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Integrating E-Calcutron into the Anesthesia Clinical Settings to Reduce Potential Medical Calculation Errors Among Student Registered Nurse Anesthetists

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INTEGRATING E-CALCUTRON INTO THE ANESTHESIA CLINICAL SETTINGS TO REDUCE POTENTIAL MEDICAL CALCULATION ERRORS AMONG STUDENT REGISTERED NURSE ANESTHETISTS

by

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ABSTRACT

Student registered nurse anesthetists (SRNAs) are educated in nurse anesthesia programs so they can one day become certified registered nurse anesthetists (CRNAs). Through the training program, SRNAs work in the anesthesia setting to apply what they learn from the classroom setting. Chipas and Mckenna (2011) found that SRNAs are more stressed than CRNAs. Melius (2012) looked at math anxiety and found a correlation between high math anxiety and poor math performance in nurses. Stress and math anxiety can cause poor math performance (Caviola, Carey, Mammarella, & Szucs, 2017). In the anesthesia clinical setting, stress and math anxiety may cause negative consequences for patients in the form of the wrong dose of medication being administered. This doctoral project created an automated medical calculation spreadsheet on Microsoft Excel. The spreadsheet is called E-Calcutron. E-Calcutron was created to aid SRNAs in calculating weight-based anesthesia medications and to improve patient safety. The investigator gave a presentation on stress, math anxiety, and E-Calcutron to SRNAs enrolled in a nurse anesthesia program in Mississippi. A pre and post-education questionnaire was utilized to gain feedback from SRNAs who participated in the study. The findings were that a majority of SRNAs sampled experienced math anxiety, and a majority of the SRNAs were experiencing stress in the clinical setting. Other findings were that the majority of SRNAs sampled indicated that E-Calcutron could help decrease medical calculation errors, stress levels, and math anxiety; and that the program should be integrated into the anesthesia clinical so SRNAs could use the program. E-Calcutron has the potential to increase patient safety by potentially decreasing dosage errors among SRNAs.

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DEDICATION

I would like to dedicate this project to Jesus Christ (my lord and savior), Yulia James (my wife), and Catalina Sanchez (my mother). I would also like to dedicate this project to my brother Jared James who passed away, and my friend Justin Toncrey who passed away. Thank you all for giving me the strength to complete this project. Finally, I would also like to dedicate this project to Drs. Christopher Shelby, Terry Millette, and Megan Lott for managing my health. I would not have made it this far without their help and encouragement.

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LIST OF ILLUSTRATIONS

LIST OF ABBREVIATIONS

AACN	American Association of Colleges of Nursing
ACGME	Accreditation Counsel for Graduate Medical Education
ACT	American College Test
ADE	Adverse Drug Events
ASA	American Society of Anesthesiologists
BB	Bayne-Bindler
CINAL	Cumulative Index of Nursing and Allied Health Literature
CPR	Cardiopulmonary Resuscitation
CRNA	Certified Registered Nurse Anesthetist
DERS	Dose Error Reduction
FDA	Food and Drug Administration
Fx	Function bar
iOS	An operating system created by Apple Incorporated that runs on mobile devices.
IRB	Institutional Review Board
IV	Intravenous
kg	Kilogram
LPN	Licensed Practical Nurse
MAS	Mathematics Anxiety Scale
mcg	Microgram
ME	Medical Error

mg	Milligram
ml	Milliliter
NSE-MATH	Nurse Self Efficacy for mathematics
PedAMINES	Pediatric Accurate Medication in Emergency Situations
PISA	The Program for International Student Assessment
RN	Registered Nurse
SRNA	Student Registered Nurse Anesthetist
TDP	Time Drug Preparation Time
U.S.	United States
USM	The University of Southern Mississippi
WM	Working Memory

CHAPTER I – INTRODUCTION

Student registered nurse anesthetists (SRNAs) are registered nurses (RNs) who are enrolled in a rigorous nurse anesthesia program where they are educated and trained to one day become certified registered nurse anesthetists (CRNAs). A normal day in the life of a CRNA entails pre-anesthesia assessments, preparation of drugs, managing patients' airways and monitoring patients' hemodynamic status (Swanson, 2018). SRNAs are trained by CRNAs in various clinical locations to practice skills and to apply concepts learned in the classroom. SRNAs deal with a lot of stress while enrolled in a nurse anesthesia program. Chipas and Mckenna (2011) found that 67% of SRNAs who were surveyed attributed most of their stress to work from their nurse anesthesia program. When using a 10-point Likert scale, SRNAs were found to have a mean stress level of 7.2 compared to CRNAs having a mean stress level of 4.7. Studies conducted by the National Institutes of Occupational Safety and Health found that some contributable factors that cause stress for the nursing profession include time pressure/haste, excessive workload, sleep deprivation, and understaffing (Turner, 2013).

One area in the training of SRNAs that is important is the preparation and calculation of intravenous (IV) weight-based anesthesia medications (Nagelhout & Elisha, 2018). With some surgeons having demanding schedules (Swanson, 2018), SRNAs are under time constraints while trying to follow the usual routine of CRNAs (e.g., setting up their anesthesia workstation, pre-anesthesia assessments, and preparation of drugs). With the busy conditions in the hospital environment, stress and math anxiety can build while calculating weight-based IV anesthetic drugs. Some things can negatively impact math performance like adverse feelings and situations that puts a person under stress (Caviola et al., 2017). Math anxiety causes a feeling of apprehension when a person must deal with solving mathematical problems. Math anxiety can be viewed as a state or experience that occurs when a person is confronted with solving a mathematical problem. When a person experiences math anxiety, they perform poorly on tasks requiring math (Luttenberger, Wimmer, & Paechter, 2018).

Problem Statement

In the stressful hospital environment, SRNAs must effectively calculate weight-based IV anesthesia drugs to administer to their patients. SRNAs under stress or experiencing math anxiety (or both) may cause errors in their calculations that can have potentially negative consequences for patients. The long-term goal of this study is to decrease medical calculation errors so patients will be safer and not experience negative complications from accidental underdosing or overdosing. Currently, no effective technological tool is integrated into the anesthesia clinical setting that can help reduce potential medical calculation errors from being made by SRNAs. The purpose of this project was to create a spreadsheet using Microsoft Excel that would make the daunting manual process of calculating weight-based intravenous anesthesia drugs, an easier, accurate and time-efficient automated process for SRNAs.

Microsoft Excel can calculate formulas automatically, and calculations can be completed in less than a second, depending on the size and set up of the spreadsheet (Williams, Brandl, Caputo, & Cai, 2017). The study looked at the feedback from the SRNAs about a technological tool created called E-Calcutron to see if they would want this program integrated into the anesthesia clinical setting to allow SRNAs to use an automated calculation program when needing to calculate weight-based medications that will be administered to their patients. The accuracy, speed, and safety of using E-Calcutron, which was created in Microsoft Excel, can help reduce potential dosage errors from taking place by SRNAs, while potentially increasing patient safety.

DNP Essentials

The American Association of Colleges of Nursing (AACN) published eight essentials for doctoral education for advanced nursing practice (DNP Essentials Task Force, 2006). The eight essentials must be met prior to completing a doctoral in nursing practicing (DNP) project (Chism, 2019).

- *Essential I: Scientific Underpinnings for Practice* (Chism, 2019). The literature search that was completed on medical calculation errors among anesthesia providers and the effectiveness of automated medical calculation programs met this essential.
- *Essential II: Organizational and Systems Leadership for Quality Improvement and Systems Thinking* (Chism, 2019). Essential II was met by doing a literature search that looked at ways to improve dosage calculations among healthcare providers. One of the goals of the DNP project was to gain feedback from SRNAs about the automated Microsoft Excel spreadsheet called E-Calcutron. Another goal is to have E-Calcutron integrated into the anesthesia clinical setting for SRNAs to use, which could help reduce medication dosage errors.
- *Essential III: Clinical Scholarship and Analytical Methods for Evidence-Based Practice* (Chism, 2019). Essential III was met by doing a literature

search to look at the evidence of how effective automated calculation devices were at reducing medical calculation errors.

