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RESEARCH ARTICLE

THE IMPORTANCE OF REALISTIC SIMULATION LEARNING IN MANAGING RARE SITUATIONS IN ANESTHESIA: MALIGNANT HYPERTHERMIA

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Abstract

Malignant hyperthermia (MH) is a rare, life-threatening pharmacogenetic disorder triggered by certain anesthetic agents, requiring rapid recognition and intervention to prevent serious complications. Given its infrequency, healthcare professionals, especially anesthesia providers, may have limited exposure to managing this critical emergency. This study aims to evaluate the impact of simulation-based training on improving the knowledge, skills, and confidence of anesthesia residents in managing malignant hyperthermia. A pre-experimental study was conducted with 50 anesthesia residents at the Mohamed V Military Instruction Hospital. Participants engaged in a simulation session designed to mimic the clinical scenario of malignant hyperthermia during surgery. Knowledge assessments conducted before and after the simulation revealed a significant improvement in the residents' understanding of MH, including its recognition, triggers, and management. Self-reported confidence in handling MH crises also increased notably. Furthermore, 90% of residents expressed overall satisfaction with the simulation-based training, highlighting its value for enhancing critical care readiness. The results underscore the effectiveness of high-fidelity simulation in preparing anesthesia residents for rare but life-threatening scenarios, thereby contributing to better patient safety and clinical outcomes in anesthesia practice.

Introduction:-

Simulation-based learning is a key educational tool in health sciences [1], especially in disciplines like anesthesia where the ability to respond promptly and effectively to rare but critical situations is paramount. Malignant hyperthermia (MH) is a life-threatening pharmacogenetic disorder triggered by certain anesthetic agents. It requires immediate recognition and intervention to prevent significant morbidity and mortality. As this crisis is rare, it poses a challenge for healthcare professionals to maintain a high level of readiness to manage it effectively [2]. This study aims to explore the impact of realistic simulation-based training on the management of malignant hyperthermia among anesthesia residents.

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Materials and Methods:-

A pre-experimental study was conducted in the simulation room of the Anesthesia and Intensive Care Unit at Mohamed V Military Instruction Hospital. The study involved 50 residents in their 2nd and 3rd years of anesthesia training. These participants were engaged in a simulation session specifically designed to mimic the clinical scenario of malignant hyperthermia.

The study utilized two primary tools:

1. **Pre- and Post-Simulation Knowledge Questionnaires**: These were used to assess changes in the residents' theoretical and practical knowledge regarding the recognition and management of malignant hyperthermia. (annex 1)
2. **Satisfaction Questionnaire**: This assessed residents' perceptions of the training session's effectiveness and their overall satisfaction with the simulation-based approach. (annex 2)

Simulation Scenario: Malignant Hyperthermia Crisis During Surgery

Scenario Overview:

The anesthesia team is performing a routine surgery under general anesthesia when the patient begins to show early signs of malignant hyperthermia. The team must quickly recognize the symptoms and initiate the correct management protocol to prevent further complications.

Scenario Details:

- **Patient:**
  A 30-year-old male undergoing elective orthopedic surgery (e.g., knee arthroscopy). The patient has no known history of malignant hyperthermia or family history of anesthetic reactions. He has no significantcomorbidities.
- **Anesthesia:**
  General anesthesia is induced with **fentanyl,propofol** and muscle relaxation is achieved with **succinylcholine**. The patient is intubated and placed on a ventilator. Monitoring equipment (e.g., capnography, ECG, pulse oximeter) is in place.

Triggering Event:

- During the procedure, approximately 30 minutes into the surgery, the anesthesia provider notices the following:
  - **Tachycardia:** Heart rate increases from a baseline of 80 bpm to 130 bpm.
  - **Hypercapnia:** End-tidal CO_2 ($ETCO_2$) begins to rise significantly, reaching 55 mmHg, despite adequate ventilation.
  - **Muscle Rigidity:** The patient's jaw becomes rigid, and there is generalized muscle stiffness observed.
  - **Elevated Temperature:** The temperature begins to rise, reaching 38.8°C.
  - **Blood Pressure Fluctuations:** Blood pressure becomes labile, with sudden drops.

