Pediatric Anesthesia Updates

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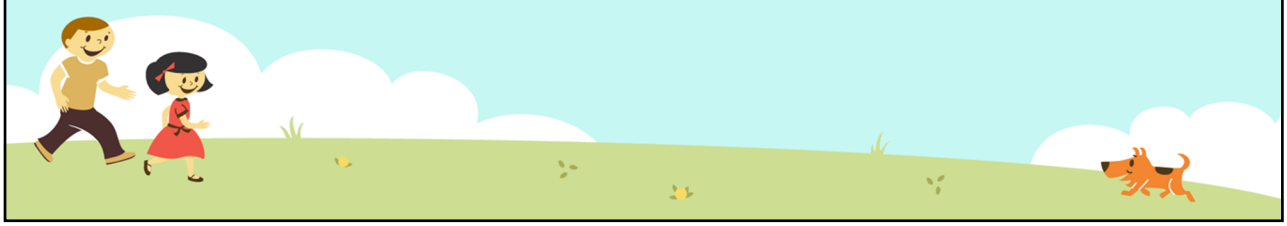
OBJECTIVES

To optimize clinical care for pediatric blood transfusions

To deliver safe and effective perioperative pain management for pediatric patients

To reduce the incidence of perioperative respiratory adverse events (PRAEs) for children undergoing general anesthesia with recent or current upper respiratory infection (URI)



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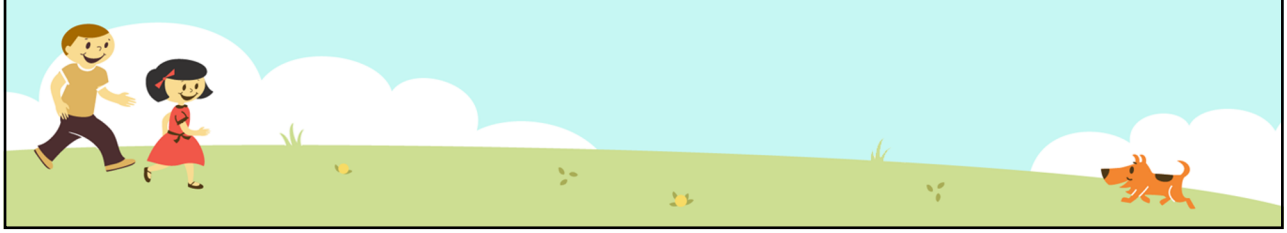
5 Preventable Error Traps in Children

1. Failure to Recognize Preoperative Anemia
2. Failure to Obtain Informed Consent and Strategize Alternatives
3. Failure to Consider Intraoperative Blood Conservation Techniques
4. Failure to Recognize and Treat Hemorrhage
5. Failure to Prevent Unnecessary Transfusion



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Preoperative Anemia

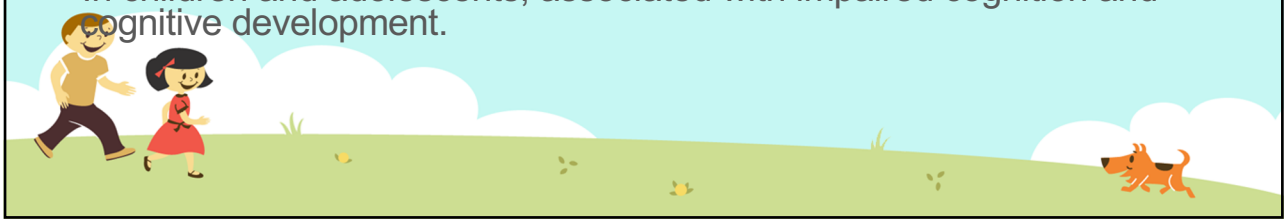
Iron Deficiency Anemia, largest contributing factor to anemia in pediatrics.

Independent predictor of intraoperative blood transfusion.

Increases mortality, LOS, SSI, & diminished QOL.

