ASSESSING MALIGNANT HYPERTHERMIA PROTOCOL FAMILIARITY THROUGH THE INCORPORATION OF SIMULATION TRAINING IN CERTIFIED REGISTERED NURSE ANESTHETISTS

Sabrina Zaleski

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Approved by:

Dr. Vadim Korogoda, DNP, CRNA	Project Team Leader
Dr. Terry Wicks, DNP, CRNA	Project Team Member
Dr. Lori Lupe DNP, CCRN, NEA-BC	DNP Program Director

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Dedications and Acknowledgments

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Abstract

Background: Malignant hyperthermia (MH) is a rare, life-threatening crisis that occurs when genetically susceptible individuals undergo general anesthesia. Survival is time-sensitive during an MH crisis and contingent upon prompt intervention and hemodynamic stabilization. Due to the scarce occurrence of MH, perioperative staff may be underprepared and lack confidence in their ability to manage a crisis. **Purpose**: The purpose of this Doctor of Nursing Practice (DNP) project was to examine the impact of an educational presentation and MH simulation on clinician confidence and competence while managing an MH crisis at an urban tertiary care hospital. **Methods**: The Awareness to Adherence model and Johns Hopkins Evidence-Based Practice model provided context for implementation. Certified registered nurse anesthetists (CRNAs) received a PowerPoint presentation followed by an MH crisis simulation reenacted by the researchers. A mixed-methods design using a pre-and post-test survey was utilized for data collection. **Results:** Seven CRNAs participated in the intervention. A Wilcoxon signed-rank test was utilized to analyze the data from the pre-and post-test surveys. The majority of the participants reported increased clinician confidence after receiving the presentation and simulation. **Conclusion:** The results indicated that the intervention effectively increased confidence and knowledge of MH management, which helps decrease morbidity and mortality if a crisis occurs. Additionally, results indicated that simulation training is beneficial to increase confidence levels while preparing for life-threatening emergencies in a safe, controlled environment.

Key Words: malignant hyperthermia, anesthesia management, education, simulation, clinician confidence

Background and Significance

Malignant hyperthermia (MH) is an extremely rare, inherited skeletal muscle disorder that manifests as a hypermetabolic reaction triggered by exposure to volatile anesthetic agents or depolarizing neuromuscular blocking agents, such as succinylcholine (Yang et al., 2020). When left undetected and untreated, MH can progress to cardiovascular collapse resulting in death. MH predominately presents in the operating room, and may occur after administering general anesthesia, immediately after exposure to triggering agents, or during the first several hours of the postoperative period (Raizi et al., 2018). The underlying pathophysiology of MH is characterized by a defect in the ryanodine receptor resulting in the improper release of calcium by the sarcoplasmic reticulum, which plays a role in calcium storage in the body. This mismanagement of calcium by the body results in sustained muscle contraction and skeletal muscle rigidity (Gupta & Hopkins, 2017). Early symptoms of MH will present as increased heart rate, increased carbon dioxide levels, and in some cases, masseter muscle rigidity (Gupta & Hopkins, 2017). Marked hyperthermia commonly presents as a late sign. When left untreated, MH causes the breakdown of muscle tissue, leading to rhabdomyolysis and predisposes patients to other life-threatening complications such as disseminated intravascular coagulation (DIC), congestive heart failure, and may eventually lead to death (Gupta & Hopkins, 2017). Consequently, during an MH crisis, patient survival is contingent upon early recognition and prompt intervention.

According to an article by Traynor, approximately "1 in 2,000 people are genetically predisposed" to MH, and an estimated "1 in 100,000 surgical procedures in adults and 1 in 30,000 surgical procedures in children" result in an MH crisis (Traynor, 2016, p. 852). Because of this infrequency, many perioperative providers may lack competence in effectively managing an MH crisis (Cain et al., 2014).

The Malignant Hyperthermia Association of the United States (MHAUS) is a nonprofit organization whose mission is to promote MH awareness and provide recommendations for optimal MH management. MHAUS sets the standard for MH management using evidence-based practice guidelines. Additionally, MHAUS offers a 24-hour emergency hotline for assistance with identifying an MH crisis and guidance on symptom management and hemodynamic stabilization. Current MHAUS treatment recommendations advise the timely administration of dantrolene, the only FDA-approved drug available for treating MH (Traynor, 2016).

According to the American Association of Nurse Anesthetists (AANA, 2018), although anesthesia providers may be the first to recognize the onset of an MH crisis, a coordinated response involving the perioperative team is vital in the effective treatment and management of MH. MH crises occur infrequently but are considered time-sensitive, life-threatening medical emergencies. An active MH crisis requires tremendous resources and coordination of the perioperative team to achieve hemodynamic stability and minimize mortality in the operating room. Therefore, continuing education is necessary for medical professionals to safely respond to and manage an MH crisis. By disseminating educational materials detailing the MH protocol, the operating room team can better enact a management system that is both reliable and proficient (Kollmann-Camaiora et al., 2017). Proper preparation and reinforced training play fundamental roles in ensuring the safety and survival of MH susceptible patients while undergoing general anesthesia.

Purpose

This Doctor of Nursing Practice (DNP) project evaluated the current training style of MH management and assessed clinician confidence in managing an MH crisis at an urban tertiary healthcare facility. The purpose was to determine both the effectiveness of an educational presentation and simulation (Appendix C) on MH detection and treatment in the operating room and their effect on increasing clinician confidence. To assess overall clinician confidence concerning MH crisis management, pre-and post-intervention assessments (Appendix A and B) were administered to the operating room staff, specifically certified registered nurse anesthetists (CRNAs). This quality improvement project met three objectives. First, the current MH protocol and the MHAUS treatment recommendations for MH management practice-based guidelines were compared. Second, the implementation of the healthcare facility's MH policy was evaluated. Finally, after providing an educational presentation and simulation (Appendix C), the healthcare facility's MH policy and implementation were assessed to determine the effects on clinician confidence and efficacy of any change to practice.

Literature Review

A review of the literature was completed for the years 2015 to 2021. The databases searched included CINAHL, MEDLINE, and PubMed. The literature review search used the following keywords: *malignant hyperthermia, anesthesia management, education, simulation, and clinician confidence*. The analysis included peer-reviewed, prospective cohort studies, retrospective cohort studies, cross-sectional studies, and government organizations' reports. Non-peer-reviewed articles, commentaries, and other nonrelevant studies were excluded from the literature analysis. A total of 15 articles were reviewed, focusing on education, simulation, and overall clinician confidence in the operating room regarding MH management.

Malignant Hyperthermia

MH is a life-threatening medical emergency characterized by a hypermetabolic syndrome resulting from a rare inherited skeletal muscle condition. A fulminant MH crisis occurs from exposure to volatile anesthetic agents or depolarizing neuromuscular blocking medications (Kollmann-Camaiora et al., 2016). Dr. Michael Denborough and his colleagues first described MH in 1961 after investigating a patient whose family members died after developing uncontrolled hyperthermia while undergoing general anesthesia with ether (MHAUS, n.d.). At the time, the mortality rate for MH was over 70% (MHAUS, n.d.). Providers noted that each case presented with persistent high body temperature and referred to this syndrome as 'malignant hyperpyrexia' or 'malignant hyperthermia.' Dr. Denborough's investigation revealed that MH was a genetic autosomal dominant trait (MHAUS, n.d.).

MH has the most significant potential to present during routine general anesthesia administration in the operating room. MH is rapid in onset, presents with a high body temperature of up to 107 degrees Fahrenheit, muscle rigidity, system-wide organ failure, and can ultimately lead to death. The most critical determinant of preventing mortality and morbidity in this patient population is early identification of MH, timely administration of dantrolene, and implementation of appropriate supportive measures (Gupta & Hopkins, 2017).

While MH is most commonly observed in the operating room, its occurrence is not limited to the operating room setting. Recrudescence, also known as the recurrence of MH symptoms, is observed in 20% of patients in the postoperative period, with 80% occurring within 16 hours of initial exposure to the triggering agent (Cieniewicz et al., 2019). Appropriate preparation of healthcare institutions providing medical services, including educated anesthesia providers, intensivists, and postanesthesia care unit (PACU) nurses, establishes a significant reduction in MH mortality. Continuous MH education amongst these healthcare providers is necessary despite the scarcity of MH episodes. Increased awareness and education ensure patient safety and promote better patient outcomes through early recognition and prompt intervention (Cieniewicz et al., 2019).

The mortality rate of MH is approximately 1.4% when treated appropriately, but mortality can be as high as 80% when left untreated (Rosenberg et al., 2015). Other significant contributors of increased MH mortality include misdiagnosis of various syndromes that possess similar symptoms, such as thyrotoxicosis, pheochromocytoma, neuroleptic malignant syndrome, serotonin syndrome, and cocaine or ecstasy intoxication (Riazi et al., 2018). During a suspected MH crisis, the MHAUS hotline serves as a resource to help determine the proper diagnosis by eliminating potential syndromes that share similar symptoms. In the first decade of the 21st century, mortality from MH increased by 14% (Riazi et al., 2018). This increased mortality was assumed to be associated with increased usage of MH-triggering agents outside of conventional hospital settings as anesthetic administration in outpatient settings increased, confirming the importance of continued education for anesthesia providers in managing an MH crisis.

