Achondroplasia, Dwarfism

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Risk

- 1 per 15,000 to 40,000 births worldwide
- Females ≥ males
- No race predilection
- Most common type of dwarfism

Perioperative Risks

- Cervical spine instability
- Spinal cord compression
- Cardiopulmonary disease

Worry About

- Difficult airway and ventilation
- Central and/or obstructive sleep apnea
- Cervicomedullary compression and foramen magnum stenosis
- Spinal cord and nerve root compression
- Restrictive lung disease
- Pulmonary hypertension, cor pulmonale

Overview

- Results from overactive FGFR3, leading to inhibition of cartilage proliferation, leading to characteristic disproportionate dwarfism with relative macrocephaly, frontal bossing, midface hypoplasia, spine deformations, long narrow trunk, short extremities, and trident hands.
- Average adult height is 4 feet 4 in. for males, 4 feet 1 in. for females.
- Average adult weight is 120 lbs (55 kg) for males, 100 lbs (45 kg) for females.
- Atlantoaxial instability, cervicomedullary compression, foramen magnum or spinal stenosis leading to cord compression and cauda equina syndrome may require neurologic intervention.
- Brainstem compression contributes to central apnea while midface structural abnormalities lead to obstructive sleep apnea.
- Kyphoscoliosis and rib cage deformities lead to restrictive lung disease.
- Chronic hypoxia and hypercarbia from restrictive lung disease and sleep apnea lead to pulmonary hypertension and cor pulmonale.
- Increased mortality from resp and neuro complications during childhood.
- Heart-disease-related mortality approaches 10 times the general population in ages 25 to 35.
- Intelligence is usually normal; overall life expectancy is decreased by 10 y.

Etiology

- Caused by mutation of FGFR3 on chromosome 4p.
- >80% of cases are spontaneous gene mutations.
- Autosomal dominant trait with complete penetrance (heterozygous parent has a 50% chance of passing on the altered gene).
- Homozygous fatal in first few wk due to severe resp or neuro impairment.
- Advanced paternal age (age >35 y) is a risk factor in de novo cases.

Usual Treatment

- ENT: tonsillectomy, adenotomy, tympanostomy tubes
- Neurosurgery: craniectomy, VP shunts, laminectomy
- Orthopedics: distraction osteogenesis, malpositioned extremities
- Spinal surgery: spinal canal stenosis, kyphoscoliosis
- Dental, bariatric, tracheostomy, C-section

Assessment Points

System	Effect	Assessment by Hx	PE	Test
HEENT	Megalocephaly, short cranial base with small foramen magnum, midface hypoplasia, short eustachian tubes, ossicular chain stiffness, narrow nasal passages, macroglossia, prominent mandible Possible tracheomalacia OSA is common, possibly improved with tonsillectomy and adenoidectomy Crowded and misaligned dentition	Recurrent otitis media Congenital or acquired hearing loss from otitis media Apnea with cyanotic spells Speech and language delay	Limited neck ROM Limited ability to visualize glottic opening Hearing loss Delayed speech acquisition	Cervical flexion/extension neck films Hearing test
CV	Pulmonary hypertension leading to cor pulmonale	SOB with routine activities, fatigue, dizziness, syncope, supplemental oxygen use	JVD distention, lower extremity edema, hypoxia, rales, orthopnea, cyanosis, tachycardia, arrhythmia	ECG, ECHO, angiography
PULM	Restrictive lung disease from severe scoliosis and rib cage deformities Expect decreased FRC, hypoxemia, hypercapnia, apnea even in childhood. Thoracic cage constriction improves over time May have bronchomalacia	Apnea with cyanotic spells, SOB Daytime somnolence, loud snoring Recurrent resp infections	Ribcage deformities, tachypnea	CXR, ABG, PFT, sleep study
GI	Obesity very common Gastric hypomotility	GERD, aspiration, dysphagia, globus hystericus	BMI	CXR
CNS	Small and funnel shaped foramen magnum may cause hydrocephalus, elevated ICP Cervical spine instability, stenosis and fusion Progressive narrowing of spinal canal caudally, possible cauda equina Spinal cord or root compression at any level	Headaches, irritability, lethargy, vomiting Cervical myelopathy, ataxia, incontinence Snoring, daytime somnolence Depression	Mental status changes, low back pain, ataxia, radiculopathy, dysesthesia, paresthesia, paraparesis, hyperreflexia, hypertonia, sustained clonus, incontinence	Axial head or spine CT or MRI motor evoked potentials, SSEP Sleep study
MS	Pectus carinatum or excavatum, genu varum, rhizomelic shortening of arms and legs, small thoracic cage	Delayed motor milestones, premature degenerative joint disease	Thoracolumbar kyphoscoliosis, proximal limbs shorter than distal limbs, brachydactyly, trident hand configuration Hyperextensibility of most joints (knees in particular), incomplete elbow extension Bowing of lower extremities	Spine films, x-rays, bone scans

