

Case Report

High-Stakes, High-Fidelity Simulation: Improving Patient Outcomes During Malignant Hyperthermia Crises

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Malignant hyperthermia (MH) is a rare, life-threatening disorder triggered by certain anesthetic agents. Prompt recognition and intervention are critical to prevent morbidity and mortality. For unique cases such as MH, many nurse anesthesia programs use high-fidelity simulation to prepare resident registered nurse anesthetists (RRNAs) for low-frequency high-stakes events. This case report highlights a RRNA who participated in a high-fidelity MH simulation prior to graduation, which provided a valuable opportunity to identify and improve technical and nontechnical skills. Three months post-graduation, the novice Certified Registered Nurse Anesthetist (CRNA) encountered a real MH event in a 38-year-old female undergoing general anesthesia post cesarean section. Drawing on the prior simulation experience, the CRNA promptly recognized the signs and initiated the MH protocol. The patient was successfully discharged a few days after the event and reunited with her infant. This case highlights the impact of simulation-based education on patient care. High-fidelity simulation fosters clinical readiness, enhances decision-making, and can directly contribute to improved patient outcomes. Nurse anesthesia programs should also consider integration of virtual reality to promote repeated exposure of these low frequency, high-stakes events.

INTRODUCTION

Malignant hyperthermia (MH), first identified in 1960, is a uniquely life-threatening disorder triggered in susceptible individuals by exposure to volatile anesthetics or succinylcholine.¹⁻³ The rate of occurrence is estimated to be between 1:5,000 to 1:50,000 for general anesthetic cases.^{2,3} The pediatric population accounts for over half of all reported MH cases.⁴ Additionally, MH occurs significantly more in males, with an estimated incidence of up to 4.5 times higher than that observed in females.^{2,5} High-incidence areas of MH include Wisconsin, Nebraska, West Virginia, and Michigan.² MH has been associated with congenital myopathies, including central core disease, King-Denborough syndrome, and multiminicore disease.² MH is characterized by abnormal depolarization of skeletal muscle membranes and mutations in the RYR1 gene, leading to excessive calcium release, sustained muscle contraction, and a life-threatening hypermetabolic state.¹⁻³ If not treated promptly, MH can cause multiple organ failure, rhabdomyolysis, and ultimately death.

Given that MH can occur in the perioperative setting, it is essential for anesthesia providers to be proficient in managing such crises. According to the Malignant Hyperthermia Association of the United States (MHAUS) the top 4 actions should be initiated to manage MH: 1) immediate cessation of all triggering agents, 2) obtain the MH cart, 3) initiation of 100% oxygen hyperventilation, and 4) prompt administration of dantrolene or ryanodex.^{2,5} There are several other required actions to effectively manage a MH cri-

sis. However, heightened anxiety and limited exposure to MH can hinder decision-making and jeopardize patient outcomes. To support preparation for this crisis, many nurse anesthesia programs integrate both didactic instruction and high-fidelity simulation to reinforce technical and nontechnical skills. High-fidelity simulation can be used for low-frequency, high-stakes events such as MH to improve critical thinking, enhance learners' confidence, and reduce anxiety⁶ ultimately enhancing preparedness and improving patient outcomes.⁷

CASE DESCRIPTION

High-fidelity simulations involving MH are typically integrated into the curriculum for second- or third-year resident registered nurse anesthetists (RRNAs) to prepare them for this rare but potentially fatal clinical event. [Table 1](#) illustrates how MH learning activities and simulation were aligned with Miller's Pyramid of Clinical Competence, demonstrating progression from foundational knowledge to performance in practice to prepare RRNAs for MH.⁸ The MH scenario was developed in alignment with the International Nursing Association for Clinical Simulation and Learning (INACSL) Standards of Best Practice: Simulation and validated by an additional content expert.⁹

TIMELINE

Each high-fidelity simulation began with a 20-minute scripted pre-brief in which 2 RRNAs received a report on

Table 1. MH Learning Activities

Event/ Simulation	Description	Semester	Application of Miller's Pyramid of Clinical Competence
MH Lecture	PowerPoint and exam	Summer	Knows
MH Lecture	Case study	Summer	Knows how
MH Simulation	-20-minute structured prebriefing -20-minute high-fidelity simulation -40-minute debriefing with good judgement using behavioral assessment tool	Spring	Shows how
MH Clinical Event	-Patient's ETCO ₂ increased to the 90s and temperature to 39.5 Celsius -CRNA responds by increasing the respiratory rate with no change in ETCO ₂ -CRNA calls for help and initiates MH protocol -Patient is appropriately treated and discharged from the hospital a few days later	Fall	Does