With the high mortality risk associated with delayed treatment, continuing education for anesthesia providers and operating room staff is essential to ensure timely identification and intervention during a crisis. Healthcare providers require routine educational training to successfully recognize and respond to MH due to this disorder’s time-sensitive nature, regardless of the staff's familiarity with the condition (Traynor, 2016). The clinician's knowledge of the pathophysiology, complications, and treatment of MH is vital to treating an MH crisis and preventing mortality; therefore, education must emphasize the disease process, recognition, treatment, and location of emergency supplies (Sousa et al., 2015). It is fundamental to have an ongoing MH readiness procedure to encompass current MHAUS guidelines and recommendations to guarantee best practice and ensure patient safety.

Simulation Training

Baseline knowledge improves with increased repetition of simulation sessions, facilitating the value of utilizing repetition to reinforce learning (Boling & Hardin-Pierce, 2015). Repetition helps increase confidence and transition skills from the conscious to the subconscious. Incorporating simulation training in a dedicated environment offers realistic experiences where learners can practice responses to clinical scenarios, debrief, and evaluate team and individual performances in a safe environment. MH simulation training promotes role clarity, improved anticipatory response, and overall team cohesion and interaction (Cain et al., 2014). Simulation enables providers to develop increased knowledge and confidence related to roles and responsibilities in an actual MH crisis (Cain et al., 2014).

The Joint Commission (2005) recommends enhancing teamwork and collaboration with simulation training as an adjunct to traditional education methods. Simulation-based education provides rapid instruction, evaluation, and reflection capabilities of the new educational information presented (Wunder, 2016). Simulation training can incorporate anesthesia administration during simple cases or various emergency scenarios that can arise within an operating room setting. The addition of simulation training into traditional education allows the participants to practice crisis scenarios in a risk-free environment where no harm will come to patients during the learning process (Boling & Hardin-Pierce, 2015). The chance of encountering an acute, critical event during clinical anesthesia training is scarce, and simulation training allows participants the opportunity to experience such an event in a lower stakes environment (Wunder, 2016). Simulation training serves as a valuable tool in clinical education and workplace safety as it enhances team and individual skills before encountering patients in the clinical setting.

Simulation improves critical thinking skills and clinical decision-making to a greater degree than conventional education alone (Boling & Hardin-Pierce, 2015). The controlled environment facilitates the development of increased comfort while managing situations that infrequently arise in practice but where a high level of performance is crucial for patient safety and well-being (Boling & Hardin-Pierce, 2015). Simulation is ideal for low-frequency, high-risk scenarios because it provides the opportunity to experience acute clinical situations without risk to patients or learners (La Cerra et al., 2019).

Sousa et al. (2015) conducted a quasi-experimental study with operating room nurses and surgical techs to evaluate an educational intervention's effectiveness on MH. The educational intervention included a PowerPoint, lecture, and quick simulation of an MH crisis where participants could choose their roles. The study showed a statistically significant difference after the educational intervention and improved knowledge growth compared to previous exams. The authors concluded the educational intervention was beneficial, as evidenced by the operating room staff's enhanced knowledge and improved patient safety.

Crisis Management for Anesthesia Providers

The AANA recommends that healthcare facilities conduct MH crisis team training with the operating room, PACU, and intensive care unit (ICU) healthcare teams. This training serves as an annual competency to prepare healthcare providers to recognize, respond to, and treat an MH crisis. The establishment of policies and protocols for competency training, mock drills, patient screening, anesthetic selection, machine preparation, emergency response, MH treatment, patient transfer, patient counseling, and continued quality improvement enhance patient safety and MH awareness (AANA, 2017).

Intraoperative resuscitation and crisis management necessitate the collaboration of a high-functioning interdisciplinary perioperative team (Gao et al., 2021). Utilizing simulation-based education for crisis management enhances patient safety by providing the ability to master crisis management and team-building skills in a safe, controlled environment (Jenkins et al., 2017). Necessary skills encompass technical and functional expertise, problem-solving and decision-making, and interpersonal and team-based competencies. The repetitive nature of crisis management simulation training reinforces and enhances these skills, strengthening clinicians' critical thinking skills and overall confidence (Jenkins et al., 2017).

Gao et al. (2021) examined the impact of operating room crisis management (ORCM) simulation on pre-clinical anesthesia undergraduate students' outcomes. The study's purpose was to determine whether ORCM would serve as a beneficial training tool to incorporate into clinical education. The training outcomes sought to evaluate the understanding of the subject matter, crisis management, non-technical skills, and user experience. The results demonstrated that the student's performance significantly improved after completing ORCM, as indicated by higher scores in all tests, clinical crisis management, and non-technical skills.

Wunder (2016) examined the effect of implementing an educational intervention on first-year anesthesia students' non-technical skills during an anesthesia crisis simulation. The non-technical skills assessed included task management, teamwork, situational awareness, and decision-making. These non-technical skills complemented the students' technical skills and contributed to efficient task performance. A deficiency in non-technical skills often causes human error. Participants were given pre-and post-educational intervention tests. The mean post-test scores showed significant improvement, indicating that instruction is effective in acquiring non-technical skills but more effective when utilized with simulation training. Therefore, emphasizing the instruction and evaluation of non-technical skill performance ensures safe patient care. Simulation-based education is beneficial for evaluating technical and non-technical skills and enables nurse anesthetists to effectively collaborate with other healthcare professionals and promote a climate of patient safety.

Mejia et al. (2018) conducted a randomized, single-blind study with first-year anesthesia residents. This study distinguished between high-fidelity simulation training and the effects of a computer-based case study regarding MH skills acquisition. The study results showed that the MH high-fidelity simulation surpassed the computer-based case study to improve the technical training and skills of MH crisis management. While computer training is frequently utilized in the workplace, incorporating simulation would improve MH responses, potentially decreasing morbidity and mortality in this patient population.

Clinician Confidence

Confidence is often used interchangeably with the term self-efficacy. According to an article by Grundy discussing how to measure confidence in clinical nursing practice, self-efficacy is defined as the "belief that one can successfully execute a specific activity" (Grundy, 1993, p. 6). There are four major contributors to self-efficacy: personal experience, vicarious experience, verbal persuasion, and the individual's physiological state. Alterations in any of these factors will influence overall confidence with individual performance. Clinician confidence is essential in implementing and managing patient care during training scenarios (Grundy, 1993).

Boling and Hardin-Pierce (2015) conducted an integrative review of current research detailing high-fidelity simulation training involving confidence levels of critical care providers. The participants' self-assessment was the most common form of measurement used to evaluate confidence. The review concluded that simulation training and continuing education enhance clinical knowledge and decision-making while reinforcing provider confidence during critical situations.

Multiple studies evaluated the implementation of mock training programs to enhance clinician confidence and improve team performance in critical situations (Rice et al., 2016). Simulation training programs consistently demonstrate increased self-confidence and improved teamwork attitudes. Herbers and Heaser (2016) implemented a mock code program that showed significant improvement in overall nursing performance and response times to medical emergencies. The nursing staff reported improved confidence levels, critical thinking ability, and teamwork, demonstrating the benefit of incorporating simulation training to facilitate confidence and competence in managing high-stress acuity crises.

The review of the literature demonstrates support for simulation in crisis management training. The benefits of incorporating simulation include improved clinician confidence, competence, critical thinking, anticipatory response, role clarity while enforcing interdisciplinary team collaboration, interaction, and communication. These traits facilitate prompt and effective crisis management and optimize patient survival.

Gaps

Among current literature, few publications compare the effect of MH simulation training to traditional education methods or its impact on overall clinical performance and patient survival outcomes. Few studies regarding anesthesia provider responses to MH crises, specifically clinician knowledge and confidence in treating a crisis, have been published (Sousa et al., 2015). Most of the available studies involve anesthesia student responses to MH crises, leaving the response of certified practitioners relatively unstudied. Current literature examines simulation studies of common cardio-circulatory and respiratory scenarios that arise during clinical training and practice. However, more studies of low frequency, high-risk scenario simulation training and its effect on clinician confidence in crisis management and patient outcomes are needed. Additionally, there is also a need for more studies that evaluate the confidence of certified anesthesia providers during such crisis scenarios.

Theoretical Framework

The theoretical approach for this DNP project is the Awareness to Adherence model. The Awareness to Adherence model helps transition from perennial guidelines to implementing up-to-date, evidence-based practice recommendations and standards into practice (Fleming et al., 2020). The model provides four subsequent steps that must take place for the application of new guidelines to be favorable. First, practitioners must be made aware of new evidence and practice-based guidelines. Second, compliance with the employment of these guidelines into practice is imperative. Third, acceptance of the new practices must integrate after providing an appropriate education. Finally, adherence to the latest evidence-based guidelines must be consistently implemented in everyday practice.

