Marian University

Leighton School of Nursing

Doctor of Nursing Practice

Final Project Report for Students Graduating in May 2024

Simulation-Based Training for Student Registered Nurse Anesthetists Managing Malignant Hyperthermia

Hilda Aveja

Marian University

Leighton School of Nursing

Project Chair: Lee Ranalli, DNP, CRNA

Date of Submission: April 22, 2024

Table of Contents

Abstract

***Background*:** Malignant hyperthermia is a disorder of the skeletal muscle that can present as a hypermetabolic response to triggering agents. Anesthesia providers frequently administer these triggers in the operating room. Therefore, it is imperative for providers to receive comprehensive education on malignant hyperthermia. Simulations help ensure their competence in the event of encountering a crisis.

***Purpose*:** This project's purpose was to improve malignant hyperthermia knowledge among student registered nurse anesthetists (SRNAs) at a small university in the Midwest through a lecture and simulation of a crisis.

Methods: The university's SRNAs were invited to participate in this project via email. The project consisted of an educational intervention through a lecture and simulation, which took place in the university's simulation center. Qualitative data was collected with malignant hyperthermia key action checklist. The investigator also collected qualitative data using a pre-test and post-test interventional design.

***Implementation*:** Ten educational sessions provided to participants (n = 32). Participants took a pre-test to assess their baseline knowledge. Then, they received a lecture, simulation, debrief, and post-test one. Post-test one was given to assess knowledge improvement. Six to eight weeks later, participants received an email to take post-test two, which assessed knowledge retention.

***Conclusion*:** Participants collectively received a mean score of 29.1 out of 30 on the key action checklist. The pre-test was assessed against each post-test using a paired samples t-test. Participants showed knowledge improvement from the pre-test to the post-test one ($p > 0.05$).This knowledge improvement was retained from the pre-test to post-test two ($p > 0.05$).

Keywords: malignant hyperthermia, simulation, mock drill, anesthesia, anesthetist, SRNA,

Simulation-Based Training for Managing Malignant Hyperthermia

Malignant hyperthermia (MH) is an autosomal dominant disorder of the skeletal muscle that presents as a hypermetabolic response when individuals are exposed to a triggering event (Rosenburg et al., 2007). Triggers for MH-susceptible patients include potent volatile anesthetics (such as sevoflurane, desflurane, and isoflurane), depolarizing neuromuscular blocking agents (such as succinylcholine), and in rare occasions, heat or exercise (Rosenburg et al., 2007). The incidence of MH is rare, but it has the potential for fatal consequences (Rosenbaum et al., 2015).

Background

The incidence of MH is estimated to range from 1:10,000 to 1:250,00 anesthetics (Rosenbaum et al., 2015). Because MH is a rare event, there is a lack of clinical experience in treating it among anesthesia providers. Anesthesia providers should be the first to recognize MH in the operating room (OR). Nevertheless, any clinician who works where MH-triggering drugs are administered should be able to recognize the signs and symptoms of the disorder. Signs and symptoms can include muscle rigidity, tachycardia, tachypnea, increased production of carbon dioxide, increased consumption of oxygen, acidosis, hyperthermia, rhabdomyolysis, and hyperkalemia (Rosenbaum et al., 2015). These symptoms are related to the body's hypermetabolic state. Rapid recognition and treatment are vital to improving patient outcomes and reducing mortality risk.

Rapid and efficient treatment of MH requires an interdisciplinary approach with effective leadership. Poor communication and team interactions have been shown to lead to poor outcomes in many settings, including the OR (Christian et al., 2006). A coordinated team effort is vital for the prompt treatment of MH. As such, it is necessary to ensure the competency of

clinical staff. The American Association of Nurse Anesthesiology (AANA) (n.d.) recommends ensuring clinical team competency through regular training and mock drills.

Problem Statement

Simulation is a safe and controlled learning environment that effectively teaches hands-on skills and improves knowledge retention. In healthcare settings, mock drills serve as an invaluable way of replicating rare real-life scenarios, ensuring clinician readiness and confidence if such cases present themselves in the clinical setting.

The purpose of this project was to improve MH knowledge among student registered nurse anesthetists (SRNAs) at a small university in the Midwest through a lecture and simulation of an MH crisis. The simulation would theoretically improve the SRNAs knowledge and understanding of how to manage and treat patients with MH. The efficacy of this intervention was evaluated through a pre-test prior to the MH lecture, a post-test immediately following the simulation, and a follow-up post-test six to eight weeks after the simulation.

Needs Assessment

Providing healthcare professionals with simulation experiences of low probability, high-impact risk scenarios like an MH crisis can allow them to practice managing these scenarios in safe environments. Simulations allow them to learn from their mistakes without harming patients. Consequently, this could lead to improved clinician responses in the clinical setting. A university in the Midwest with a newer nurse anesthesia program has an excellent simulation center for its students. However, it was noted that while the program curriculum covered MH in multiple lectures, it was not covered in simulation. Implementation of an MH lecture concurrently with a simulated MH crisis was still necessary.

Literature Review

Search Methodology

The purpose of this literature review was to examine the current state of literature as it pertains to perceptions of MH simulations and their effectiveness. The databases used to perform the literature search were PubMed and CINAHL. The searches we conducted using the following BOOLEAN phrase "malignant hyperthermia" AND "simulation" AND "education OR training". The key words being malignant hyperthermia, simulation, education, and training. The search in PubMed was completed on November 29, 2022, and it initially yielded 25 results. The results were reduced to 13 documents by filtering in texts that were from 2012 to 2022, studies related to humans, and articles in the English language. The search in CINAHL was completed on November 7, 2022, and it yielded 17 results. The results were reduced to 9 by the use of the same filters used in PubMed. Of the total 42 articles 2 were duplicates. Therefore, 40 articles were screened for eligibility. Subsequently, 11 articles were excluded because they did not relate to MH and simulations. Overall, 10 full text articles were retrieved and assessed for eligibility and all 10 are included in this literature review. Articles older than 10 years were considered if used as a reference in multiple studies retrieved. A PRISMA Flow Diagram for the search methodology is found in APPENDIX A.

Importance of Simulations

During the literature review, multiple studies assessed the significance of simulation to clinical practice. Many of these studies concluded that simulations allowed participants to experience low-frequency clinical events without risking harm to patients (Bashaw, 2014; Cain et al., 2014; Mullen & Byrd, 2013). Bradshaw (2014) noted that simulation allowed participants to improve their performance. A similar conclusion was also made in studies conducted by Thompson et al. (2017) and Henrichs et al. (2002). These studies showed that their participants

reported an increased sense of preparedness for high-stress events such as MH. Matsco et al. (2020) and many studies reported a positive reaction from their participants. Furthermore, the positive reaction led to the implementation of additional simulations (Matsco et al., 2020).

Although simulations were found to be an essential tool in experiencing low-frequency events, multiple drawbacks/limitations were identified in the literature. In many of the studies identified, the simulations were provided by employers to their employees or by schools to their students. This is important because the cost of the simulation is usually covered by the business entity to meet the needs of the company instead of the individual. Cannon-Diehl et al. (2014) noted that simulations are an important tool that can be used in continuing education for nurse anesthetists. However, the high cost of simulation technology can limit the development of high-fidelity simulation by many smaller/low-cost educators.

Several studies assessed the value of simulation in relation to low-frequency events. However, the data in relation to MH remains preliminary. More data needs to be collected within this realm, particularly as it relates to the benefits of an interdisciplinary MH simulation and its effects on collaboration, communication, and knowledge retention.

