Clinical Pediatric Anesthesiology >

## Chapter 34: Intraoperative Complications and Crisis Management

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# INTRODUCTION

**FOCUS POINTS**

1. Complications can occur even when we provide excellent care to patients.

2. Successful anesthesia complication and crisis management requires a structured team-based approach.

3. Simulation helps teams practice crisis scenarios in a protected, safe environment. Simulation helps improve performance when actual crisis situations occur. Simulation is especially helpful for situations not commonly encountered in routine practice.

4. Cognitive aids can help prevent complications before they occur and also help manage active crises. Such aids include checklists, protocols, guidelines, and smartphone applications.

5. Complications and bad outcomes must always be discussed fully and honestly with patients and their families.

6. Malpractice lawsuits can arise from complications; therefore, risk managers and attorneys may provide guidance to involved parties.

7. Delivery of bad news must be joint effort between involved surgeons and anesthesiologists. The SPIKES protocol discussed within provides a family-centered framework for bad news discussions.

8. Complications encountered in pediatric anesthesia practice include medication errors, cardiac events, aspiration, laryngospasm, dental injury, and malignant hyperthermia.

Complications and crises occur during anesthetic care even with meticulous attention to clinical detail. The best complication and crisis management strategies rely on forward thinking and planning rather than unorganized or reactionary behavior. Thus, training, simulation, and resource mobilization are hallmarks of effective crisis management. This preemptive approach embodies the ideal anesthesiologist mindset. With preparation and planning an anesthesiologist can successfully manage a full spectrum of complications from routine to rare.

Precise complication rates in pediatric anesthesiology are difficult to quantify; most are minor and quickly resolved with appropriate management, and therefore are not uniformly documented or transferred to complication registries. Laryngospasm, for example, is common in pediatric anesthesia practice. Many practitioners do not document or database laryngospasm when resolved quickly by positive pressure ventilation. However, major complications like cardiac arrest are nearly universally documented, and often are databased in registries. Therefore, we have anecdotal data on statistics of minor complications and more concrete data regarding frequency of major complications.

This chapter examines crisis management topics including simulation, cognitive aids, discussion of bad news, and legal issues. It will then explore common complications and select uncommon complications, along with their respective management.

# CRISIS MANAGEMENT PRINCIPLES

Conceptual framework for anesthesiology crisis management has been adapted from strategies found in commercial aviation. This is not surprising, as aviation shares many attributes with anesthesiology including periods of "smooth sailing" punctuated by potential crisis events that the lay public

(and even other medical practitioners) never know of, appreciate, or understand.

Structured crisis management training in medicine had at one point been nearly nonexistent. Anesthesiologists made major efforts in the 1990s to incorporate formalized crisis training into residency education, with efforts focused on simulation.[1] In fact, anesthesiology as a field has pioneered crisis management within medicine. Our efforts have spread into nearly every other field of medicine and even into governmental health policy efforts.

Crisis resource management principles guide effective team-based responses. These principles are as follows: establish and support a leader, establish followers, engage in effective communication, seek global assessments, seek support, and use available human and physical resources.[2] In conjunction with these principles nontechnical crisis management skills must be developed to enable effective management. These skills include decision making, situational awareness, teamwork, task management, information exchange, and assertiveness.[3]

Team building is crucial in successful crisis management. When anesthesia emergencies occur, team members frequently have never worked together. Similarly, they may have never managed the emergency at hand. Repeated exposure to simulation will orient team members to each other's roles and illustrate how they can function best on a team. Note that available operating room staff typically includes anesthesiologists, surgeons, nurses, and technologists; ideal simulations should involve members of each aforementioned field.[2]

# SIMULATION

Simulation is a modern tool that provides crisis education to trainees and experienced practitioners. It provides exposure to both common and uncommon emergencies. High-fidelity simulation is available via commercially available mannequins, often complemented by human actor interactions. Also common are computer-based simulations such as those seen with pediatric advanced life support (PALS) and advanced cardiac lice support (ACLS) training websites. Other simulation experiences include standardized patients and task training exercises.[4] Simulation is of particular value in pediatric anesthesiology, as there are key differences between pediatric and adult populations. These differences are often not fully appreciated by those who less commonly manage pediatric patients.[4]

Simulation provides real-time assessment, feedback, remediation, and support. Moreover, this practice is done without exposure to risk, as there are no real patients involved. Simulation done in one's workplace can reveal system failures within that institution, and can therefore provide rich opportunities for internal quality improvement.[4]

Standardized patient simulation gives trainees an opportunity to work with real patients in a protected setting. It allows trainees to practice a variety of skills including performing a physical exam, obtaining informed consent, and delivering bad news.