This DNP project evaluated the current MH management protocol on training style and clinician confidence in managing an MH crisis at an urban tertiary care hospital. The project intervention included an educational presentation and simulation of a mock MH crisis (Appendix C). This education was designed to enhance MH recognition strategies to increase clinician familiarity and proficiency. Pre- and post-intervention surveys (Appendix A and B) assessed data regarding the CRNAs comfort and confidence in MH management.

Incorporating a step-wise preface and new material cultivation requires effectively implementing educational presentations and simulations into practice. The administration of a survey/questionnaire (Appendix A and B) examined prior expertise and knowledge acquired after receiving the MH educational presentation and simulation (Appendix C). Comparing the data gathered from the surveys (Appendix A and B) determined the overall effectiveness of the MH educational presentation and simulation (Appendix C) on current practice strategies and alterations in clinician confidence in managing this patient population.

Methods

Project Design

The project design utilized a mixed-methods quality improvement approach. A pre-and post-test (Appendix A and B) was designed to evaluate the current MH protocol at an urban tertiary care hospital and the effectiveness of an educational intervention comprised of a PowerPoint presentation and MH simulation (Appendix C) to enhance confidence. The principal investigator (PI) was a student registered nurse anesthetist (SRNA). The project's objective was to understand the effects of a simulation (Appendix C) on MH recognition and crisis management to enhance clinician confidence in CRNAs. Data was collected using paper pre-and post-intervention surveys (Appendix A and B) to address the following question: Does the incorporation of simulation training on MH improve CRNAs' knowledge and confidence in treating an MH crisis? The project participants consisted of CRNAs employed at the designated urban tertiary care hospital. The simulation included a scripted MH crisis (Appendix C) reenacted by the researchers utilizing updated MHAUS protocols and proper emergency equipment. Before implementation, the scripted MH crisis simulation (Appendix C) was reviewed for content accuracy by the anesthesia department's MH educator and the clinical coordinator. Pre-and post-test surveys (Appendix A and B) were administered to examine overall clinician confidence and competence concerning MH crisis management.

This project had three stages of implementation: (1) development of the educational PowerPoint presentation and MH crisis management simulation script (Appendix C), (2) creation of the pre-and post-test paper surveys (Appendix A and B), and (3) evaluation of the educational presentation and MH simulation (Appendix C) via a pre-and post-test survey (Appendix A and B) created by the PI. Since this was not a controlled study, participants were not divided into intervention and control groups; this gave the participants an equal opportunity to learn through the educational PowerPoint presentation and simulation (Appendix C).

Evidence-Based Practice Model

The Johns Hopkins Evidence-Based Practice (EBP) model (Appendix D) was utilized to help guide the development and implementation of this DNP project. This EBP model strives to facilitate the swift and efficient implementation of current evidence-based research into patient care. The Johns Hopkins EBP model includes three fundamental steps: practice question, evidence, and translation (Johns Hopkins Medicine, 2019). This three-step process details developing a practice question, using best practice evidence to answer the question, and translating the evidence into current practice.

The first step of this model requires the development of a practice question of interest by identifying the problem, establishing a research team, and delegating leadership roles. This project examines MH training and the effects of simulation education on clinician confidence. This DNP student, co-investigator, and the University of North Carolina at Greensboro (UNCG) faculty advisor comprised the project research team. The second step involved conducting a literature review of current evidence and collecting data concerning interest populations. The third and final step included collecting evidence and transforming it into an achievable clinical action plan. The educational PowerPoint presentation and MH crisis simulation (Appendix C) incorporated evidence-based findings from current literature to evaluate their effect on overall clinical confidence in managing an MH crisis.

Permissions

Written approval to conduct this DNP project at an urban tertiary care hospital was obtained from the assistant chief CRNA and clinical coordinator. The anesthesia department's MH educator served as the advisor and clinical point of contact for implementing this project. Institutional Review Board (IRB) approval was obtained by UNCG and the hospital before implementing the educational presentation and MH simulation training (Appendix C).

Sample and Setting

The educational presentation and MH simulation (Appendix C) were conducted at an urban tertiary care facility containing 11 operating rooms. Convenience sampling was used. The target population consisted of CRNAs employed at the designated healthcare facility. The educational PowerPoint presentation and MH simulation training (Appendix C) were conducted during a morning and afternoon staff meeting. Before implementing the educational presentation and simulation (Appendix C), potential participants were given a recruitment speech (Appendix E) during both morning and afternoon staff meetings. The recruitment speech (Appendix E) included the purpose of the DNP project, a description of the educational presentation and simulation (Appendix C), and information regarding the pre-and post-test surveys (Appendix A and B). An information sheet was then distributed to the potential participants, which detailed the rights of the participants, any potential risks associated, and the researcher's contact information for additional questions and concerns. Voluntary participation in the project was emphasized, and potential participants were informed that there was no penalty for not participating.

There were 27 eligible project participants at this hospital, but only 9 CRNAs participated on the day of the training. Non-anesthesia providers and anesthesia providers employed outside this facility were excluded from participation. Participation in this quality improvement project was strictly voluntary, and participants were able to withdraw participation at any time without penalty.

Due to the predominance of MH presenting in the operating room, this quality improvement project was conducted in an empty operating room suite. Clear communication with the anesthesia and operating room nursing staff was conducted to ensure this training did not conflict with the operating room schedule. Conducting the simulation in the operating room enhanced the simulation's efficacy by utilizing the proper personnel and emergency equipment. The anesthesia department's MH educator collaborated with the research team to implement this educational presentation and MH simulation (Appendix C).

Implementation Plan

The training was conducted during a morning staff meeting and again during an afternoon staff meeting for the oncoming evening shift. An educational presentation and MH simulation (Appendix C) on symptom recognition and crisis management were conducted in an empty operating room suite. CRNAs were informed and recruited for the MH educational presentation and simulation (Appendix C) training during morning and afternoon staff meetings through a recruitment speech (Appendix E). Sufficient time was given to allow subjects to consider participation and ask any necessary questions. Before completing the pre-test survey (Appendix A), an information sheet was distributed to the CRNAs (Appendix A) detailing the rights of the participants.

After completing the pre-test survey (Appendix A), participants placed completed surveys in envelopes and returned them to the researchers. Participants then observed an educational presentation followed by an MH crisis simulation (Appendix C). The educational presentation consisted of a PowerPoint discussing MH pathophysiology, differentiation of early and late signs and symptoms, perioperative stabilization, and postoperative management. Facility-specific MH protocols and policies were also discussed during the presentation. The educational presentation was followed by a scripted simulation (Appendix C) of an active MH crisis reenacted by the researchers. To establish and clarify role responsibilities, one researcher portrayed an operating room nurse, and the other took on the role of a CRNA. The simulation (Appendix C) encompassed a patient care scenario from beginning to end. The scenario highlighted the appearance of early MH symptoms while undergoing a routine procedure under general anesthesia and the actions required for intraoperative stabilization of this patient population.

Supplemental materials were created to portray vital sign changes during the scenario to symbolize alterations in patient hemodynamic stability throughout a real MH crisis. These additional materials assisted in facilitating visual confirmation regarding successful and unsuccessful interventions during the simulation (Appendix C). The facility's MH cart and related supplies were utilized for the simulation training. The simulation (Appendix C) incorporated performing as many hands-on tasks as possible. To best simulate an actual MH crisis, these tasks included retrieving buckets of ice, the MH cart, and the code cart from their designated locations, calling overhead for additional personnel, and acting out each vital intervention as the simulation progressed. Requiring participants to leave the operating room to retrieve supplies instead of having them readily available was explicitly included in the simulation (Appendix C) to emphasize supply locations and the time it takes to obtain them during an emergency. The researchers went through a step-by-step breakdown of what a proper emergency response should entail, from early symptom detection to postoperative disposition. During the patient scenario, the MH cart was opened to allow the utilization of proper rescue supplies. At the end of the simulation (Appendix C), time was dedicated to familiarizing the CRNAs with the MH cart's contents and storage information.

A pre-test survey (Appendix A) developed by the PI was distributed before the educational training to establish a baseline of knowledge and clinician confidence. To assess for changes in practice and to measure knowledge retention, a post-test survey (Appendix B) was administered four weeks after the project implementation. The post-test survey (Appendix B) was developed by the PI and designed to collect data regarding clinician confidence and competence of CRNAs in managing an MH crisis after implementing the educational training session and simulation (Appendix C). The pre-and post-test surveys (Appendix A and B) were placed in unmarked envelopes upon completion before being returned to the researcher.

Data Collection

Procedures

Envelopes containing the information sheet, pre-test survey (Appendix A), and the MH simulation script (Appendix C) were distributed to potential participants at the beginning of morning and afternoon staff meetings. Implied consent was obtained before the educational PowerPoint presentation and simulation (Appendix C) by completing the pre-test survey (Appendix A). The completed pre-test surveys (Appendix A) were placed back into the envelopes and returned to the researcher. These results were used to establish a baseline of knowledge and clinician confidence. The participants that chose not to participate returned blank questionnaires to the researcher in the envelopes provided, protecting the anonymity of the non-participants. The researcher was unaware of which CRNAs chose not to participate in the intervention.

