

TECHNICAL REPORT

The Anesthesia Machine and Malignant Hyperthermia

Malignant hyperthermia (MH) is a rare pharmacogenetic disorder triggered by potent volatile anesthetic gases and succinylcholine. The disorder involves the uncontrolled release of calcium from the sarcoplasmic reticulum into the myoplasm by the ryanodine receptor type I, resulting in a sustained generalized skeletal muscle contraction.¹ The process of excitation-contraction coupling and reuptake of calcium significantly increases oxygen and energy (ATP) consumption.^{1,2} This hypermetabolic state produces a mixed metabolic and respiratory acidosis associated with hyperkalemia, rhabdomyolysis and hyperthermia.

Preoperative screening for MH susceptible patients would require a massive undertaking to determine who is at risk for an adverse event from exposure to potent inhaled anesthetics. The only treatment is dantrolene sodium and prophylaxis with dantrolene has been discouraged. Many patients are unaware of their condition and may have multiple anesthetics prior to experiencing a MH crisis.³ Those patients who do experience a clinical episode of MH are referred to testing centers for further confirmation of their presumptive diagnosis or are labeled as MH-susceptible without testing. Certain genetic disorders, such as central core disease or King Denborough syndrome have been well recognized as being related to malignant hyperthermia. Other conditions related to myopathies, channelopathies, heat stroke are still unproven to be definitively related to MH susceptibility.

Morbidity and mortality can be high if not diagnosed early and treated appropriately with dantrolene sodium³. The initial therapy requires immediate cessation of the offending agent and ventilation with a high fresh gas flow of oxygen. This action helps facilitate the removal of anesthetic gas from the patient, as well as to dilute the concentration of gas found within the breathing system. The replacement of the CO₂ absorbent and canister and the patient breathing circuit may help expedite the reduction of the anesthetic gas concentration. In addition, treatment should be focused on correcting the many physiologic derangements associated with the disorder. Ultimately, the only effective treatment for an MH crisis is the intravenous administration of dantrolene sodium.

Patients with known MH-susceptibility status should not be exposed to potent inhaled volatile anesthetic gas concentrations beyond 5 ppm⁴. Prior recommendations for preparing anesthesia machines included flushing the system with a high fresh gas flow of 10 lpm of oxygen for 20 minutes, while ventilating a breathing bag[†]. A recent review of published articles on the washout of anesthetic gases from various systems demonstrated marked differences in methods and time⁵. However, a common finding was the need to maintain a high fresh gas flow and replace the disposable components of the patient circuit. The Aisys*, Avance*, Aespire* and the Aestiva* represent a new generation of anesthesia Carestations* and systems manufactured by GE Healthcare. The washout of volatile anesthetic gases from these systems have not been previously studied or published. Therefore, a study was conducted of each system, excluding similar models, to develop the optimal method by which to prepare an anesthesia system for an MH-susceptible patient⁶. The following information represents the culmination of all these studies.



Acute Episodes of Malignant Hyperthermia

Based on Dr. Tae W. Kim's research the following are recommendations for acute episodes of malignant hyperthermia:

1. Activate your institution's protocol for treatment of malignant hyperthermia.
2. Discontinue any and all halogenated volatile anesthetic agents.
3. Remove the inhalation agent vaporizers from the anesthesia system, if possible, to prevent inadvertent use.
4. When possible increase the oxygen fresh gas flow rate to 15 liters per minute. Remember that after the agent has been delivered to the patient, the patient remains the greatest source of agent in the system. Keeping the highest fresh gas flow rate that is also above the patient's minute volume effectively creates a non-rebreathing system, so exhaled agent is not reintroduced to the patient.
5. If possible, change patient breathing circuit.
6. If possible, change carbon-dioxide absorbent.

The following is a guideline that may be used in the development of a site specific clinical Malignant Hyperthermia guide where GE Healthcare anesthesia machines are used.

Anesthesia System Preparation for Patients with Known Susceptibility to Malignant Hyperthermia Guideline

The current understanding of the maximum safe level of exposure to a volatile anesthetic gas for a MH-susceptible patient is ≤ 5 ppm. Based on the findings of the research done on the Aisys*, Avance*, Aespire* and the Aestiva* anesthesia systems, Dr. Tae W. Kim and GE Healthcare recommends the following steps to prepare a GE Healthcare anesthesia system for a MH-susceptible patient:

1. Remove all vaporizers from the anesthesia system to prevent their inadvertent use.
2. Attach a new patient breathing circuit to the anesthesia breathing system and connect a new breathing bag to the patient Y-piece.
3. With either oxygen or air, flush the system using mechanical ventilation (700 ml tidal volume, I:E ratio of 1:2, RR of 12, PEEP Off, and fresh gas flow rate of 15 lpm) for the minimum required time specified for the machine to be used. (see table 1) Please note the time needed to prepare an anesthesia delivery system must be based on the slowest gas available on the system. Desflurane has been found to be the slowest gas followed in order by isoflurane and sevoflurane in a recent study of GE Healthcare anesthesia Carestations. (manuscripts submitted for publication)
4. With the bag-vent switch set to the vent position, remove the patient breathing circuit. Allow the bellows to completely deflate. Replace with a new patient breathing circuit and new carbon dioxide absorbent and canister. Perform the pre-use check out.
5. Before connecting the breathing circuit to the patient at the beginning of the anesthesia case, activate the O2 flush for 10 s. Whenever possible set a total fresh gas flow rate of 15 lpm. Keeping the highest fresh gas flow rate that is also above the patient's minute volume functionally creates a non-rebreathing system and minimizes rebound of residual gas at low fresh gas flows rates.

Minimum washout times (in minutes)

Anesthesia Systems	Exposed to Desflurane	Not exposed to Desflurane
Aisys*	35 minutes	30 minutes
Avance* or Aespire*	30 minutes	25 minutes
Aestiva*	40 minutes	35 minutes

For more information on malignant hyperthermia, visit the MHAUS website at www.mhaus.org.

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The material presented in this technical report is not intended to replace the User Reference Manual of the particular anesthesia system. Always refer to the official written materials (labeling) provided with the anesthesia system for proper operation.

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‡. <http://medical.mhaus.org/index.cfm/fuseaction/Content.Display/PagePK/MedicalFAQs.cfm> Accessed June 6, 2011

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