- In contrast to children, adults may also present with intracranial hemorrhage.
- TIA, headache, and seizures are other presenting symptoms.
- Symptoms are precipitated by activities that involve hyperventilation that results in hypocarbia (e.g., crying, exercise).

Etiology

- Poorly understood but probably involves both genetic and environmental factors
- Autosomal dominant with low penetrance or polygenic mode
- Moyamoya disease (congenital): Vasculopathy without known associated risk factors, usually bilateral
- Moyamoya syndrome: Vasculopathy with other known associated conditions (e.g., sickle cell disease, neurofibromatosis, SLE, Graves disease, trisomy 21, prior radiation therapy to head or neck, brain tumors, and tuberculous meningitis)

Usual Treatment

- Medical:
  - Does not stop progression.
  - Antiplatelet agents (e.g., aspirin, ticlopidine).
  - Vasodilators (e.g., calcium channel blockers).
  - Rheologic therapy (e.g., pentoxifylline).
- Surgical:
  - Direct: Superficial temporal artery to middle cerebral artery (STA-MCA) bypass; also known as extracranial-intracranial bypass.
  - Usually done in adults, technically difficult in children.
  - Indirect: EDAS. Scalp or temporal artery is placed onto the arachnoid surface of the brain. Collaterals occur over time.
  - Usually done in children; combined with STA-MCA bypass in adults.
  - EMS: Temporalis muscle is attached to brain surface.

Assessment Points

System	Effect	Assessment by Hx	PE	Test
CNS	Decreased CBF Seizures	TIAs, strokes	Neuro deficits	CT/MRI/MRA EEG

Key References: Parray T, Martin TW, Siddiqui S: Moyamoya disease: a review of the disease and anesthetic management, *J Neurosurg Anesthesiol* 23(2):100–109, 2011; Chui J, Manninen P, Sacho RH, et al.: Anethetic management of patients undergoing intracranial bypass procedures, *Anesth Analg* 120(1):193–203, 2015.

Perioperative Implications

Preoperative Preparation

- Assess for associated abnormalities.
- Review of chronic medications. Continue antiseizure and calcium channel blocker.
- Premedication:
  - In children, anxiolysis may be beneficial to avoid hyperventilation from crying.
  - Caution with sedatives and opioids that may result in hypercarbia.

Monitoring

- Arterial line for BP monitoring and blood gas analysis

Induction

- Inhalation or IV.
- Avoid hyperventilation and hypoventilation.
- Avoid hypotension that will impair CBF.
- Avoid muscle relaxants that release histamine or cause hemodynamic changes.

Maintenance

- Balanced anesthesia or total IV anesthesia.
- Nitrous oxide use is controversial.
- Maintaining cerebral and systemic hemodynamics is paramount.
- Avoid cerebrovasodilators.
- Minimize increases in $CMRO_2$ with adequate levels of anesthesia during painful stimuli.
- Ensure adequate CBF by avoiding hypotension, hypocarbia, and hypercarbia.
- Maintain normovolemia to hypervolemia.
- Maintain normothermia with warming blanket if needed.

Postoperative Period

- Monitor for hypoventilation to avoid hypercarbia-induced neurologic symptoms.
- Provide adequate analgesia.
- Maintain normotension, normocarbia, normovolemia, and normothermia.

Anticipated Problems/Concern

- TIA/stroke
- Intracranial hemorrhage
- Infection

Mucopolysaccharidoses

Megan A. Brockel | James J. Fehr

Risk

- All forms of MPS are autosomal recessive except MPS II (also known as Hunter syndrome), which is X-linked recessive (only males affected).
- Estimated incidence in USA: 1:30,000.

Perioperative Risks

- MPS pts are at increased anesthetic risk (most complications are associated with airway obstruction), and surgery is associated with a high mortality rate.

