical errors caused by human factors was provided followed by an explanation of James Reason's "Swiss Cheese" model of human errors. Studies of training in these areas have demonstrated improved decision making processes and decision outcomes (Stieger, Neelankavil, Canales, & Dhillon, 2012). The general topic of human factors was defined, followed by an in-depth explanation of the top rated human factors errors as identified by the needs assessment survey.

The objectives of the human factors seminar were:

1. To review the background of medical errors and the contribution of human factors.

2. To discuss the "Swiss cheese" model of human error.

3. To review the most common human factors errors in nurse anesthesia trainees.

4. To discuss how to prevent errors through improved decision-making processes.

5. To break into groups and discuss real world examples of how human factors can lead to errors and how to prevent them using the mental model provided.

The needs assessment survey successfully used expert feedback to narrow down the list of the most applicable human factors errors to the decision-making processes of nurse anesthesia trainees. The top rated human factors errors that

were included in the seminar included overconfidence, anchoring, premature closure, commission bias, omission bias, feedback bias, and situational awareness. Each of these human factors was defined, examples were given, then several avoidance strategies were provided.

Although James Reason has provided much of the sociological basis of human factors, Dr. Gaba has provided much of the anesthesia-related application of metacognition. Dr. Gaba's dynamic decision-making model has been used in the literature since its design in the early 1990s and it was chosen for use in the seminar because of its ease of understanding and applicability to anesthesia. The model was described in detail followed by resource management skills that can both be used to improve decision-making processes and avoid human factors errors.

Students then broke into small groups and each group was given a case scenario. Stiegler (2012) recognized the use of case scenarios as an effective metacognitive teaching tool because of its ability to help transfer education to patient care settings, allow for follow up and feedback, provide debriefing, and mimic simulation. For each scenario, students were asked to answer three questions:

1. Which human factors contributed to the situation?

2. Which resource management skills could have improved the outcome of the situation?

3. How could the situation have been better handled using the dynamic decision making model?

After giving each group 5-10 minutes to develop their answers, they were asked to present their scenario and answers to the class. The scenarios were designed to highlight real world examples of how human factors can contribute to poor decision-making and medical errors. The scenarios were chosen based on the list of most frequent and most dangerous human factors errors as identified by the needs assessment survey. Then students were encouraged to use the resource management skills and dynamic decision-making model that had been presented in the seminar. A copy of the human factors seminar content, including case scenarios can be found in Appendix H.

Phase 2 Study Tool: Acceptability Survey

Participants were provided with educational materials and then asked to actively engage in an intervention, so proper evaluation was needed in order to determine if the seminar had its desired effect (Tariman, Berry, Halpenny, Wolpin, & Schepp, 2011). Ultimately, the summation of evaluation responses could be used to help guide the human factors seminar's future development. If students' evaluation feedback was included in program development, they would be more likely to find value in its content. And if the students found value in the seminar's content, they are more likely to integrate it into their clinical practice. If they integrate it into their practice, the nurse anesthetists and anesthesiologists with whom these students work will notice superior decision-making, more developed coping skills, more sound clinical judgments, and ultimately, improved patient safety.

Goals of this post-seminar evaluation phase of the study included:

1. Seminar information must be applicable to nurse anesthesia trainees.

2. Seminar information must be usable to nurse anesthesia trainees once they enter their clinical residency.

3. Seminar information must be presented in an easy-to-understand format and in a timely manner.

In order to achieve these goals, an adaptation of an acceptability survey developed by Tariman and colleagues (2011) was used. Tariman and colleagues developed a six-item survey that was used to assess the acceptability and usability of an intervention, then conducted a longitudinal, randomized clinical trial to prove its reliability in assessing the impressions and attitudes of participants towards a program. The acceptability survey used a Likert scale to assess how easy and enjoyable a program was, how understandable the information was, how helpful completion of the program was, whether the participant liked the program, whether the amount of time to complete the program was acceptable, and the overall satisfaction with the program (Tariman et al., 2011). This evaluation tool was chosen because it could be easily adapted to the human factors seminar, it was proven to have excellent reliability and construct validity, it was easy to understand (readability is at the fifth-grade level), and could be completed in less than two minutes.