Benefits of Malignant Hyperthermia Simulations

Only two studies identified in the literature focused solely on MH simulation-based training (Gallegos & Hennen, 2022; Schaad, 2017). Both of these studies noted that MH simulations improved clinical knowledge and competency. Additionally, Schaad noted that simulation-based training enhanced communication among team members. This is particularly important in regard to MH. During an MH episode, prompt recognition and treatment are crucial. Staff need to be able to communicate and delegate roles appropriately.

Use of Cognitive Aids in Simulations

Two of the studies identified evaluated the role of cognitive aids (Gallegos & Hennen, 2020; Hardy et al., 2020). Both noted that using a checklist during an MH simulation greatly improved participant adherence to critical steps and guidelines. These two studies highlight the importance of developing effective visual aids and encouraging their use in simulation and real life.

The literature matrix is found in APPENDIX B.

Theoretical Framework

Theoretical frameworks can be used to support and guide new research. The NLN Jeffries Simulation Theory serves as a guide for nurse educators to develop, implement, and evaluate simulation-based education (Cowperthwait, 2020). The theory delineates seven key elements: context, background, design, facilitator/educational practices, participant, simulation experience, and outcomes (Jeffries et al., 2015).

1. *Context* involves an understanding of how many factors affect a simulation. These can include the environment in which the simulation takes place, the purpose of the simulation, and the evaluation criteria.
2. *Background* involves elements that are embedded within the context. Background includes resource allocation, goals, expectations of the simulation, and how the simulation fits within a larger curriculum.
3. *Design* involves the actual development of a simulation and describes key elements such as specific learning objectives, planned facilitator responses, role assignments, simulation flow, and briefing/debriefing strategies.
4. *Facilitator and educational practices* explain a facilitator's extensive role in the simulation's progression. Facilitators must be able to respond to participant needs by

prebriefing participants, adjusting the simulation based on its progression, providing appropriate cues, and debriefing following the simulation.

5. *Participant* describes how simulation participants affect the simulation. Participant attributes such as age, gender, level of anxiety, self-confidence, and level of preparedness will all affect the simulation.
6. *Simulation experience* should account for an environment that is learner centered in which learners can be interactive and collaborate. For the simulation to be successful there needs to be trust between the facilitator and participants. This will allow for participant "buy-in" and promote engagement.
7. *Outcomes* are divided into three areas: participant, patient, and system outcomes. Research commonly focuses on assessing participant outcomes such as knowledge, confidence, or behavior improvement. However, this theory can also guide research in other ways, such as evaluating patient safety outcomes or organizational cost effectiveness.

The NLN Jeffries Simulation Theory served as the theoretical framework for developing this project's simulation-based training for SRNAs managing MH. The theory describes how context and background affect the project. As such, proper planning permitted project members to make changes that provided for the best simulation experience. Furthermore, the theory delineates simulation facilitator and participant attributes conducive to a successful learning environment and simulation experience. These are all concepts that were relevant to developing a successful MH simulation.

For a visual representation of this theory please see APPENDIX C.

Aim and Objectives

This project aimed to improve SRNAs' education and knowledge retention of MH. Consequently, SRNAs' response to MH in the clinical setting should improve, leading to increased patient safety.

The main objective was to provide SRNAs with a comprehensive lecture on MH followed by a simulated MH crisis. During the crisis, they would be able to implement knowledge learned in the lecture. The simulation would cover managing the patient's status, adjusting the anesthetic, reconstituting/administering dantrolene and other drugs, and placement of charcoal filters. The simulation and debrief session would also allow participants to note the importance of using visual guides and maintaining effective communication. Ultimately, the success of the educational intervention was tested using a pre-test, initial post-test, and follow-up post-test. The goal was to show an improvement in the post-test scores compared to the pre-test scores.

SWOT Analysis

A SWOT analysis was performed for this project to assess the project for opportunities. For a visual representation of the SWOT analysis please see APPENDIX D.

Stakeholders in this project included the author, the university, MH-susceptible patients, and SRNAs. Simulation-based education provides an excellent opportunity for SRNAs to practice managing an MH crisis, all while ensuring patient safety remains uncompromised. Possible threats to this project included poor participant involvement, poor data collection, and facility unwillingness to implement the simulation. However, with the support of the anesthesia faculty, there was strong organizational support. Some possible weaknesses of this project could have been poor resource allocation, lack of MH simulation equipment, and busy student schedules. Potential opportunities for improvement were allocating supplies from medical

companies so that a more authentic simulation could be provided. This project presented an opportunity to educate SRNAs on MH and demonstrate that simulation-based training can potentially improve patient care.

Methods

Project Design

This quality improvement project was centered around an MH educational intervention. The project gathered qualitative data through a pre-test and post-test interventional design. The post-test results were then analyzed to assess participants' knowledge improvement and retention. The primary aim was to enhance SRNAs' education on MH and consequently improve their recognition of and response to MH.

- Pre-test
    - Established MH knowledge baseline
- MH lecture
- MH crisis simulation
- Simulation debriefing session
- Post-test one

    Evaluated for MH knowledge improvement
- Post-test two (six to eight weeks later)
    - Evaluated for MH knowledge retention

Setting

This project took place in a simulation center for nurse anesthesia at a small private university in the Midwest. The simulation center contained two mock OR suites with high fidelity mannequins. The simulation took place in one of the mock ORs. This allowed SRNAs to

use a mannequin, anesthesia machine, OR supplies, and monitors with visual/auditory feedback.

Population

The sample was a convenience sample of SRNAs from the university. SRNAs from all cohorts were invited to attend. The exclusion criteria were any participant who could not participate during the whole lecture or simulation. The investigator sent several emails inviting all SRNAs to attend.

A total of 32 SRNAs participated in the pre-test, lecture, and simulation. Of the initial 32 participants, only 31 completed post-test one. 18 participants took post-test two. However, only 12 of the 18 tests could be linked to their pre-test and post-test one. Below, readers will find a table representation depicting the age range, anticipated graduation year, and sex of the participants who took the tests.

Pre-test (n=32)		
Demographics	Count	% of sample
20-30 years old	20	62.50%
30-40 years old	12	37.50%
2024	2	6.25%
2025	7	21.88%
2026	23	71.88%
Male	8	25.00%
Female	24	75.00%

Post-test 1 (n=31)		
Demographics	Count	% of sample
20-30 years old	20	64.52%
30-40 years old	11	35.48%
2024	2	6.45%
2025	7	22.58%
2026	22	70.96%
Male	7	22.58%
Female	24	75.00%

Post-test 2 (n=12)		
Demographics	Count	% of sample
20-30 years old	9	75.00%
30-40 years old	3	25.00%
2024	0	0.00%
2025	1	8.33%
2026	11	91.66%
Male	4	33.33%
Female	8	66.66%

Instructional design

The MH lecture (APPENDIX E) was developed based on current MH knowledge. The resources used included Miller's Anesthesia, 8th edition (Gropper & Miller, 2020), Clinical Anesthesia, 8th ed. (Barash et al., 2017), Obstetrics Anesthesia (Chestnut et al., 2020), and the Malignant Hyperthermia Association of the United States (MHAUS). MHAUS is a leading professional organization that promotes optimum care and scientific understanding of MH (Malignant Hyperthermia Association of the United States, n.d.). The lecture covers the pathophysiology of the disease, diagnostic criteria, and treatment options. The lecture was

assessed by Dr. Lee Ranalli, CRNA and DNP chair of this project, for face validity. The lecture was presented in person to SRNAs, and time was allotted for questions. Ten lectures were provided from February 12, 2024, to February 15, 2024. Ten education sessions were provided to ensure maximum attendance. After each lecture, an MH crisis simulation took place.