- *Essential IV: Information Systems/Technology and Patient Care Technology for the Improvement and Transformation of Health Care* (Chism, 2019). E-Calcutron is a technological software program built on Microsoft Excel. The essential was met demonstrating its use to SRNAs so that they could provide feedback about the software.
- *Essential V: Health Care Policy for Advocacy in Health Care* (Chism, 2019). This essential was met through the advocacy of wanting patients to be safer through potentially reducing dosage errors among patients. E-Calcutron can perform automated calculations, which may help reduce dosage errors and make patients safer.
- *Essential VI. Interprofessional Collaboration for Improving Patient and Population Health Outcomes* (Chism, 2019). Collaborating with an expert panel comprised of CRNAs, an information technologist, and a pharmacist met this essential.
- *Essential VII. Clinical Prevention and Population Health for Improving the Nation's Health* (Chism, 2019). This essential was met by demonstrating the automated process of E-Calcutron to SRNAs. SRNAs who saw a benefit of this technological tool in reducing medication dosage errors may potentially do future studies involving E-Calcutron. Graduating SRNAs may carry the knowledge about E-Calcutron to other facilities they practice and implement

practice changes involving utilizing automated calculation devices to potentially reduce dosage errors among patients.

- *Essential VIII. Advanced Nursing Practice* (Chism, 2019). This essential was met by having an expert panel comprised of advance practice nurses who are also CRNAs. They offered guidance, input, and recommendations in the process of creating the final version of E-Calcutron.

Available Knowledge

Math anxiety can be defined as a feeling of apprehension, nervousness, worry, and tension when a person is dealing with math (Luttenberger et al., 2018). These feelings can hinder a person's ability to successfully solve math-related problems. Physiological symptoms of math anxiety can include clammy hands and increased heart rate. The outcome of having math anxiety is performing negatively when attempting to solve mathematical problems. Ninety-three percent of adults in the United States (U.S.) stated that they experience math anxiety to some extent (Luttenberger et al., 2018).

Math anxiety can begin in early childhood if a parent or teacher passes down negative attitudes about math to a child. Math anxiety and poor performance in math can become a problem throughout a student's entire schooling experience (Furner, 2016). The Program for International Student Assessment (PISA) placed the U.S. in 38^{th} place when it came to their math ability (Desilver, 2017). Recent American College Test (ACT) math scores have reached a 20-year low with students averaging a 20.5 on the test in 2018. The average scores have declined from the average ACT math scores of 20.9 in 2013. Little progress has been made since 1998 when the average math scores on the ACT were 20.6 (Gewertz, 2018).

“Working memory is the small amount of information that can be held in mind and used in the execution of cognitive tasks…It has often been connected or related to intelligence, information processing, executive function, comprehension, problem-solving, and learning” (Cowan, 2014, p. 197). Cognitive processes are continuous tasks the brain performs (Salazar, 2019). Contributable factors to negative impacts on working memory (WM) and cognitive processes are math anxiety and stress. Math anxiety can have a negative impact on cognitive processes overloading the working memory system with intrusive, worrying thoughts that are off-task when attempting to solve a mathematical problem. Math anxiety ultimately results in poor math performance. Cognitive processes can also be negatively influenced by stressful, pressured situations. Stress can influence working memory, which can cause an overall negative impact (Caviola, Carey, Mammarella, & Szucs, 2017). Nurses have been shown to suffer from math anxiety and poor math performance.

Melius (2012) examined the correlation between math anxiety and math self-efficacy regarding nurses calculating medication dosages. Melius used the Mathematics Anxiety Scale (MAS) to measure participants apprehension to math, the Nurse Self Efficacy for Mathematics (NSE-Math) questionnaire to measure the confidence of participants when performing math problems, and the Bayne-Bindler (BB) medication calculation test to see how well the participants performed on the test. This test consisted of 20 medical calculations. The test was fill-in-the-blank, and participants were able to use calculators. Some of the question types on the test ranged from simple IV volume calculation questions and calculating oral tablet dosages to more complex weight-based IV questions. A demographic questionnaire was also given to the nurses to complete. The sample size was 84 with 8% being licensed practical nurses (LPNs) and 92% being registered nurses (RNs). The nurses in the sample pool worked in an acute care setting (Melius, 2012).

The BB medical calculation test scores ranged from 55% to 100%. When combing all scores, the average score was 83%. A weight-based dopamine infusion question asking for the answer to be provided in micrograms per kilograms per minute (mcg/kg/min) was missed by 67% of the nurses. The study found a correlation between BB medical calculation test, the MAS scores, and the NSE-Math questionnaire. When test scores were low, nurse math self-efficacy was low and MAS scores were high. Melius (2012) also noted that the more hours a nurse worked, the lower their score was on the BB medical calculation test. Since 67% of nurses missed the weight-based dopamine infusion question, Melius (2012) recommended technology like computerized infusion pumps to calculate complex math for the nurses.

Computerized infusion pumps/IV smart pumps can automatically calculate infusion rates of medications chosen from a built-in library of medications. Computerized infusion pumps/IV smart pumps make patients safer because there is no longer a need to calculate complex infusion doses manually. Calculating complex infusion dosages manually could potentially increase the likelihood of a medical calculation error occurring. With IV smart pumps, the user enters the pertinent patient information and chooses the medication that is going to be administered to the patient. Dose error reduction (DERS) is included in IV smart pumps like soft dose limits and hard dose limits. Soft dose limits send a warning to the user indicating that the dose may be elevated but allows the user to proceed after the user acknowledges the warning. Hard dose limits will not allow the user to proceed (Giuliano, 2015). The hard dose limit not allowing a user to proceed could be because the system detected a critical high dose level.

Evidence Review

A search in the literature was completed to identify studies focused on medical calculation errors among anesthesia providers. A search of the literature was also done looking for evidence dealing with how effective automated calculation programs could be at reducing medical calculation errors. Google Scholar, Medline, and Cumulative Index of Nursing and Allied Health Literature (CINAHL) with full text were used. When searching for medical calculation errors among anesthesia providers, the keywords that were used were anesthesia, medical errors, medical calculation errors, pediatric, and adult. When searching for medical calculation programs, the keywords that were used were anesthesia, medical calculation, mobile applications, applications, automated, pediatric, and adult. An evidence matrix that includes the studies found and used in the literature review can be found in Appendix A.

Medical Calculation Errors in Anesthesia

Medical calculation errors can cause grievous outcomes for patients undergoing anesthesia. These patients are unable to verbalize symptoms attributable to a medication error like an awake patient could (Dhawan, Tewari, Sehgal, & Sinha, 2017). Nanji, Patel, Shaikh, Seger, and Bates (2016) did a prospective observational study over an 8-month period to find out how many medical errors (MEs) and/or adverse drug events (ADEs) occurred when anesthesia providers administered medications to patients. The data was collected at a medical center. Pediatric and heart surgeries were excluded from the study. Data collection included direct observation of cases by three anesthesiologists and one

CRNA. Data was also retrieved directly from patients' anesthesia charts by anesthesiologists. The sample size was 226 with 32.7% being anesthesiologists, 22.6% being CRNAs and 44.7% being house staff. Ultimately, 193 events were found, including MEs and/or ADEs (Nanji et al., 2016).

Not all MEs led to ADEs, and not all ADEs were involved with MEs. The study found that with the 51 (33.3%) MEs that led to ADEs, one of the most prevalent errors was the medication dose being wrong (N=24 or 47.1%). The study found no statically significant difference between the event rates of the anesthesiologist, CRNAs, or the house staff. The study determined that 1 in every 20 medications administered perioperatively involved a ME and/or ADE. The authors recommended technology-based interventions as one of their solutions to reduce MEs and ADEs. "Specific drug decision support, including features such as dose calculators and maximum dose checking, has the capacity to reduce the incidence of wrong dose and wrong drug errors" (Nanji et al., 2016, p. 8).

