Assessment Points

System	Effect	History	PE	Tests
HEENT (most effects in MPS pts, less so in those with lipid storage disorders)	Facial dysmorphism Macroglossia Micrognathia Enlarged supraglottic tissues Narrowed nasopharynx Excessive secretions Short neck Cervical spine stenosis Floppy or malformed tracheal cartilage High, elongated epiglottis	Previous anesthesia records, history of difficult airway (note usually gets worse with age)	Facial features Mallampati score Thyromental distance Neck ROM Anterior anatomical landmarks	Cervical spine imaging (plain films, MRI)
RESP	Sleep apnea Restrictive lung disease Recurrent URTIs	Snoring, apneic episodes Hx of lung disease	Coarse facial features, macroglossia Pectus excavatum	Sleep study LFTs
CV	Valvular insufficiency (especially mitral and aortic) Cardiomyopathy Cor pulmonale (less common)	Exercise tolerance	CV examination	ECG ECHO 6-min walk test
MS	Flexion deformities Myopathy Short stature Overweight	Variable mobility ranging from independent to wheelchair-bound		
CNS	Developmental delay Neurobehavioral problems Cognitive impairment Visual or hearing loss	Variable spectrum according to specific condition. Some are cognitively intact.		
HEME	Hepatosplenomegaly Possible bleeding tendency Lymphadenopathy, pancytopenia (lipid storage disorders)		Abdominal exam	Baseline full blood count and coagulation profile

Key References: Stuart G, Ahmad N: Perioperative care of children with inherited metabolic disorders, *Contin Educ Anaesth Crit Care Pain* 11(2):62–68, 2010; Cade J, Jansen N: Anesthetic challenges in an adult with mucopolysaccharidosis type VI, *A Case Rep* 2(12):152–154, 2014.

Perioperative Implications

Preoperative Preparation

- Tertiary center with ICU facilities ideal.
- Experienced anesthesia team.
- Consult previous anesthesia records.
- Multidisciplinary team approach (pediatrician, geneticist, and orthopedic or neurosurgeon if cervical spine an issue).
- Optimize: No concurrent infection, consider investigations as appropriate (ECG, ECHO, sleep study, lung function tests, cervical spine imaging), continue enzyme replacement therapy if pt already on it.

Lines

- May have claw deformities (implications for radial arterial lines and peripheral IV lines)

Airway

- Pre-med: Avoid sedatives. An antisialagogue, such as glycopyrrolate, is useful.
- Equipment: Difficult airway equipment prepared, including fiberoptic bronchoscope, video laryngoscope, surgical airway equipment, and second anesthetist.
- Bag-mask ventilation: Can be difficult because prone to obstruction; oropharyngeal airway may not help due to elongated epiglottis.
- Laryngoscopy: Cervical stenosis may limit safety of neck manipulation, and direct laryngoscopy may be difficult. Narrow trachea may necessitate smaller tube.
- Nasal intubation: Narrow nasopharynx may make nasal intubation difficult. Some success with nasopharyngeal airways to relieve airway obstruction during induction, but choose smaller size and beware bleeding from prominent nasal turbinates.
- Bronchoscopy: Consider awake fiber optic intubation if feasible and older pt. Variable success with both inhalational induction maintaining spontaneous ventilation and asleep fiber optic techniques in children. Confirming endotracheal placement with bronchoscope can be misleading due to abnormal tracheal anatomy.
- Surgical airway: Short, stiff neck can make identification of anatomical landmarks for surgical airway difficult. ENT surgeon present if high risk.
- LMA may be useful to relieve obstruction or as a conduit for intubation.

Maintenance

- Ventilation management for restrictive lung disease if present (higher RR, low TV).
- Careful pressure care and padding, especially if pt has flexion deformities.
- Maintain normothermia, especially if coexisting myopathy.

Drugs

- Consider routine dexamethasone, particularly in children (thickened glottic tissues more prone to swelling).
- Risk of hyperkalemia with suxamethonium if pt has prolonged immobility or significant myopathy.
- Ensure nondepolarizing relaxants are fully reversed prior to attempted extubation (use nerve stimulator or consider sugammadex if available).
- Care with opioids and other long-acting sedative drugs. Consider regional analgesia and multimodal approach.
- May have increased bleeding tendency; judicious use of anticoagulants.