The MH scenario was based on typical clinical presentations discussed in the lecture. The specific case details can be found in APPENDIX F. The simulation occurred in one of the university's ORs with a high-fidelity mannequin and anesthesia machine. The OR was also equipped with continuous auditory and visual feedback vital signs. SRNAs had access to medical supplies and equipment during the simulated case. There were mock charcoal filters to practice placing them on the breathing circuit during simulation, and educational Ryanodex formulations were also available to practice reconstituting the drug.

During the simulation, the performance of each group of participants was observed, and key tasks/actions were documented in a checklist. These were documented so that the investigator could provide feedback to each group during the debriefing sessions. During the debrief, participants were also able to share their thoughts on the experience.

Measurement instruments

One pre-test and two post-tests were given. All three tests were identical. Once participants agreed to partake in the project, they were asked a few demographic questions. These questions included age range, gender, and anticipated graduation year. Additionally, the tests contained five knowledge-based questions covered in the MH lecture. The knowledge-based questions remained the same in the pre-test and post-tests to allow for comparison and evaluation of knowledge retention. These tests were assessed for face validity by Dr. Ranalli. This test can be found in APPENDIX G.

During the simulation, participant groups were observed for technical tasks being performed. The tasks were assessed with a key action checklist. The checklist consisted of tasks that are critical in the treatment of a patient experiencing an MH crisis. Groups were expected to perform these tasks. The observer noted when tasks were met, partially met, and unmet. The group's overall performance was discussed in the debrief session. The debrief covered areas in which the group performed appropriately and areas that needed improvement. The checklist was assessed for content validity by Dr. Ranalli. See APPENDIX H for the key action checklist created. The creation of this checklist was influenced by Murray et al.'s (2005) checklist and key action scoring system for simulation exercises.

Data Collection

Participants were recruited for this project by the investigator via an email invitation. The email invitation included a link to sign up for the MH simulation. Recipients of this email included SRNAs from all cohorts at the university. Attendance of the education and simulation was voluntary. The educational intervention took place February 12-15, 2024. Ten educational sessions were held with groups of one to five participants. During simulation days, data was voluntarily collected before the lecture via an anonymous Qualtrics link to the pre-test, during the simulation via a key action checklist, and after the debriefing via an anonymous Qualtrics link to post-test one. Six to eight weeks following the simulation, two additional emails were sent to the SRNA cohorts inviting them to click on an anonymous Qualtrics link to take post-test two. Post-test two was the last data collected from participants.

Informed consent was provided to participants in attendance. Individuals were informed of this project's purpose, aim, and objectives via the invitational email before initiating the pre-test. They were informed that their participation in the project was voluntary. If they

chose not to participate or wished to withdraw from the project at any time, there would be no consequences. The investigator provided participants with an email address and phone number that they could use to contact the investigator with any questions, concerns, or needs related to this project.

The pre-test was given to participants in the lecture room via a scannable QR code that led them to the test. The investigator gave them the pre-test prior to the lecture. Following the lecture and simulation, participants received post-test one. Participants found the link to the test via a scannable QR code. This test was assessed for knowledge improvement. Six to eight weeks after the education, participants received post-test two via an anonymous Qualtrics link. Post-test two assessed for knowledge retention. These tests were used to assess a participant's knowledge improvement and retention. Data was also collected via direct observation during the simulation. This data was recorded using the key action checklist.

Ethical Considerations/ Protection of Human Subjects

The identity of participants was kept private and protected. For data collection purposes, participants were asked to provide the last four digits of their student ID number or any four-digit code they could remember before taking the pre-test and post-tests. These four-digit codes were used to link tests. All participants' anonymity was protected. The project creator cannot access participants' identities with the last four digits they provided. Additionally, only the project creator had access to their individualized data to protect their identity further. The university only had access to aggregate data. Data was transferred from Qualtrics to Microsoft Excel for evaluation purposes, and it was kept on a password-protected computer that was stored in a safe and secure location.

IRB approval from Marian University was attained prior to implementing this project. This is found in APPENDIX I.

Results

Key Action List

Ten groups participated in the simulation experience. The groups consisted of one to five participants, comprising 32 participants. Their actions were observed and scored during the simulation using a key action checklist. Groups fully meeting an action warranted three points, partially meeting an action warranted two points, and not meeting an action warranted one point. The maximum number of points the ten groups could collectively earn in each category was 30. The mean score for each category was 29.1 (95% CI[28.6-29.6]). Table one shows how the ten groups scored in the key action checklist..

Table 1

Malignant Hyperthermia Checklist	Met: 3pts	Partially met: 2 pts	Did not meet: 1 pt	Collective points
1. Call for help & notify surgeon	10 groups			30
2. Get MH cart, code cart, cooling measures, call MHAUS	10 groups			30
3. Discontinue triggering agent; continue IV sedation	9 groups	1 group		29
4. Hyperventilate the patient with 100% FiO2	9 groups	1 group		29
5. Increase fresh gas flow ≥ 10 L/min	10 groups			30
6. Insert activated charcoal filters	9 groups	1 group		29
7. Administer dantrolene	9 groups	1 group		29
8. Administer bicarbonate	10 groups			30
9. Monitor core temperature	10 groups			30
10. Control patient temperature appropriately	9 groups	1 group		29
11. Monitor and treat arrythmias	9 groups		1 group	28
12. Maintain urine output > 1-2 mL/kg/hr with foley catheter	8 groups	2 groups		28
13. Monitor blood gases, electrolytes, CK	8 groups	1 group	1 group	27
14. Analyze coagulation studies	9 groups	1 group		29
15. Transfer to ICU & monitor 24-48 hours	9 groups	1 group		29

Scoring of the Tests

The three tests were scored from zero to five points (0-100%). Participants received zero points if they answered a question incorrectly and one point if they answered a question correctly.

Knowledge Improvement

A total of 32 participants took the pre-test, which was given before the lecture and simulation to establish baseline knowledge. Immediately following the simulation debrief session, participants were invited to take post-test one. Only 31 of these participants took post-test one.

The post-test one was given to compare its results to the pre-test. The mean scores of both these tests were evaluated using a paired t-test. The mean score achieved by participants taking the pre-test was 2.5 points. Meanwhile, the mean score achieved by participants taking post-test one was 4.5 points. The data showed that the mean score from the pre-test to post-test one increased by 2 points (95% CI [1.52-2.5]). This was a statistically significant improvement ($p < 0.05$). Tables two and three show the paired t-test results described above and the descriptive statistics on the mean score differences between the two tests.

Table 2

	Post-test 1	*Pre-test*
Mean	4.580645161	2.5483871
Variance	0.31827957	1.38924731
Observations	31	31
Pearson Correlation	-0.14391726	
Hypothesized Mean Difference	0	
df	30	
t Stat	8.211184815	
P(T<=t) one-tail	1.81828E-09	
t Critical one-tail	1.697260887	
P(T<=t) two-tail	3.63657E-09	
t Critical two-tail	2.042272456	

Table 3

Differences	
Mean	2.0322581
Standard Error	0.2474988
Median	2
Mode	2
Standard Deviation	1.3780148
Sample Variance	1.8989247
Kurtosis	-0.689778
Skewness	0.3470417
Range	5
Minimum	0
Maximum	5
Sum	63
Count	31
Confidence Level(95.0%)	0.5054599

Knowledge Retention

Of the 32 participants who took the pre-test, only 12 took both post-tests. The mean scores of the pre-test, post-test one, and post-test two were compared to assess MH knowledge retention among these 12 participants.