Cooper, DiGiovanni, Schultz, Taylor, and Nossaman (2012) did a prospective observational study exploring the incidence and reporting of medication errors from anesthesia providers. The study was completed at a teaching hospital with a variety of surgical cases. Participants in the study included 35 anesthesiologists, 21 anesthesiology residents, 50 CRNAs, and 10 SRNAs. SRNAs and anesthesia residences were categorized as trainees in anesthesia, and CRNAs and anesthesiologists were categorized as experienced providers. Participants could voluntarily give a medication error report form to the researchers while remaining anonymous. Over a 6-month period, report forms were attached to each patient's chart. Out of the 10,574 cases, 8,777 (83%) were returned to the researchers. The study identified 17 forms that had near misses and 35 forms that reported a medical error. The trainees in anesthesia (SRNAs and anesthesiology residences) had a greater reporting rate (two times as many reports when compared to CRNAs and anesthesiologists). The errors mostly reported were the dose being incorrect and medications being substituted. Some contributable factors that were reported by the anesthesia providers as possible causes for the medication errors were haste, being under stress, and pressure (12.5%).

Lobaugh, Martin, Schleelein, Tyler, and Litman (2017) reviewed six years' worth of pediatric anesthesia medication errors made by anesthesia providers. The data was reported to the researchers by 32 participating institutions. Through analyzing the data, they identified 2,087 adverse advents, which included 276 medication errors. Out of all the medication errors reported, the administration of the wrong dose (n=84) was the top error made. The percentage of errors that reached the patient was 80%, with 50% of the errors causing actual harm to the patients.

Gariel, Cogniat, Desgranges, Chassard, and Bouvet (2017) did a prospective incident monitoring study on medication errors in pediatric anesthesia. Attending anesthesiologists from a pediatric surgical center could submit an anonymous incidence report voluntarily. The study found that 1400 (73%) incidences were submitted out of 1935 cases. Thirty-seven incidence reports reported at least one medication error (2.6%). The most-reported error was the medication dose being incorrect (n=27, 67.5%). Fatigue and pressure were reported as a contributable factor to a medication error being made in 2 cases (5%).

Automated Medical Calculation Applications

Siebert et al. (2017) did a randomized control trial to see if a mobile application could reduce the preparation time and the medication delivery time to the pediatric population during a cardiopulmonary arrest. Another aim of the study was to reduce medication dosage errors. Siebert et al. (2017) talked about how vasoactive infusions are complex and time-consuming to prepare and administer, which can increase the likelihood of medication errors to occur. Pediatric Accurate Medication in Emergency Situations (PedAMINES) was created and used during the study. Twenty nurses were randomized into either the group that used an infusion table or the group that used the PedAMINES application. The study had two study periods. A pediatric cardiac pulmonary resuscitation simulation was performed using a realistic manikin, and after the return of spontaneous circulation, the nurses were asked to prepare a weight-based dopamine infusion with the dose being 5 mcg/kg/min. Later, they were also asked to prepare a 0.1mcg/kg/min norepinephrine infusion.

The study results showed the group using PedAMINES made zero errors. The group using infusion tables made eight errors for the first study period and six errors for the second study period. Out of the 8 errors made during the first study period, 5 of the errors resulted in critically high overdoses ranging from 100% to 5,233% over the correct dose. PedAMINES also resulted in a reduced drug preparation time (TDP) compared to the group that did not use the application. Sietbert et al. (2017) talked about (as cited in Luten et al., 2002) how external conditions and intrusive anxiety during cardiopulmonary resuscitation (CPR) increases a nurse’s cognitive workload, which can lead to errors. Siebert et al. (2017) recommended using automated applications like their PedAMINES application that can performed automated calculations and are fast and reliable. Segal, Arevalo, Franke, and Palazuelos (2015) did a prospective study in Guatemala evaluating efficiency and accuracy when calculating oral dosages using a mobile medical calculation application that they developed. A school's classroom was made into a clinic to see patients who were mostly pediatric. The application was tested by six interns who were trained to use the application. Ninety-eight patients were seen in the clinic before the residents used the application, and 178 patients were seen when the application was in use by the residents. Three hundred and sixty-six prescriptions were written. When using the application, medication dose accuracy improved from 65.7% to 92.4%. By using the application, the calculated dosages were 40% more likely to be accurate. In a "time-constrained context" (Segal et al., 2015, p. 111) and being "under pressure," (Segal et al., 2015, p. 113) efficiency in the clinic increased by 20%, and patients' clinic times were decreased by 1.5 minutes. Patients seen in the clinic before the applications intervention had a mean visit time of 7.15 minutes. After the application intervention, the mean visit time decreased to 5.23 minutes (Segal et al., 2015).

A systematic review was conducted by Kaufmann et al, 2017 and evidence suggested the benefits of using technology to reduce medical calculation dosage errors. "Calculation of drug doses should be supported by electronic means (e.g., calculators or spreadsheet programs), which have been shown to minimize drug dosing errors" (Kaufmann et al., 2017, p. 674). The researchers also discussed how these types of tools are necessary for medications that require complex calculations. Measures that decrease the cognitive demand for the person who plans to administer the drug will help with patient safety when it comes to administering the proper dose (Kaufmann et al., 2017).

Green, Mathew, Venkatesh, Green, and Tariq (2018) studied the utilization of smartphone applications by anesthesia providers. They used the Apple play store, Google Play store, and Windows store for anesthesia-related applications. A survey was sent out to program directors of 136 anesthesiology programs accredited by the Accreditation Council for Graduate Medical Education (ACGME) to find out information pertaining to what anesthesia mobile application category was used the most, how frequently did anesthesia providers use anesthesia mobile applications, and which applications were the most popular. The sample was 416 anesthesiology residents, anesthesiologists, CRNAs, and one SRNA. The study indicated that more than 99% of the participants had access to anesthesia applications. The application category that was scored the highest was dosage/pharmaceutical applications (mean score 78.73). Epocrates was rated as the most used application. The researchers were interested in mobile applications being integrated into anesthesia practice. “One particular area of interest is the use of apps as a clinical tool in integration technology with clinical practice” (Green et al., 2018, p. 6).

Zhao (2016) examined smartphone ownership and mobile application use as a learning tool among SRNAs. Surveys were sent to 2,983 SRNAs with the final sample size being 468. Some study results indicated that (n=465) 99.36% of respondents were smartphone owners, (n=426) 91.02% had at least one anesthesia application installed on their phone, and (n=330) 73.49% used their anesthesia applications for medical calculations. One study recommendation was to develop a nurse anesthesia program-specific smartphone application.

The Rationale for Using E-Calcutron

The cognitive workload can be decreased using an electronic automated process to calculate weight-based anesthesia medications, instead of allowing healthcare providers to manually calculate dosages themselves (Kaufmann et al., 2017; Siebert et al., 2017). E-Calcutron was created using Microsoft Excel. Excel is an electronic spreadsheet program that can perform deep and complex calculations instantaneously (Graham, Golfer, Thake, & Cannon, 2019). Excel can be used by researchers to perform statistical analysis (Divisi, Leonardo, Zaccagna, & Crisci, 2017). Excel also allows users to lock cells and formulas in their spreadsheet to prevent accidental changes or deletion (Cheusheva, 2018).

If a formula was created to calculate the safe dose range of a weight-based intravenous medication, a user would be able to lock cells so other users will not unintentionally change the safe dose range. Locking cells and formulas are within itself a safety feature that could prevent a medical calculation error from happening due to a user unintentionally changing the dose range or the formula itself. Excel also has a feature called data validation. Data validation allows users to set limits on numbers entered. A drug can have a safe dose range of 1 to 5mg/kg, and data validation can set a limit to where users are not able to enter numbers under 1 or over 5. Data validation also features customizable error messages that will display if another user enters a number that is outside of the data validation limits (Bruns, 2017). E-Calcutron utilizes the safety features offered by Excel.