At the conclusion of the human factors seminar, the students were handed paper copies of the acceptability survey (a copy of the acceptability survey to be presented to students participating in the seminar can be found in Appendix A: Phase 2 Acceptability Survey). Demographic questions included age, gender, ethnic origin, and years of intensive care unit experience prior to starting anesthesia

school. Because the sample size was small, there was a concern over maintaining the anonymity of the students. To combat this problem, the demographic information was placed on a separate page from the acceptability survey and each were returned to separate envelopes after completion. This made it impossible to match a student's demographic information with their acceptability survey responses and anonymity was effectively maintained.

Project Phase 3: Post-Seminar Evaluation

As previously described in the objectives for post-seminar evaluation of the project, it was important that the information presented in the human factors seminar be useable, understandable, and applicable to the nurse anesthesia trainee. Since the seminar content was designed to be used in the real world setting of the operating room, it was important to evaluate the seminar after the students had actual clinical time. Students were presented with the human factors seminar in November of 2014. They started their clinical residency in January of 2015. After four weeks in the operating room, the students were given a survey to evaluate how useable they felt the seminar content was now that they had time in the operating room environment. Four weeks was chosen because it allowed enough time for students to have had an opportunity to use the information presented but not so much time that they forgot the details of the seminar.

Phase 3 Study Tool: Usability Survey

An adaptation of the usability survey created by Otani, Morita, Uno, Yamamoto, Hirose, Matsubara, Takigawa, and Sasaki (2013) was used. In their research on the usability of a delirium leaflet, Otani et al., (2013) developed a survey

based on a review of the literature, results from their previous studies, and discussion amongst the authors. In their study, families who had received the leaflet were mailed the 13-item survey and asked to rate their perceived usefulness. Prior to its implementation, Otani et al., (2013) assessed face validity of their survey by complete agreement of the authors and then performed a pilot test to determine the survey's appropriateness. This survey was adapted to fit the objectives of the human factors survey including clarity of information, usefulness of the information, and applicability of information to practice. Students were asked to rate their level of agreement with each of the 13 statements on the usability survey using a 5-point Likert-type scale with scores ranging from 1 (disagree) to 5 (strongly agree). A copy of this survey can be found in Appendix A: Phase 3 Usability Survey.

During their clinical residency, students in the NSUHSNA return to the classroom for one day every two weeks for didactic material. This presented a convenient opportunity to access the same sample of students that had participated in the human factors seminar. After four weeks in the operating room, the students were given the usability survey to complete while at the school for a classroom day. The technique for administration of the paper survey was the same as for the acceptability survey; demographic information was contained on a separate page from the survey and each were returned to separate envelopes.

Results

Phase 1 Needs Assessment Survey Results

29 out of 85 faculty completed the survey in its entirety for a 34% response rate. No surveys contained partial information or incomplete responses. Questions

one through seven pertained to demographic information. 64% of those who completed the survey were nurse anesthetists while the other 36% were anesthesiologists. The majority of the respondents were white females, ranging in age from 30 to 39, with greater than 10 years of experience. 55% of the respondents worked with students once or twice a week. A copy of the needs assessment survey can be found in Appendix A and a full list of results can be found in Appendix G.

Items eight through 37 of the needs assessment survey asked questions pertaining to the human factors errors that had been identified in the anesthesia literature. Each of the 15 human factors errors were defined, then two questions were asked with answers provided via a Likert scale. The first question asked how often the respondents noticed the error occurring in anesthesia trainees on a scale from 1 (very rarely) to 5(very frequently). The second question asked how dangerous the respondents felt the error was in contributing to poor decision-making by nurse anesthesia trainees on a scale from 1 (not dangerous at all) to 5 (very dangerous). Survey results were downloaded from Survey Monkey into the Statistical Package for the Social Sciences (SPSS) Software, Version 22.