The mean score of the participants taking the pre-test was 3.2 points. The mean score of post-test one was 4.5 points. While the mean score of post-test two was also 4.5 points. Table 4 shows these four mean scores.

Table 4

n=12	*Pre-test*	*Post-test 1*	*Post-test 2*
Mean	3.166666667	4.5	4.5

When comparing the mean score of the pre-test versus post-test two, there was an average improvement in scores of 1.3 points (95% CI [0.83-1.83]). This improvement was statistically significant ($p < 0.05$). Tables five and six show the paired t-test results described above and the descriptive statistics on the mean score differences between the two tests

Table 5

	Post-test 2	*Pre-test*
Mean	4.5	3.1666667
Variance	0.636363636	1.0606061
Observations	12	12
Pearson Correlation	0.663940002	
Hypothesized Mean Difference	0	
df	11	
t Stat	5.93295879	
P(T<=t) one-tail	4.91565E-05	
t Critical one-tail	1.795884819	
P(T<=t) two-tail	9.8313E-05	
t Critical two-tail	2.20098516	

Table 6

Difference	
Mean	1.3333333
Standard Error	0.2247333
Median	1
Mode	1
Standard Deviation	0.7784989
Sample Variance	0.6060606
Kurtosis	0.924
Skewness	0.6679521
Range	3
Minimum	0
Maximum	3
Sum	16
Count	12
Confidence Level(95.0%)	0.4946346

Interestingly, the mean scores of the post-test one and post-test two were the same: 4.5 points. However, this was not statistically significant ($p = 1$). The data showed that the difference between the mean score of post-test one and the post-test two was 0 (95% CI [-0.72-0.72]). Please refer to tables seven and eight below. Tables seven and eight show the paired t-test results described above and the descriptive statistics on the mean score differences between the two tests.

Table 7

	Post-test 2	*Post-test 1*
Mean	4.5	4.5
Variance	0.636363636	0.454545455
Observations	12	12
Pearson Correlation	-0.169030851	
Hypothesized Mean Difference	0	
df	11	
t Stat	0	
P(T<=t) one-tail	0.5	
t Critical one-tail	1.795884819	
P(T<=t) two-tail	1	
t Critical two-tail	2.20098516	

Table 8

Difference	
Mean	0
Standard Error	0.3256695
Median	0
Mode	0
Standard Deviation	1.1281521
Sample Variance	1.2727273
Kurtosis	-0.3367347
Skewness	0
Range	4
Minimum	-2
Maximum	2
Sum	0
Count	12
Confidence Level(95.0%)	0.7167937

Discussion

Collectively, the groups scored fairly well during the simulation. When responding to crisis situations, team dynamics are essential. In a study conducted by Christian et al. (2006), they found that a major contributor to compromising patient safety was communication breakdown and information loss. During the MH lecture, participants were encouraged to use closed-loop communication, delegate roles and tasks, and use visual aids while in the simulation. There were several key actions during the simulations that groups missed due to poor communication and lack of using an MH checklist/guide. Coordinated team efforts are necessary for the prompt treatment of an MH crisis. Teams should always set roles and delegate tasks during a crisis. Additionally, they should ensure closed-loop communication with frequent check-ins to see what tasks have been done and what still needs to be done.

Simulation-based training is an effective means of improving educational outcomes. Participants taking the pre-test had a mean score of 64%. Following the lecture, simulation, and debrief session, participants who took post-test one had a mean score of 90%. This improved mean score remained at 90% in post-test two despite being taken six to eight weeks following the

simulation. These results support the proposal that simulation-based training will improve MH knowledge and retention among SRNAs.

While this project has provided valuable insights, it is important to acknowledge its limitations. The small sample size, with a higher attendance rate from first and second year SRNAs, is a factor that needs to be addressed in future studies. It is crucial to replicate this project at other healthcare centers and schools to further validate its findings and ensure its applicability across different settings.

Conclusion

It is well known that MH is a rare event in the OR. Many anesthetists may never experience an MH crisis throughout their careers. For this reason, it would be beneficial for healthcare centers that provide MH triggering agents to implement regular intervals of MH crisis simulations. These simulations could provide clinicians with the opportunity to practice treating crises in a safe setting, improving their overall knowledge of MH.

References

American Association of Nurse Anesthesiology. (n.d.). Malignant Hyperthermia Crisis Preparedness and Treatment. https://www.aana.com/docs/default-source/practice-aana-com-web-documents-(all)/malignant-hyperthermia-crisis-preparedness-and-treatment.pdf?sfvrsn=630049b1_8

Barash, P. G., Cullen, B. F., Stoelting, R. K., Cahalan, M. K., Stock, M. C., Ortega, R., Sharar, S. R., & Holt, N. F. (2017). *Clinical anesthesia* (8th ed.). Lippincott Williams & Wilkins.

Bashaw, M. (2016). Integrating simulations into perioperative education for undergraduate nursing students. *AORN Journal*, *103*(2). https://doi.org/10.1016/j.aorn.2015.12.017

Cain, C. L., Riess, M. L., Gettrust, L., & Novalija, J. (2014). Malignant hyperthermia crisis: Optimizing patient outcomes through simulation and interdisciplinary collaboration. *AORN Journal*, *99*(2), 300–311. https://doi.org/10.1016/j.aorn.2013.06.012

Chestnut, D. H., Wong, C. A., Tsen, L. C., Ngan Kee, W. D., Beilin , Y., Mhyre , J. M., & Bateman , B. T. (2020). *Chestnut's obstetric anesthesia: Principles and practice* (6th ed.). Elsevier.

Christian, C. K., Gustafson, M. L., Roth, E. M., Sheridan, T. B., Gandhi, T. K., Dwyer, K., Zinner, M. J., & Dierks, M. M. (2006). A prospective study of patient safety in the operating room. *Surgery*, *139*(2), 159–173. https://doi.org/10.1016/j.surg.2005.07.037

Cowperthwait, A. (2020). NLN/Jeffries Simulation Framework for simulated participant methodology. *Clinical Simulation in Nursing*, *42*, 12–21. https://doi.org/10.1016/j.ecns.2019.12.009

Gallegos, E., & Hennen, B. (2022). Malignant hyperthermia preparedness training: Using cognitive aids and emergency checklists in the perioperative setting. *Journal of PeriAnesthesia Nursing*, *37*(1), 24–28. https://doi.org/10.1016/j.jopan.2020.09.020

Gropper, M. A., & Miller, R. D. (2020). *Miller's anesthesia* (9th ed.). Elsevier.