Excel is an accurate tool and has been used to evaluate the accuracy of other calculation programs. Bierbrier, Lo, and Wu (2014) used Excel to evaluate the accuracy of mobile medical calculation applications. The researchers found 14 medical calculation applications and tested 13 functions for each application. The answers were considered correct if the answer yielded the same results when doing the calculation on Excel with a rounding error. The study found an overall accuracy of 98.6% with the functions that were tested in the 14 applications, but some errors were found in 8 applications when it came to the applications calculating the Child-Pugh scores and Model for End-stage Liver, which could result in a clinically significant change in prognosis. Bierbrier et al. (2014) found that the smartphone applications they tested were, for the most part, accurate but stressed the need for validation of medical calculation application accuracy before they are used in the care of patients. In this study, Microsoft Excel was a trusted tool by the researchers to evaluate the accuracy of mobile medical calculation applications.

Summary

Math anxiety is a problem that can lead to poor math performance. SRNAs deal with an increasing amount of stress and strain in high-pressure work environments that may entail working long hours. SRNAs are vulnerable to stress and math anxiety, which may lead to medical calculation errors. These errors can have grave consequences for patients. Automated calculation programs are ways to bypass doing math manually. Making medical calculations an automated process can decrease cognitive workloads, can reduce medical calculation errors from occurring and may make patients safer.

E-Calcutron is a spreadsheet program that eliminates the need to do manual calculations by doing the calculations automatically. E-Calcutron may reduce anesthesia-related medical calculation errors that could occur with SRNAs dealing with stress or math anxiety (or both) in a high-pressured induced hospital environment. Details about the development of E-Calcutron and the methodology of the study will be explained in Chapter II.

CHAPTER II – METHODOLOGY

The goal of the doctoral project was to create a Microsoft Excel spreadsheet that will automatically calculate weight-based anesthesia drugs for SRNAs and to obtain their feedback about the Microsoft Excel spreadsheet. An education session with the SRNAs was conducted. Pre and post-education session questionnaires were utilized to get feedback from the SRNAs about the topics discussed in the education session. The Microsoft Excel spreadsheet was created and named E-Calutron. The Institutional Review Board (IRB) of The University of Southern Mississippi (USM) approved the project (Protocol number: IRB-19-285) (Appendix B). A panel of experts consisting of three CRNAs (who were also faculty members at the University in which the study was completed) was created. An information technologist, a pharmacist, and an additional CRNA were later added to the panel of experts. The panel of experts gave their input to E-Calcutron. With help from the panel of experts, the final version of E-Calcutron was created (Figures 1 and 2).

Population

The population consisted of 59 SRNAs who are enrolled in a doctoral-level nurse anesthesia program located in the southeastern region of the United States. The population consisted of first, second, and third-year students. The inclusion criteria to participate in the study was for the participant to be a SRNA currently enrolled in the nurse anesthesia program at the University.

Design

A live education session was conducted with each nurse anesthesia class. Before the education session, students were given a pre-education questionnaire (Appendix C).

The questionnaire was an anonymous questionnaire. Consent to participate in the study was obtained through asking “Do you consent to participate in this study?” with the participant marking either “Yes” or “No.” The consent question was placed on both pre-education and post-education session questionnaires. Also placed on pre and post-questionnaires was the statement, “Participation in answering the questionnaire is voluntary. All participants will remain anonymous. Please do not put your name on the questionnaire. There will be no consequences for not participating.” The pre-education questionnaire asked the following questions:

1. Are you a first, second or third-year nurse anesthesia student?
2. Are you male or female?
3. On a scale of 1 to 4, please rate your stress level in the anesthesia clinical setting (1= no stress, 2=mild stress, 3=moderate stress, 4=severe stress).
4. Math anxiety can occur when a person is in a stressed induced situation and must do mathematical tasks (e.g., medical calculations). This can cause negative feelings like apprehension, feeling tense and can cause worrisome thoughts to occur. Have you ever experienced math anxiety when having to calculate weight-based anesthetic medications (e.g., preop anxiolytics, induction drugs, paralytics, reversal agents) in the anesthesia clinical setting?
5. Have you ever experienced math anxiety when having to calculate weight-based medications on a medical calculation test?

A live education session was conducted using Microsoft PowerPoint and Microsoft Excel. Each class (first, second, and third-year) were met with individually at different times. Topics discussed during the Microsoft PowerPoint portion of the education session were medication dosage errors among anesthesia providers, cognitive processes, working memory, math anxiety, stress, and automated calculation programs. At the end of the Microsoft PowerPoint presentation, the automated spreadsheet program, E-Calcutron, was then introduced to the class. E-Calcutron was then opened and displayed to the class using Microsoft Excel. A live demonstration on how E-Calcutron functioned was presented to the class. Information about E-Calcutron was also presented to the classes. The information included:

- A medication's safe dose range included in E-Calcutron were found in three anesthesia textbooks: Flood, Rathmell and Shafer's (2015) anesthesia pharmacology book called *Stoelting's Pharmacology and Physiology in anesthetic practice (5th edition.),* Nagelhout and Elisha's (2018) *Nurse Anesthesia* (6th ed.), and Cote, Lerman, and Anderson's (2019) pediatric anesthesia book called *A practice of Anesthesia for Infants and Children.* Any dosages not found in these books were taken from the Food and Drug Administration (FDA).
- Each Excel cell that contains a medication's name is highlighted based on the American Society of Anesthesiologists (ASA) *Statement on Creating Labels of Pharmaceuticals for Use in Anesthesiology*, which was approved in 2004 and last amended in 2015.
- Concentrations supplied were taken from companies in the United States that manufacture the medication. The information was pooled from Drugbank, which is an online medication database that obtains information on

medications through manual searches, the FDA, PubChem, and PubMed (Drugbank, 2019).

- Utilizing E-Calcutron to obtain the final safe dose range.
- The adult and pediatric section in E-Calcutron.
- The function (Fx) bar is used to input numerical data in the highlighted yellow cells. The highlighted yellow cells are the only cells that can be manipulated.
- Data validation (Bruns, 2017) and cell locking (Cheusheva, 2018) are safety features of E-Calcutron. E-Calcutron has warning messages if a user goes under or above a certain dose, concentration, or weight.
- Input data gives users friendly reminders when selecting a cell. For example, when selecting suggamadex 2mg/kg, it will show a message "2 train-of-four (TOF) twitches," meaning, suggamadex 2mg/kg is supposed to be given when the patient has two TOF twitches (Nagelhout & Elisha, 2018).
- E-Calcutron sheet 2 allows for the exact dose to be entered, enabling the user to enter dosages in between the safe dose range.
- Asterisks near the medication mean there were conversions done between milligrams and micrograms. The conversions were done to make the calculation process easier for E-Calcutron.
- References of all the dosages and concentrations are at the bottom of E-Calcutron. An abbreviation key is included at the bottom of E-Calcutron.
- E-Calcutron can work on a desktop, laptop, or mobile format (best in the horizontal view).

- All students were informed they would receive a free copy of E-Calcutron with an instruction manual on how to use the program.

After the presentation was completed, a post-education questionnaire (Appendix D) was completed by the SRNAs. The questions in the post-education questionnaire were:

1. Do you think E-Calcutron can help SRNAs in the reduction of weight-based medical calculation errors?
2. Do you think E-Calcutron should be integrated into the anesthesia clinical setting so SRNAs can use this tool in the clinical setting?
3. Do you think E-Calcutron could decrease your stress level in clinicals?
4. Do you think E-Calcutron could help decrease your math anxiety when faced with calculating weight-based anesthesia medications in the future?

