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In Situ Simulation to Plan Malignant Hyperthermia Workflow for the Emergency Department

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Abstract

Understanding the pathophysiology of malignant hyperthermia as well as its clinical manifestations is important. This is despite the fact that it only occurs very rarely. However, when it does occur, the recognition and management has to be rapid in order to reduce the mortality and morbidity to the patient. To prepare for such rare incidents as this, simulation offers a powerful methodology for immersive and experiential training. This can also be done in situ; in the clinical area of work such that the familiarity will help staff remember and recall all the necessary management steps, equipment and drugs, where they are kept, and refer to their displayed cognitive aids. Hopefully, all the latent treats would have been identified and rectified when the simulation exercises were conducted.

The only known direct antidote for malignant hyperthermia, Dantrolene, has brought down the mortality from over 90%, to less than 10%. Knowing about this drug, how to dilute and reconstitute it as well as administer it is crucial when the situation arises. Having practiced through the use of in situ simulation, the next steps would include sharing with all staff, creating awareness, setting up your own malignant hyperthermia cart or box, as well as developing posters and cognitive aids to be displayed, especially in the resuscitation room and operating theatre suits. Being prepared is absolutely necessary to uplift patient safety and reduce mortality and morbidity.

Key Words: *malignant hyperthermia, in situ simulation, Dantrolene, latent threats.*

Introduction

Simulation-based learning (SBL) has gone through a paradigm shift and is utilized in many context in healthcare today. (1-5) The recent Covid 19 pandemic also served to highlight the wide spectrum of applications of SBL. SBL is commonly used for (4-6):

a. Training for commonly encountered clinical cases in the different work environments
b. Preparing teams to handle rare cases, which are not encountered often, but when they do surface, they require staff to know what exactly to do. This often needs to be done quickly in a time-dependent manner. Examples would be performing Emergency Department Thoracotomy for the appropriate cardiac arrest patients and Peri-mortem Caesarean Section in a mum, in advanced pregnancy presenting with cardiac arrest. These infrequent presentations mean staff may not be getting sufficient clinical exposure in managing them. Thus, SBL offers a platform to keep abreast of the skills and management required.
c. Preparing for the handling of latent threats that are present in the ward or department, which may not be obvious to everyone. These can act as 'blind spots'
d. For the practice of inter-professional collaborative practice skills and values
e. For focused training of certain skills and capabilities, where repetitive, deliberate practice will help inculcate competencies
f. Disaster or crisis preparedness training, in order to familiarize with pathways and flow, especially when the system may become over-whelmed.

SBL helps staff through immersive, experiential learning, where they can learn, share experiences and perhaps, subsequently, even change or modify their practice as relevant. Against this background, we planned for in situ simulation sessions in the Emergency Department (ED) to assist us in:

a. Creating awareness and educating our staff on Malignant Hyperthermia (MH), as well as
b. Planning a comprehensive pathway and protocol for the management of MH, when a case is encountered in the ED.

Malignant Hyperthermia (MH)

MH is a genetic disorder whereby patients will manifest hyper-metabolic responses to certain drugs or situations. The former would include exposure to inhalational agents such as halothane, isoflurane, desflurane and other anaesthetic gases, as well as suxamethonium, a depolarizing muscle relaxant. There have also been reports of the manifestations of MH with vigorous exercise and significant heat

exposure. Without these triggers, the affected person is completely normal. There have also been reports of some genetic conditions which predispose to the development of MH. These include Central Core Disease, central nuclear myopathy and King Denborough Syndrome. (7-10)

The incidence of MH has been quoted to be anything between 1: 10 000 to 1: 250 000. An MH crisis can manifest in the first exposure to the offending agent or, there have been reports of first onset of clinical symptoms after an average of 3 anaesthetic triggers. The acute onset of symptoms can be immediate, upon receipt of the offending agents or may be potentially possible within 12 hours of receiving the drugs. (7, 11, 12)