Hardy, J.-B., Gouin, A., Damm, C., Compère, V., Veber, B., & Dureuil, B. (2018). The use of a checklist improves anaesthesiologists' technical and non-technical performance for simulated malignant hyperthermia management. *Anaesthesia Critical Care & Pain Medicine*, *37*(1), 17–23. https://doi.org/10.1016/j.accpm.2017.07.009

Jeffries, P. R., Rodgers, B., & Adamson, K. (2015). NLN Jeffries Simulation Theory: Brief Narrative Description. *Nursing Education Perspectives*, *36*(5), 292–293. https://doi.org/10.5480/1536-5026-36.5.292

Malignant Hyperthermia Association of the United States. (n.d.). *What is MH / MHAUS?* MHAUS. Retrieved January 15, 2023, from https://www.mhaus.org/about/what-is-mh-mhaus/

Matsco, M., Marich, M., & Parke, P. (2020). Setting the foundation for an in situ simulation program through the development of a malignant hyperthermia simulation in the Operating Room. *The Journal of Continuing Education in Nursing*, *51*(11), 523–527. https://doi.org/10.3928/00220124-20201014-09

Murray, D., Boulet, J., Kras, J., McAllister, J., & Cox, T. (2005). A simulation-based acute skills performance assessment for anesthesia training. Anesthesia & Analgesia, 101(4), 1127-1134. 10.1213/01.ane.0000169335.88763.9a

Mullen, L., & Byrd, D. (2013). Using simulation training to improve perioperative patient safety. *AORN Journal*, *97*(4), 419–427. https://doi.org/10.1016/j.aorn.2013.02.001

National League for Nursing. (2022). *Tools and Instruments*. National League for Nursing. Retrieved January 13, 2023, from https://www.nln.org/education/teaching-resources/tools-and-instruments

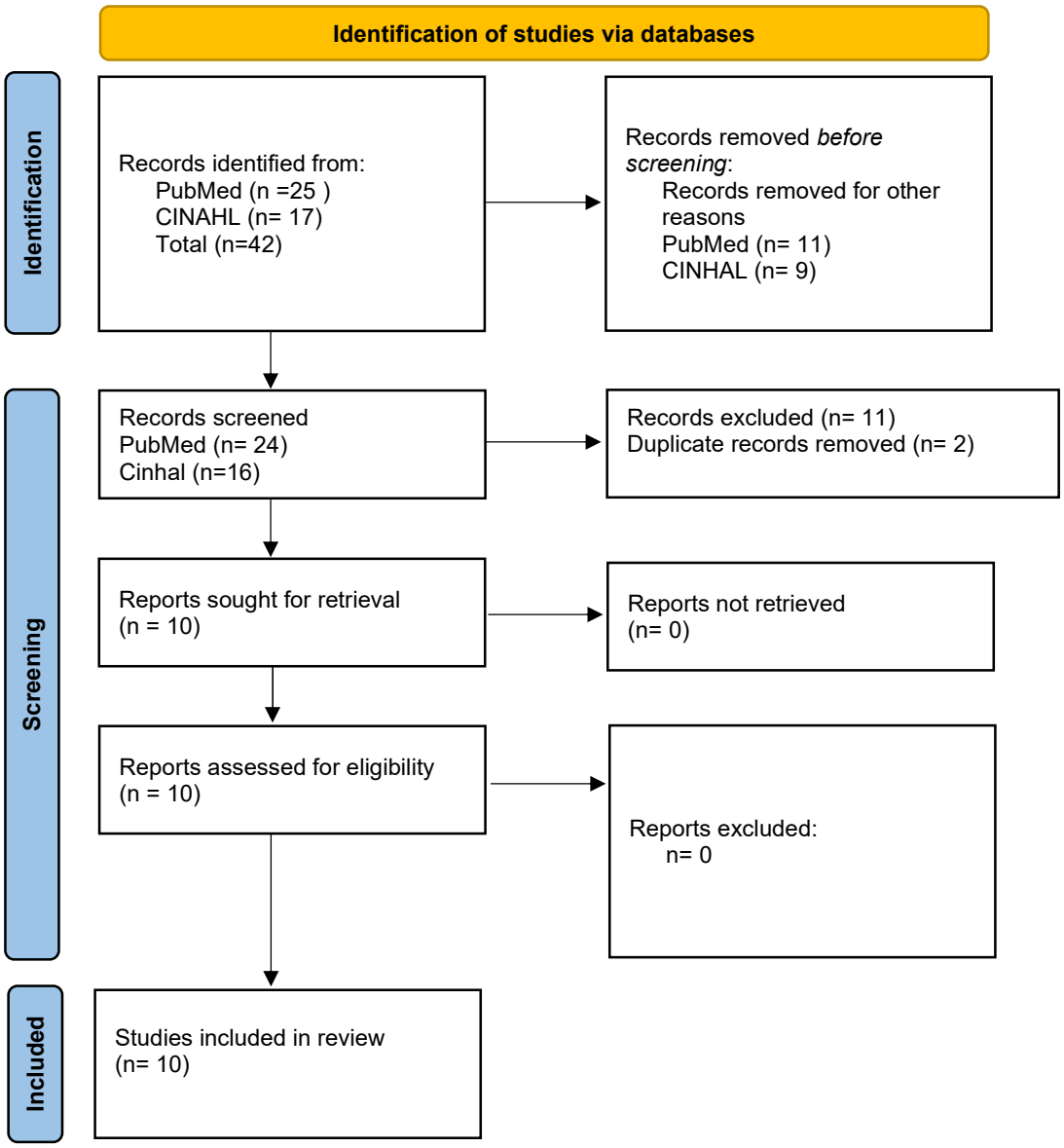
Rosenberg, H., Davis, M., James, D., Pollock, N., & Stowell, K. (2007). Malignant hyperthermia. *Orphanet Journal of Rare Diseases*, *2*(1). https://doi.org/10.1186/1750-1172-2-21

Rosenberg, H., Pollock, N., Schiemann, A., Bulger, T., & Stowell, K. (2015). Malignant hyperthermia: A Review. *Orphanet Journal of Rare Diseases*, *10*(1). https://doi.org/10.1186/s13023-015-0310-1

Schaad, S. (2017). Simulation-based training: Malignant hyperthermia. *AORN Journal*, *106*(2), 158–161. https://doi.org/10.1016/j.aorn.2017.06.008

Thompson Bastin, M. L., Cook, A. M., & Flannery, A. H. (2017). Use of simulation training to prepare pharmacy residents for medical emergencies. *American Journal of Health-System Pharmacy*, *74*(6), 424–429. https://doi.org/10.2146/ajhp160129

Appendix A



*Consider, if feasible to do so, reporting the number of records identified from each database or register searched (rather than the total number across all databases/registers).

From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71. doi: 10.1136/bmj.n71

For more information, visit: http://www.prisma-statement.org/

Appendix B

Citation	Research Design & Level of Evidence	Population / Sample size n=x	Major Variables	Instruments / Data collection	Results
Bashaw, M. (2016). Integrating simulations into perioperative education for undergraduate nursing students. *AORN Journal*, *103*(2). https://doi.org/10.1016/j.aorn.2015.12.017	Qualitative evaluation; level 3	9	-Only nursing roles -Mock OR -Class hours-> convenience sample -High fidelity simulator -Clinical faculty members who hold CNOR certification led the simulation experience.	Debrief QSEN competencies discussed	Simulation allows students to experience untoward patient outcomes without jeopardizing patients, especially for low-volume, high-risk scenarios. Also allowed student nurses to evaluate and improve their performance in a safe learning environment without risking harm to actual patients. Clarifying who performs the different tasks in an MH emergency simulation improves efficiency in an emergency response.
Cain, C. L., Riess, M. L., Gettrust, L., & Novalija, J. (2014). Malignant hyperthermia crisis: Optimizing patient outcomes through simulation and interdisciplinary collaboration. *AORN Journal, 99*(2), 300–311. https://doi.org/10.1016/j.aorn.2013.06.012	Quality improvement project; Level 5	33	n/a	Debrief and observational	Simulation is a recognized educational method that can be used to help personnel acquire the skills necessary to respond efficiently to an MH event.
Cannon-Diehl, M. R., Rugari, S. M., & Jones,, T. S. (2012). High-fidelity simulation for continuing education in nurse anesthesia. *AANA Journal*, *80*(3), 191–196.	Needs assessment non experimental study, level 3	22	-Age -Years of practice -Practice setting -Experience with HFS	Pilot survey	The higher cost of simulation technology, as opposed to traditional teaching and learning methods, has been cited as a barrier to simulation. 59% of nurse anesthetists polled would pay extra to experience HFS for continuing education. High-risk, low frequency events such as cardiopulmonary resuscitation, anesthesia machine mishaps, and malignant hyperthermia