Extubation

- Extubate fully awake, reversed, and with minimal or no airway swelling; consider leaving exchange wire in older pts if extreme difficulty encountered with intubation.

Postoperative Period

- Consider ICU/HDU.
- Longer monitoring in recovery room for postextubation complications.
- Risk for postop pulm edema.

Malignant Hyperthermia and Other Anesthetic-Induced Myodystrophies

Michael R. King | Ronald S. Litman

Risk

- Incidence of MH impossible to know because of lack of reporting mechanisms; Malignant Hyperthermia Association of the US hears of approximately 1–2 cases per week in North America.
- More common in males (approximately 2:1).
- Family Hx of MH or unexplained death during surgery associated with MH occurrence.

Perioperative Risks

- Mortality with MH unknown. Malignant Hyperthermia Association of the US hears of approximately 1–2 deaths directly related to MH every 1–2 years.
- Occurrence of MH reduced by avoidance of triggering agents in MH susceptible individuals, and use of succinylcholine only when indicated.
- Immediate availability of dantrolene has greatly reduced morbidity and mortality from MH.
- Myopathies associated with MH are those associated with mutations in RYR1; most common is central core disease.
- Some obscure myopathies associated with risk of MH when caused by mutations in RYR1, STAC3, or CACNL1A3 genes. These include

King-Denborough syndrome (RYR1), multiminicore disease (RYR1), congenital myopathy with cores and rods (RYR1), congenital fiber type disproportion (RYR1), Native American myopathy (STAC3), and hypokalemic periodic paralysis (CACNL1A3).
- Pts with unexpected severity of rhabdomyolysis in response to hot environment, exercise, or statin administration may have increased chance of MH susceptibility. These occurrences probably unmask RYR1 inheritance.
- Myopathies associated with hyperkalemic cardiac arrest following administration of succinylcholine: Duchenne and Becker muscular dystrophies; also reports of arrest with volatile agents only.
- Other neuromuscular diseases not associated with MH susceptibility include mitochondrial myopathies, Noonan syndrome, Freeman-Sheldon syndrome, and osteogenesis imperfecta.
- Muscle rigidity can be seen in all myotonias following succinylcholine administration.

Worry About

- Unexplained increase in $PETCO_2$, hyperthermia, tachycardia, or tachypnea (if spontaneous breathing) during GA with triggering agents
- Generalized muscle rigidity with or without trismus sensitive indicator for development of MH
- Recrudescence of MH in 25% of cases despite treatment

Overview

Malignant Hyperthermia

- No phenotypic signs predict MH susceptibility other than previous Hx of MH or family Hx or unexplained elevated CK.
- Hypermetabolic disorder manifested by increased CO_2 production and O_2 consumption, acidosis, hyperkalemia, myoglobinuria/myoglobinemia, rhabdomyolysis, tachycardia, tachypnea, increased $ETCO_2$, and hyperthermia (if severe leads to DIC).
- Dx by CHCT of biopsied muscle is most sensitive and specific. Sensitivity is approximately 80%; specificity close to 100%.
- DNA testing available in USA and in many centers in Europe. Sensitivity is approximately 50%, specificity close to 100%.
- Information for provider and pt available through the Malignant Hyperthermia Association of the US, Sherburne NY (www.mhaus.org, 607-674-7901).

Other Anesthetic-Induced Myodystrophies

- Pts with muscular dystrophy may develop hyperkalemic cardiac arrest with succinylcholine and rarely with potent volatiles only.
- Signs of dystrophy subtle; may not be apparent in young children.
- Obtain muscle specimens for dystrophin analysis; blood or other tissue for mutation analysis.
- Test for CK elevation in suspicious cases.

Etiology

Malignant Hyperthermia

- Autosomal dominant mutation, most often in ryanodine receptor (RYR-1 gene on chromosome 19).
- Resulting defect allows uncontrolled intracellular calcium release from sarcoplasmic reticulum when triggered, increasing muscle and metabolic activity.