Abbreviations: MH, malignant hyperthermia; ETCO₂, end-tidal CO₂; CRNA, Certified Registered Nurse Anesthetist

an 18-year-old male undergoing a laparoscopic appendectomy. Following the pre-brief, RRNAs were immersed in a 20-minute MH high-fidelity simulation. A behavioral assessment tool (BAT) was created and used by faculty to guide the 40-minute debriefing session. The objectives listed in the BAT were 1) identify signs and symptoms of MH, 2) identify MH crisis, 3) initiate and implement treatment for MH, and 4) demonstrate effective teamwork, leadership, delegation, and closed-loop communication during a MH crisis. A 40-minute debriefing session using the "Debriefing with Good Judgment" model concluded each simulation. This structured process was consistently applied across all simulations. All RRNAs participated in the high-fidelity simulation during training. However, this case study highlights a RRNA who, after graduation, encountered an actual MH event in clinical practice. An MH event in the clinical setting is exceedingly rare, as most anesthesia providers never experience an MH event, and it is particularly uncommon for such an event to occur as a novice certified registered nurse anesthetist (CRNA).¹⁰

During the MH high-fidelity simulation, the RRNA exhibited heightened anxiety and decreased confidence in managing MH. This contributed to missed critical interventions necessary for the effective treatment and management of the simulated MH scenario. However, during the structured debriefing session, the RRNA engaged in reflective practice, identifying gaps in knowledge, skills, and attitudes. The debriefing facilitated a meaningful discussion of key takeaways, reinforcing the importance of early recognition, timely intervention, and adherence to MH protocols.

A few months post-graduation, the novice CRNA encountered an MH crisis in the clinical setting. The patient was a 38-year-old female patient undergoing general anesthesia. The patient had an unremarkable medical history aside from a cesarean section performed a few months earlier. Approximately 3 hours into the procedure, the surgeon announced that 10 minutes were left in the case. The patient had been pharmacologically reversed and was spontaneously ventilating with minimal anesthetic gas remaining.

Hemodynamic parameters were stable. The novice CRNA began to notice changes in the patient's hemodynamics. The patient's end-tidal CO₂ (ETCO₂) rose sharply from the 40s to the 60s. The CRNA responded by switching the patient to synchronized intermittent mandatory ventilation and increasing the respiratory rate. Despite these efforts, ETCO₂ continued to climb into the 90s and the patient's temperature increased to 39.5 Celsius. Recognizing the signs of MH and recalling the prior MH simulation, the novice CRNA called for assistance and in collaboration with the attending anesthesiologist promptly initiated the MH protocol.

The patient underwent successful treatment and was subsequently transferred to the intensive care unit for 24-hour observation. Following a stable recovery, the patient was safely discharged home a few days later, reunited with her infant. Throughout the case, the novice CRNA demonstrated application of knowledge and skill which contributed to improving this patient's outcome. This case highlights the unique value of high-fidelity simulation in preparing RRNAs for rare, high-stakes emergencies such as MH. The CRNA's swift recognition and decisive action was rooted in prior simulation experience and were critical to the successful management of this life-threatening event.

FOLLOW UP OR ADJUSTMENTS NEEDED

In this case report, RRNAs received didactic instruction, completed examinations to assess knowledge, and participated in a single high-fidelity simulation. While multiple exposures to low-frequency, high-stakes simulations would be ideal, such experiences are often constrained by significant demands on time, cost, and personnel. Given these limitations, one potential curricular adjustment is the integration of virtual reality (VR) simulation. VR offers an opportunity for students to engage in low-frequency, high-stakes scenarios such as MH outside of scheduled simulations or workshops to maximize learning.^{11,12}

This structured approach further aligns with Miller's Pyramid of Clinical Competence.⁸ RRNAs begin at the *knows* level by acquiring foundational knowledge through lectures, quizzes, and examinations. RRNAs advance to the *knows how* level by applying this knowledge in VR scenarios. Participation in high-fidelity simulations allows RRNAs to reach the *shows how* level, demonstrating both technical and nontechnical skills in a simulated clinical environment. Ultimately, the goal is for RRNAs to achieve the *does* level, where they apply these skills in practice. This approach may further strengthen the confidence, preparedness, and performance of RRNAs and novice providers in managing complex, high-stakes events in the community.