In neonates, associated with poor feeding, neonatal infection, ICU admission, neurocognitive alterations, increased risk of ADHD, ASD, & perinatal mortality.

In children and adolescents, associated with impaired cognition and cognitive development.



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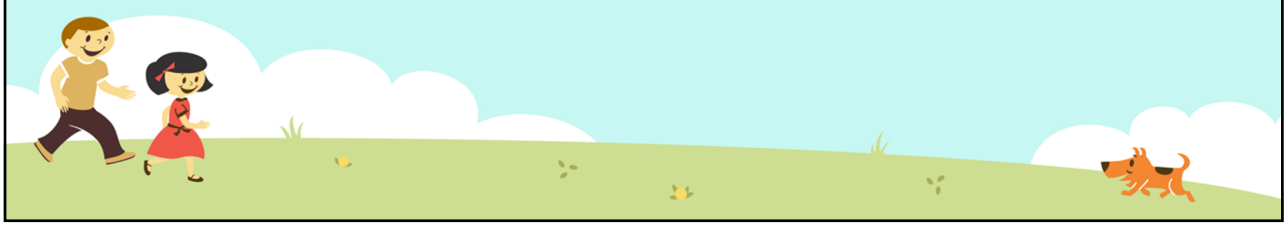
Informed Consent

Provides information about the risks, benefits, and alternatives of a blood transfusion and involves shared decision-making with patient and their parent (s)/guardian (s).

Children are 3.5 x more likely to have an adverse reaction w/ pRBCs and 3.6 x more likely with a platelet transfusion.

Discussion of alternatives such as iron, EPO, acute normovolemic hemodilution, cell salvage, and TXA administration.



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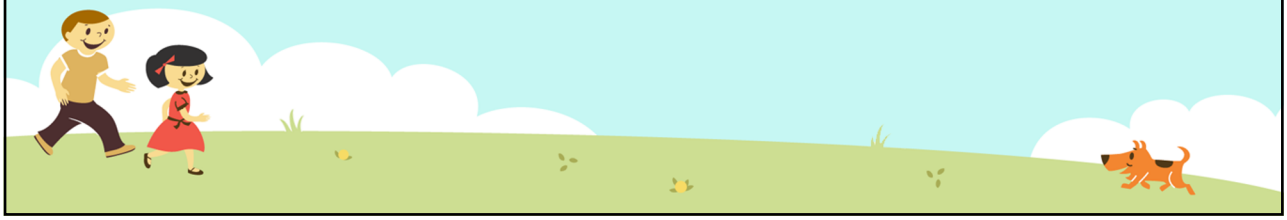
Blood Conservation Techniques

Improvement of CS technology – Better RBC deformability & higher 2, 3-diphosphoglycerate. Consider if anticipated blood loss is >8 mL/kg in children weighing > 10kg.

Acute normovolemic hemodilution - Reserve up to 20% of circulating blood volume for fresh autologous whole blood. Calculate ABL.

Antifibrinolytics (TXA) for moderate to major blood loss surgeries. Recommendation to load TXA between 10-30 mg/kg (max of 2g) over 15 min, followed by a continuous infusion of 5-10 mg/kg/hr.



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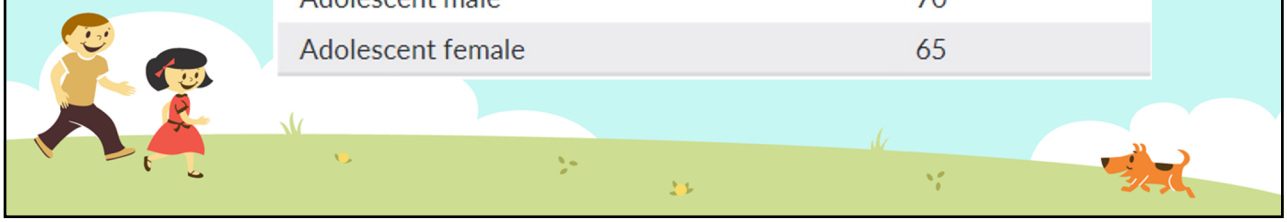
Estimated Blood Volume