Other Anesthetic-Induced Myodystrophies

- Muscular dystrophies: Heterogeneous X-linked mutations.

Usual Treatment

Malignant Hyperthermia

- D/C triggering agents.
- Hyperventilate patient with 100% O_2.
- Dantrolene 2.5 mg/kg IV; continue treatment for at least 24 h at 1–2 mg/kg every 4–6 h
- Treat metabolic acidosis; actively cool.
- Increase fluids 1.5 to 2 times maintenance to maintain UO 1–2 mL/kg; diuretics if necessary.
- Assess for hyperkalemia and treat appropriately.
- Monitor for DIC.
- For additional guidance call MH hotline at 800-MH–HYPER.

Other Anesthetic-Induced Myodystrophies

- Treat for hyperkalemia (IV calcium, albuterol, bicarbonate, hyperventilation).

Assessment Points

System	Effect	Assessment by Hx and PE	Test
HEENT	Masseter muscle rigidity		ABG/acidosis Hypercarbia Myoglobinuria
CV	MH: Tachycardia, arrhythmias AIMs: Sudden bradycardia VFIB, asystole	Htn/hypotension	Mixed venous and ABG: increased $ETCO_2$, myoglobinuria, hyperkalemia
RESP	Tachypnea	Tachypnea	Increased $ETCO_2$
MS	Generalized rigidity	Developmental delay Muscle weakness	CK Muscle biopsy contracture test and histology DNA testing
RENAL	Renal failure	Low UO Dark urine	Myoglobin in serum and urine, serum potassium
DERM	Vasoconstriction heat	Mottled appearance (late) Hot skin Sweating	Core temperature

Note: The caffeine/halothane contracture test is used to assess MH susceptibility.

Key References: Rosenberg H, Pollack N, Schiemann A, et al.: Malignant hyperthermia: a review, *Orphanet J Rare Dis* 10:93, 2015; Larach MG, Gronert GA, Allen GC, et al.: Clinical presentation, treatment, and complications of malignant hyperthermia in North America from 1987 to 2006, *Anesth Analg* 110(2):498–507, 2010.

Perioperative Implications

Perioperative Preparation for Known Malignant Hyperthermia

- Purge machine with 100% O_2 15–20 min prior to case. Newer anesthesia workstations (e.g., Drager Fabius) require longer period of purging (>60 min for some models).
- Avoid triggers (succinylcholine, all potent volatile agents).
- Safe GA: Propofol, ketamine, dexmedetomidine, nitrous oxide, barbiturates, all nondepolarizing muscle relaxants, opioids, benzodiazepines, local anesthetics.
- Consider RA (epidural, spinal, regional block) or monitored anesthesia care. Use TIVA if GA needed.
- Anesthesia machine:
  - Change circuit and bag.
  - Tape over vaporizers to remind not to use.
  - O_2 flow at 10 L/min for 15–20 min prior to use.
  - Insertion of charcoal filters reduces flush time to several min.
- Ensure availability of dantrolene.
- If working in ambulatory center, prearranged transfer protocol and blood gas analysis.

Monitoring

- Standard monitors plus core temperature if case expected to last more than 30 min. Core temperature monitoring decreases mortality compared with skin or no temperature monitoring due to improved detection.
- Increased CO_2 production/increased $ETCO_2$ is a sensitive early sign in the mechanically ventilated pt (tachypnea develops in the spontaneously ventilated pt).

Perioperative Implications in Other Anesthetic-Induced Myodystrophies

- Some pts with DMD and Becker dystrophy have developed hyperkalemia with MH triggers.
- Avoid succinylcholine in pts with myotonia and most other myopathies and neuromuscular disorders involving muscle atrophy.

Anticipated Problems/Concerns

- Sudden cardiac arrest in PACU.
- Myoglobinuria and renal failure.
- Postop rhabdomyolysis, follow CKs.
- Hyperkalemia.
  - Postop muscle pain or weakness and persistently elevated CK.
  - Have pt enter the North American MH Registry of Malignant Hyperthermia Association of the US (MHreg.org).

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