Physical task training stations allow for exposure to airway management tools, neuraxial anesthesia, ultrasound scanning, and difficult intravenous line placement. Some of these topics may include less frequently used emergency devices including cricothyrotomy kits, intraosseous line devices, and chest tube kits.[4]

High-fidelity simulation is key to development of nontechnical crisis management skills. Successful development of these skills requires focused debriefing and assessment of these skills. Effective debriefing includes feedback from all members of the team (not just the anesthesiologist) and intended focus on the aforementioned crisis resource management principles and nontechnical crisis management skills.[2] Focused nontechnical skills assessment may benefit from a systematized approach rather than less structured discussion.[3]

# COGNITIVE AIDS

Cognitive aids are tools that provide structured tangible assistance during crisis situations. As opposed to perioperative checklists, protocols, and guidelines, they are meant to be used while a situation is occurring.[4] Their inherent benefit is that they provide steps a clinician can take during crisis while allowing that clinician to have concise guidance on clinical management steps, differentials to consider, and tasks that must be delegated.[5] Note that many crisis situations, such as malignant hyperthermia (MA), are rare events; therefore, anesthesiologists may not have complex working knowledge of such issues.[5] Cognitive aids augment and supplement provider knowledge in these situations.

Cognitive aids take many forms including mnemonics, checklists, information sheets, and electronic applications. Effective cognitive aids contain

information most relevant to the crisis at hand without extemporaneous information or distraction. For example, a cognitive aid on laryngospasm should include immediate management techniques while excluding risk factors or preoperative workup suggestions. Familiarity and agreed-upon validation of cognitive aids are essential for utility in a crisis scenario. Therefore, hospital administration and staff should review cognitive aids before their implementation.

When well-designed cognitive aids are used, evidence suggests improved crisis management performance and improved outcomes.[6] For example, a study of anesthesiology resident management of MA showed that use of the Malignant Hyperthermia Association of the United States (MHAUS) cognitive aid correlated with improved MH management performance. In that study providers who did not use the cognitive aid scored the worst in MH treatment performance, and those who did use the aid scored the best in MH treatment.[6] Similarly, a seminal study assessed central-line placement checklists in ICUs, and found that use of this cognitive aid reduced hospital mortality.[7]

While the aforementioned evidence highlights the potential benefits of cognitive aids, consider that not every cognitive aid is well designed or useful. Even the best-intentioned aid may unintentionally cause confusion or misinformation.[5] The U.S. Food and Drug Administration (USFDA), for example, provided a machine checkout cognitive aid, which many regard as confusing and not useful.[6] Adequate assessment of cognitive aids is therefore essential before their dissemination and use. Assessment tools include the Cognitive Aids in Medicine Assessment Tool, which is a derivative of assessment tools used in commercial aviation.[8]

We recommend referencing the following well-regarded pediatric anesthesiology cognitive aids:

- Pedi Crisis App

- Pedi Crisis Cards

- ACLS and PALS training, including flow cards

- MHAUS Malignant Hyperthermia Poster and Hotline

## LEGAL ASPECTS OF COMPLICATIONS

Some patients and their families pursue malpractice lawsuits when complications occur. Given this reality in our healthcare system, we strongly recommend discussing anesthesia complications with your risk management department and with a qualified attorney. Risk managers offer risk-based post-indecent management advice, and may also be available to discuss strategies for discussing events with patients and family. Note, however, that risk managers have a duty to their employer, whether that is a hospital legal department, an insurer, or a private physician group. You should, therefore, consider speaking with your own attorney, as your legal interests may at times differ from other defendant parties.