DISCUSSION

This case report demonstrates the usefulness of high-fidelity simulation in nurse anesthesia programs to help improve patient outcomes. High-fidelity simulations support effective teaching through timely feedback, deliberate practice, and a safe, controlled learning environment.^{13,14} One of the key challenges for novice providers is translating knowledge into effective clinical decision-making, which can be achieved through high-fidelity simulations.¹³⁻¹⁵ Periodic education and limited clinical exposure alone are not sufficient to fully prepare RRNAs and CRNAs for the timely and complete management of MH or any crisis in the operating room.¹³⁻¹⁷ Integrating high-fidelity simulation into nurse anesthesia education may help bridge the gap between theory and practice, ultimately improving patient safety.^{14,17} This case highlights the value of incorporating low frequency, high-stakes simulations into anesthesia curricula, rather than relying on didactic content alone.

One limitation of simulation-based education is the variability in RRNA engagement and the ability to suspend disbelief during high-fidelity scenarios. Not all learners are able to fully immerse themselves in the simulated environment, which may affect the depth of their learning and reflection. In contrast, the RRNA in this case report demonstrated a high level of engagement, actively participating in both the scenario and the debriefing process. The experience prompted further reflection, leading the RRNA to independently seek out additional information on key concepts that had initially been missed during the simulation.

Another challenge is the limited exposure RRNAs may have to low-frequency, high-stakes clinical events such as

MH during their training. Without repeated opportunities to practice these scenarios, RRNAs may struggle to retain critical information, including appropriate medication dosages and emergency interventions. The principles of competency-based education emphasize the demonstration of expertise over time through repeated practice.¹⁸ Integrating high-fidelity simulation with VR in nurse anesthesia programs may allow RRNAs to repeatedly practice rare, high-stakes scenarios like MH, ultimately improving clinical preparedness and patient outcomes.¹⁹

PERSPECTIVE

During the debriefing session, the RRNA reported the simulation as having gone "horribly," and having missed key interventions. Closed-loop communication, teamwork, leadership, and delegation were challenging to execute during the simulation. However, when faced with an actual MH event in the operating room a few months after the high-fidelity simulation, the novice CRNA played an active role in identifying, treating, and managing the crisis. After the MH event in the operating room, the novice CRNA described the simulation as a "defining moment" in their training, attributing clinical readiness gained through simulation.

Although MH is a rare clinical occurrence and one that many anesthesia providers may never encounter in their careers, this case illustrates the critical importance of simulation in preparing providers for high-stakes, low-frequency events. The patient involved in the MH event was successfully extubated the following day and was reunited with her infant, underscoring the real-world impact of simulation-based education. Evidence supports that simulation enhances clinical decision-making, confidence, and performance in the clinical setting, and can contribute to improved patient outcomes.¹⁴⁻¹⁷ The use of VR for training RRNAs may be beneficial to enhance immersive learning experiences and provide realistic, interactive environments to improve patient outcomes.¹⁹ Even a single positive patient outcome validates the inclusion of such scenarios in anesthesia curricula. The utilization of high-fidelity simulation can be a valuable tool to prepare RRNAs for patient care.