Post-test surveys (Appendix B) were distributed four weeks after the simulation training to assess practice changes and knowledge retention. The data collection period lasted for one week. The researcher provided envelopes containing the post-test surveys (Appendix B) to assess changes in clinician confidence and practice change. The envelopes containing the post-test surveys (Appendix B) were placed in the anesthesia breakroom for CRNAs who were present during the MH educational presentation and simulation (Appendix C) to complete. The completed post-test surveys (Appendix B) were placed back in the envelopes and returned to the researcher.

No personal identifying information was collected during this quality improvement project. A unique identifier was used to link the pre-and post-test surveys (Appendix A and B). The anonymous paper surveys (Appendix A and B) were collected immediately before and four weeks after the MH simulation training (Appendix C). The pre-and post-test surveys (Appendix A and B) were used to determine the intervention's effectiveness on clinician confidence and competence in MH management.

Instruments

The pre-test survey (Appendix A) developed by the PI was administered before the educational PowerPoint presentation. The pre-test survey (Appendix A) included Likert-scale questions to assess baseline knowledge and clinician confidence. Questions included confidence-related questions evaluating cardiac and airway emergency management, followed by pointed questions concerning MH management, role responsibility, symptom recognition, and dantrolene administration. Lastly, two questions were dedicated to assessing the value of an MH simulation (Appendix C), comparing it to traditional educational methods.

The post-test survey (Appendix B) developed by the PI was administered four weeks after the presentation and simulation (Appendix C). The post-test survey (Appendix B) collected clinician confidence and training satisfaction data to determine whether the participant CRNAs perceived a need for an MH demonstration/simulation. The post-test survey (Appendix B) included Likert-scale questions to assess clinician confidence and competence in managing an MH crisis. The last question on the post-test survey (Appendix B) evaluated the presence of potential barriers to MH management at the facility.

Data Analysis

Nine CRNAs completed the pre-test survey (Appendix A), but only seven CRNAs (78%) completed the post-test survey (Appendix B). Therefore, two of the pre-test surveys (Appendix A) were discarded as erroneous data from the analysis. Data from the completed seven linked pre-and post-test surveys (Appendix A and B) were entered into Microsoft Excel software version 16 and analyzed using descriptive statistics. Using a Wilcoxon signed-rank test, the pre- and post-test survey (Appendix A and B) results were compared to evaluate whether CRNAs exhibited increased confidence in MH management after the simulation (Appendix C) training. A Wilcoxon signed-rank test compares two paired groups to determine if the pairs are different in a statistically significant matter. It does not assume that the data is normally distributed. A Wilcoxon sign-ranked test was selected due to the study having a small sample size. An alpha value of 0.05 and a critical value of 2 were used for a two-tailed test. The test statistic, or 'W,' was determined. If the obtained value was less than or equal to the critical value of the data set, the difference between the data is considered statistically significant.

A qualitative content analysis was implemented to analyze the data from the pre-and post-test surveys (Appendix A and B) for commonalities between responses given by CRNAs before and after the educational intervention and simulation (Appendix C) (Hsieh & Shannon, 2005). Correctness and knowledge attainment were assessed through the content analysis to determine the success of the PowerPoint presentation and MH simulation (Appendix C) of increasing the knowledge and confidence of CRNAs regarding the recognition and management of an MH crisis. The student PI developed the pre-and post-test surveys (Appendix A and B); therefore, there is no reliability or validity score.

Budget, Time, and Resources

No financial resources were required to implement this DNP project. This quality improvement project required one hour to implement. Five minutes were dedicated to the recruitment speech (Appendix E), information sheet, and any potential questions prior to the PowerPoint presentation. Ten minutes were devoted to completing the pre-test survey (Appendix A). The PowerPoint presentation and MH simulation (Appendix C) comprised thirty minutes. Lastly, ten minutes were dedicated to going through the MH cart and familiarizing anesthesia staff with its contents at the end of the simulation (Appendix C). The post-test surveys (Appendix B) required ten minutes to complete during the data collection phase.

Results

Prior to receiving the MH presentation and simulation (Appendix C), CRNAs were asked to rate their confidence level in their roles and responsibilities, MH-related technical skills, symptom recognition, ability to manage an MH crisis, and their opinions of simulation education on a scale of 1 to 5, with 1 being ‘strongly disagree’ and 5 being ‘strongly agree.’ Participants were asked to rate their confidence level using the same rated scale four weeks after receiving the presentation and simulation (Appendix C) to determine any changes in clinician confidence.

The survey’s (Appendix A and B) questions were organized into five categories: confidence, MH management, role and responsibility, symptom recognition, and simulation-related questions. The confidence-related questions consisted of questions #1, #2, #3, and #4.

The MH management questions included questions #5, #6, #7, and #11. Roles and responsibilities were evaluated by questions #4 and #9. The symptom recognition question was evaluated by #8. The simulation-related questions comprised #10 and #12.

Questions #4 and #9 addressed clinician confidence in role clarity and responsibilities during an MH crisis. These two questions demonstrated an increase in scores when comparing the pre-and post-test survey (Appendix A and B) results. The post-test (Appendix B) demonstrated that 85.7% of CRNAs reported increased confidence in their role during the management in an MH crisis, whereas 71.4% of CRNAs reported increased knowledge of their role and responsibilities in an MH crisis.

When closely examining the confidence-related questions, the pre-test (Appendix A) revealed that 14.3% of CRNAs did not feel confident in their skills during direct patient care crises, whereas 42.9% of CRNAs did not feel confident in their role during the management of an MH crisis. The post-test (Appendix B) revealed that 28.6% of CRNAs reported an increase in confidence in their skills during direct patient care emergencies, whereas 85.7% of CRNAs reported increased confidence in their role during an MH crisis. With cardiac arrests and airway emergencies, 100% of CRNAs reported feeling confident in their roles on the pre-and post-test surveys (Appendix A and B).

Examining the MH management and related skills questions, 71.4% of CRNAs reported feeling confident in their knowledge of initial interventions of an MH crisis. After the intervention, 100% of CRNAs reported feeling confident in their knowledge of the initial interventions of MH management. When asked about the ability to reconstitute and dose dantrolene, 42.9% of CRNAs reported a lack of confidence in performing these skills. After the intervention, 100% of CRNAs reported feeling confident reconstituting and dosing dantrolene during an MH crisis. All surveyed CRNAs were familiar with the location of the MH cart prior to the intervention, these results remained unchanged on the post-test (Appendix B).

Question #8 examined MH symptom recognition;14.3% of CRNAs reported not feeling very confident in their ability to recognize MH symptoms prior to the presentation and simulation (Appendix C). In contrast, 85.7% of CRNAs reported already feeling confident by answering ‘agree’ on the pre-test (Appendix A). After the intervention, 100% of the CRNAs reported increased confidence by selecting ‘strongly agree’ on the post-test (Appendix B).

The post-test survey (Appendix B) results demonstrated that the CRNAs who participated in this DNP project reported increased confidence regarding role clarity, MH crisis management, and associated technical kills after the simulation (Appendix C) training. Compared to more traditional education methods such as PowerPoints and online educational modules, all seven participants (100%) believed that an MH simulation was a better delivery method and would increase clinician confidence. However, according to the Wilcoxon signed-rank test, no statistical significance was established for questions #8 and #11 which indicates that participants' confidence in MH symptom recognition or knowledge regarding the location of the MH cart did not show a statistically significant increase after the project intervention.

Discussion

After the simulation (Appendix C), all CRNAs reported increased confidence, knowledge of roles and responsibilities, and comfort with their performance of MH-related technical skills. To be competent, clinicians must be knowledgeable and confident in their ability to make critical decisions and perform necessary clinical actions (Kim et al., 2020).

Though clinical confidence does not replace technical knowledge and skills, research indicates that increased confidence supports the development of clinical competence through a combination of learning techniques such as traditional oral instruction and clinical simulation (Owens & Keller, 2018). Studies show that clinical confidence is strongly associated with training and education, and providers who predominantly receive oral or written education generally report lower levels of confidence (Kim et al., 2020). In comparison, providers who engage in clinical simulation and role-play training reported significantly higher levels of confidence (Kim et al., 2020). Furthermore, clinician confidence is associated with high patient volume, which, in the case of rare disorders such as MH, educational training can be supplemented with high fidelity simulations. Training, familiarization, and clinician confidence are essential components to the overall improvement of healthcare and patient outcomes.

Confidence is one of the most influential factors affecting clinical performance (Owens & Keller, 2018). Increasing confidence has been shown to improve not only clinical performance but also enhance overall patient care and positively influence patient outcomes. Clinical confidence in healthcare is essential because it results in increased accuracy of initial diagnosis, early intervention and detection of deterioration, reduced care variation, and produces more predictable patient outcomes (Philips, 2021). Accurate diagnosis and prompt intervention significantly improve patient management and outcomes, especially in time-sensitive emergencies. Clinical confidence has an even more significant impact on healthcare teams by providing highly skilled care to patients. More confident providers tend to deliver higher quality care in emergent situations such as an MH crisis, where patient survival is contingent upon early recognition and intervention; losing time due to uncertainty and low confidence will likely result in adverse patient outcomes (Kim et al., 2020).