The key clinical features that would prompt the onset of MH in a susceptible patient include: (7, 11, 14-16)

a. Increase in the end tidal CO2, despite increase in the minute ventilation. This is often described as one of the earliest signs of MH
b. Muscle rigidity. Often the masseter muscle is the first to be affected, but not all masseter spasms are linked to MH.
c. Tachycardia response. This is linked to the increased metabolic state as well as the increase in temperature
d. Increase in temperature. It has been noted that the core body temperature can increase by 1-2 degrees Centigrade every 5 minutes. Severe cases have been reported showing a core temperature of 44 degrees Centigrade or higher, where the mortality is extremely high (11)
e. Acidosis
f. Hyperkalemia
g. Dysrhythmia, as a result of the many electrolyte and metabolic changes
h. Acute kidney injury, rhabdomyolyss and potentially, myoglobinuria
i. Cardiac arrest can result if the signs are not recognized and diagnosis as well as treatment is delayed. Cardiac arrest can also be the resultant of the many electrolyte/ metabolic changes seen in MH

A few other manifestations have also been noted and usually these are linked to complications of any of the above, ie. disseminated intravascular coagulopathy, congestive heart failure, bowel ischaemia and compartment syndrome from severe muscle swelling. (7, 14)

The Pathophysiology and Antidote

MH occurs because of the uncontrolled release of intra-cellular calcium ions from the sarcoplasmic reticulum membrane in skeletal muscle. This is the fundamental reason for the manifestation of the hyper-metabolic response. Patients affected by this have either of two genes, which have been definitively associated with the causative mutations; RYR1 and CACNA1S. (7, 8) Clinically, differentials to consider may be thyroid storm, sepsis, phaeochromocytoma, overheating situations and neuroleptic malignant syndrome (a hyperthermic syndrome resulting often from drugs such as anti-psychotics and haloperidol).

The mortality from MH has significantly been reduced from over 90% to less than 10% with the introduction of Dantrolene. This drug relaxes the muscle by inhibiting calcium ions release from the sarcoplasmic reticulum. (MH results in uncontrolled release of intracellular calcium from skeletal muscle sarcoplasmic reticulum). With the mutation that occurs in MH, there will be defective regulation of this process, in the presence of the offending drugs or agents. This will result in increased calcium in the myocytes cytoplasm because the genetically controlled channel receptor now opens easily at the lowered threshold and is also kept open, longer. Due to this the capacity to carry the calcium back into the sarcoplasmic reticulum is overwhelmed, resulting in sustained, prolonged muscle contractions. (Fig 1) (9, 12, 17)

The antidote, Dantrolene, is not readily available as a standard drug in most Emergency Departments (ED). As it is not frequently used, special arrangements would have to be made when it is required. For EDs to prepare to handle the malignant hyperthermia crisis, prior arrangements and plans must be made. Evidence-based protocols must be practiced and be made readily available. Dantrolene stocks will have to be procured. Here, the balance between usage frequency and cost effectiveness must be taken into account especially in view that this drug is not used often, and expired stocks would have to be discarded. A practical plan would be to stock the initial vials needed in the ED and retrieve the rest from a centrally shared stock in the institution. Obtaining this additional supply should not be the rate limiting factor. This would also mean the location of the centrally kept stock should not be too far remote from the ED. A word of advice is that the second dose must be available and is being reconstituted, as the first dose of Dantrolene is being administered. This is so as to avoid delays which can be linked to higher mortality and morbidity. (12, 13, 17)