The American Society of Anesthesiologists Closed Claims Project analyzes and catalogs liability claims made against anesthesiologists. Their most recent pediatric anesthesia liability study found that between the years 1970 and 2001 children between 0 and 3 years of age made up 53% of claims. Death and brain death have been the most common claim types.[9] Other claims included, in order of frequency, burns, cardiac arrest, nerve injury, airway injury, skin inflammation, and other medical related issues. Note that lawsuits related to respiratory-related issues have decreased markedly since the 1990s due to the widespread use of pulse oximetry and capnography.[9] Similarly, claims for cardiac issues have decreased due to decreased use of halothane, which is arythmogenic.[9]

Malpractice insurance has decreased in cost from $39,303 in 1985 to $19,594 in 2013 for a $1 million per incident/$3 million per year policy (the most common policy type). This reduction in cost is likely due to the aforementioned implementations of pulse oximetry and capnography. Both of these life-saving quality improvements were pioneered by anesthesiologists.[10]

## DELIVERING BAD NEWS

Pediatric anesthesiologists care for children with the intent of delivering safe, complication-free care. But complications and bad outcomes are unavoidable, and all practicing anesthesiologists will need to at some point deliver bad news to patients' families and patients themselves.

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The SPIKES protocol (Table 34-1) is a mnemonic that outlines mindful presentation of bad news.[11] The SPIKES protocol was originally developed by oncologists to deliver challenging news to oncology patients, but has since been adapted by those in many other specialties including anesthesiology.[11]

Table 34-1

**SPIKES Protocol**

| S | Setting up the stage | Introduce yourself and state your role in medical team<br>Ensure a private, comfortable location for discussion |
|---|---|---|
| P | Perception | Assess understanding and knowledge |
| I | Invitation | Allow patient to request information |
| K | Knowledge | Explain events timeline<br>Use appropriate language without euphemisms<br>Allow for reaction to news and questions |
| E | Emotions | Show concern for patient and validate emotions<br>Show empathy |
| S | Strategy summary | Discuss plan for future care |

Ideally the anesthesiologist and surgeon should together deliver bad news to parents. The providers should set the stage with an appropriate environment for this discussion, ideally a private room. Care should be taken to be seated and to be at eye level of parents. The providers should introduce themselves to the parents, and remind the parent of each provider's respective roles. Note that in emergency procedures the anesthesiologist may not have met the parent in person prior to the procedure. Similarly, parents meet several healthcare professionals in the perioperative period, and may not remember the role of all involved parties.

The next step is to ascertain parent's perception including the level of understanding the parents have of the current situation and to assess their medical knowledge and ability to understand complex situations.

At the parent's invitation, the anesthesiologist and surgeon can then inform the parents of the timeline of events, using plain language avoiding medical jargon. Once the parents have heard the news, the anesthesiologist should allow them time to react to the information and a chance to have all their questions answered.

Being prepared with a mindset of empathy to a parent's emotional response can help ease one of the biggest challenges of delivering unfavorable information. At the conclusion of the conversation, providers should summarize the situation and determine the next steps of care.[11] The anesthesiologist should be honest in his or her presentation of the facts and provide assurance of availability in the future. Note that the purpose of this protocol is not to determine guilt, nor is it a legal briefing.

When using the SPIKES protocol as a tool for delivering bad news, it is important to remember that it was developed initially for oncologists whose clinical situation is very different from the anesthesiologist. The anesthesiologist will need to communicate effectively and use a patient and family-centered approach to delivering bad news.[12–14] Communication characteristics that are necessary for a patient-centered approach include that the provider be friendly, supportive, nonintimidating, available (not distracted or rushed), and informative.[14,15]

As in other medical specialties such as emergency medicine, this can be difficult because of the stressfulness of the situation. The anesthesiologist may have just emerged from a code situation after performing Pediatric Advanced Life Support (PALS) or possibly a massive resuscitation effort. A healthy child may have suffered a devastating and unexpected complication during an elective surgery. An anesthesiologist may feel sadness, guilt, and inadequacy along with stress and anxiety so he or she may need to take a few moments alone, with a trusted colleague, or in discussion with legal counsel prior to starting the conversation with the patient's parents. The provider may feel inadequate or unprepared to deliver bad news,[12,14,16] so this time can be used to calm the provider and rehearse the information to be delivered to the parents. Because of the need to practice adequate communication of bad news, training opportunities for anesthesia fellows and residents have gone beyond the classroom into simulation education[12,16] using protocols like SPIKES to improve communication skills and physician comfort with this difficult task.