Age	Estimated blood volume (mL/kg)
Premature infant	90–100
Term infant to 3 months[a]	80–90
Infant/children >3 months	75
Obese children	65
Adolescent male	70
Adolescent female	65



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Recognize Hemorrhage

Pediatric massive transfusion activations are in trauma (46%), elective surgery (34%), and medically complex patients (20%).

In neonates/young infants, BP and volume status correlate closely with signs of hypovolemia due to lower physiologic reserve, under-developed sympathetic nervous system, and limited ability to increase stroke volume to improve cardiac output.

Decreased function of coagulation, anti-coagulation, and fibrinolytic pathways < 1 year of age.

Lethal triad: Hypothermia, acidosis, and coagulopathy.

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Child's Anatomy

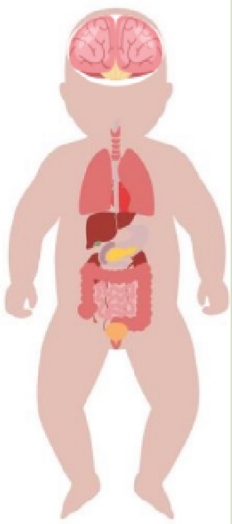
Issues of size

Blood loss assessment
- Often underestimated; blood volume 7kg infant =1.5 cans of soda pop

Vascular access & invasive monitoring
- Challenging & smaller gauge; may need ultra-sound-guidance & intra-osseus access

Blood component/crystalloid administration
- Easy to administer high-volume rapidly
- Prone to TACO, hemodilution, hypothermia (< 36°C), acidosis, hyperkalemia (RBCs), hypocalcemia (RBCs & plasma) & iatrogenic coagulopathy
- Excessive crystalloid may worsen TBI
- Rapid flow fluid warmer indicated IV >20 gauge

Drug dosing
- Needs to be weight-based
- IV calcium chloride (15-20 mg/kg) may be preferred vs gluconate (45-60 mg/kg) with hemodynamic instability and ↓ liver perfusion



Unique anatomy

Disproportionate larger head & reduced head control
- Higher frequency of TBI
- Larger blood loss from scalp or significant intra-cranial bleeding due to open cranial sutures

Tightly packed internal organs
- Prone to more solid organ injury from both blunt & penetrating mechanisms
- Non-operative management of blunt intra-abdominal solid organ injury is common
- Unrecognized intra-abdominal bleeding is a leading cause of fatal traumatic injury

Pliable skeleton
- Traumatic skeletal fractures uncommon; if present, indicates significant force
- Large amounts of blood loss associated with long bone fractures

Large body surface area: volume ratio
- Prone to hypothermia (< 36°C) & increased risk of coagulopathy and in-hospital mortality

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Prevent Unnecessary Transfusion

Discourage "tanking up" a child to finish standard adult unit and provide cushion for ABL - increases risk for mortality and transfusion-associated complications.

Children undergoing non-cardiac surgery who received RBC transfusions of >40 mL/kg have higher mortality.

Increase in postoperative infection when transfusion >20 mL/kg.

Post-transfusion goal: Relieve indication for transfusion, not to achieve a normal Hb level. Reasonable target goal for hemodynamically stable pediatric patients is 7.0-9.0 g/dL.

Choosing Wisely Pediatric and Neonatal Medicine recommends: "Avoid dependence on standard laboratory values for transfusion decisions; Consideration of patient's clinical status is requisite."