Learning Objectives:

1. **Recognize** the early signs of malignant hyperthermia during anesthesia.
2. **Initiate the MH protocol** (discontinue triggering agents, administer dantrolene).
3. **Manage symptoms** such as hyperthermia, muscle rigidity, and acidosis.
4. **Communicate effectively** with the surgical team and other healthcare providers to manage the crisis.

Expected Actions:

1. **Recognize early signs of MH:**
   The anesthesia provider should suspect malignant hyperthermia when the above symptoms are observed. Early recognition iscritical for a favorable outcome.
2. **Discontinue triggering agents:**
   The provider should immediately stop the administration of **volatile anesthetics** (e.g., sevoflurane) and **succinylcholine**. This is crucial to prevent further progression of the crisis.
3. **Administer dantrolene:**
   The first dose of **dantrolene** (2.5 mg/kg) should be administered immediately, with subsequent doses given as needed. The drug should be prepared and administered as soon as possible.

4. **Cool the patient:**
   Cooling measures should be initiated to reduce the body temperature. This can include ice packs, cooling blankets, and infusion of iced saline through the IV.
5. **Supportive management:**
- **Ventilate** the patient adequately (increase tidal volume or ventilation if needed).
- **Monitor electrolytes** and correct any imbalances (e.g., hyperkalemia, acidosis).
- **Ensure aggressive hydration** with intravenous fluids to support renal perfusion and help with cooling.
- If required, initiate **cardiac monitoring** and prepare for any arrhythmias (e.g., defibrillation).

Debriefing:
After the scenario, the instructor should lead a debrief with the participants, discussing the following:
- **What went well:** Identifying and managing MH early.
- **What could be improved:** Speed of dantrolene administration, communication with the surgical team.
- **Real-life application:** Discuss how this scenario could be applied in the real operating room setting and how team communication and preparedness are key to managing MH.

Simulation Goal:
The goal of this simulation is to give anesthesia providers experience in recognizing and managing a rare but critical event (malignant hyperthermia) in a controlled environment. By practicing the proper steps in a high-pressure situation, the providers will be better prepared to manage the crisis effectively in real clinical practice.

Results:-

Out of the 50 residents initially enrolled, 40 (80%) participated in the study. A significant improvement in both theoretical and practical knowledge of malignant hyperthermia was observed post-simulation. The results from the questionnaires revealed the following:

Knowledge Assessment
Pre-Simulation Knowledge Scores:
- Prior to the simulation, most residents had an incomplete understanding of key aspects of malignant hyperthermia, including its symptoms, triggers, and treatments.

Post-Simulation Knowledge Scores:
- After the simulation, residents demonstrated a marked improvement in their understanding of MH. For example, the correct identification of the anesthetic agents that trigger MH (e.g., halothane) and the first-line treatment (dantrolene) increased significantly.

Question	Pre-Training (%)	Post-Training (%)	Improvement
What is malignant hyperthermia?	30%	95%	+65%
Which anesthetic agent is known to trigger malignant hyperthermia?	50%	92%	+42%
What are common signs of malignant hyperthermia?	40%	87.5%	+47.5%
What is the first-line treatment for malignant hyperthermia?	60%	97.5%	+37.5%
How can malignant hyperthermia be diagnosed during surgery?	45%	90%	+45%

Table 1:- Knowledge Assessment Questionnaire Results.

Confidence Levels:

- The residents' self-reported confidence in managing malignant hyperthermia increased substantially. The majority of participants rated their confidence as **4 or 5 out of 5** (Very Confident) on the confidence scale.

Reduction in Response Time:

- The average response time to the questionnaire-based knowledge test decreased after the simulation, indicating an improvement in the residents' ability to recall and apply information under pressure.

Metric	Pre-Training	Post-Training	Difference
Average Response Time (seconds)	23 sec	14 sec	-9 sec

Table 2:- Reduction in Response Time.

Satisfaction Survey:

- Overall satisfaction with the training session was very high, with 90% of participants expressing that they were satisfied with the session and recommending this type of training for other critical anesthesia situations.