## MEDICATION ERRORS

Medication errors are potentially catastrophic events in pediatric anesthesia practice. Pediatric anesthesiologists frequently dilute drugs by factors of 10 or 100 and also dose most drugs based on weight. Thus, there is potential for very large dosing errors. Other error types include drug swaps, drug misidentification, and inadvertent dosing of drugs to which the patient is allergic.

Determining frequency of medication error is challenging because many errors go unreported or are subjectively under-interpreted.[17] Adverse outcomes may therefore be difficult to link to said errors.[17] The overall frequency of drug administration error depends on study techniques, and estimates of drug errors vary quite widely. One large study of three South African hospitals (combining pediatric and adult practice) suggested the error rate is one in 245 anesthetics. The rate of error at the examined pediatric hospitals was 1 in 329 anesthetics.[18] Note that these studies exclude near-miss events, which are likely much more common than the aforementioned statistics.

In assessing adult and pediatric anesthesiology practice overall, the most common errors are drug substitutions or swaps followed by dosing errors.[17,18] Overall the most common drug swap error involved administering muscle relaxants instead of reversal agents.[17] Ampule or vial misidentification was also a major issue.[18]

When examining the pediatric anesthesia practice specifically, drug dosing errors were as common as drug swaps. This is likely due to increased potential for error inherent in diluting drugs and weight-based dosing of drugs.[18,19]

Treatment of medication error depends on the exact drug given and is beyond the scope of this chapter. More important is discussion of medication error prevention. Suggested safety measures include systematic management, storage, and labeling of drugs (including color coding).[18] Drug syringes should be legibly labeled and all ampules or vials should be read before drugs are drawn up—examination of drug name and concentration are both key.[19] When possible, a second provider should verify drug dilutions and labels.[19] Ideally, premade pediatric formulations of medications should be available to avoid dilution and dosing errors. Note also that widespread lack of precise pharmacokinetic data and lack of appropriate formulations make pediatric medication administration challenging even with otherwise appropriate checks and balances on dosing.[19]

## CARDIAC EVENTS AND CARDIAC ARREST

The Pediatric Perioperative Cardiac Arrest (POCA) registry follows causes of perioperative cardiac arrest. Its current evidence suggests 49% of perioperative cardiac arrests are related to anesthesia. Of these events, causes included cardiovascular (79%), respiratory (53%), medication (35%), and equipment (9%). Cardiovascular causes included hemorrhage-associated hypovolemia, electrolyte imbalance, and nonhemorrhage-associated hypovolemia being the most common causes. Respiratory causes included laryngospasm, airway obstruction, and other forms of inadequate oxygenation and ventilation. Medication causes included first halothane-induced cardiovascular depression, followed by sevoflurane-induced cardiovascular depression, then other medication-induced issues. Equipment issues included central-line complication, followed by kinked or plugged endotracheal tubes, then peripheral intravenous line issues.[20,21]

Cardiac event management is issue specific and often follows the PALS pathways. Please refer to Chapter 39 for more information on cardiopulmonary resuscitation (CPR).

## ASPIRATION

Perioperative pulmonary aspiration occurs when contents from the stomach, esophagus, mouth, or nose pass into the respiratory tract after induction of anesthesia, during a procedure or surgery or in the immediate postoperative period, including during extubation. Aspirated materials can include particulate matter such as food particles or other foreign objects. Aspirated material may also include nonparticulate matter such as stomach acid, saliva, blood, or gastrointestinal contents. The American Society of Anesthesiologists (ASA) compiled guidelines for preoperative fasting based on currently available clinical data and practitioner opinion.