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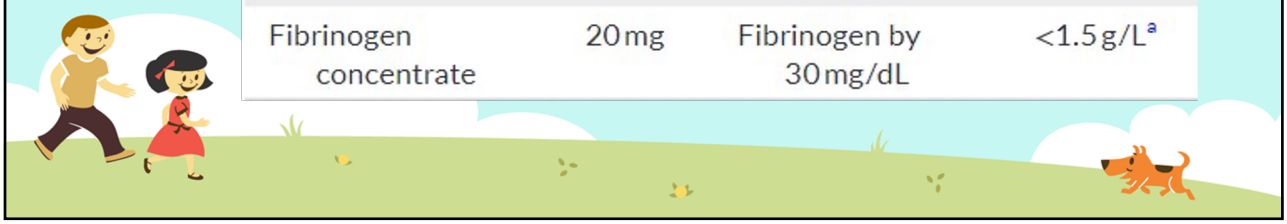
Blood Transfusion Guideline

Blood component/ product	Dose per kg	Anticipated increase	Treatment Threshold
Red blood cells	10 mL[b]	2 g/dL (20 g/L)	<8 g/dL[c]
Frozen plasma	10 mL	Coagulation factors by 20%	INR >1.8
Platelets	10 mL	150×10^9	$<50 \times 10^{9}$[d]
Cryoprecipitate	5 mL	Fibrinogen by 30 mg/dL	<1.5 g/L
Fibrinogen concentrate	20 mg	Fibrinogen by 30 mg/dL	<1.5 g/L[a]



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Prescribing Opioids for Acute Pain in Children & Adolescents in Outpatient Settings

First clinical practice guideline from the American Academy of Pediatrics.

Input from patients, caregivers, government entities, politicians, special interest groups, and advocates.

Acute pain lasting < 1 month.

Evidence-based approach to safely prescribe opioids and treat pediatric pain, address racial disparities, and promote equity for children with physical, developmental and intellectual disabilities.

Illicitly manufactured fentanyl is most common cause of poisoning and overdose death in children and adolescents. Inappropriate opioid prescription contributes to rising rates of negative opioid-related outcomes.

5% of adolescents exposed to opioids for postoperative analgesia at risk for persistent opioid use.

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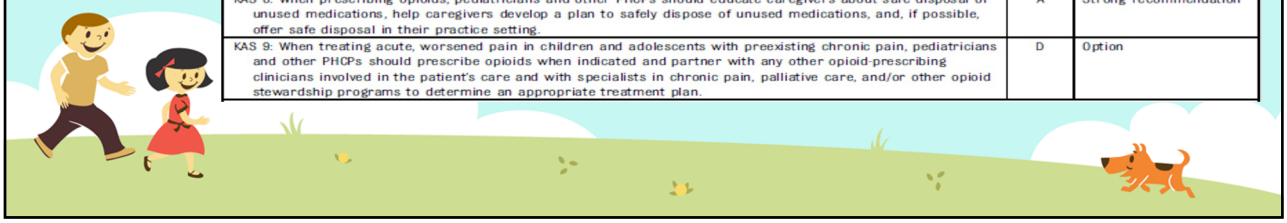
Key Action Statement