					were cited as highly effective events to be used in simulation
Gallegos, E., & Hennen, B. (2022). Malignant hyperthermia preparedness training: Using cognitive aids and emergency checklists in the perioperative setting. *Journal of PeriAnesthesia Nursing*, *37*(1), 24–28. https://doi.org/10.1016/j.jopan.2020.09.02	Qualitative study; level 3	13	-previous experience with cognitive aid education -participants different work backgrounds/ experience	Post implementation survey	The use of simulated exercises incorporating cognitive aid tools was the best way to ensure participants would include critical MH treatment steps in their response and retain this information in the long term
Hardy, J.-B., Gouin, A., Damm, C., Compère, V., Veber, B., & Dureuil, B. (2018). The use of a checklist improves anaesthesiologists' technical and non-technical performance for simulated malignant hyperthermia management. *Anaesthesia Critical Care & Pain Medicine*, *37*(1), 17–23. https://doi.org/10.1016/j.accpm.2017.07.009	Prospective study; level 2	24	-previous experience with simulations -years of experience -clinical experience with MH	Performance evaluation tool based on SFAR guidelines	Anesthesiologists' use of the MH checklist during a simulation session widely improved their adherence to guidelines and non-technical skill
Henrichs, B., Rule, A., Grady, M., & Ellis, W. (2002). Nurse anesthesia students' perceptions of the anesthesia patient simulator: a qualitative study. *AANA Journal*, *70*(3), 219–225.	Qualitative study; level 3	12	Scenario, group size, time	Observation, journal entries, focus group interview	Disadvantages include the lack of reality, lack of knowledge on handling crisis events, possibility of fixation errors, and the presence of anxiety. Advantages include improved critical thinking and decision-making skills, increased confidence, and improved clinical preparation. Results can be used to assist instructors in improving the students' learning experiences a
Matsco, M., Marich, M., & Parke, P. (2020). Setting the foundation for an in situ simulation program through the development of a malignant hyperthermia simulation in the Operating Room. *The Journal of Continuing Education in Nursing*, *51*(11), 523–527.	Descriptive simulation evaluation; level 5	n/a	-staff scheduled to work -staff unaware simulation taking place before hand	Observational timeline collection, debrief with theme collection	positive reaction from this in situ training led to additional simulation requests for the education department.

https://doi.org/10.3928/00220124-20201014-09					
Mullen, L., & Byrd, D. (2013). Using simulation training to improve perioperative patient safety. *AORN Journal*, *97*(4), 419–427. https://doi.org/10.1016/j.aorn.2013.02.001	Descriptive simulation evaluation; level 5	n/a	n/a	Observational recording	Simulations safely identify problems that can happen during emergencies and allow staff members to evaluate their performance and improve it without risking harm to patients
Schaad, S. (2017). Simulation-based training: Malignant hyperthermia. *AORN Journal*, *106*(2), 158–161. https://doi.org/10.1016/j.aorn.2017.06.008	Nonexperimental study; level 3	>100	n/a	Verbal feedback	Improved clinical knowledge and competency relate. SBT enhanced communication among team members.
Thompson Bastin, M. L., Cook, A. M., & Flannery, A. H. (2017). Use of simulation training to prepare pharmacy residents for medical emergencies. *American Journal of Health-System Pharmacy*, *74*(6), 424–429. https://doi.org/10.2146/ajhp160129	Qualitative research; level 3	20	-Clinical scenario -PGY1 vs PGY2	Survey	Simulation training increased pharmacy residents' self-reported preparedness for high-stress, high-impact clinical scenarios and medical emergencies

Appendix C

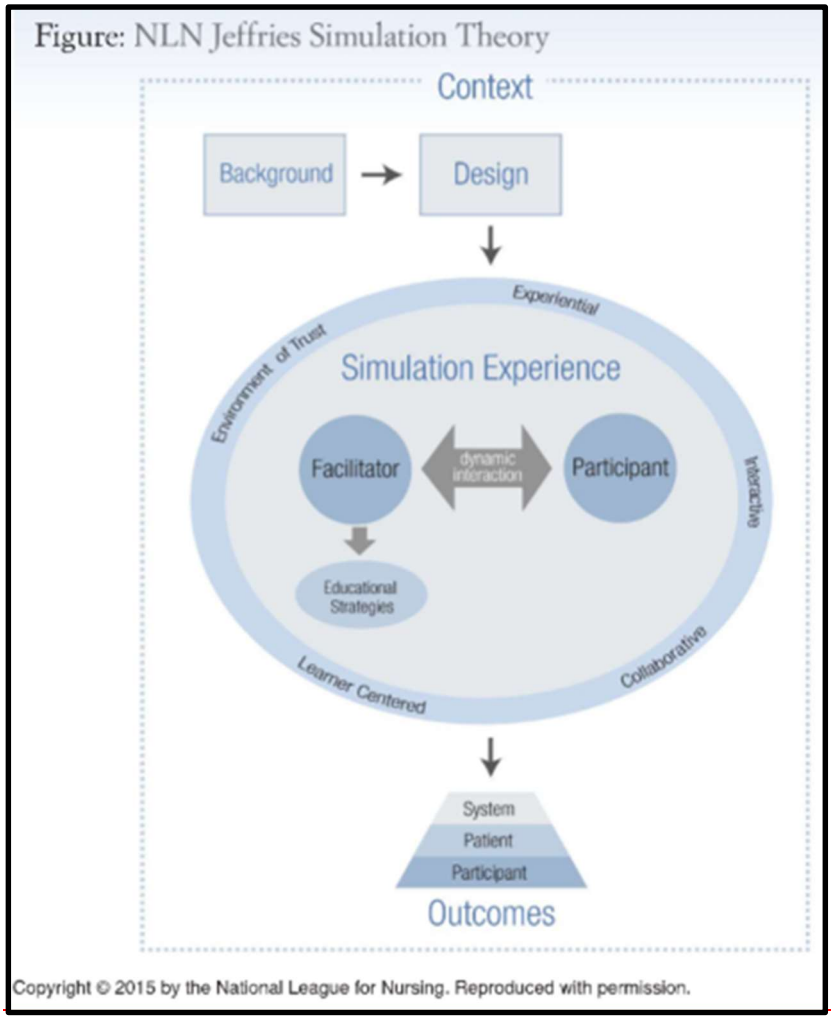
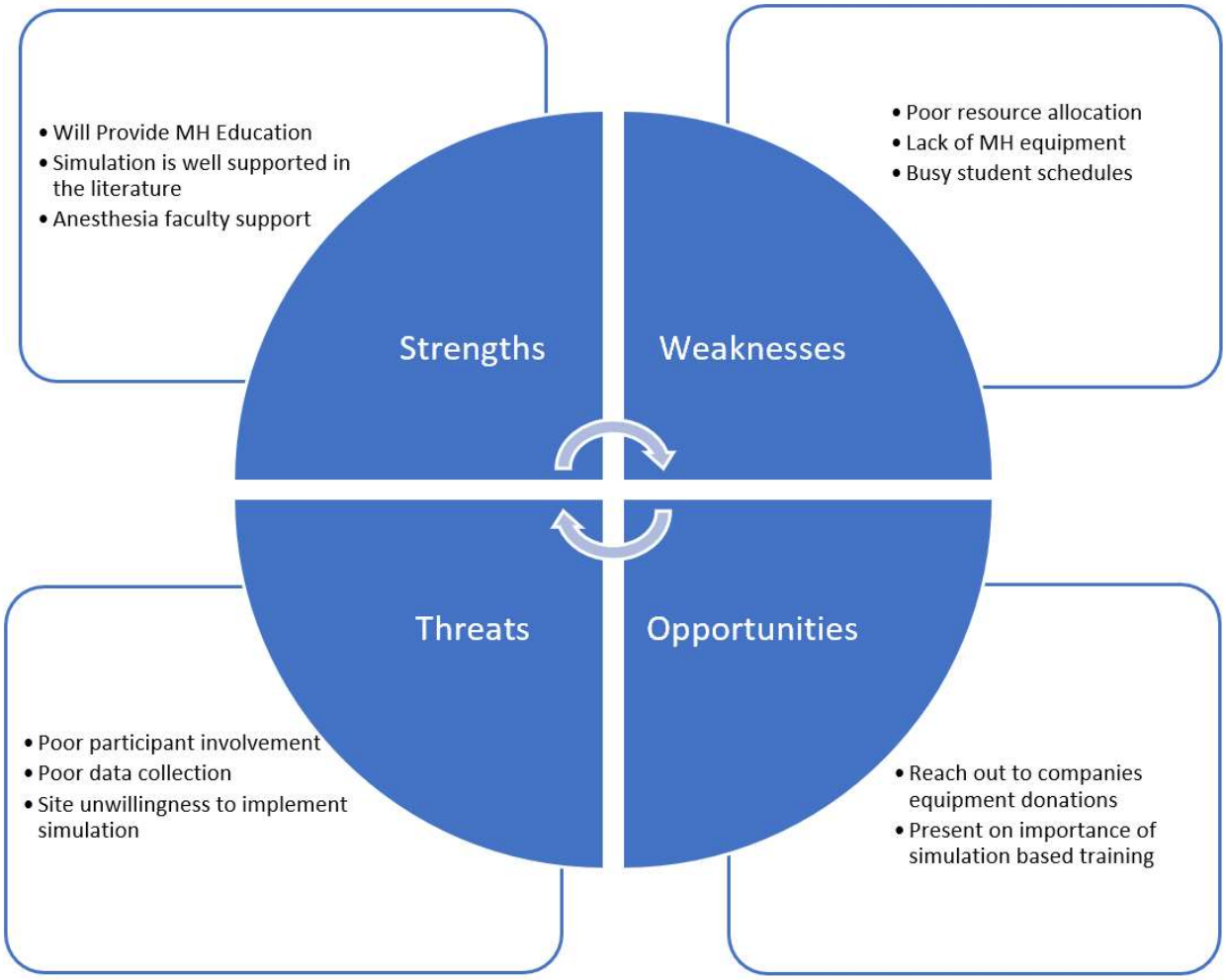