Providers with clinical confidence allow healthcare teams to perform at the top of their skill set to deliver highly skilled and safe patient care. Clinicians who lack confidence may have difficulty rapidly recognizing early MH symptoms and being decisive enough to intervene promptly. Confidence allows clinicians to effectively cope with challenging tasks by improving resiliency and decreasing stress (Owens & Keller, 2018). This allows them to adapt to challenges to maintain high-quality care. Increasing the confidence of individual clinicians has been shown to improve the overall confidence and performance of the clinical care team (Philips, 2021). Likewise, individual team members' low confidence and performance can have long-term effects on the rest of the care team. Without high levels of reported confidence, providers are more likely to experience burnout which rapidly deteriorates the quality of their care (Philips, 2021). Both patients and clinicians suffer when clinicians lack confidence in their abilities, ultimately affecting the quality of care provided.

When asked about their perceptions of simulation training, the majority of the CRNAs reported simulation as a superior educational tool compared to more traditional methods. This was evident when examining the simulation-related questions on the pre-test survey (Appendix A). The participants also recognized its benefit when incorporated into MH education and crisis management training to provide the opportunity for skill development, establishing teamwork and interdisciplinary communication, and fostering problem-solving strategies. In the literature, simulation has been shown to decrease medical errors, thereby improving patient safety (Elder, 2017). When compared to the post-test (Appendix B), these simulation-related scores increased to demonstrate the positive correlation between simulation training and increased education. These results demonstrate the effectiveness and desire for advanced practitioners to have simulation training incorporated into their education. In the future, more education should focus on simulation training in conjunction with traditional educational methods. Through repetition of clinical MH scenarios, confidence, efficiency, and experience improve, leading to a cohesive and organized team response (Mejia et al., 2018).

The last question on the post-test survey (Appendix B) inquired about existing barriers to implementing evidence-based changes to MH management and treatment at the designated facility. Several CRNAs agreed that barriers precluded their ability to provide safe and effective treatment in this patient population. Perceived barriers present at this facility included requiring committee approval before making changes to MH education, policy and procedures, making it difficult and time-consuming to adjust and improve existing content.

The most significant obstacle to MH treatment present at this facility was the lack of anesthesia staff oversight of the MH cart supplies. The facility's pharmacy staff oversees the provision of MH cart supplies and determines how the cart is stocked irrespective of current MHAUS guidelines. Necessary laboratory tubes, syringes, foley catheters, and other essential supplies were not stocked in the MH cart, and therefore, were unavailable during the simulation (Appendix C). The lack of vital emergency supplies made it challenging to portray the proper response scenario during the simulation (Appendix C). Participants spent additional time locating and obtaining these supplies, which interfered with overall response time and quality of patient care. Recommendations were made to the facility to reorganize the MH cart based on MHAUS guidelines. Incorporating these essential supplies in their carts will decrease response time and increase their chances of successfully managing an MH crisis. Recommendations were also made to incorporate education on the MH cart contents and location into the required annual MH educational training.

Limitations

The primary limitations of this project are the sample size and the number of responses received during the data collection period. Targeting the facility's CRNAs limited the number of possible participants. Some CRNAs were not available during the day of the presentation and simulation (Appendix C), which further limited the sample size. Lastly, not all CRNAs who completed a pre-test survey (Appendix A) also completed a post-test survey (Appendix B) during the data collection period, which further reduced the sample size of this project.

Using a convenience sample led to a selection bias, which indicates that those who elected to participate may share characteristics that make them different from those who chose not to. Because of the selection bias, proper randomization was not achieved, failing to ensure the sample obtained was representative of the population the project intended to analyze. The data used was only collected at one facility and focused on an educational intervention and simulation (Appendix C) training for a case scenario conducted for only one day.

During the simulation (Appendix C), it was discovered that the MH cart was missing several essential supplies deemed fundamental for MH management by MHAUS guidelines. The lack of vital emergency supplies made it challenging to portray the proper response scenario during the simulation (Appendix C). However, this further demonstrated the need for crisis simulation training with proper equipment and supplies available to enhance user familiarity and identify gaps.

Recommendations for Future Study

This quality improvement project can be replicated in other healthcare facilities with their perioperative teams to increase the results' reliability. Conducting multiple educational and simulation trainings at the same facility would provide a larger sample size. Utilizing an online survey tool or digital version of the pre-and post-test surveys (Appendix A and B) may facilitate participant compliance and improve post-test survey (Appendix B) completion by making them more easily accessible. Future implications include improving data collection and developing

MH simulations where the perioperative staff could participate instead of watching a simulation re-enactment. Incorporating an interactive simulation would further enhance clinician confidence in MH crisis management.

Further research is needed to explore this educational tool to determine its impact on patient outcomes and should focus on three areas. First, anesthesia providers should remain up-to-date with current MHAUS guidelines and recommendations. Second, the perioperative team should remain aware of the facility's MH cart location and contents. Finally, mock simulations should incorporate the entire perioperative team, include high-fidelity hands-on training, and go through all the crisis management steps to ensure safe and optimal patient care.

Relevance and Recommendations for Clinical Practice

Increased knowledge and clinician confidence from an MH presentation and simulation (Appendix C) could potentially decrease morbidity and mortality in the event an MH crisis occurs. The long-term impact is that the MH presentation and simulation (Appendix C) will provide annual education to healthcare providers in the perioperative setting, where patients are most frequently exposed to MH triggering agents. Incorporating simulations alongside mandatory MH training will facilitate knowledge and skill retention among healthcare providers. Including current MHAUS guidelines and recommendations into simulation training will further ensure patient care remains within current best practice standards. Furthermore, reviewing facility policies and MH crisis procedures may reveal inefficiencies and prevent adverse patient outcomes. This project can be replicated at any facility requiring MH recognition and management education.

Conclusion

The aim of this project was to examine the impact of an educational presentation and MH simulation (Appendix C) on CRNA knowledge and confidence while managing an MH crisis at an urban tertiary care hospital. This DNP project also evaluated the benefits of incorporating simulation training to meet the educational needs of CRNAs.

The project met its aims by conducting a quality improvement project focused on increasing CRNA confidence in MH management through simulation training. Pre-test surveys (Appendix A) were administered to obtain baseline knowledge and confidence before conducting an educational presentation that detailed MH pathophysiology, symptom recognition, and treatment management. Following the presentation, participants took part in an MH crisis simulation (Appendix C). The simulation (Appendix C) scenario emphasized the appearance of early MH symptoms under general anesthesia and the proper response required for intraoperative stabilization of the target patient population. A post-test survey (Appendix B) was administered four weeks later to assess changes in clinician confidence, attitudes towards simulation training, and barriers to MH management at the facility.

The results of this project demonstrate that simulation training can positively impact clinician confidence. Following the simulation training (Appendix C), all participating CRNAs reported increased confidence levels. Additionally, CRNAs reported increased clarity and knowledge of their roles and responsibilities along with increased confidence in their ability to perform MH-related technical skills, such as reconstituting and dosing dantrolene. Throughout the project, participants expressed a desire to continue incorporating simulation into their education. This project also identified gaps in the facility's current MH management policies and offered recommendations to ensure its protocols align with MHAUS guidelines.

Continuing education of perioperative and anesthesia staff is an integral part of emergency preparedness. The use of simulation training helps enhance traditional education methods. Consistent utilization of simulation training in MH crisis education can advance MH management, create better patient outcomes and increase patient safety within the operating room. The results of this project were consistent with previous literature demonstrating the positive effects of simulation in crisis management training and its impacts on enhancing clinician confidence. Therefore, this project recommends incorporating simulation-based training into MH education to increase clinician confidence and knowledge in responding to and managing an MH crisis.

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Appendix A

Malignant Hyperthermia Pre-Test Survey

Part I

1. What is your mother's birthday (mm/dd/yy)? ____________________________
2. In what role/capacity do you practice (e.g. MD, CRNA, RN)? _________
   a. If you are an RN, do you primarily work in the OR? ___________

Part II

SD: (strongly disagree); D: (disagree); UN: (undecided): A: (agree); SA: (strongly agree)

Questions	SD	D	UN	A	SA
1. I feel confident in my skills during a crisis involving direct patient care.					
2. I feel confident in my role during a cardiac arrest.					
3. I feel confident in my role during an airway emergency (e.g. cannot ventilate or intubate).					
4. I feel confident in my role during the management in an MH crisis.					
5. I know the initial interventions in MH management.					
6. I feel confident in dosing Dantrolene during an MH crisis.					
7. I feel confident in my ability to reconstitute Dantrolene.					
8. I am confident in my ability to recognize initial MH signs and symptoms					
9. I know my role and responsibilities during an MH crisis.					
10. An MH educational briefing and demonstration is beneficial to increase confidence and competence in the management of an MH crisis?					
11. I know the location of the MH cart.					
12. Simulation education is superior to a PowerPoint or online module alone in teaching the management of an MH crisis.					