The goal of the needs assessment survey was to help guide the development of the human factors seminar. To meet this goal, it was important to include only the human factors errors that the respondents felt were most common and most dangerous to poor decision making. A mean score for each answer was computed and compared to determine the highest rated errors for inclusion in the human factors seminar. To fit within the time constraints of a one-hour seminar, only the

top five human factors errors for each of the two questions (how often and how dangerous) would be included. The human factors errors that were rated as occurring most often by nurse anesthesia trainees were anchoring (mean 3.55), situational awareness (3.52), overconfidence (3.43), feedback bias (3.41), and commission bias (3.25). The human factors errors that were rated as being most dangerous were overconfidence (mean 4.5), omission bias (3.86), anchoring (3.86), situational awareness (3.63), and commission bias (3.61). A full breakdown of the survey results can be found in Appendix G.

Phase 2: Acceptability Survey Results

The envelopes containing students' demographic information and acceptability survey results were entered into the SPSS software. Twenty students attended the seminar and all twenty completed the survey for a 100% response rate. The majority of students were white females, between the ages of 30 to 39, and had between three and four years of ICU experience prior to starting anesthesia school. A full breakdown of demographic information and statistical analysis of this phase of the study can be found in Appendix G.

The acceptability survey questions were answered on a Likert scale from 1 to 5. The mean response rating was calculated for each of the six questions using the SPSS software. The overall mean rating of all six questions 4.95 out of 5. The standard deviation was calculated at 0.224 for each of the six questions with a Cronbach alpha coefficient of 0.778.

Phase 3: Usability Survey Results

Results from the usability survey were entered into the SPSS software. The same cohort of students who had completed survey 2 also completed survey 3, minus two students (this loss was due to attrition during the anesthesia program). Of the remaining 18 students, all of them completed the usability survey. Demographic information was largely similar to survey 2 and can be found in Appendix G. Ratings were based on a Likert scale from 1 to 4. Average ratings ranged from 3.06 (question 16) up to 3.83 (question 7). Standard deviations were small and ranged from 0.38348 to 0.75840. A Cronbach alpha coefficient was calculated at 0.898.

Discussion

Phase 1 Needs Assessment Survey Discussion

The needs assessment survey successfully answered all of the intended questions listed earlier. Demographic data demonstrated that a good variety of respondents completed the survey. It was important that the opinions of both men and women, as well as anesthesiologists and nurse anesthetists, provided their feedback. The data showed that the majority of respondents had greater than 10 years of experience, worked full time, and greater than 65% of respondents worked with nurse anesthesia trainees on a daily to weekly basis. This demonstrated that the majority of respondents had been in the field of anesthesia long enough and had worked with students with enough frequency to offer a very valuable expert opinion. Since the results of this needs assessment survey were used in the development of the human factors seminar, it was important that the results were of value in their reliability.

Question 38 asked if the respondents felt that training in human factors errors could improve the quality of decision-making in nurse anesthesia trainees. 100% of respondents answered yes to this question. This fully supports the efforts of the principle investigator in developing the human factors seminar.

Question 39 offered a free text option for respondents to provide any feedback to the principle investigator during the development phase of the seminar. A full list of responses to question 39 can be found in Appendix G. Some of these responses offered additional guidance in the development of the seminar content. For example, several respondents mentioned that effective communication with the surgical and anesthesia team was important. Two of the resource-management skills taught in the seminar pertained to effective communication and leadership. Another respondent mentioned that the use of actual examples would assist in explaining the cause and effect nature of the human factors errors. Seminar content did include case scenarios with group discussions regarding cause and effect. A list of case scenarios that were discussed during the seminar can be found in Appendix H.

Other responses to question 39 offered ideas for future research. For example, one respondent mentioned that human factors training would be valuable if used in the simulation setting. Research into the use of this type of training in the simulation setting would be a valuable tool, especially when dealing with crisis management scenarios. Another respondent mentioned that this training would be valuable not just for trainees, but for all practitioners. Perhaps the principle investigator can provide training to the entire anesthesia department in the future.

Dissemination of the study results can also be provided through lectures at regional and national meetings as well as through publication. Another respondent mentioned that some of the human factors errors might be through improved screening of applicants. It would be extremely valuable if applicants to anesthesia programs could be screened for traits such as overconfidence, lack of vigilance, and leadership skills. An area of future research might be the development of a screening tool that can be used on applicants to determine if they possess the intrinsic character traits to avoid human factors errors in the first place.