Key Action Statement (KAS)	Evidence Quality	Recommendation Strength
KAS 1: Pediatricians and other pediatric health care providers (PHCPs) should treat acute pain using a multimodal approach that includes the appropriate use of nonpharmacologic therapies, nonopioid medications, and, when needed, opioid medications.	B	Strong recommendation
KAS 2: Pediatricians and other PHCPs should NOT prescribe opioids as monotherapy for children and adolescents who have acute pain.	B	Strong recommendation
KAS 3: When prescribing opioids for acute pain in children and adolescents, PHCPs should provide immediate-release opioid formulations, start with the lowest age- and weight-appropriate doses, and provide an initial supply of 5 days or fewer, unless the pain is related to trauma or surgery with an expected duration of pain of more than 5 days.	C	Recommendation
KAS 4.1: When treating acute pain in children and adolescents younger than 12 years, pediatricians and other PHCPs should NOT prescribe codeine or tramadol.	X	Strong recommendation
KAS 4.2: When treating acute pain in adolescents 12–18 years of age who have obesity, obstructive sleep apnea, or severe lung disease, pediatricians and other PHCPs should NOT prescribe codeine or tramadol.	X	Strong recommendation
KAS 4.3: When treating postsurgical pain after tonsillectomy or adenoidectomy in children and adolescents younger than 18 years, pediatricians and other PHCPs should NOT prescribe codeine or tramadol.	X	Strong recommendation
KAS 4.4: When treating acute pain in people of any age who are breastfeeding, pediatricians and other PHCPS should NOT prescribe codeine or tramadol.	X	Strong recommendation
KAS 5: When treating acute pain in children or adolescents who are taking sedating medications, such as benzodiazepines, pediatricians and other PHCPs should use caution when prescribing opioids.	X	Strong recommendation
KAS 6: When prescribing opioids, pediatricians and other PHCPs should provide naloxone and counsel patients and families on the signs of opioid overdose and on how to respond to an overdose.	X	Recommendation
KAS 7: When prescribing opioids, pediatricians and other PHCPs should educate caregivers about safe storage and directly observed administration of medications to children and adolescents.	D	Option
KAS 8: When prescribing opioids, pediatricians and other PHCPs should educate caregivers about safe disposal of unused medications, help caregivers develop a plan to safely dispose of unused medications, and, if possible, offer safe disposal in their practice setting.	A	Strong recommendation
KAS 9: When treating acute, worsened pain in children and adolescents with preexisting chronic pain, pediatricians and other PHCPs should prescribe opioids when indicated and partner with any other opioid-prescribing clinicians involved in the patient's care and with specialists in chronic pain, palliative care, and/or other opioid stewardship programs to determine an appropriate treatment plan.	D	Option



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Multimodal Approach

- Adverse effects of opiates: Constipation, pruritus, nausea and vomiting, sedation, respiratory depression, opioid-induced hyperalgesia, opioid tolerance, opioid dependence, addiction, and death.
- Effective analgesia for tonsillectomy, third molar surgery, inguinal hernia repair, and acute fractures with acetaminophen and NSAIDs alone.
- Optimize non-opioid medications and treatment before considering opiates for mild-moderate pain. If severe, start opioid at the same time as non-opioid.
- Set realistic expectations.
- Non-pharmacologic strategies: Ice or heat, massage, transcutaneous electrical nerve stimulation, injured area above heart level to decrease swelling, music therapy, cognitive behavioral therapy, acupuncture, distraction strategies, complementary therapies.
- Acetaminophen and NSAIDs ATC, topical agents and regional analgesia, gabapentinoids and/or antidepressants for neuropathic pain, and muscle relaxants for spasms.
- Consult pain management specialist for acute on chronic pain.

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Common Medications for Acute & Chronic Pain in Children

- Gabapentinoids - Gabapentin, Pregabalin
- Dysautonomia
- Spasticity
- TCAs - Nortriptyline, Amitriptyline
- Opioids - Tramadol, Morphine, Methadone
- Alpha-2 adrenergic receptor agonist - Clonidine
- Cannabinoids - Dronabinol
- Benzodiazepines - Clonazepam, Lorazepam, Midazolam

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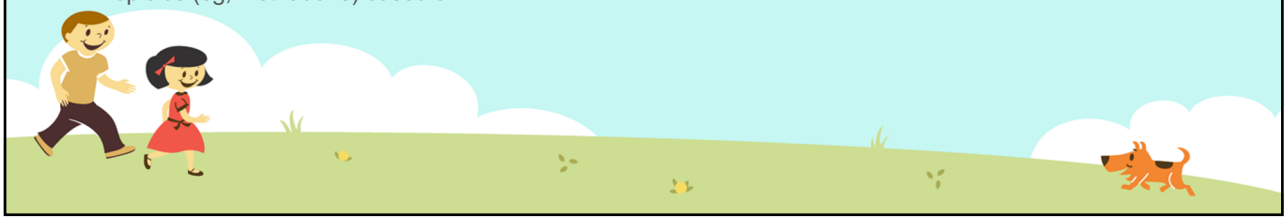
Lowest Appropriate Dose, Immediate-Release Opioids

Opiate use among adolescents: Older age, Surgery type (PSF), and higher patient-reported pain.