Appendix B

Malignant Hyperthermia Demonstration Post-test Survey

Part I

1. What is your mother's birthday (mm/dd/yy)? ____________________________
2. In what role/capacity do you practice (e.g. MD, CRNA, RN)? _________
    a. If you are an RN, do you primarily work in the OR? ___________

Part II

SD: (strongly disagree); D: (disagree); UN: (undecided): A: (agree); SA: (strongly agree)

Questions	SD	D	UN	A	SA
1. I feel confident in my skills during a crisis involving direct patient care.					
2. I feel confident in my role during a cardiac arrest.					
3. I feel confident in my role during an airway emergency (e.g. cannot ventilate or intubate).					
4. I feel confident in my role during the management in an MH crisis.					
5. I know the initial interventions in MH management.					
6. I feel confident in dosing Dantrolene during an MH crisis.					
7. I feel confident in my ability to reconstitute Dantrolene.					
8. I am confident in my ability to recognize initial MH signs and symptoms.					
9. I know my role and responsibilities during an MH crisis.					
10. An MH educational briefing and demonstration is beneficial to increase confidence and competence in managing an MH crisis?					
11. I know the location of the MH cart.					
12. Simulation education is superior to a PowerPoint or online module alone in teaching the management of an MH crisis.					
13. There are barriers to MH treatment at this facility.					

If yes, what are the barriers?

Appendix C

MH crisis Demonstration Script

Roles:
CRNA: Sabrina Zaleski
OR circulator: Liz McKeithan
Anesthesia tech: MH educator

MH Scenario: Barbara Jones is a healthy 18-year-old scheduled for a right knee arthroscopy who weighs 154 lb (70 kg). Her past surgical history includes a tonsillectomy at the age of 7. There is no other significant healthy history to report and no history of problems with anesthesia. The patient is scheduled to have a general anesthetic with an LMA (laryngeal mask airway).

The patient has been under anesthesia for 15 minutes. The surgeon is complaining the patient's right leg feels rigid while trying to position the patient.

VS:
- Temperature is 39 C.
- $ETCO_2$ 70 mmHg.
- Blood pressure is 169/88.
- Oxygen saturation is 90%
- Respiratory rate is 26/min.
- Heart rate is 130.

Responsibility	**Action**
CRNA	Announce the suspicion of MH to the staff in the room. - Call for the MH cart and code cart to be brought to the room. Tell circulator to call overhead for additional help. Notify the surgeon about concern for MH and to stop the procedure. - If the procedure is emergent, discontinue the use of volatile agents and continue with non-triggering anesthetics (convert to a TIVA). - If the procedure is non-emergent - abort the procedure to stabilize the patient.
OR Circulator	Call for help overhead. - “MH Crisis in OR 5” - This will get anesthesia and additional personnel in the operating room quickly to help and provide additional hands. Call the OR charge nurse and notify them of the situation. Will be delegating tasks to OR staff. - Assign roles to OR staff: o Obtain the MH cart and code cart. o Call the MHAUS hotline. o Getting bags of ice and cooled saline. o Running labs. o Grabbing supplies - new anesthesia gas machine or regular ventilator, ISTAT, etc.
Anesthesia tech	Runs to bring the MH cart from the OR front desk area. - Go ahead and break open the MH cart.
In the MH Cart:	Drugs:

	- Dantrolene at least 36 vials. - Sterile water to reconstitute Dantrolene. - Sodium Bicarbonate 50 mL x4. - Dextrose 50% - 50 mL vials x 2. - Calcium Chloride 10% 10 mL vials x2. - Regular Insulin - 100 units/mL x 1 (needs to be refrigerated). - Lidocaine 2% 100 mg/5 mL or 100 mg/10 mL in preloaded syringes x 3. o Amiodarone is also acceptable. - Refrigerated cold saline - minimum of 3L for IV cooling. General equipment: - Charcoal filters - 2 pairs. Check expiration date. - 60 mL syringes x 5 - to dilute Dantrolene. - IV catheters - multiple different sizes x 4 each. - Catheters for an arterial line. - NGT - multiple sizes and irrigation syringes - 60 mL x 2 with adapters for NGT irrigation. Monitoring equipment: - Core temp probes - esophageal, nasopharyngeal, tympanic, rectal, bladder, PA, etc. - CVP kits. - Transducer kits for arterial and central venous cannulation. Nursing supplies: - Large sterile steri-drape - for rapid drape of a wound. - Urine meter x1. - Irrigation tray with piston - 60 mL irrigation syringe. - Large clear plastic bags for ice x 4. - Small plastic bags for ice x 4. - Bucket for ice. - Test strips for urine hemoglobin. Lab supplies: - Syringes (3 mL) for ABGs or ABG kits x 6 for point of care monitors - ISTAT. - Blood specimen tubes for CK, myoglobin, LDH, electrolytes, thyroid studies, PT/PTT, fibrinogen, fibrin split products, lactate, CBC, platelets. - Blood cultures - useful to rule out bacteremia. - Urine collection container for myoglobin level.
OR circulator – or any additional staff member can do this.	Runs to bring the code cart from the OR front desk area. - Attach defibrillator pad to the patient.
Additional RN	Calls MHAUS hotline (1-800-644-9737) from personal cell phone. - There is only 1 OR phone which will be used to call for additional assistance and/or supplies. - MHAUS hotline will provide additional advice for acute management. - May want to speak with an anesthesia prover - can place them on speaker to communicate.
Anesthesia tech	Runs to grab bags of ice and cooled saline from the refrigerator from the OR front desk area. - Can get extra ice from the coffee shop on the 1st floor near the main entrance. - The clinical administrator can also get ice downstairs if needed.

CRNA and additional anesthesia providers.	Discontinue the triggering agent. Turn off any anesthetic gas. - Hyperventilate with 100% oxygen with high flows of at least 10 L/min to enhance the elimination of the anesthetic gas. Since the patient is not intubated - go ahead and intubate to secure the airway. - For neuromuscular relaxation use a nondepolarizing neuromuscular blocking agent (Rocuronium). Do not use Succinylcholine, since it is a trigger for MH and will make the situation worse. - Increase ventilation rate and/or tidal volume to maximize ventilation and attempt to reduce ETCO2. - Maintain anesthetic with a Propofol drip. Insert activated charcoal filters into the inspiratory and expiratory limbs of the breathing circuit on the gas machine. - There are 2 sets of the charcoal filters on the MH cart and extra filters in the anesthesia office. - Run for 10 minutes. - Depending on the type of charcoal filters used - Vapor-Clean filters become saturated after 1 hour and should be replaced hourly. Another option is to maintain ventilation with an ambu bag and Propofol drip. - Can request either a new gas machine or a regular ventilator to be brought into the operating room. Turn off bair hugger to facilitate cooling the patient.
All staff	Actively cool patient with ice packs or chilled saline, lavage if the abdomen is open. - Pack groin, neck, head, and axilla with ice packs. - But in reality, will actually just place ice in places you can get to. Stop cooling at core temp of 38°C.
Anesthesia tech	Runs to obtain a new anesthesia gas machine or obtain a regular ventilator if needed. Also available to run and grab any needed supplies. - Istat machine - for blood gases. - Glucometer - to monitor glucose levels. - Other necessary supplies.
CRNA - In a real crisis, will have additional help. This will be done by multiple anesthesia providers simultaneously.	Will need more IV access. - Start additional large bore IV. Place arterial line for close monitoring of blood pressure and lab draws. - Obtain labs: ABG, BMP, CKMB, Lactate, Coagulation studies. Based on ABG results, may need to give sodium bicarbonate 1-2 mEq/kg to treat metabolic acidosis to maintain a base excess > -8 mEq/L. - Max dose of sodium bicarbonate is 50 mEq.
OR circulator - In a real crisis, will have additional hands to help.	To place the lab orders in the computer and print out necessary patient labels - Type in “MH” and an order set should appear with all the required labs. - Print labels and attach to the correct lab vials after receiving them from anesthesia. - Give labs to the anesthesia tech to deliver to the lab.