Phase 2: Acceptability Survey Discussion

All twenty students who attended the seminar also completed the survey in its entirety. This shows that the students were engaged enough in the information that was presented to put in the extra effort to complete the surveys. Based on the overall high ratings of each of the survey responses, it is clear that the students found the human factors seminar to be easy and enjoyable, understandable, helpful, and completed in an acceptable time period. The small standard deviation value demonstrated that there was minimal variability in how the twenty students rated each question. Which such a small sample size and short survey, internal consistency can be difficult to measure. The Cronbach alpha coefficient for the six item survey, however, was 0.778, suggesting that the items had relatively high internal consistency.

Based on these results, it can be concluded that the acceptability survey provided a reliable way to determine that the seminar was effective and that the feedback received from this survey can be used in the future to make adjustments to

the seminar. Ongoing evaluation and improvements to the seminar are necessary to ensure that the seminar is meeting its objectives and satisfying all of its stakeholders.

Phase 3: Usability Survey Discussion

Every question in the usability survey was ranked above 3 on a 4 point Likert scale indicating that the students found the seminar content useful overall. The highest scored questions were question 7 (mean 3.83), question 5 (mean 3.72), and question 11 (mean 3.67). These questions pertained to how useful the seminar was in helping the students understand what human factors are, how they can contribute to poor clinical decisions, and in explaining strategies to avoid human factors errors. This demonstrates that the overall content of the seminar was valuable for the students once that they had several weeks in the operating room environment to apply the knowledge.

The lowest scored questions were question 16 (mean 3.06), question 14 (mean 3.11), and question 15 (mean 3.22). These questions pertained to how useful the seminar was in preparing students to ask their preceptors question regarding good clinical decisions, in relieving anxiety and worry about making good clinical decisions, and in making the students feel more comfortable in making good clinical decisions. Since the students had only been in the operating room environment for four weeks at the time of this survey, it is natural to expect that they still possess fears, anxieties, and uncertainty when it comes to making good clinical decisions. Although relieving anesthesia trainee anxiety was not a core goal of the seminar, it is an important piece to keep in mind when making changes to seminar content in the

future. The results of this survey confirmed the investigator's belief that a student who is well prepared in the classroom may still enter the operating room with an inability to properly handle the fast-paced, stressful anesthesia environment. If a student has overwhelming anxiety, it can cloud their judgments and potentially lead to human errors in itself. The resources to improve clinical judgments that were provided in the current human factors seminar included topics such as communication, leadership, vigilance, and prioritization. But perhaps future areas of focus could include stress reduction strategies.

Limitations

The present study was small in scale and limited to one cohort of anesthesia trainees, therefore its findings may not be grossly generalizable. Although other anesthesia training programs may educate their trainees differently or have a different demographic mix, the findings of this study so strongly point to the usefulness of human factors training, that it should be applicable in other settings. The student population was predominantly female, which is typical of the profession, but may have created a gender imbalance in the findings. Perhaps there is a difference in which human factors are more prevalent or which dynamic decision-making model is found to be more useful by men versus women. Future studies with a larger sample size would be needed to do a useful population subset analysis.

Another limitation of the current study is the connection of the principle investigator to the trainees who participated in the study. The principle investigator was a faculty member of the NSUHSNA and the trainees who participated were all

students within that same program. There is potential for students to have felt obligated to attend the seminar and to evaluate it more positively because the seminar presenter was also their instructor. In order to minimize this potential effect, the students were sent an email prior to the seminar and survey participation to inform them of the voluntary nature of the study and to provide them with the information sheet for participation in research as required by DePaul University's IRB. A copy of the email sent to students was described earlier and the information sheet for participation in research can be found in Appendix D.

Ethical Considerations

As students represent a vulnerable population, it is important to use caution during research. Participation in all facets of this course was voluntary and free of coercion. With the exception of the needs assessment survey, all evaluation modalities had been previously tested and proven to be reliable and valid. These questionnaires were not known to cause any personal harm, injury, or psychological distress to study participants. Although all three surveys asked questions regarding demographic information, steps were taken to keep that information anonymous. In the phase one needs assessment survey, participants completed the survey over email. Responses were not linked to email addresses and were therefore blinded to the principle investigator. In phases two and three of the study, the demographic questions were on a separate piece of paper from the survey questions and were returned to separate envelopes after completion. Especially with such small sample size and the familiarity of the student study population to the principle investigator,

it was imperative that there be no way to link demographic information with survey responses.