Summary

An education session was conducted that explained possible contributable factors to medication dosage errors. The education session also explained and demonstrated the use of the automated calculation program created called E-Calcutron. A pre-questionnaire and post-questionnaire were utilized for data collection. The project's goal was to get feedback from SRNAs to see if E-Calcutron would be a good technological tool to be integrated into the anesthesia clinical settings so SRNAs can use this tool in the clinical setting to help reduce dosage calculation errors. The long-term goal for the project is to increase patient safety through SRNAs utilizing an automated calculation tool to calculate weight-based anesthesia medications.

CHAPTER III – RESULTS

An education session about E-Calcutron and contributable factors to medication dosage errors was conducted with all three nurse anesthesia classes. Students who participated in the study completed a pre-education session questionnaire and a post-education session questionnaire. Microsoft Excel was used to analyze the data.

Guidelines for the Data

Since the questionnaires asked open-ended questions, guidelines were created to better analyze the data. The guidelines created are as follows:

- For question 1 on the pre-education session questionnaire, both pre and post-questionnaire surveys were not used in the study if a participant did not specify which class they are in (first, second, or third-year). This decision was made because statistical analysis could not be used to determine if there were any statistically significant differences between the nurse anesthesia classes' answers if a participant did not specify their class year.
- For question 2 on the pre-education session questionnaire, participants who did not write male or female but drew out the male Mars gender sign will be marked as "Male" and females who drew out the female Venus gender sign will be marked as "Female." All other participants who did not specify whether they were male or female were placed in the "other category".
- Pre-education question 3 used a 4-point Likert scale. Participants' answers were excluded from data analysis if the answer was not in the Likert scale's 4-point range (1, 2, 3, or 4).

- For questions 4 and 5 on the pre-education session questionnaire and 1-4 on the post-education questionnaire survey, all answers with a positive affirmation (e.g., absolutely, sure, etc.) were counted as a "Yes." All answers that include a negative affirmation (e.g., never, no way, etc.) were counted as a "No." All answers that include "maybe, perhaps, possibly, etc.." were counted as a "Maybe." All answers outside of the "Yes, No, or Maybe" category and all answers that were "n/a" answers were not included in the data analysis.
- All first-year students' answers for pre-test Questions 3 and 4 will be excluded from the data analysis since these questions were geared towards students who were working in the anesthesia clinical setting. At the time of the data collection, the first-year students were not working in the anesthesia clinical setting.
- For question 3 on the post-education questionnaire, most first-year students answered the question. Although this question was meant for students currently in the anesthesia clinical setting, it is possible the first-year students viewed this question as if it was asking them if E-Calcutron could help with their stress levels once they started their anesthesia clinical rotations. Data will be analyzed for the first-year class because of there being a possibility the question was thought to be asking about stress levels in the future. The results from the first-year class will not be combined with the second and third-year classes' results.

- For question 3 on the post-education questionnaire, SRNAs answers will not be included in the data analysis if they stated they had no stress in clinicals for their answer for pre-education questionnaire question 3.
- For question 4 on the post-education questionnaire survey, some students who had answered: "No" for pre-questionnaire questions 4 and 5 (questions that asked if they ever experienced math anxiety), marked post-education questionnaire question 4 as "Yes" (which asked if they thought E-Calcutron could help with their math anxiety). Answers for this question will be included in the data analysis only if a participant gave a "Yes" answer to pre-questionnaire questions 4 or 5.
- Any comments made on the spreadsheet was not included in data analysis but were discussed after the results of the analyzed data.

Results of the Analyzed Data

The number of SRNAs who participated in the study was 55. The number of students included in the data analysis was 54. One student, 2% (n=1), did not specify the class they were in, so the student's answers were not included in the data analysis. The results for question 1 for the pre-education questionnaire that asked SRNAs which class year they were in showed that 33.3% (n=18) of students were in the first-year class, 33.3% (n=18) were in the second-year class and 33.3% (n=18) were in the third-year class. The results for pre-education questionnaire question 2 that asked the SRNAs (first, second and third-years) their gender, showed that 54% (n=29) were males, 44% (n=24) were females, and 2% (n=1) was other. Pre-education questionnaire question 3 used a 4-point Likert scale to look at second and third-year students (n=36) stress levels in the clinical setting. One student's (3%, n=1) answer was not included in the statistical analysis for failing to answer the question in accordance with the established data guidelines. The student's answer not being included made the sample size for this question n=35.

The results showed that 3% (n=1) stated they experience no stress, 51% (n=18) stated they experience mild stress, 46% (n=16) stated they experience moderate stress, and 0% stated they experience severe stress. Overall, 97% (n=34) of respondents experience some level of stress in the anesthesia clinical setting. When the two classes were looked at separately, second-year students had 0% experience no stress, 41% (n=7) of experience mild stress, 59% (n=10) experience moderate stress and 0% stated they experience severe stress. Third-year students showed 6% (n=1) experience no stress, 61% (n=11) experience mild stress, 33% (n=6) experience moderate stress, and 0% stated they experienced severe stress.

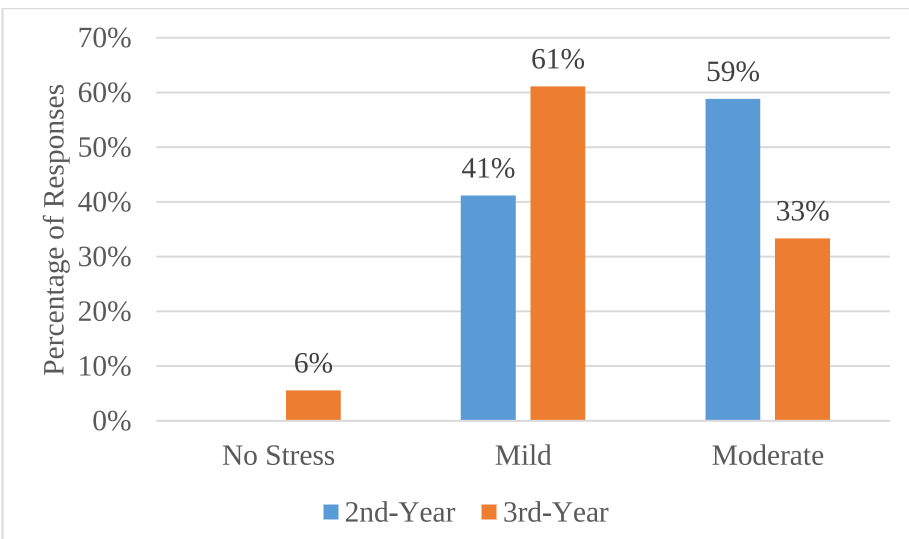

Figure 1. Pre-Education Questionnaire Question 3 Responses from Second and Third-Year Students

A further look into the two different classes' responses was done. The second and third-year class to determine whether there was a statistically significant difference between the two classes stress levels. A Chi-square test was conducted, and the result was 0.304, which was less than 0.05. A statistically significant difference between the two classes stress levels was not found.

Question 4 for the pre-education questionnaire looked to see if second and third-year students ever experienced math anxiety in the clinical setting. The results showed that 75% (n=27) experienced math anxiety in the anesthesia clinical setting, and 25% (n=9) did not. A comparison was done looking at male and female responses to the question in the second and third-year classes. One participant (n=1) marked as other for gender was not included in the comparison because of the low sample size (3%), bringing the sample to n=35 with n=16 being females and n=19 being males. For males, 74% (n=14) experienced math anxiety in the anesthesia clinical setting were, and 26 (n=5) never experienced math anxiety in the clinical setting. For females, 81% (n=13) experienced math anxiety in the anesthesia clinical setting 19% (n=3) did not.