	Start preparing Dantrolene. - Designate at least two people to reconstitute 2.5 mg/kg IV bolus. Dilute each 20 mg Dantrolene vial in 60 mL preservative-free sterile water - mix until the solution is clear. - Ex: 70 kg person give 175 mg - prepare 9 vials of 20 mg Dantrolene - Can also pour the sterile water into a sterile bowl to mix Dantrolene - this allows you to make more at a time. If the institution has Ryanodex supplied in 250 mg vials - it should be reconstituted with 5 mL sterile water and shaken until the orange color is a uniform, opaque suspension. There is extra Dantrolene in the central Pyxis. - Type in “Malignant” into the Pyxis in order to pull it out.
CRNA	Begin administering Dantrolene when it is available. - Rapidly administer Dantrolene 2.5 mg/kg IV bolus. - Dantrolene reverses the acute hypermetabolic process caused by MH within minutes. Continue giving Dantrolene until the patient is stable. - Administer subsequent doses of 1 mg/kg IV until the signs of MH decrease. May need to give > 10 mg/kg for patients with persistent contractures or rigidity. This can be seen with muscular males. - Will see decreased ETCO2, decreased muscle rigidity, and/or a lowered heart rate.
CRNA and Anesthesia tech	If necessary, swap out gas machines to a new anesthesia gas machine or a regular ventilator. If using a new gas machine: - Remove the vaporizer cartridges from the machine, so no anesthetic gas can be accidentally delivered to the patient.
Anesthesia tech	Run to deliver drawn labs to the lab.
OR circulator	Place Foley and monitor urine output. - Perform cold lavage to the bladder. If able to - can insert rectal tube for lavage. - If one is already present, can perform a rectal lavage to facilitate cooling.
CRNA	Fluid Management: Administer cool IV fluids (Normal Saline 0.9%) to maintain a urine output of at least 1-2 mL/kg/hr. Monitor renal function - rhabdomyolysis can occur. - Monitor for cola-colored urine. This indicates myoglobinuria. Might have to administer Lasix to reduce fluid overload and promote excretion of K+ and Na+ to help prevent myoglobin-induced renal failure.
CRNA	Treat hyperkalemia: - Calcium chloride 10 mg/kg or Calcium gluconate 10-50 mg/kg - D50 1 Amp IV (25g/50 ml Dextrose) and Regular Insulin 10 units IV - Sodium Bicarbonate 1-2 mEq/kg

	For refractory hyperkalemia, consider albuterol or other beta-agonists, kayexalate, and dialysis in extreme cases. Monitor glucose levels hourly.
CRNA	Treat dysrhythmias with Beta-blockers. - Do not give Calcium channel blockers. They may cause hyperkalemia or cardiac arrest in the presence of Dantrolene.
CRNA	Continue Dantrolene 1 mg/kg every 4-6 hours or 0.25 mg/kg/hr infusion for at least 24 hours (25 % of MH events relapse) - Provide supportive care to maintain hemodynamic stability. - Continue resuscitation. - Will need ventilatory and may require vasopressor support.
OR Circulator	Once stable, arrange ICU bed and call report. - The patient will be observed in the ICU for at least 24 hours.
CRNA	Continue to monitor heart rate, core temperature, ETCO2, minute ventilation, ABGs, K+, CK, urine myoglobin, and coagulation studies. - Maintain the patient on a Propofol drip.
	Signs of stability: - ETCO is declining or normal. - Heart rate is stable or decreasing with no signs of dysrhythmias. - Hyperthermia is resolving. - Generalized muscle rigidity has resolved. Monitor for MH recurrence: - Occurs in approximately 20% of patients after initial treatment. - Mean of 13 hours afterwards. - Additional boluses of Dantrolene may be needed.

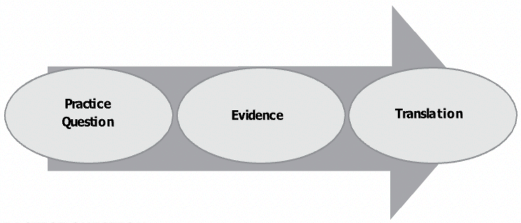
In the event of an MH crisis at night:
Call a code blue overhead to bring in ICU and Emergency Department providers and staff to get extra hands available to help.

Appendix D

Johns Hopkins Nursing Evidence-Based Practice: PET Management Guide

Johns Hopkins Nursing Evidence-Based Practice

Appendix A
PET Management Guide



PRACTICE QUESTION
Step 1: Recruit interprofessional team
Step 2: Define the problem
Step 3: Develop and refine the EBP question
Step 4: Identify stakeholders
Step 5: Determine responsibility for project leadership
Step 6: Schedule team meetings

EVIDENCE
Step 7: Conduct internal and external search for evidence
Step 8: Appraise the level and quality of each piece of evidence
Step 9: Summarize the individual evidence
Step 10: Synthesize overall strength and quality of evidence
Step 11: Develop recommendations for change based on evidence synthesis
- Strong, compelling evidence, consistent results
- Good evidence, consistent results
- Good evidence, conflicting results
- Insufficient or absent evidence

TRANSLATION
Step 12: Determine fit, feasibility, and appropriateness of recommendation(s) for translation path
Step 13: Create action plan
Step 14: Secure support and resources to implement action plan
Step 15: Implement action plan
Step 16: Evaluate outcomes
Step 17: Report outcomes to stakeholders
Step 18: Identify next steps
Step 19: Disseminate findings

Johns Hopkins Nursing Evidence-Based Practice

Appendix A
PET Management Guide

Initial EBP Question: Does the incorporation of simulation training into traditional educational briefings regarding Malignant Hyperthermia (MH) aid in MH protocol familiarity among OR nursing staff and CRNA staff?

EBP Team Leader(s): David Salzer

EBP Team Members: Sabrina Zaleski and Elizabeth McKeithan

Activities	Start Date	Days Required	End Date	Person Assigned	Milestone	Comment/ Resources Required
PRACTICE QUESTION:						
Step 1: Recruit interprofessional team	date	# days	date	name	milestone	comments
Step 2: Define the problem	date	# days	date	name	milestone	comments
Step 3: Develop and refine the EBP question	date	# days	date	name	milestone	comments
Step 4: Identify stakeholders	date	# days	date	name	milestone	comments
Step 5: Determine responsibility for project leadership	date	# days	date	name	milestone	comments
Step 6: Schedule team meetings	date	# days	date	name	milestone	comments
EVIDENCE:						
Step 7: Conduct internal and external search for evidence	date	# days	date	name	milestone	comments
Step 8: Appraise the level and quality of each piece of evidence	date	# days	date	name	milestone	comments
Step 9: Summarize the individual evidence	date	# days	date	name	milestone	comments
Step 10: Synthesize overall strength + quality of evidence	date	# days	date	name	milestone	comments
Step 11: Develop recommendations for change based on evidence synthesis: • Strong, compelling evidence, consistent results • Good evidence, consistent results • Good evidence, conflicting results • Insufficient or absent evidence	date	# days	date	name	milestone	comments

Johns Hopkins Nursing Evidence-Based Practice

Appendix A
PET Management Guide

Activities	Start Date	Days Required	End Date	Person Assigned	Milestone	Comment/ Resources Required
TRANSLATION:						
Step 12: Determine fit, feasibility, and appropriateness of recommendation(s) for translation path	date	# days	date	name	milestone	comments
Step 13: Create action plan	date	# days	date	name	milestone	comments
Step 14: Secure support and resources to implement action plan	date	# days	date	name	milestone	comments
Step 15: Implement action plan	date	# days	date	name	milestone	comments
Step 16: Evaluate outcomes	date	# days	date	name	milestone	comments
Step 17: Report outcomes to stakeholders	date	# days	date	name	milestone	comments
Step 18: Identify next steps.	date	# days	date	name	milestone	comments
Step 19: Disseminate findings.	date	# days	date	name	milestone	comments

Appendix E

Recruitment Speech

Good morning/afternoon,

My name is Sabrina Zaleski, and this is Liz McKeithan. We are both 2nd year Student Registered Nurse Anesthetists (SRNAs) at the University of North Carolina at Greensboro. We are conducting our Doctorate of Nursing Practice (DNP) project on Malignant Hyperthermia (MH) and the effect of an educational briefing and simulation on clinician confidence in managing an MH crisis. Our population of interest includes certified registered nurse anesthetists (CRNAs) and operating room (OR) nurses. Participation is strictly voluntary. You may take breaks as needed or withdraw participation at any time. Participants will partake in an interdisciplinary MH educational briefing that includes a PowerPoint presentation and MH crisis demonstration in the operating room, which will take 30 minutes. We plan to walk through a hypothetical MH crisis scenario from start to finish and the interventions necessary to maintain hemodynamic stability. Lastly, we plan to familiarize the perioperative staff with the MH cart and its contents and location. Written surveys will be given to participants before the training and 3 weeks after to assess any changes in clinician confidence and practice. The surveys will take approximately 5-10 minutes to complete. The surveys will be anonymous. To link the surveys, we plan to use a unique identifier listed on the surveys. No one will know individual responses. Completed paper surveys will be kept in a locked cabinet at UNCG. We would be grateful for your participation in our quality improvement project. Any questions or concerns?

Appendix F

Malignant Hyperthermia

UNCG School of Nursing, DNP Project

Sabrina Zaleski and Elizabeth Chapman

Presentation Outline

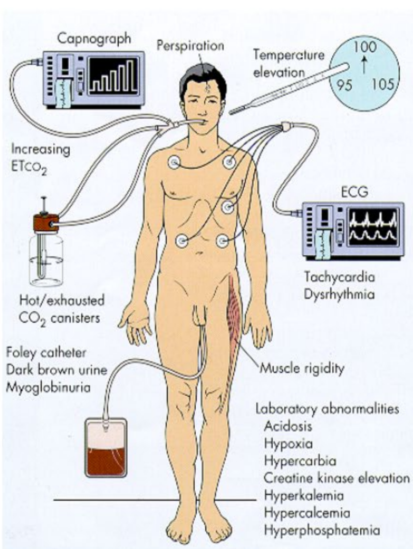
- Pathophysiology of Malignant Hyperthermia (MH)
- Clinical Signs and Symptoms
  - Vital sign changes
  - Ventilatory changes
  - Laboratory values
- MH Treatment Protocol and Management
- Differential Diagnoses
- Equipment and Preparation at WakeMed Cary
- MHAUS Contact Information

Pathophysiology of Malignant Hyperthermia

What is Malignant Hyperthermia (MH)?