One way to prevent aspiration is to recognize which patients are at highest risk of aspiration during the preoperative assessment. The preoperative assessment should evaluate the patient's adherence to preoperative fasting guidelines, comorbidities, and physical assessment. The preoperative fasting guidelines summarized below have been established to reduce the risk of aspiration during anesthesia for an elective procedure on a healthy patient.[22] A more in-depth discussion of the fasting guidelines is available in Chapter 10.

Risk factors of aspiration that are particularly important for children include:[23,24]

- Emergency surgery, especially abdominal surgery

- Recent ingestion of food

- Trauma

- Decreased consciousness

- Neuromuscular diseases especially those which decreased ability to protect trachea

- Delayed gastric emptying, bowel obstruction, ileus

- Difficult airway

- Increased ASA physical status

- Young age

| Timing Before Surgery | Guidelines |
|---|---|
| 8 hours | Stop fatty food |
| 6 hours | Stop light meals, infant formula, and nonhuman milk |
| 4 hours | Stop breast milk |
| 2 hours | Stop clear liquids |

Included in the preoperative assessment should be an evaluation of patient's teeth as loose deciduous teeth are a common occurrence in pediatric anesthesia and should be electively removed after induction of anesthesia to prevent aspiration. Removal of the loose tooth should be discussed with parents or guardians during the preoperative evaluation. Nonpermanent orthodontic hardware should also be removed prior to induction. Gastric decompression with a nasogastric or an oral gastric tube may be necessary in patients with bowel obstruction prior to induction of anesthesia. A rapid sequence induction with cricoid pressure is preferred if the patient is at risk for aspiration and is not a difficult airway. Even after a seemingly minor trauma (broken arm) and adherence to preoperative fasting guidelines, peristalsis may be delayed due to the traumatic nature of the incidence and use of opioids for preoperative analgesics, requiring rapid sequence induction.

If a patient has a difficult airway and is at risk of aspiration, the anesthesiologist must carefully consider the risks prior to induction and intubation. In general, children do not tolerate awake intubations, making it difficult to keep a child spontaneously breathing and able to protect his or her airway

during an awake intubation. Likewise, regional anesthetic techniques without general anesthesia are not tolerated by children. It is important to remember that even with an endotracheal tube in place, aspiration prevention is not guaranteed.

Prior to extubation after emergency procedures, examples of which include bleeding tonsils (evacuate blood), trauma (delayed gastric emptying), and appendectomy (ileus), the patient's stomach should be suctioned to remove residual gastric contents. At the end of procedures for children at risk of aspiration, the provider should also ensure that the patient is fully awake to maximize airway protection prior to extubation.

Signs and symptoms of aspiration include coughing, wheezing, cyanosis, and hypoxia with increased oxygen requirements. Fever and tachypnea may also develop, while radiographic changes may be delayed. Aspiration can occur silently without visualization of gastric contents in the oropharynx.

Aspiration contents can be divided into three categories, each with different clinical effects: acidic fluid, nonacidic fluid, and particulate. Acidic fluid aspiration first causes a chemical pneumonitis when the lung tissue reacts to the acid, and then a second phase being an inflammatory response to the original pneumonitis. Nonacidic fluid aspiration causes atelectasis and alveolar collapse, but is generally less severe than with acidic fluid aspiration. Particulate matter aspiration causes a physical obstruction of airway which results in hypoxia and hypercapnia with radiographic findings of hyperinflation and atelectasis.

Treatment for aspiration is supportive.[25] Suctioning of any visualized gastric contents should be implemented immediately. The provider may choose to leave the endotracheal tube in place and delay extubation or reintubate if there is concern for severe aspiration and the patient may require ventilator support in an ICU setting. Some cases may respond to positive end expiratory pressure which can help decrease atelectasis and alveolar collapse. For the less severe cases, only supplementary oxygen may be required. Neither antibiotics nor steroids should be routinely administered. Antibiotics may be considered in the case of aspiration of bowel contents. Bronchoscopy may be required in the case of aspiration of large particulates which cause obstruction of airway passages. Lung lavage is discouraged as it can push particulates further down into the lungs.