Key References: Baum V: Achondroplasia. In *Anesthesia for genetic, metabolic, and dysmorphic syndromes of childhood,* ed 3, Philadelphia, PA, 2015, Lippincott Williams & Wilkins, pp 47–54; Oppitz F, Speulda E, Goeters C, et al.: Anesthesia recommendations for patients suffering from achondroplasia. <www.orpha.net/data/patho/Pro/en/Achondroplasia_EN.pdf>, 2011.

Perioperative Implications

Preoperative Preparation

- General anesthesia is usually the method of choice.
- Neuraxial anesthesia is possible, but is difficult due to anatomy and carries increased risk.
- Conscious sedation is also possible, a concern for sleep apnea syndrome.
- Assess individual pt based on systems approach and review relevant studies.
- Assume difficult intubation, ventilation and unstable cervical neck. High spinal cord injury and death have been reported with routine neck manipulation.
- Consider prophylaxis for gastroesophageal reflux and hypersalivation.
- Pts generally more anxious but avoid presedation if possible.

Monitoring

- Standard ASA monitors
- A-line recommended for invasive surgeries or any cardiopulmonary compromise.
- Foley; CVP; MEP; SSEP (spinal cord surgeries or abnormal positioning to identify early cord compression).
- Use appropriate BP cuff (two-thirds upper arm length) to avoid falsely elevated BP.

Airway

- Anticipate difficult mask ventilation due to facial anatomy.
- Nasal airway/intubation difficult due to narrow nasopharynx and choanal stenosis.
- Oral airway often necessary to relieve obstruction from macroglossia.
- Avoid hyperextension or hyperflexion, especially in those with atlantoaxial instability or foramen magnum stenosis, thus AFOI is the safest/preferred method.
- Most require intubation due to restrictive lung disease, but have LMA as rescue device.

- ETT sizes correlate better with weight than age; they have a smaller tube ready.

Induction

- No specific drug contraindications; limited data on dosages.
- Low functional residual capacity can lead to rapid desaturation with induction.
- Avoid hypoxia, hypercarbia, and acidosis, which can worsen pulmonary hypertension.

Maintenance

- Mechanical ventilation may require reduced tidal volume and higher rate.
- Pressure-controlled ventilation may be superior; careful attention to PAP.
- Careful positioning of hyperextensible joints.
- Consider OG tube for gastric decompression.
- Use peripheral nerve stimulator to guide NMBD dosage.

Postoperative Period

- Continuous pulse oximetry due to high incidence of sleep apnea.
- Prepare for prolonged resp insufficiency and mechanical ventilation.
- May need to remain intubated and/or monitored in an ICU.
- Pain control critical to postop resp status.

Anticipated Problems/Concerns

- Difficult airway and ventilation
- Neurologic impairment
- Resp insufficiency and postop ventilation
- Pain control

Acidosis, Lactic/Metabolic

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Risk

- Incidence in USA: Unknown
- Present in a variety of disease states, from mild to severe systemic illness

Perioperative Risks

- Hemodynamic instability (due to arteriolar vasodilation and decreased cardiac output)
- Hyperkalemia
- Insulin resistance and hyperglycemia
- Stimulation of inflammation and suppression of immune response
- Acute resp failure

Worry About

- Decreased responsiveness to vasopressors and inotropes
- Decreased activity of local anesthetic agents
- Arrhythmias

Overview

- Physiologic disturbance resulting from excess acid production, failure of organic acid excretion, or inappropriate bicarbonate loss causing increased serum acidity.
- A marker of an underlying disease process.
- Severe when, in the presence of resp compensation, serum $[HCO_3]$ is ≤10 mmol/L or pH < 7.20.
- Acute metabolic acidosis is associated with increased morbidity and mortality.