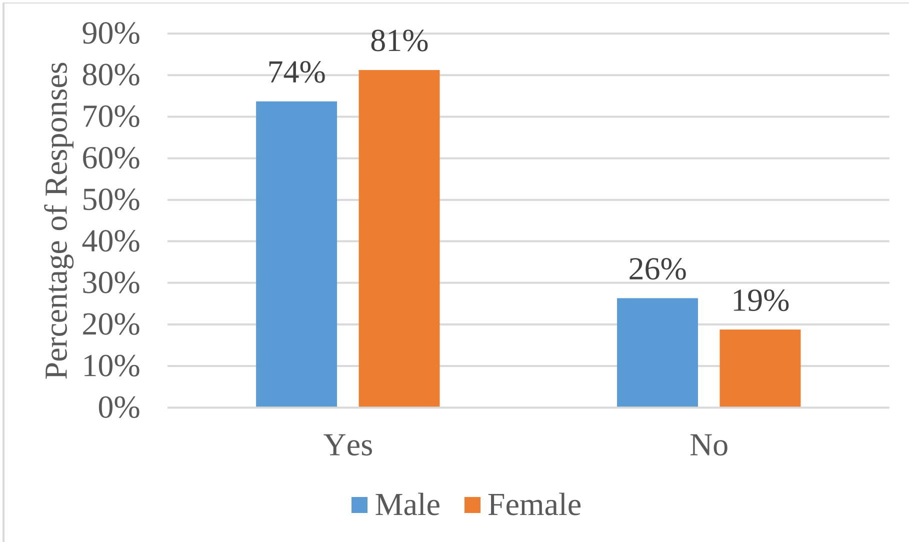

Figure 2. Pre-Education Questionnaire Question 4 Responses from Second and Third-Year Males and Females

A difference between the responses was further examined. A Chi-square test was performed to see if there was a statistically significant difference between the responses between males and females. The result was 0.595, which was greater than 0.05. A statistically significant finding between male and female responses were not found.

Pre-education questionnaire question 5 asked if the SRNAs ever experienced math anxiety while having to calculate weight-based medications on a medical test. Responses came from first, second, and third-year students. The final sample size for this question was (n=51) because 6% (n=3) students did not answer the question in accordance with the set data guidelines. SRNAs who had experienced math anxiety during a weight-based medical calculation test before were 63% (n=32), and 37% (n=19) of SRNAs never experienced math anxiety during a weight-based medical calculation test. When looking at males' responses to the question, 57% (n=16) of males had experienced math anxiety before while taking a weight-based medical calculation test, and 43% (n=12) never did. With females, 73% (n=16) had experienced math anxiety before while taking a weight-based medical calculation test, and 27% (n=6) did not.

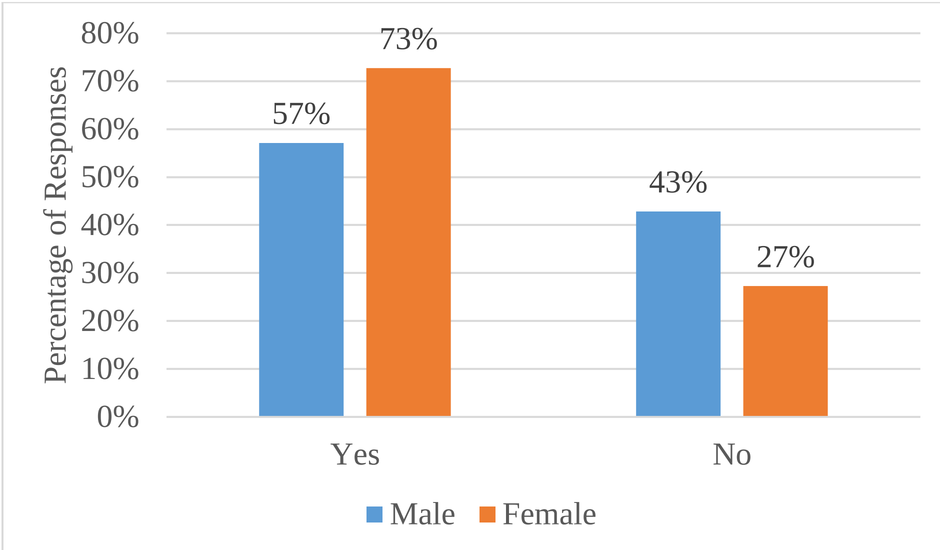

Figure 3. Pre-Education Questionnaire Question 5 Responses from First, Second, and Third Year Males and Females.

A Chi-square test was conducted to see if there was a statistically significant difference between male and female responses. The result was 0.254, which was greater than 0.05. A statistically significant finding between male and female responses was not found. Males and females both experienced math anxiety, without one gender experiencing math anxiety more than the other.

Post-education questionnaire question 1 asked if students thought E-Calutron could help reduce weight-based medical calculation errors. The combined results for the first, second, and third-year students (n=54) were 93% (n=50) stated yes, 5.6% (n=3) stated no, and 1.9% (n=1) stated maybe. Post-education question 2 asked if students thought E-Calcutron should be integrated into the anesthesia clinical setting. The combined results (n= 53) were 87% (n=46) yes, 11% (n=6) no, and 2% (n=1) maybe.

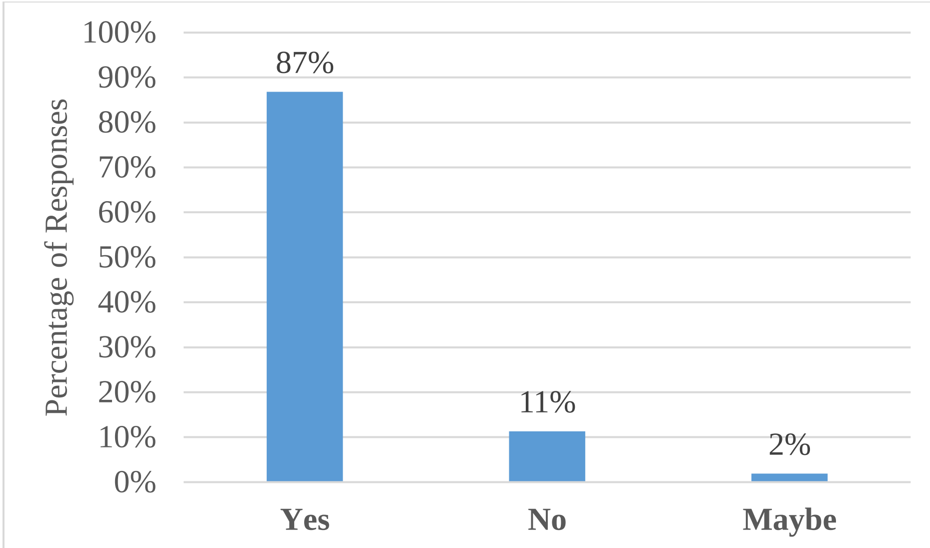

Figure 4. Post-Education Questionnaire Question 2 Responses from First, Second, and Third-Year Students.

Post-education questionnaire question 3 asked if SRNAs thought E-Calcutron could decrease their stress levels in clinicals. The results come from second and first-year students (n=36). One student's (3%) answer was not included in the data analysis since the student stated he or she did not have any stress in clinicals in pre-education questionnaire question 3. The student's answer not being included brought the sample size to (n=35). The results were 83% (n=29) yes, 14% (n=5) no, and 3% (n=1) maybe. The majority of the first-year SRNAs answered this question, although this question was intended for students currently in clinicals (second and third-years). The first-year SRNAs may have read the question as if it was asking if E-Calcutron would help with their stress levels in the future, and because of this possibility, the first-years' answers were analyzed. One student (6%) was not included in the statistical analysis because he or she stated n/a for their answer. The student not being included made the final sample size (n=17). The results were 94% (n=16) yes, 0% no, and 6% (n=1) maybe.