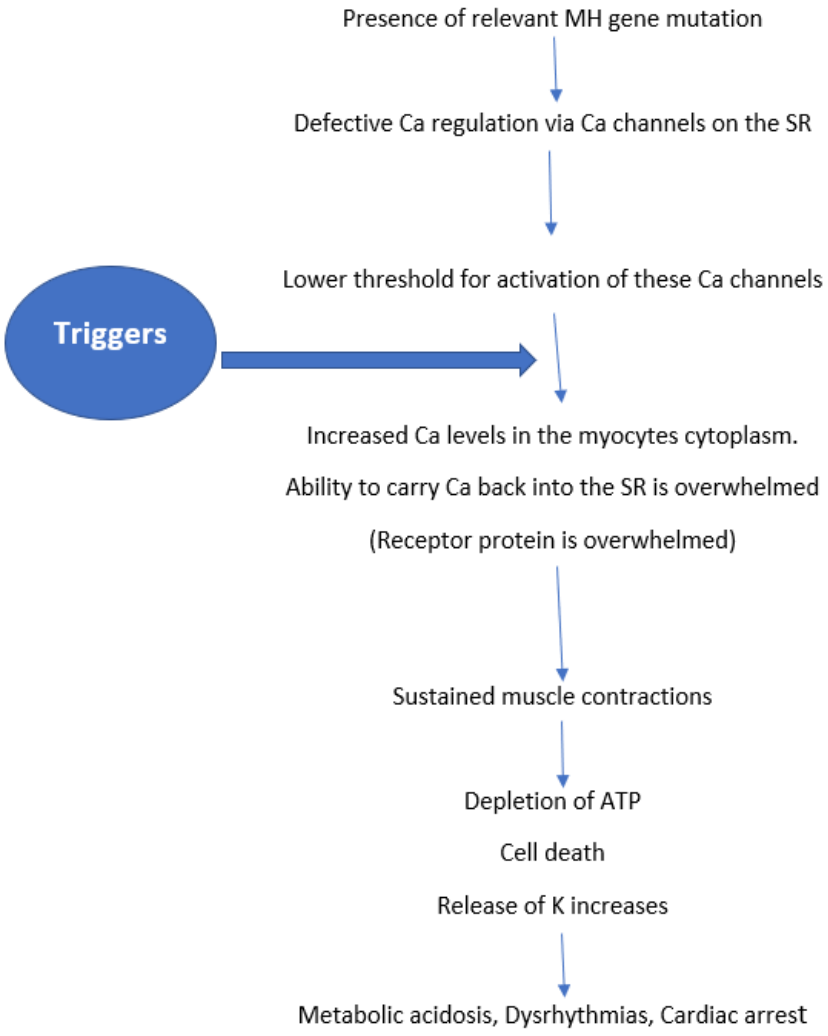

Figure 1: Pathophysiology of Malignant Hyperthermia

Key:

MH: Malignant hyperthermia

Ca: Calcium ion

SR: sarcoplasmic reticulum

ATP: adenosine triphosphate

K: Potassium

In The ED Context	Rapid sequence intubation using Suxmethonium Known Past history of MH Family history of MH
Identification (High Index of Suspicion)	Increased muscle rigidity (especially masseter/ early) Increased in ETCO2 (unexplained) Increased Heart Rate (unexplained) Increased Oxygen Requirements Increased temperature (may be late)
Interventions and Immediate Management	1. Muscle Rigidity: IV Dantrolene 2.5 mg/ kg bolus immediately Followed by 1 mg/kg boluses to be repeated as needed (as symptoms/ signs subside) to a maximum of 10 mg/kg 2. Hyperkalemia Management: CaCl2, calcium gluconate, Dextrose/Insulin/ NaHCO3 3. Metabolic acidosis: Hyperventilate, 100% O2, NaHCO3 4. Arrhythmia: Manage as appropriate/ AVOID Calcium Channel Blockers as they interact with Dantrolene 5. Myoglobinaemia/ Myoglobinuria: Forced Alkaline Diuresis using Mannitol, Frusemide, NaHCO3 as needed/ May require RRT 6. DIVC: Support with blood products/ usually late presentation 7. Cooling Measures: cool fluids, ice packs, CarbonCool, fans, airconditioner adjustments. Consider need for internal cooling through Naso-Gastric tube, urine and rectal catheter
Integrated Monitoring	Vitals sign, Blood Pressure Electrocardiography monitor and defibrillator Core temp ETCO2 SpO2 CVP (option, as needed)
Investigations	Full blood count Urea, creatinine, Extended Electrolytes Creatine Kinase and MB fraction, Troponin Coagulation profile Arterial blood gas Blood Sugar level at Bedside

Important Contacts	Toxicology HotLine Adverse Drug Reaction (ADR) Pharmacy Line/ same as Pharmacy 24 Hotline: Tel: 63265155 ED Pharmacy (stocks 10 vials of Dantrolene, 20 mg each and 2 bags of 500 ml Water for Injection with Spikes) Inpatient Pharmacy: stocks 24 vials of Dantrolene Call number: 65762358/ 65762485 for additional stocks of Dantrolene.