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REFERENCES

1. Hopkins PM. Malignant hyperthermia. *Br J Anaesth*. 2000;85(1):118-128. doi:[10.1093/bja/85.1.118](https://doi.org/10.1093/bja/85.1.118)
2. MHAUS. *Managing a Crisis*. Malignant Hyperthermia Association of the United States; 2025. Accessed November 11, 2025. <https://www.mhaus.org/healthcare-professionals/managing-a-crisis/>
3. Hopkins PM, Girard T, Dalay S, et al. Malignant hyperthermia 2020: guideline from the Association of Anaesthetists. *Anaesthesia*. 2021;76(5):655-664. doi:[10.1111/anae.15317](https://doi.org/10.1111/anae.15317)
4. Nelson P, Litman RS. Malignant hyperthermia in children: an analysis of the North American malignant hyperthermia registry. *Anesth Analg*. 2014;118(2):369-374. doi:[10.1213/ANE.0b013e3182a8fad0](https://doi.org/10.1213/ANE.0b013e3182a8fad0)
5. Rosenberg H, Davis M, James D, Pollock N, Stowell K. Malignant hyperthermia. *Orphanet J Rare Dis*. 2007;2:21. doi:[10.1186/1750-1172-2-21](https://doi.org/10.1186/1750-1172-2-21)
6. Elendu C, Amaechi DC, Okatta AU, et al. The impact of simulation-based training in medical education: a review. *Medicine*. 2024;103(27):1-14. doi:[10.1097/MD.00000000000038813](https://doi.org/10.1097/MD.00000000000038813)
7. Quick J, Murthy R, Goyal N, Margolis S, Pond G, Jenkins K. Malignant hyperthermia: an anesthesiology simulation case for early anesthesia providers. *MedEdPORTAL*. 2017;13:1-5. doi:[10.15766/mep_2374-8265.10550](https://doi.org/10.15766/mep_2374-8265.10550)
8. Miller GE. The assessment of clinical skills/competence/performance. *Acad Med*. 1990;65:63-67. doi:[10.1097/00001888-199009000-00045](https://doi.org/10.1097/00001888-199009000-00045)
9. INACSL. *Healthcare Simulation Standards of Best Practice*. International Nursing Association for Clinical Simulation and Learning; 2025. Accessed November 11, 2025. <https://www.inacsl.org/healthcare-simulation-standards-of-best-practice->
10. Parsons SM, Kuszajewski ML, Merritt DR, Muckler VC. High-fidelity simulation training for nurse anesthetists managing malignant hyperthermia: a quality improvement project. *Clin Sim Nurs*. 2019;26:72-80. doi:[10.1016/j.ecns.2018.10.003](https://doi.org/10.1016/j.ecns.2018.10.003)
11. Choi J, Thompson CE, Choi J, Waddill CB, Choi S. Effectiveness of immersive virtual reality in nursing education: systematic review. *Nurse Educ*. 2022;47(3):57-61. doi:[10.1097/NNE.0000000000001117](https://doi.org/10.1097/NNE.0000000000001117)
12. Sim JJM, Rusli KDB, Seah B, Levett-Jones T, Lau Y, Liaw SY. Virtual simulation to enhance clinical reasoning in nursing: a systematic review and meta-analysis. *Clin Sim Nurs*. 2022;69:26-39. doi:[10.1016/j.ecns.2022.05.006](https://doi.org/10.1016/j.ecns.2022.05.006)
13. Merchant DC. Does high-fidelity simulation improve clinical outcomes? *J Nurses Prof Dev*. 2012;28(1):1-8. doi:[10.1097/NND.0b013e318240a728](https://doi.org/10.1097/NND.0b013e318240a728)
14. La Cerra C, Dante A, Caponnetto V, et al. Effects of high-fidelity simulation based on life-threatening clinical condition scenarios on learning outcomes of undergraduate and postgraduate nursing students: a systematic review and meta-analysis. *BMJ Open*. 2019;9(2):1-11. doi:[10.1136/bmjopen-2018-025306](https://doi.org/10.1136/bmjopen-2018-025306)
15. Boling B, Hardin-Pierce M. The effect of high-fidelity simulation on knowledge and confidence in critical care training: an integrative review. *Nurse Educ Pract*. 2016;16(1):287-293. doi:[10.1016/j.nepr.2015.10.004](https://doi.org/10.1016/j.nepr.2015.10.004)
16. Armenia S, Thangamathesvaran L, Caine AD, et al. The role of high-fidelity team-based simulation in acute care settings: a systematic review. *Surgery J (N Y)*. 2018;4(3):136-151. doi:[10.1055/s-0038-1667315](https://doi.org/10.1055/s-0038-1667315)
17. Cain CL, Riess ML, Gettrust L, Novalija J. Malignant hyperthermia crisis: optimizing patient outcomes through simulation and interdisciplinary collaboration. *AORN J*. 2014;99(2):301-308. doi:[10.1016/j.aorn.2013.06.012](https://doi.org/10.1016/j.aorn.2013.06.012)
18. Lewis LS, Rebesch LM, Hunt E. Nursing education practice update 2022: competency-based education in nursing. *SAGE Open Nurs*. 2022;8:1-6. doi:[10.1177/23779608221140774](https://doi.org/10.1177/23779608221140774)
19. Wang W, Gao L, Lin Y, et al. Virtual reality is emerging training applications for anesthesia simulation. *Eur J Med Res*. 2025;30:1-8. doi:[10.1186/s40001-025-03054-9](https://doi.org/10.1186/s40001-025-03054-9)