Post-education questionnaire question 4 asked if SRNAs thought E-Calcutron could help decrease their math anxiety when calculating weight-based anesthesia medications in the future. Participants who stated they experienced math anxiety in pre-education questionnaire questions 4 or 5 were included in the data analysis (n=39) 72%. SRNAs excluded from the data analysis for this question were the ones that never experienced math anxiety (28%, n=15). First, second, and third-years were included in the sample size (n=39). The results were 95% (n=37) yes, 2.6% (n=1) no, and 2.6% (n=1). Comments were left on some questionnaire surveys. A fear of E-Calcutron being used as the only means for SRNAs to calculate weight-based anesthesia medications was one of the comment themes. Some SRNAs indicated that students should be able to calculate the math in their heads. Other comment themes were that expert anesthesia providers do not calculate dosages because they know what to administer to each patient.

Summary

The results indicated that the SRNAs sampled do experience stress in the clinical settings and have experienced math anxiety. The majority of SRNAs indicated that E-Calcutron could help reduce medical calculation errors, could help decrease their stress levels in clinicals, and could help decrease their math anxiety when faced with calculating weight-based medications. Lastly, the majority of SRNAs sampled are for E-Calcutron being integrated into the clinical setting. An in-depth discussion of the findings of the project, recommendations for further studies, and limitations of the project are discussed in Chapter IV.

CHAPTER IV – CONCLUSION

Discussion

The goal of this doctoral project was to create an automated electronic tool to aid SRNAs in the calculation of weight-based anesthetic medications. The tool (E-Calcutron) was created and modified with the help of an expert panel. SRNAs being under stress and experiencing math anxiety were seen to be more susceptible to making medical calculation errors due to poor math performance. Stress and math anxiety can be contributable factors to poor math performance (Caviola et al., 2017). Searching the literature revealed that one of the top medication errors made among anesthesia providers was the dose being wrong (Cooper et al., 2012; Gariel et al., 2017; Lobaugh et al., 2017; Nanji et al., 2016).

This doctoral project's results suggested that many of the SRNAs sampled had experienced math anxiety in the past (whether it was in the anesthesia clinical setting or on a medical calculation test). Also, the results indicated that SRNAs deal with different levels of stress in the anesthesia clinical setting. In their study, Chipas and Mckenna (2011) reported that SRNAs mean stress level was 7.2, with CRNAs having a mean stress level of 4.7. Stress may cause poor math performance (Caviola et al., 2017). SRNAs who are stressed having to calculate weight-based anesthesia medications could potentially cause poor patient outcomes.

With this doctoral project, 93% (n=50) of the SRNAs sample indicated that E-Calcutron could help SRNAs in reducing weight-based medical calculation errors. Out of the SRNAs who experienced stress in the clinical settings, 83% (n=29) indicated that E-Calcutron could help decrease their stress levels. Out of the SRNAs who experienced math anxiety in the past, 95% (n=37) indicated that E-Calcutron could help decrease their math anxiety when faced with calculating weight-based anesthesia medications in the future. Ninety-three percent (n=50) of SRNAs indicated that E-Calcutron should be integrated into the anesthesia clinical setting. The electronic automated tool, E-Calcutron, was created to aid SRNAs with calculating weight-based anesthesia medications. The goal was to increase patient safety. The majority of SRNAs sampled responded favorably to the automated calculation program called E-Calcutron.

Implications for Future Practice

SRNAs are experiencing stress and math anxiety. An automated calculation program like E-Calcutron can aid SRNAs in calculating weight-based anesthesia medications. E-Calcutron can potentially increase patient safety. The investigator reported that E-Calcutron should be integrated into the anesthesia clinical setting for SRNAs to use. E-Calcutron can be used on Microsoft Excel installed on a computer, laptop, or on a mobile device running I operating system (iOS) or an Android operating system. Some negative comments were on the questionnaires that dealt with a fear of E-Calcutron being used as the sole instrument to calculate weight-based anesthesia medications. E-Calcutron is not a replacement for teaching SRNAs how to do manual weight-based calculations in the didactic setting. SRNAs and CRNAs must understand the foundation of the calculations that E-Calcutron performs. A future study could integrate E-Calcutron into the didactic pharmacology portion of a nurse anesthesia program through the creation of a policy. SRNAs can then receive training on E-Calcutron before utilizing it in the anesthesia clinical setting.

A study examining how E-Calcutron performs against conventional methods of calculating weight-based anesthesia medications (handheld calculator, paper and pencil or doing math in one's head) is needed. An anesthesia emergency simulation can be carried out in a simulation laboratory. This study could be based on the study carried out by Siebert et al. (2017) which compared an automated medical calculation application called PedAMINES to infusion tables when weight-based pediatric medications were calculated during a pediatric code simulation by nurses. A post-questionnaire survey could explore SRNAs stress levels and whether any SRNAs will experience math anxiety during the simulation. Lastly, a future study could develop a policy through working with a healthcare facility that will allow SRNAs to use E-Calcutron in the anesthesia clinical setting

Limitations

A limitation of the doctoral project was that the questionnaires were opened ended. Questions were asked in a way that the investigator expected the participants to give a yes, no or not applicable response. Although participants do answer the question in a way expected by the investigator, some participants did not. Questions asked that were meant for second and third-year students were being answered by first-year students. Data guidelines had to be created to better analyze the data. To fix this limitation, the survey could have had multiple choice answers and could have told the participant to "circle the answer." All questions meant for SRNAs in anesthesia clinicals at the time (second and third-year students) could have been marked "only answer if you are a second or third-year student).

Conclusions

E-Calcutron is an automated medical calculation spreadsheet that can potentially aid SRNAs in the calculation of weight-based anesthesia medications. SRNAs under stress or experiencing math anxiety may benefit from its use because it turns the manual calculation process of calculating weight-based anesthesia medications into an automated process. The questionnaires received favorable responses for E-Calcutron from the SRNAs who were sampled, with the majority wanting E-Calcutorn integrated into the anesthesia clinical setting and believing E-Calcutron could aid them in reducing medical calculation errors, math anxiety, and stress in the anesthesia clinical setting. This doctoral student hopes that E-Calcutron (through a future doctoral project) will one day be integrated into the anesthesia clinical setting.

APPENDIX A - Evidence Matrix

Author/Year/ Title	**Level/ Grade**	**Design**	**Sample/Data Collection**	**Findings**	**Recommendations**
Cooper, DiGiovanni, Schultz, Taylor, & Nossaman (2012) “Influences observed on incidence and reporting of medication errors in anesthesia”	The design does not fall under any levels of the evidence matrix	Prospective observational study	Sample size 116 and consisted of 50 CRNAs and 10 SRNAs, 35 anesthesiologists and 21 anesthesiology residents. Data was collected by anonymous error reporting forms on a voluntary basis.	8,777 report forms were turned in. 17 forms had near misses with 35 forms reporting a medical error. SRNAs and anesthesiology residents had a greater reporting rate (twice the amount of reports turned in than CRNAs and anesthesiolo-gists).	Automated solutions and bar-code labeled medications to better track the reporting of medication errors.
Gariel, Cogniat, Desgranges, Chassard & Bouvet (2017) “Incidence, characteristics, and predictive factors for medication errors in pediatric anesthesia: a prospective incident monitoring study”	The design does not fall under any levels of the evidence matrix	Prospective study	A sample size of participants not given Voluntary submission of incidence reports.	1400 incidence reports were submitted. 37 reports had at least one medication error (2.6%). The most frequent error was the dose being wrong (n=27) 67.5%. The main contributable factor to an error being made was disturbance during anesthesia being administered (n=10, 25%).	Prevention strategies like color-coded labeling, preparation and administration of the drug by a single person and prefilled syringes.