Prior to implementation, Institutional Review Board (IRB) approval was obtained from both NorthShore University HealthSystem as well as the DePaul University. The study met all legal and ethical considerations that were required of both IRBs. The principle investigator also completed extensive CITI training (Collaborative Institutional Training Initiative) prior to the start of the study. Training included, but was not limited to modules related to FDA regulations, information security, student research, ethics in research, research on human subjects, privacy and confidentiality, and conflicts of interest. Copies of proof of CITI training can be found in Appendix B.

Future Recommendations

An initial review of the literature and current practice recommendations revealed that the application of human factors education to medicine is in its infancy. Further research into the human factors associated with anesthesia-related medical errors is necessary. The goal of this project was to develop and implement a human factors seminar for nurse anesthesia trainees that was usable, applicable, and effective in improving the quality of decision-making processes. The seminar was very well received and the data proved that the students overwhelmingly felt that the seminar content was applicable and useful in improving their decision-making processes. This study addressed the students' perceptions of their own decision-making capacity, but future research could look at the qualitative changes in students' ability to make good clinical decisions in the operating room.

The seminar content and evaluation results were shared with stakeholders including the director and assistant director of the NSUHSNA. Their input will influence the principle investigator's permission to present future seminars, the content, and any adjustments based on survey results. Ongoing evaluation of the seminar will ensure that program goals are being achieved, and that students as well as practicing anesthesia providers continue to see value in human factors education.

The major source of patient safety lies not just within an individual caregiver, but within the system surrounding those caregivers (Dekker, 2011). In order to truly encompass all facets of human factors, the effects of the organization, administration, design, resources, and technology must be addressed. As the complexity of patient care and a reliance on technology grows, changes will need to be made to seminar content in order to meet the growing needs of the anesthesia provider. An organizational culture of safety must be developed and cultivated in order for the workforce to provide safe, high quality care. Department-wide principles with proven ability to improve patient safety include providing effective leadership, respecting human limits in process design, promoting effective team functioning, anticipating the unexpected and creating a learning environment (Koh, Corrigan, & Donaldson, 2000).

An exploration into the use of high-fidelity simulated operating rooms in the development of situational awareness and the enhancement of non-technical skills such as decision-making and problem solving is needed. This hands-on applied teaching method gives educators the opportunity to enhance students' critical

thinking skills and explore the elements of successful crisis management while using human factors training, and without posing a risk to patients (Wright & Fallacaro, 2011). Both the Joint Commission and the Institute of Medicine have advocated for the use of simulation training as part of critical events and patient safety plans (Jericho, 2012). One study found that the use of simulation training in the emergency department reduced the clinical error rate from 31% to 4% and made improvements in team behavior, performance, and attitudes and opinions towards teamwork (Jericho, 2012). The data gained from this project can be integrated seamlessly into simulation exercises, and could act as the building blocks for future research in the area.

Results from the needs assessment survey also provided ideas for future research. Future study questions could include how can human factors be implemented in simulation training? Is the seminar content applicable and useful to practicing anesthesia providers? Would study results be different if third year trainees were studied as opposed to second year trainees? Can the lessons learned be used to improve the anesthesia candidate application and acceptance process?

Conclusion

The goals of this study were all successfully met through this project. The results of the needs assessment survey were used to develop a human factors seminar that was found to be useful and applicable by the anesthesia trainees. The open-ended responses submitted in the needs assessment survey also provided opportunities for future research. As an anesthesia provider, the principle investigator's "customer" is the patient, so high-quality, safe patient care is a

priority. But as an educator, the principle investigator's "customer" is the anesthesia trainee, so a seminar that was deemed useful by the trainee was also a priority. The development and implementation of this human factors seminar successfully met the needs of both the patient and the anesthesia trainee with the ultimate goal of providing safer care.

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