Prescribe when:

1. Severe pain exists (pain scores of 7-10).
2. Severe pain is expected to occur and nonpharmacologic and non-opioid pain control is insufficient.
3. Opioids are expected to be effective.
4. The source of pain is known.

- Prescribe at lowest effective dose for age and weight, and for the shortest duration needed. Ex. Oxycodone 0.1 to 0.2 mg/kg per dose Q4-6 hrs for children and adolescents <50 kg.
- Obese children, consult pharmacist - hydrophilic opioids (eg, oxycodone, morphine) dosed on IBW vs lipophilic opioids (eg, methadone) based on TBW.



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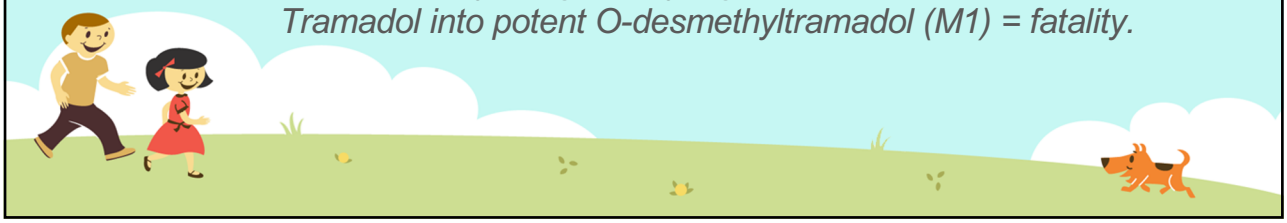
Codeine and Tramadol

- FDA assigned its strongest warning, a contraindication, restricting use of codeine and tramadol in children younger than 12 years. Recommends against codeine and tramadol use in adolescents with obesity, OSA and underlying lung pathology.
- Contraindicated post tonsillectomy or adenoidectomy.
- Prescription stems from belief that because they are lower in potency, less likely to contribute to addiction or overdose.
    - *Children are ultra-rapid metabolizers of CYP2D6 (Cytochrome P450 isoenzyme 2D6 genotype) and quickly convert codeine into potentially dangerously high levels of morphine & convert Tramadol into potent O-desmethyltramadol (M1) = fatality.*



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T&A

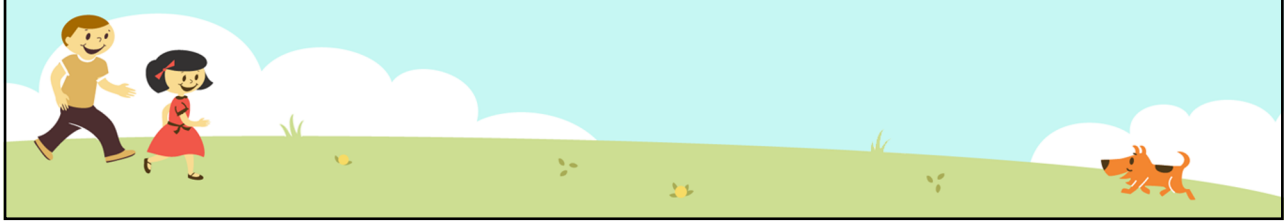
The American Academy of Otolaryngology-Head and Neck Surgery Clinical Practice Guideline updates.

Pain is leading cause of morbidity following T&A. Pain leads to decreased oral intake, dehydration, and potentially bleeding complications from dry mucous membranes.