Figure: NLN Jeffries Simulation Theory
Context
Background
Design
Experiential
Environment of Trust
Simulation Experience
Facilitator
dynamic interaction
Participant
Interactive
Educational Strategies
Learner Centered
Collaborative
System
Patient
Participant
Outcomes
Copyright © 2015 by the National League for Nursing. Reproduced with permission.

Appendix D

Project SWOT Analysis



APPENDIX E

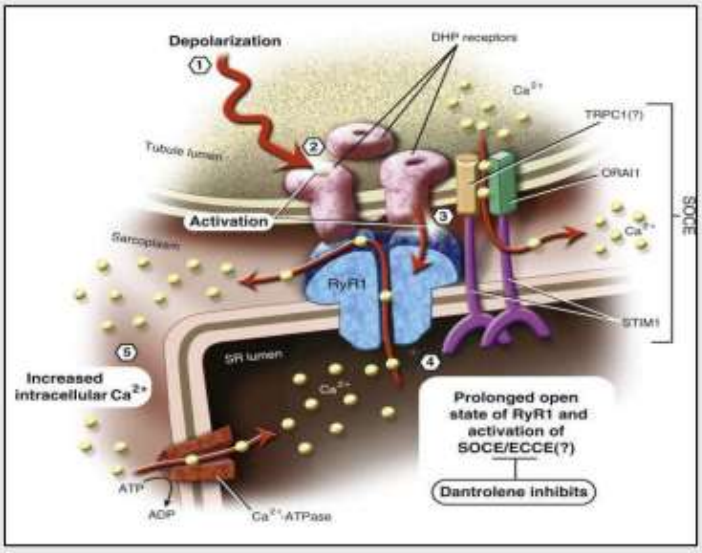
Malignant Hyperthermia

DNP Project By: Hilda Aveja SRNA

Project Chair: Dr. Lee Ranalli CRNA

1

MH Pathophysiology



2

Clinical Signs of MH

Early Signs

- Elevated $EtCO_2$
- Tachypnea/ tachycardia
- Masseter spasm
- Generalized muscle rigidity
- Mixed metabolic & respiratory acidosis
- Profuse sweating
- Mottling of the skin
- Cardiac arrythmias
- Unstable blood pressure

Late Signs

- Rapid increase in core body temperature
- Hyperkalemia
- Elevated creatine phosphokinase levels
- Gross myoglobinuria
- Disseminated intravascular coagulation
- Cardiac arrest

3

Diagnosis of MH

- Early recognition is vital for optimal outcome
  - Mortality rate of up to 80% if dantrolene is not given
  - Early administration can reduce mortality rate to 4%
- Two or more abnormal signs should be observed
- Arterial or venous blood gas analysis
  - Venous sampling may show signs hypermetabolism earlier
  - Mixed lactic and respiratory acidosis

4

Treatment of MH

1. Call for help & notify surgeon
2. Get MH CART & call MHAUS
3. Discontinue triggering agent; continue IV sedation
4. Hyperventilate the patient
5. Increase fresh gas flow ≥ 10 L/min
6. Insert activated charcoal filters
   - Replace every 60 minutes
7. Administer dantrolene (large bore IV)
   - 2.5 mg/kg Q5-10min with max dose of 30mg/kg
8. Administer bicarbonate
   - 1-4 mEq/kg IV
9. Control fever when > 38°C
   - Iced fluids, cooling blankets, heat exchanger
10. Monitor and treat arrythmias
    - Avoid calcium channel blockers
11. Place arterial line and central line
12. Maintain urine output > 1-2 mL/kg/hr
    - Place a foley catheter
13. Monitor blood gases, electrolytes, CK
    - Treat hyperkalemia (>5.9)
    - Ensure adequate magnesium levels
14. Analyze coagulation studies
15. Transfer to ICU & monitor 24-48 hr

5

Dantrolene Acute Administration

- Large bore IV
- 20 mg vial + 60 mL of STERILE WATER
- 2.5 mg/kg rapid IVP
  - Repeat until signs of MH end
  - May need up to 10-30 mg/kg

https://imgcdn.mckesson.com/CumulusWeb/Images/Original_Image/677808_ppkgright.jpg

6

Ryanodex Acute Administration

- Large bore IV
- 250 mg vial + 5 mL of STERILE WATER
- 2.5 mg/kg rapid IVP
  - Repeat until signs of MH end
  - May need up to 10-30 mg/kg

7

Post MH Episode

- Monitor for MH relapse
  - Can occur in up to 25% of cases
  - Untreated relapse can be fatal
- Continue to assess
  - CK levels Q6H
  - Blood gases PRN
  - Urine myoglobin
- Dantrolene Post Acute Phase
  - 1mg/kg IV Q4-6 hr