Pediatric patients regurgitate or vomit in approximately 1 in 200 procedures,[26] but the incidence of perioperative pulmonary aspiration of gastric contents is much lower, approximately 4 to 10 in 10,000 pediatric anesthetics[23,25] and death occurring from perioperative aspiration is very rare.[26] However, compared to adults, the risk of aspiration in children is double.[25]

## LARYNGOSPASM

Laryngospasm is a potentially life-threatening complication that involves reflex closing of the laryngeal muscles and inability to ventilate the patient. It can be either partial or complete. It is caused by a combination of uninhibited reflex pathways associated with inadequate depth of anesthesia and stimulation. Inciting stimulation includes direct laryngoscopy or suctioning, secretions or blood hitting the glottic opening, or airway adjunct inadvertently irritating the glottis opening.[27] Major risk factors for perioperative laryngospasm include presence of upper respiratory infection, airway anomalies,[28] light anesthesia, and use of Desflurane.[29]

Laryngospasm is far more common in pediatric populations as compared to adults, with a rate of approximately 17 in 1000 anesthetics delivered in pediatric populations, as compared to 8.7 per 100 anesthetics in the general population. Of note, laryngospasm is the leading respiratory cause of cardiac arrest in children.[21] In addition to cardiac arrest, laryngospasm can cause hypoxia, bradycardia, and pulmonary edema.

Laryngospasm is a clinical diagnosis that necessitates prompt treatment even if this diagnosis is not entirely clear. It presents with loss of end-tidal carbon dioxide, paradoxical chest movement, and chest or neck retractions, and a stridorous noise in the case of partial laryngospasm.[27] Prolonged laryngospasm symptoms include oxygen desaturation, bradycardia, and potential cardiac arrest.

Treatment of laryngospasm includes first administering 100% oxygen with continuous positive airway pressure. Next, intravenous agents such as propofol at 0.5 mg/kg to 0.8 mg/kg and succinylcholine 1 to 2 mg/kg with atropine 0.02 mg/kg should be administed.[27] Note that a smaller dose of succinylcholine may be equally effective with fewer side effects. If hypoxia or bradycardia is present, propofol should be avoided due to its myocardial depressant activity. If intravenous access is lost or not established, it is recommended to administer intramuscular succinylcholine 4 mg/kg and atropine at 0.02 mg/kg.[27,29]

## DENTAL INJURY

Pediatric patients are at risk for dental injury during intubation, especially during their transition from primary to secondary teeth. Children's primary teeth emerge between 8 months for central incisors all the way through 33 months for secondary incisors. These primary teeth are replaced by permanent teeth starting at 6 years old for primary incisors through 12 years old for secondary incisors. The highest incidence of dental injury in children is between ages 7 and 8 years old.[30]

Incidence of dental injury during pediatric anesthetics occurs at a rate of approximately 0.05% per anesthetic.[30] This study found a relationship between inaccurate preoperative dental history and examination, and dental injury. Many cases were due to inadequate anesthesiologist history and exam; some were also due to children having loose teeth that parents were unaware of. Studies are conflicted on whether emergency surgery or difficulty during intubation are associated with dental injury.[30]

If dental injury occurs, it is recommended to have a pediatric dentist perform an intra-oral exam to determine the extent of the injury and to determine whether any immediate repair or reimplantation is appropriate. If there is any question of lost tooth fragments, a chest X-ray is indicated to rule out tooth aspiration or ingestion.[31] Tooth aspiration is an emergency, and tooth or fragment retrieval may require bronchoscopy or gastroscopy for retrieval.[30]

Uncomplicated avulsion of primary teeth does not require further intervention. Avulsion of permanent teeth may require reimplantation, and these teeth should be stored in normal saline or cold milk. Reimplantation within 30 minutes is associated with a good dental prognosis.[31]

## MALIGNANT HYPERTHERMIA

Malignant hyperthermia (MH) is an autosomal dominant genetic disorder of the RYR1 or DHP receptor that clinically manifests as increase in metabolic rate after exposure to a triggering agent such as succinylcholine or a volatile anesthetic. Individuals who are MH susceptible have an abnormal muscle receptor that allows intracellular calcium accumulation from the sarcoplasmic reticulum after exposure to a triggering agent, which in turn leads to sustained muscle contraction, muscle breakdown leading to rhabdomyolysis, anaerobic metabolism, and acidosis.[32]