- Acute, but rare, hypermetabolic crisis that occurs in response to the administration of Succinylcholine or volatile anesthetic gases
- Patients susceptible to MH possess skeletal muscle receptor abnormalities that lead to the following:
  - Magnesium-induced dysregulation of calcium transport through the Ryanodine receptor
  - Excessive intracellular calcium accumulation
  - Sustained muscular contraction
  - Rhabdomyolysis (muscle breakdown)
    - Hyperkalemia
    - Myoglobinuria
  - Cellular hypermetabolism
  - Anaerobic metabolism
  - Acidosis

Clinical Signs and Symptoms



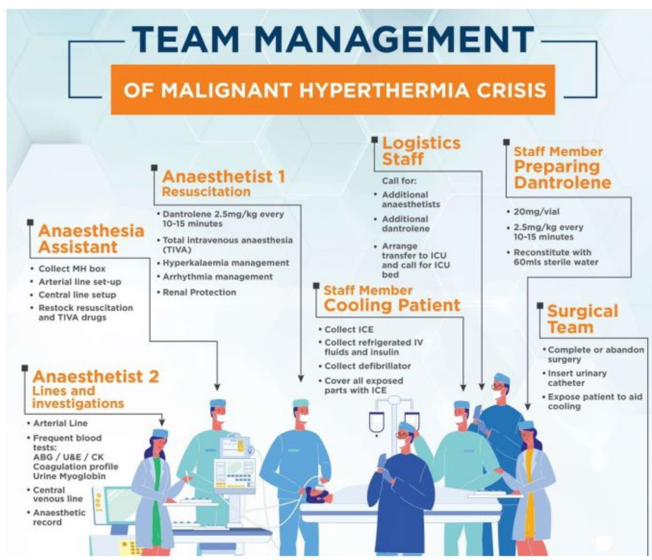
MH Crisis: Patient Symptoms

- Tachycardia
- Ventricular dysrhythmias
- Hypertension
- Tachypnea
  - Increased minute ventilation
- Rapid increase in $ETCO_2$, which represents an EARLY sign
- Myoglobinuria (brown urine output)
- Muscular rigidity (masseter rigidity or generalized)
- Sweaty and mottled skin
- Hyperthermia, which represents a LATE sign

MH Crisis: Laboratory Findings

- Hyperkalemia
- Hypercalcemia
- Hypermagnesemia
- Coagulopathies
- Elevated serum and urine myoglobin
- Metabolic acidosis
- Respiratory acidosis

MH Treatment Protocol and Management



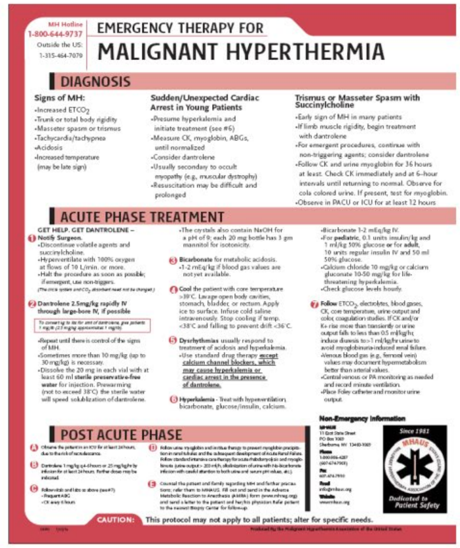
Acute Therapy

-The following steps should be taken **immediately** when a MH crisis is suspected in an OR patient:

- **-Discontinue** volatile agents and **notify** the surgeon and the circulating nurse.
- **-Hyperventilate** with 100% oxygen and **call** for help.
- **-Mix** Dantrolene Sodium **2.5 mg/kg** IV Push
- **-Treat** acidosis, dysrhythmias, and hyperkalemia
- **-Cool** the patient.

-Dantrolene, sold as **Ryanodex**, contains 250mg per bottle.

- -Dissolve the 250 mg in **5mL** of **sterile bacteriostatic water**
- -Administer a **2.5mg/kg** dose immediately and repeat as necessary



MH Hotline
1-800-644-9737
Outside the US:
1-315-464-7079

EMERGENCY THERAPY FOR
MALIGNANT HYPERTHERMIA

DIAGNOSIS

Signs of MH:
- Increased $ETCO_2$
- Trunk or total body rigidity
- Masseter spasm or trismus
- Tachycardia/tachypnea
- Acidosis
- Increased temperature (may be late sign)

Sudden/Unexpected Cardiac Arrest in Young Patients
- Presume hyperkalemia and initiate treatment (see #6)
- Measure CK, myoglobin, ABGs, until normalized
- Consider dantrolene
- Usually secondary to occult myopathy (e.g., muscular dystrophy)
- Resuscitation may be difficult and prolonged

Trismus or Masseter Spasm with Succinylcholine
- Early sign of MH in many patients
- If limb muscle rigidity, begin treatment with dantrolene
- For emergent procedures, continue with non-triggering agents; consider dantrolene
- Follow CK and urine myoglobin for 36 hours at least. Check CK immediately and at 6–hour intervals until returning to normal. Observe for cola colored urine. If present, test for myoglobin.
- Observe in PACU or ICU for at least 12 hours

ACUTE PHASE TREATMENT

GET HELP. GET DANTROLENE –

1. **Notify Surgeon.**
   - Discontinue volatile agents and succinylcholine.
   - Hyperventilate with 100% oxygen at flows of 10 L/min. or more.
   - Halt the procedure as soon as possible; if emergent, use non-triggers.
   - [illegible]
2. **Dantrolene 2.5mg/kg rapidly IV through large-bore IV, if possible**
   - [illegible]
   - Repeat until there is control of the signs of MH.
   - Sometimes more than 10 mg/kg (up to 30 mg/kg) is necessary.
   - Dissolve the 20 mg in each vial with at least 60 ml **sterile preservative-free water** for injection. Prewarming (not to exceed 38°C) the sterile water will speed solublization of dantrolene.
   - The crystals also contain NaOH for a pH of 9; each 20 mg bottle has 3 gm mannitol for isotonicity.
3. **Bicarbonate** for metabolic acidosis.
   - 1-2 mEq/kg if blood gas values are not yet available.
4. **Cool** the patient with core temperature >39°C. Lavage open body cavities, stomach, bladder, or rectum. Apply ice to surface. Infuse cold saline intravenously. Stop cooling if temp. <38°C and falling to prevent drift <36°C.
5. **Dysrhythmias** usually respond to treatment of acidosis and hyperkalemia.
   - Use standard drug therapy **except calcium channel blockers, which may cause hyperkalemia or cardiac arrest in the presence of dantrolene.**
6. **Hyperkalemia** - Treat with hyperventilation, bicarbonate, glucose/insulin, calcium.
   - Bicarbonate 1-2 mEq/kg IV.
   - For **pediatric**, 0.1 units insulin/kg and 1 ml/kg 50% glucose **or** for **adult**, 10 units regular insulin IV and 50 ml 50% glucose.
   - Calcium chloride 10 mg/kg or calcium gluconate 10-50 mg/kg for life-threatening hyperkalemia.
   - Check glucose levels hourly.
7. **Follow** $ETCO_2$, electrolytes, blood gases, CK, core temperature, urine output and color, coagulation studies. If CK and/or K+ rise more than transiently or urine output falls to less than 0.5 ml/kg/hr, induce diuresis to >1 ml/kg/hr urine to avoid myoglobinuria-induced renal failure.
   - Venous blood gas (e.g., femoral vein) values may document hypermetabolism better than arterial values.
   - Central venous or PA monitoring as needed and record minute ventilation.
   - Place Foley catheter and monitor urine output.

POST ACUTE PHASE

[illegible]

Non-Emergency Information

[illegible]

Since 1981
MHAUS
Dedicated to Patient Safety

CAUTION: This protocol may not apply to all patients; alter for specific needs.

MH Treatment Protocol: **Cooling** the Patient

- Uncover the patient
- Place ice packs on the patient's neck, groin, and axilla
- Cool IV fluids
- Have the surgical team place sterile ice in the surgical field
- Turn down the room temperature

MH Treatment Protocol: **Dysrhythmias**

- Treat the metabolic acidosis with Bicarbonate.
  - Use a starting dose of 1-2 mEq/kg until laboratory values are available
- To treat the hyperkalemia, use the following:
  - Bicarbonate
  - Glucose/Insulin
  - Calcium

Equipment and Preparation

- Ice and cold saline are located in the refrigerator near the main Pyxis at the OR control desk.
  - Extra ice is located in the coffee shop on the first floor
  - Ice will be attained by the anesthesia tech in the event of a MH crisis.
- The MH cart is located near the OR front desk. The MH cart as well as the Code Cart should be brought to the OR.
- **AT NIGHT**: Call a Code Blue if a MH crisis event occurs. This will assemble a team made up of ICU and ER team members.


MHAUS Contact Information
Hotline: 1-800-MH-HYPER (800-644-9737)
Information: 1-800-98-MHAUS
Website: www.mhaus.org


SIMULATION