    OR
  - 0.25 mg/kg/hr IV infusion for at least 24 hr
- Educate patient/family
  - Refer to MHAUS
  - Fill out AMRA form

8

Evaluating for MH Susceptibility

- History of heat stroke
- History of dark-colored urine
- Previous episode of rhabdomyolysis
- History of unexplained fevers
- Presence of MultiminiCore Disease, CentralCore Disease, or other RyR1 associated myopathies
- Known MH-susceptible (MHS) relative
- High level of suspicion:
  - Caffeine-halothane contracture test

9

Anesthesia for MH Susceptible Patients

- Avoid MH triggering agents (halogenated anesthetics and depolarizing muscle relaxants)
  - Consider IV sedatives, nondepolarizing muscle relaxants, & regional anesthesia
- Do not pretreat with dantrolene
- Be aware of possible "stress" induced MH
- Prepare a cleansed anesthesia machine
  - Can take 10-104 minutes
  - Refer to manufacturer's guidelines
- Keep FGF ≥ 10 L/min
- Charcoal filters
- Ensure you have enough dantrolene available

10

Obstetric Considerations

- Non-MHS mother with possibly MHS fetus
  - Treat mother as is she were MHS until delivery
  - Avoid use of succinylcholine despite little evidence of placental transfer
- Dantrolene
  - Safe to use in obstetrics
  - Will cross the placenta
  - Expect weakness in the neonate

11

Team Dynamic

- Ask for help early
- Team leader
  - Delegate tasks
  - Set roles
  - Closed loop communication
  - Check-ins Q5-10 min
- Use checklist

12

MHAUS

24-HOUR MH HOTLINE
800-644-9737
Outside NA: 001-209-417-3722
FOR EMERGENCIES ONLY

13

References

- American Association of Nurse Anesthesiology. (n.d.). Malignant Hyperthermia Crisis Preparedness and Treatment. https://www.aana.com/docs/default-source/practice-aana-com-web-documents-(all)/malignant-hyperthermia-crisis-preparedness-and-treatment.pdf?sfvrsn=630049b1_8
- Chestnut, D. H., Wong, C. A., Tsen, L. C., Ngan Kee, W. D., Beilin , Y., Mhyre , J. M., & Bateman , B. T. (2020). *Chestnut's obstetric anesthesia: Principles and practice* (6th ed.). Elsevier.
- Gropper, M. A., & Miller, R. D. (2020). *Miller's anesthesia* (9th ed.). Elsevier.
- Malignant Hyperthermia Association of the United States. (n.d.). *What is MH / MHAUS?* MHAUS. Retrieved January 15, 2023, from https://www.mhaus.org/about/what-is-mh-mhaus/

14

Appendix F

Case:

Natalie Maye

Age: 17 year old

Gender: female

Weight: 55 kg

Height: 160 cm

Surgery: left rotator cuff repair

Anesthesia: general

Surgical position: sitting

Past medical history: none

No known allergies

Full code

Family history:

Father: (43 years old) no anesthesia history

Mother: (40 years old) history of appendectomy at 14 years old without complications

No siblings

Appendix G

Pre-test/ post-test one/ post-test two

1. Select 2 early clinical signs of MH:
    a. Hyperthermia
    b. Tachypnea
    c. Elevated EtCo2
    d. Hyperkalemia
2. What is the initial dose of dantrolene used to treat malignant hyperthermia?
    a. 0.25 mg/kg
    b. 2.5 mg/kg
    c. 0.15 mg/kg
    d. 1.5 mg/kg
3. What 2 conditions are NOT associated with malignant hyperthermia?
    a. Multiminicore disease
    b. Duchenne muscular dystrophy
    c. RyR1 myopathy
    d. Becker muscular dystrophy
4. Select the 2 answer choices that are NOT a trigger for malignant hyperthermia?
    a. Halogenated anesthetics
    b. Depolarizing muscle relaxants
    c. Non-depolarizing muscle relaxants
    d. IV anesthetics
5. Which test can be used to test for malignant hyperthermia susceptibility?
    a. Dibucaine inhibition test
    b. Caffeine halothane contracture test
    c. Total serum tryptase
    d. MTHFR gene detection

Appendix H

Malignant Hyperthermia Checklist	Met	Partially Met	Did Not Meet	Notes
1. Call for help & notify surgeon	10			
2. Get MH cart, code cart, cooling measures, call MHAUS	10			
3. Discontinue triggering agent; continue IV sedation	9	1 (did not start TIVA until further prompted)		
4. Hyperventilate the patient with 100% FiO2	9	1(only increased FiO2)		
5. Increase fresh gas flow ≥ 10 L/min	10			
6. Insert activated charcoal filters	9	1 (placed incorrectly)		
7. Administer dantrolene	9	1 (mixed drug and forgot to give it until further prompted)		
8. Administer bicarbonate	10			1-2 meq/kg (corrects lactic acidosis)
9. Monitor core temperature	10			
10. Control patient temperature appropriately	9	1 (cold IVF & lavage)		Cools to 38 degrees then stops Cold IVF Lavage Icepacks
11. Monitor and treat arrythmias	9		1 (did not teat life threatening arrythmia promptly with CPR)	Procainamide 15 mg.kg IV Lidocaine 2 mg/kg IV No CaCH blocker→ life threatening hyperkalemia
12. Maintain urine output > 1-2 mL/kg/hr with foley catheter	8	2 (forgot to place foley and give diuretics until further prompting)		IV hydration Mannitol 0.25g/kg Lasix 1 mg/kg IV
13. Monitor blood gases, electrolytes, CK	8	1 (did not order labs until further prompted)	1 (late treatment of hyperkalemia)	High k= 5-10mg/kg CaCl Insulin 0.15 u/kg +D50 1mL/kg Hyperventilate
14. Analyze coagulation studies	9	1 (did not order labs until further prompted)		
15. Transfer to ICU & monitor 24-48 hours	9	1 (needed prompting)		

Appendix I

MARIAN UNIVERSITY
Indianapolis ®

Institutional Review Board

DATE:	11/28/2023
TO:	Hilda Aveja & Lee Ranalli
FROM:	Institutional Review Board
RE:	S23.206
TITLE:	Simulation-based training for student registered nurse anesthetists managing malignant hyperthermia
SUBMISSION TYPE:	New Project
ACTION:	Determination of EXEMPT Status following Limited Review
DECISION DATE:	11/21/2023

The Institutional Review Board at Marian University has reviewed your protocol and has determined the procedures proposed are appropriate for exemption under the federal regulation. As such, there will be no further review of your protocol and you are cleared to proceed with your project. The protocol will remain on file with the Marian University IRB as a matter of record.

Although researchers for exempt studies are not required to complete online CITI training for research involving human subjects, the IRB **recommends** that they do so, particularly as a learning exercise in the case of student researchers. Information on CITI training can be found on the IRB's website: http://www.marian.edu/academics/institutional-review-board.

It is the responsibility of the PI (and, if applicable, the faculty supervisor) to inform the IRB if the procedures presented in this protocol are to be modified of if problems related to human research participants arise in connection with this project. Any procedural modifications must be evaluated by the IRB before being implemented, as some modifications may change the review status of this project. Please contact me if you are unsure whether your proposed modification requires review. Proposed modifications should be addressed in writing to the IRB. **Please reference the above IRB protocol number in any communication to the IRB regarding this project.**

Christina Pepin, Ph.D., RN, CNE
Chair, Marian University Institutional Review Board