Table 1: Emergency Department Management of Malignant Hyperthermia

Key:

MH: malignant hyperthermia

ETCO2: end tidal CO2

CaCl2: calcium chloride

NaHCO3: sodium bicarbonate

RRT: renal replacement therapy

DIVC: disseminated intravascular coagulopathy

CVP: central venous pressure line

CarbonCool: cooling pads

SPO2: oxygen saturation

Planning The inSitu Simulation

In situ simulation is an effective way to teach and practice high risk scenarios and procedural management to enhance patient safety. At the same time, it can also be useful to identify latent threats, inculcate teamwork, team values as well as enhance inter-professional communications. It is suitable for testing out the MH response in the ED. (3, 4, 18, 19) The following represent the steps and work to be carried out during each phase of the exercise:

Pre-Simulation and Pre-Briefing:

Set the realistic learning objectives for the in-situ simulation scenario

Ensure availability of supplies and countercheck all equipment as well as cognitive aids

Conduct dry runs as needed

Brief team so they are clear on the objectives of the session, principles of the insitu simulation, maintenance of confidentiality and the fiction contract

The In-situ Simulation

The venue for conduct is in the ED resuscitation room

Use of high-fidelity manikin and the usual rang of ED equipment and devices

Inter-professional staff participants

This can be repeated as many times as needed and different groups of staff can be involved as well

The Debrief

Allocate sufficient time

To understand the importance of debrief, with respect to reflection and also the learning potential

Inputs from different staff eg. doctors, nurses, pharmacist are valuable to identify latent threats and ensure smooth workflow and understanding by all parties involved, especially in the management of MH which is very complex

Use of feedback and inputs to fine-tune the initial draft of the MH Protocol

Algorithm for Action

Once finalized, the MH protocol/ pathway must be shared with the department through peer-review session, common meetings or townhall sessions. This is crucial to get buy in and final confirmation before execution of the pathway

Final edits should be done and any blind-spots and gaps must be filled

Prepare charts and posters to be placed at strategic locations in the resuscitation room to serve as reminders and memory jerk.

Place cognitive aids in prominent location so that all staff are aware of this.

If there happens to be a case of MH being managed, ensure post management forms are completed, stocks depleted are replenished and any issues or problems that arise are addressed and also shared with the department as part of the dyamic, continual improvement process. (20)

Cooling Measures

These measures would include the use of both external as well as internal cooling. External cooling involves the use of ambient temperature control using the thermostat of the air-conditioner of the room, adding fans or fans with water mist, ice packs and cooling towels applied externally ad even the use of commercially available pads for TTM (therapeutic temperature management) such as Carbon Cool. Internal cooling requires the use of cold, refrigerated fluids for infusion. This is usually kept at least 4 degrees Celcius. Hydration is also important when cooling patients. Cold fluid lavage through naso-gastric tube and urinary catheter can also be considered in severe cases.

Conclusion

MH is a rare but life-threatening condition. Despite its infrequent incidence, front line physicians, Emergency Physicians, anaesthesiologist and others who deal with the potentially offending drugs should be aware and prepare to handle it. Simulation, both in the laboratory and in situ, will be able to help physicians prepare and train for such rare incidents. This methodology can be a very powerful immersive and experiential learning tool. From such activities, departments and staff can plan the management of MH as well as prepare their MH response plans and algorithms. The use of MH carts stocked with all the necessary antidote, Dantrolene and drugs for reversal / treatment of the complications is a very important, strategic move and useful step. Regular sharing and reinforcements with all staff concerned to create awareness and get their buy-in is crucial. (21, 22)

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