Early clinical signs of MH include hypercarbia and mixed respiratory/metabolic acidosis. These signs occur when aerobic metabolism provides energy for the muscle, resulting in oxygen and adenosine triphosphate consumption and carbon dioxide production. The switch to anaerobic metabolism increases acidosis and lactate production. Rhabdomyolysis occurs with subsequent hyperkalemia and myoglobinuria. Hyperthermia occurs because the sustained muscle contraction generates heat that the body is not able to eliminate, which in turns causes increased carbon dioxide production and oxygen usage.

Hyperthermia is actually a later sign in MH, with hypercarbia that is resistant to modifications in ventilator settings being a more important early clinical sign. Another early clinical sign is generalized muscle rigidity when neuromuscular blockade is in use. Abnormal laboratory findings include a mixed metabolic/respiratory acidosis and then subsequent hyperkalemia, elevated creatine kinase, and myoglobinuria, which may all be especially pronounced in muscular patients.[33] In children, the most common clinical sign in the presentation of MH is tachycardia.[34]

The diagnosis of MH is made based on clinical signs (as noted above) while laboratory findings will also support the diagnosis, but are not necessary to initiate treatment of MH. Supporting laboratory studies include an arterial blood gas (ABG) with acidosis, elevated creatine kinase, elevated serum and urine myoglobin and potassium. Of note, MH can rarely occur postoperatively, with the onset generally within 40 minutes of stopping the anesthetic.[35]

Even while initiating treatment of MH, the anesthesia provider should consider other potential differential diagnoses including fever, sepsis, transfusion reaction, neuroleptic malignant syndrome, pheochromocytoma, thyroid storm, serotonin syndrome, inadequate ventilation, carbon dioxide absorption from laparoscopy, and allergic reactions.

If MH is suspected, the institution's MH protocol should be initiated. Request the MH treatment cart or tray, which should include emergency medications including dantrolene—the only known treatment for MH. Additional assistance should be requested in the operating room for help in assessing and treating the patient. Triggering agents should be stopped and the surgery halted or concluded as soon as possible. If additional support is needed, the MHAUS hotline (1-800-644-9737) is always available for help in managing the MH crisis. Acidosis, hyperkalemia, and hyperthermia caused by the MH should be treated. Below is the list of steps to be taken for treatment of MH, which has been summarized on the Pedi-Crisis Mobile Application.[36]

1. Obtain the MH Kit.

2. Notify surgeon/proceduralist and conclude procedure.

3. Stop triggering agents (volatile anesthetic agents and/or succinylcholine). Start non-triggering anesthetic.

4. Place charcoal filters on the anesthesia circuit and increase oxygen flows to 10 L/min.

5. Intubate if not already. Hyperventilate patient to decrease EtCO$_2$.

6. Administer dantrolene at 2.5 mg/kg IV, every 5 minutes until resolution of symptoms.

7. Maintain pH 7.2 using sodium bicarbonate 1 to 2 mEq/kg IV for metabolic acidosis.

8. Cool patient if >39°C to goal temperature of 38°C with ice to axilla, groin, and around head, cold saline infusion, or cold water NG lavage.

9. Treat hyperkalemia with calcium gluconate 30 mg/kg IV or calcium chloride 10 mg/kg IV, sodium bicarbonate 1 to 2 mEq/kg IV and regular insulin 0.1 U/kg with dextrose 0.5 g/kg.

10. For ventricular tachycardia or atrial fibrillation, do not use calcium channel blocker; treat with amiodarone 5 mg/kg.

11. Send Labs: arterial blood gas (ABG)/venous blood gas (VBG), electrolytes, serum creatine kinase, serum/urine myoglobin, coagulation profile.

12. Place urinary catheter to monitor urine output. Place large-bore IV and arterial line.

13. Call ICU and arrange bed.

14. Be prepared in case of cardiac arrest to perform advanced life support/CPR/extracorporeal membrane oxygenation (ECMO).

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