Author/Year/ Title	Level/ Grade	Design	Sample/Data Collection	Findings	Recommendations
Green, Mathew, Venkatesh, Green, & Tariq (2018) “Utilization of smartphone applications by anesthesia providers”	The design does not fall under any levels of the evidence matrix	Survey study	The sample size was 416. Attending anesthesiologists (n=157), anesthesiology residents (n= 149), anesthesiology fellows (n=8), CRNAs (n=95) and SRNAs (n=1) Surveys were sent out to collect data on the number of participants that had smartphones, anesthesia application use, the cost a participant was willing to pay for an application, a participant’s favorite application, a rating of the usefulness of different features an application offered.	99.3% (n=410) was using smartphones. 11.4%(n=45) never used mobile anesthesia applications. Dosage/pharmaceutical applications scored the highest categorical score for usefulness in anesthesia applications (mean score: 78.73). Epocrates was rated as the most used application.	The integration of mobile anesthesia applications into the anesthesia clinical setting.

Author/Year/ Title	Level/ Grade	Design	Sample/Data Collection	Findings	Recommendations
Kaufmann et al. (2017) “Drug safety in pediatric anesthesia”	V	Systematic Review	N/A	The inexperienced staff guided and monitored by experienced staff. A person must be constantly aware of a medication error threat. Confusing drugs with similar-looking ampules should be properly labeled. Drug dose calculations should be supported by electronic devices. Structure sheets and computer base forms to have more accurate prescribing. When preparing drugs don’t be distracted. To avoid drug administration errors, use smart IV pumps with a drug database. Verify the right patient, route, dose, time and route.	To use the findings on a daily basis, the team must accept the changes, and it must not be implemented in a way where it becomes a burden to the healthcare workers. Safety culture must be developed in the team.

Author/Year/ Title	Level/ Grade	Design	Sample/Data Collection	Findings	Recommendations
Lobaugh, Martin, Schleelein, Tyler, & Litman (2017) "Medication errors in pediatric anesthesia: A report from the wake up safe quality improvement initiative"	The design does not fall under any levels of the evidence matrix		32 institutions participated in data collection over a 6-year period. Data collected were adverse events and medication errors made by anesthesia providers.	2,087 adverse events were reported, and this included 276 medication errors. The top error made was the wrong dose being administered (n=84). The second highest error was administering the wrong syringe on accident (syringe swap) (n=84).	Prefilled syringes, syringe labeling, and bar code scanning.
Nanji et al. (2016) "Evaluation of perioperative medication errors and adverse drug events."	The design does not fall under any levels of the evidence matrix	Prospective observation study	The sample size was 226. anesthesiologists (32.7%) CRNAs (22.6%) house staff (44.7%). Data to find adverse events (ADEs) or medical errors (MEs) was done through direct observation of cases or by pulling information from patients' anesthesia charts.	193 events were found. The dose being wrong (n=24,41.7%) was one of the most prevalent error types (comprised of 51 MEs (33%) that led to ADEs.). From the 153 errors, (33.3%) were significant, 99 (64.7%) serious and 3 (2.0%) life-threatening.	Technology-based interventions like dose checking and calculators can reduce drug errors and the medication's dose is wrong.

Author/Year/ Title	Level/ Grade	Design	Sample/Data Collection	Findings	Recommendations
Segal, Arevalo, Franke, & Palazuelos (2015) "Reducing dosing errors and increasing clinical efficiency in Guatemala: First report of a novel health medication dosing app in a developing country."	The design does not fall under any levels of the evidence matrix	Prospective study	98 patients were seen before using the application, and 178 patients were seen when the application was in use. 336 prescriptions were written by the residents.	Resident's efficiency increased by 20% with the average patient visit time decreasing to 1.5minutes. When using the applications, dosages calculated likely to be accurate by 40%. Improvements in accuracy were seen: (N=156) 65.7% to (N=210) 92.4%.	Using medical calculation applications can be effective in reducing errors in developing countries. When introducing a new application to healthcare providers, consideration needs to be made on how receptive and trusting they will be of a new application.
Siebert et al. (2017) "A mobile device app to reduce time to drug delivery and medication during simulated pediatric cardiopulmonary resuscitation: A randomized controlled trial"	II	Randomized-controlled trial	20 Registered Nurses randomized into either the group that used the PedAMINES application or a group that used infusion tables.	A weight-based dopamine infusion was calculated. Zero errors were made using the PedAMINES application. 8 errors were made for the first study period and 6 errors were made for the second study period using infusion tables only. Reduced in drug preparation time was found in the first study period when using PedAMINES	Using automated applications like their PedAMINES application to have faster and reliable dosage calculations.

Author/Year/ Title	Level/ Grade	Design	Sample/Data Collection	Findings	Recommendations
Zhao (2016) "Incidence of student registered nurse anesthetists in the United States who own and use smartphone as supplemental learning tools"	The design does not fall under any levels of the evidence matrix	Descriptive correlational survey study	The sample size was 465. Data collection was collected through surveys.	99.36% (n=465) of SRNAs owned a smartphone, (n=426) 91.02% had at least one anesthesia mobile application, (n=330) 73.49% used anesthesia applications that could perform medical calculations.94 .65 (n=443) used it for a drug reference.	Future studies on student's performance when using anesthesia applications, developing policies to regulate smartphone use and development of applications that will fit into a university program.

APPENDIX B - USM IRB Approval Letter

Office *of*
Research Integrity

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

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NOTICE OF INSTITUTIONAL REVIEW BOARD ACTION

The project below has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services regulations (45 CFR Part 46), and University Policy to ensure:

- The risks to subjects are minimized and reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered involving risks to subjects must be reported immediately. Problems should be reported to ORI via the Incident template on Cayuse IRB.
- The period of approval is twelve months. An application for renewal must be submitted for projects exceeding twelve months.

PROTOCOL NUMBER: IRB-19-285
PROJECT TITLE: Integrating E-Calcutron into the Anesthesia Clinical Setting to Reduce Potential Medical Calculation Errors Among Student Registered Nurse Anesthetists
SCHOOL/PROGRAM: School of LANP, Leadership & Advanced Nursing
RESEARCHER(S): Eric James, Michong Rayborn

IRB COMMITTEE ACTION: Approved
CATEGORY: Expedited

7. Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

APPENDIX C - Pre-Education Questionnaire

Pre-Education Questionnaire Form

Participation in answering the questionnaire is voluntary. All participants will remain anonymous. Please do not put your name on the questionnaire. There will be no consequences for not participating.

Do you consent to participate in this study? Yes_____   No_____

Please write not applicable (n/a) if a question doesn't apply to you.

1. Are you a first, second or third-year nurse anesthesia student?
2. Are you male or female?
3. On a scale of 1 to 4, please rate your stress level in the anesthesia clinical setting (1= no stress, 2=mild stress, 3=moderate stress, 4=severe stress).
4. Math anxiety can occur when a person is in a stressed induced situation and must do mathematical tasks (e.g., medical calculations). This can cause negative feelings like apprehension, feeling tense and can cause worrisome thoughts to occur. Have you ever experienced math anxiety when having to calculate weight-based anesthetic medications (e.g., preop anxiolytics, induction drugs, paralytics, reversal agents) in the anesthesia clinical setting?
5. Have you ever experienced math anxiety when having to calculate weight-based medications on a medical calculation test?

APPENDIX D - Post-Education Questionnaire

Post-Education Questionnaire Form

Participation in answering the questionnaire is voluntary. All participants will remain anonymous. Please do not put your name on the questionnaire. There will be no consequences for not participating.

Do you consent to participate in this study? Yes_____ No_____

Please write not applicable (n/a) if a question doesn't apply to you.

1. Do you think E-Calcutron can help SRNAs in the reduction of weight-based medical calculation errors?
2. Do you think E-Calcutron should be integrated into the anesthesia clinical setting so SRNAs can use this tool in the clinical setting?
3. Do you think E-Calcutron could decrease your stress level in clinicals?
4. Do you think E-Calcutron could help decrease your math anxiety when faced with calculating weight-based anesthesia medications in the future?

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