Variable data regarding post-tonsillectomy bleed with administration of NSAIDs, thus acetaminophen may be preferred first-line medication.

For severe pain following T&A not fully responsive to non-opioid medications, consider opioids other than codeine or tramadol, for example, oxycodone or hydrocodone.

Combination of benzodiazepines and opioids can cause significant respiratory depression, oversedation, and death.



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Acute on Chronic Pain

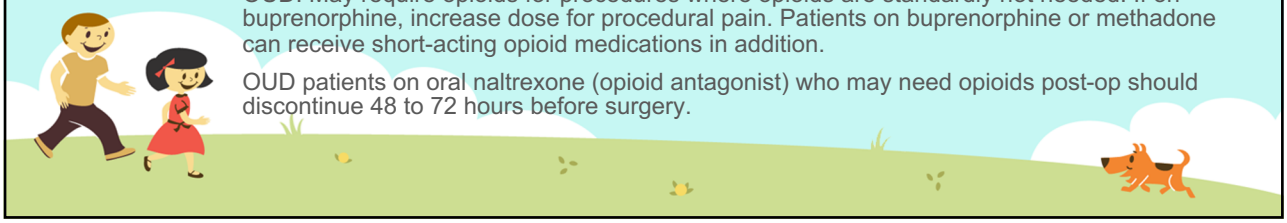
Common chronic pain: HAs, abdominal, lower back and muscular pain. Generally should not be treated with opioids - masks a more serious underlying diagnosis.

Opioids commonly prescribed for sickle cell disease, osteogenesis imperfecta, and epidermolysis bullosa.

Central sensitization to pain and nociception = increase in pain from surgery or trauma.

Maintain baseline opioid dosing and add additional opioids appropriate to the degree of injury. Opioids should not be rapidly tapered or discontinued.

- N-methyl-D-aspartate antagonists (ketamine) and mixed opioid agonist or N-methyl-D-aspartate antagonists (methadone) may improve effectiveness of opioids perioperatively by minimizing or reversing opioid tolerance.
- Regional analgesia whenever possible for chronic pain.
- OUD: May require opioids for procedures where opioids are standardly not needed. If on buprenorphine, increase dose for procedural pain. Patients on buprenorphine or methadone can receive short-acting opioid medications in addition.
- OUD patients on oral naltrexone (opioid antagonist) who may need opioids post-op should discontinue 48 to 72 hours before surgery.



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Pain Behaviors in Nonverbal Children With SNI

Vocalizations: Crying, whimpering, moaning, gasping, sharp intake of breath

Facial expression: Grimacing, frowning, furrowed brow, squinting, eyes wide open, clenched teeth, teeth grinding, distressed look

Consolability: Inability to be consoled and made comfortable

Interaction: Withdrawn, seeking comfort

Sleep: Disturbed sleep, increased or decreased sleep

Movement: Increase from baseline in movement of arms and legs, restless and fidgety, startles easily, pulls away when touched, twists or turns

Tone: Stiffening of extremities, clenching of fists, back arching, resists movement

Physiologic: Tachycardia, sweating, shivering, change in color, pallor, breath holding, tears

Atypical features: Blunted facial expression, laughter, breath holding, self-injurious behaviors

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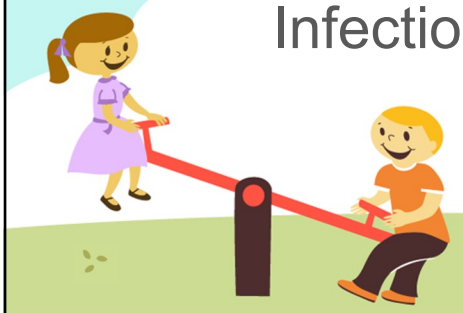
Perioperative Respiratory Adverse Events with Upper Respiratory Infection in Pediatrics



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URIs

Most frequent medical problem in pediatrics, leading medical cause to defer surgery.