Statement	Agree/Strongly Agree (%)
The simulation was realistic and closely mimicked a real-life clinical scenario.	95%
The learning objectives were clearly communicated at the beginning of the session.	90%
The simulation helped improve my understanding of malignant hyperthermia.	92.5%
I feel confident in managing malignant hyperthermia after this training.	87.5%
Overall, I am satisfied with the simulation session.	90%

Table 3:- Satisfaction Survey.

Discussion:-

The results of this study highlight the significant value of simulation-based training in anesthesia. Malignant hyperthermia is a rare but critical emergency, and the ability to act swiftly and correctly can dramatically impact patient outcomes. Simulation training enhances both **theoretical knowledge** and **practical skills**, preparing residents to manage such crises confidently [3]. The improvement in knowledge, the reduction in response time, and the high levels of satisfaction with the training session all suggest that simulation is an effective pedagogical tool [4].

The study found that after participating in the simulation session, the residents' knowledge of malignant hyperthermia improved markedly. They demonstrated a deeper understanding of how to identify the signs of MH, the drugs that trigger the condition, and the appropriate emergency response, such as administering **dantrolene** and using **cooling measures**. The scenario-based question also showed that residents' decision-making skills were significantly enhanced by the simulation [5].

The **satisfaction survey** indicated that the majority of participants found the simulation session beneficial and would recommend its use for training in other critical anesthesia emergencies. This reinforces the idea that simulation provides a unique and irreplaceable learning experience, especially in situations that require rapid decision-making under pressure [6].

Conclusion:-

Simulation-based training is a powerful tool in preparing anesthesia residents to manage rare but critical situations like malignant hyperthermia. This study demonstrated that simulation significantly improves both theoretical knowledge and practical skills, while also boosting residents' confidence in their ability to respond to an MH crisis. The high satisfaction rate and the residents' recommendation for similar training in other critical scenarios underscore the value of this method. Ultimately, incorporating high-fidelity simulation into the curriculum of anesthesia training programs could lead to improved patient safety and better management of high-stakes emergencies in the operating room.

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Annex 1 :Malignant Hyperthermia Knowledge Questionnaire

Demographic Information:

1. Name: _____
2. Year of Residency: _____
3. Previous Training in Anesthesia (Yes/No): _____

KnowledgeAssessment:

1. What is malignant hyperthermia?
   a) A life-threatening reaction to certain anesthetics
   b) A type of muscle disorder
   c) An infection
   d) A normal physiological response
2. Which anesthetic agent is known to trigger malignant hyperthermia?
   a) Propofol
   b) Nitrous oxide
   c) Halothane
   d) Local anesthetics
3. What are common signs of malignant hyperthermia? (Select all that apply)
   a) Rapid heart rate
   b) High fever
   c) Muscle rigidity
   d) Nausea
4. What is the first-line treatment for malignant hyperthermia?
   a) Dantrolene
   b) Calcium channel blockers

c) Aspirin
d) Corticosteroids

5. How can malignant hyperthermia be diagnosed during surgery?
   a) Blood tests
   b) Monitoring vital signs and symptoms
   c) Imaging
   d) Patient history only
6. Which preventive measure is crucial for at-risk patients?
   a) Using non-triggering anesthetics
   b) Avoiding anesthesia altogether
   c) Pre-medication with antibiotics

Annex 2 :Satisfaction Questionnaire

1. **The simulation was realistic and closely mimicked a real-life clinical scenario.**
   - Strongly Disagree (1) | Disagree (2) | Neutral (3) | Agree (4) | Strongly Agree (5)
2. **The learning objectives were clearly communicated at the beginning of the session.**
   - Strongly Disagree (1) | Disagree (2) | Neutral (3) | Agree (4) | Strongly Agree (5)
3. **The simulation helped improve my understanding of malignant hyperthermia.**
   - Strongly Disagree (1) | Disagree (2) | Neutral (3) | Agree (4) | Strongly Agree (5)
4. **I feel confident in managing malignant hyperthermia after this training.**
   - Strongly Disagree (1) | Disagree (2) | Neutral (3) | Agree (4) | Strongly Agree (5)
5. **Overall, I am satisfied with the simulation session.**
   - Strongly Disagree (1) | Disagree (2) | Neutral (3) | Agree (4) | Strongly Agree (5)