Worry About

- Airway obstruction, difficult airway management, cardiac pathology, obstructive and restrictive lung disease, cervical instability, spinal canal narrowing with cord compression

Overview

- MPSs are a group of rare, inherited, progressive lysosomal storage diseases caused by a lack of lysosomal enzymes required to break down glycosaminoglycans, resulting in their accumulation in tissues and organs.
- Children may appear normal at birth but begin developing symptoms by 1 y of age.
- Diagnosis is made by clinical features and increased urine mucopolysaccharides.
- Typical clinical manifestations include coarse facial features, impaired vision and hearing, airway abnormalities, cardiac problems, pulm disease, organomegaly, cervical instability, spinal cord compression, joint contractures, growth impairment, and hernias.
- Some types are associated with cognitive impairment.
- Several different subtypes are described, with differing clinical manifestations, rates of progression, and anesthetic implications:
  - Type IH (Hurler): Considered the prototypic and most severe subtype of MPS I, it is characterized by coarse facial features and airway narrowing, leading to difficult intubation, cardiac involvement, hepatosplenomegaly, atlantoaxial subluxation, joint stiffness, and contractures.
  - Type IH/S (Hurler-Scheie): Characterized by macrocephaly, micrognathia, and mental capacity ranging from mild deficiency to normal intelligence.
  - Type IS (Scheie, formerly classified as type V): Characterized by mandibular prognathism, normal intelligence, aortic insufficiency, and joint stiffness.
  - Type II (Hunter): Characterized by coarse facial features and airway narrowing leading to difficult intubation, severe mental deficiency, valvular heart disease, hepatosplenomegaly, joint stiffness, and dwarfism.
  - Type III (Sanfilippo): Characterized by mildly coarse facial features and severe mental deficiency.
  - Type IV (Morquio): Characterized by mildly coarse facial features, aortic regurgitation, restrictive lung disease, atlantoaxial instability and narrowing of the spinal canal, and joint laxity.

Etiology

- Lack of lysosomal enzymes required to break down glycosaminoglycans results in their intracellular accumulation in tissues throughout the body, leading to progressive alteration of cellular structure and function.

Usual Treatment

- Life expectancy is decreased in pts with MPS but has improved with the introduction of HSCT and ERT, both of which have beneficial effects on pulm function.
  - HSCT must be performed early in the disease course (before developmental deterioration begins); it can prevent and/or reverse many clinical features of MPS (it appears to reduce airway complications in children treated at less than 2 y of age).
  - ERT is generally initiated later and also improves airway patency but does not cross the blood brain barrier and therefore cannot preserve CNS function.

Assessment Points

System	Effect	Assessment by Hx	PE	Test
HEENT	Macroglossia, adenotonsillar hypertrophy, tracheobronchomalacia	Symptoms of sleep-disordered breathing	Airway exam including neck range of motion	X-ray, sleep study
CV	Valvular disease (most common cardiac pathology), coronary artery disease, heart failure, arrhythmias, pulm Htn	Exercise tolerance, history of angina	Auscultation for murmurs, exam for signs of heart failure	ECG, ECHO, CXR
RESP	Restrictive lung disease, obstructive sleep apnea (can lead to pulm Htn and cor pulmonale)	Exercise tolerance, symptoms of sleep-disordered breathing	Auscultation, exam for chest wall deformities	PFTs, sleep study, CXR
CNS	Spinal canal narrowing with spinal cord compression, atlantoaxial instability from odontoid hypoplasia	Neurologic symptoms	Neck range of motion	X-ray, CT, MRI

Key References: Walker R, Belani K, Braunlin E, et al.: Anaesthesia and airway management in mucopolysaccharidosis, *J Inherit Metab Dis* 36(2):211–219, 2013; Wheeler M, Cote C, Todres D: The pediatric airway. In Cote J, Lerman J, Todres D, editors: *A practice of anesthesia for infants and children,* ed 4, Philadelphia, PA, 2009, Elsevier, pp 237–278.

Perioperative Implications

Preoperative Preparation

- A thorough discussion with pt and family regarding the anesthetic and operative risk should occur prior to any surgical procedure.
- Anxiolysis with benzodiazepines can be helpful in a lower-than-normal dose (reducing the dose is especially important in those with obstructive sleep apnea).
- Antisialagogues may useful to reduce secretions, and many pts will require fiberoptic bronchoscopy to secure the airway.