Etiology

- Broadly differentiated by calculating the AG: AG = $[Na^+]$ – ($[Cl^-]$ + $[HCO_3^-]$). The AG corresponds to the presence of unmeasured anions in serum. The presence or absence of an elevated AG helps to determine the underlying cause and direct appropriate therapy. Normal AG is 7 ± 4 mEq/L and decreases 2.5 mEq/L for every 1 g/dL decrease in serum albumin. Corrected AG can be calculated:
  - Corrected AG = Calculated AG – {2.5 * (4.0 – [albumin])}.
- High AG metabolic acidosis: Results from an accumulation of excess acid in the serum. Specific causes are due to production of lactate or ketones (diabetic, alcoholic, or starvation ketoacidosis), toxic ingestion (methanol, ethylene glycol, salicylates), uremia, or medication side effects (propofol infusion syndrome, lactic acidosis associated with metformin).
- Normal AG (hyperchloremic) metabolic acidosis: Associated with excess HCO_3^- loss from the kidney or GI tract, failure of the kidney to excrete H^+, or rapid IV infusion of unbuffered solutions (e.g., normal saline).
- Delta gap (ΔΔ): Used to determine the presence of concomitant metabolic derangements and is calculated as ΔAG/Δ $[HCO_3^-]$, where ΔAG = (calculated AG – expected AG) and Δ $[HCO_3^-]$ = (24–$[HCO_3^-]$). ΔΔ < 1 indicates AG metabolic acidosis *and* concurrent non-AG acidosis. ΔΔ > 2 indicates AG metabolic acidosis and concurrent metabolic alkalosis. ΔΔ = 1 to 2 indicates a pure AG metabolic acidosis.

Usual Treatment

- Centered on rapid identification and treatment of the underlying physiologic disturbance (e.g., DKA, sepsis, inadequate resuscitation, CV failure, abdominal ischemia).
- In high AG metabolic acidosis, alkali therapy may be indicated as a temporizing measure for acute, severe acidemia (pH <7.20). In normal AG metabolic acidosis, alkali therapy may be indicated to replace bicarbonate losses.
  - Sodium bicarbonate remains the most widely used buffer; however, its use in correcting acute metabolic acidosis is controversial because it may increase $PaCO_2$ and paradoxically worsen intracellular acidosis. Other untoward effects of bicarbonate include hyperosmolarity and hypernatremia. Bicarbonate administration has not been proven to improve cellular function or reduce mortality in lactic or ketoacidosis.
  - THAM is an alternate buffer designed to limit CO_2 generation, offering theoretical benefits over bicarbonate. It buffers via the ammonia moiety, but elimination of protons is dependent on urinary excretion or removal via dialysis.
  - When alkali therapy is indicated, the bicarbonate deficit can be calculated to guide appropriate dosing. Bicarbonate should be administered as an isotonic infusion, rather than a bolus of hypertonic solution. Bicarbonate deficit (mEq) = 0.4 × body weight (kg) × (24 – $[HCO_3^-]$).
- In some instances (hyperventilation syndromes, high altitude), acidosis may be compensatory and not require treatment.

Assessment Points

System	Effect	Assessment by Hx	PE	Test
NEURO	Altered mental status, seizures	Level of consciousness, delirium, somnolence nausea/vomiting, seizures, toxic ingestion	Obtunded, confused, somnolent	Toxicology screen, osmolal gap, serum lytes
CV	Arteriolar vasodilation, hypotension, decreased response to vasopressors and inotropes, arrhythmias, hypocontractility	Signs of end-organ hypoperfusion	Tachycardia, hypotension, poor peripheral pulses, cold extremities, poor capillary refill	Invasive hemodynamic monitoring, ECHO, ECG
PULM	Hypoxemia, hyperventilation, resp failure	Tachypnea, dyspnea	Rapid and shallow breathing, accessory muscle use, hypoxia, hypercarbia	CXR, ABG, pulse oximetry
RENAL	Oliguria, acute kidney injury, ATN	Urine output, chronic renal disease	Signs of hypovolemia or hypervolemia	UO, Cr, BUN, urine lytes, UA, serum lytes
GI		Nausea, vomiting, diarrhea, melena, abdominal pain	Abdominal pain to palpation	Serum lactate, radiographic imaging, upper/lower endoscopy
ID		Fever, rigors	Hyperthermia or hypothermia, signs of focal infection	WBC with differential, cultures, radiographic imaging
ENDO	Hyperglycemia, insulin resistance	DM, polyuria, polydipsia, hyperphagia	Signs of dehydration	Blood glucose, serum ketones

Key References: Kraut JA, Madias NE: Metabolic acidosis: pathophysiology, diagnosis and management, *Nat Rev Nephrol* 6:274–285, 2010; Kraut JA, Madias NE: Treatment of acute metabolic acidosis: a pathophysiologic approach, *Nat Rev Nephrol* 8:589–601, 2012; Kimmoun A, Novy E, Auchet T, et al.: Hemodynamic consequences of severe lactic acidosis in shock states: from bench to bedside, *Crit Care* 19:175, 2015.