Intraoperative Considerations

- A careful induction (either inhalational or IV) with preservation of spontaneous ventilation is often safest, as severe obstruction can develop with any sedation.
- A nasopharyngeal airway, an LMA, or lateral positioning may be helpful to maintain airway patency.
- Fiberoptic bronchoscopy or videolaryngoscopy is often the safest way to place an endotracheal tube (especially in those with unstable cervical spines).
- MPS pts often require a smaller-sized endotracheal tube than would be expected for age.
- Even a surgical tracheostomy can be very challenging owing to the tendency of MPS pts to have short necks and thickened soft tissues.
- Neurophysiologic monitoring should be considered for those at risk for spinal cord compression.

Postoperative Period

- Extubation should take place with the pt fully awake, adequately oxygenating and ventilating, and moving purposefully in a setting where all the personnel and equipment necessary to reintubate are readily available.

Anticipated Problems/Concerns

- Most serious anesthetic complications result from severe airway obstruction.
- Involvement of the cardiac and pulm systems can also increase anesthetic challenges and risks.

Multiple Endocrine Neoplasia Type 1 and 2

Mary A. Blanchette

Risk

- Neoplastic syndromes inherited in an autosomal dominant pattern; variable penetrance and rare incidence. Syndromes involve more than one endocrine gland.
- MEN tumors and their effects may be underdiagnosed and unrecognized when pt presents for nonrelated surgery (MEN 2a and 2b associated with pheochromocytoma).
- Medullary carcinoma of thyroid (MEN 2a and 2b) is inherited, with almost 100% penetrance; prophylactic thyroidectomy is recommended. Genetic screening tests are available.

Perioperative Risks

- See specific syndrome topics; risk related to functional components of tumors.

Overview

- MEN 1 "Werner syndrome" includes parathyroid hyperplasia (95%), anterior pituitary tumors (30%), pancreas (insulinoma, glucagonoma) (50%), and gastrinoma ("Zollinger-Ellison") (20–60%).
- MEN 2 has three distinct clinical subtypes: 2a, 2b, and FMTC.
- MEN 2a: "Sipple syndrome" includes medullary carcinoma of the thyroid (97%), parathyroid hyperplasia (20%), pheochromocytoma (50%).
- MEN 2b: Extremely rare subtype (5% of all MEN 2 syndrome) includes medullary carcinoma of thyroid, pheochromocytoma, neuromas of oral mucosa, intestinal ganglioneuromas, marfanoid body habitus, rare parathyroid hyperplasia.

Etiology

- MEN 1/2: Autosomal dominant, variable penetrance. MEN 1 caused by mutation in MEN-1 gene (tumor suppressor/regulatory); men and women equally affected. MEN 2 caused by oncogenic mutation in c-Ret gene (regulatory). Incidence of MEN 2a >FMTC >MEN 2b.

Usual Treatment

- MEN 1: Parathyroid hyperplasia; treat hypercalcemia medically; surgical resection of hyperplastic tissue with parathyroid reimplantation. Pituitary adenoma; prolactinoma (58%) treated medically with dopamine agonist, growth hormone adenoma/acromegaly (23%), and nonsecreting adenoma (10%); treated surgically with transsphenoidal resection. Pancreatic tumors treated surgically with glucose management (insulinomas); gastrinoma treated medically, then surgery.
- MEN 2a: Parathyroid hyperplasia; treat as in MEN 1. Medullary carcinoma treated with total thyroidectomy and neck dissection. Pheochromocytoma pts must be medically optimized with alpha-adrenergic blockade first, then beta-blockade, before surgical resection of tumor is attempted, otherwise high morbidity and mortality. Pts with Hx of pheochromocytoma and parathyroid hyperplasia should have prophylactic total thyroidectomy.
- MEN 2b: Treatment for medullary carcinoma is total thyroidectomy; pheochromocytoma. Same treatment as in MEN 2a.