Clinical syndrome of cough, nasal congestion, discharge, fever, malaise, sore throat, and sneezing are caused by approximately 200 viruses.

- Rhino, parainfluenza, and influenza viruses most common.
- Infant + Preschool child: Respiratory syncytial virus, parainfluenza viruses, adenovirus most common.

Hyper-reactive airway that can persist for 6 weeks.

Issue whether to proceed with elective surgery.

- Deferring surgery can have social, economic, and emotional consequences to the child, family and health system.
- Trend to safely perform anesthesia in children with URIs after careful assessment of potential risks and benefits for child.

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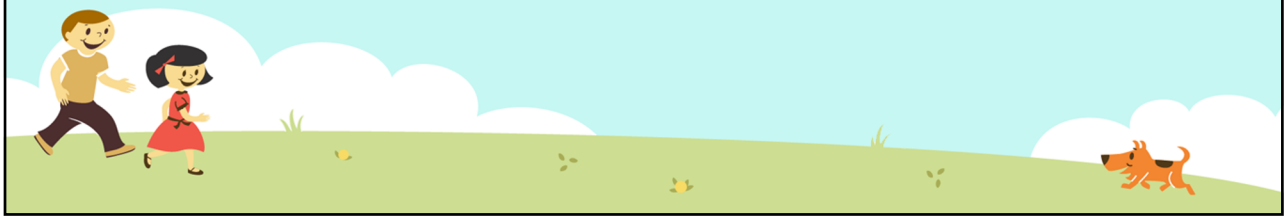
Pathophysiology of URI

Viral invasion of respiratory epithelium and mucosa leads to airway inflammation, edema, dyscriny, and bronchoconstriction – sensitizes the airway to secretions and volatile agents.

Viral infection interacts with ANS by inhibiting cholinergic muscarinic M2 receptors, followed by increase in acetylcholine. In addition, viral induced liberation of tachykinin and neuropeptidases with constriction of smooth muscles in the respiratory tract for weeks result in bronchial hyper-reactivity which can persist for up to 6 weeks beyond disappearance of all clinical symptoms.

Bronchial hyperreactivity can trigger laryngospasm and bronchospasm, both leading to fatal hypoxemia which is the main cause of perioperative morbidity and mortality in children.



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Perioperative Respiratory Adverse Events

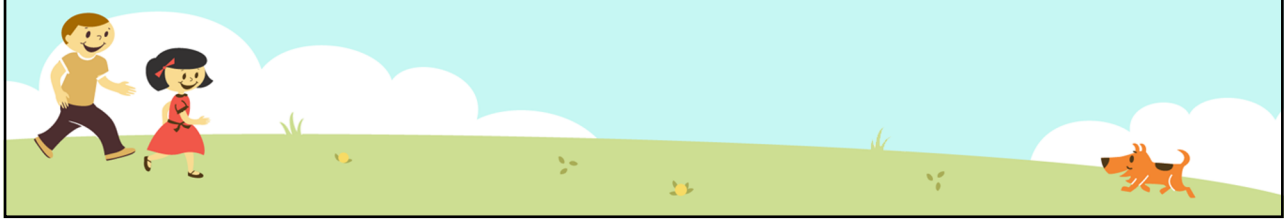
Major complications during intraoperative and postoperative period in children with URI.

Typical adverse events are laryngospasm, bronchospasm, breath holding, atelectasis, arterial oxygen desaturation, bacterial pneumonia, and unplanned hospital admission.

Potential for lower respiratory tract infection after URI is relatively common in children.

- Listen for rhonchi or wheezing
- Greater propensity for wheezing or bronchospasm during anesthesia

Independent risk factors for PRAEs: Passive smoking, Age <6 years old, Infants < 1 year with severe signs and symptoms of URI, children with respiratory or pulmonary comorbidity, ENT or eye surgery, upper abdominal surgery, and cardiac surgery.



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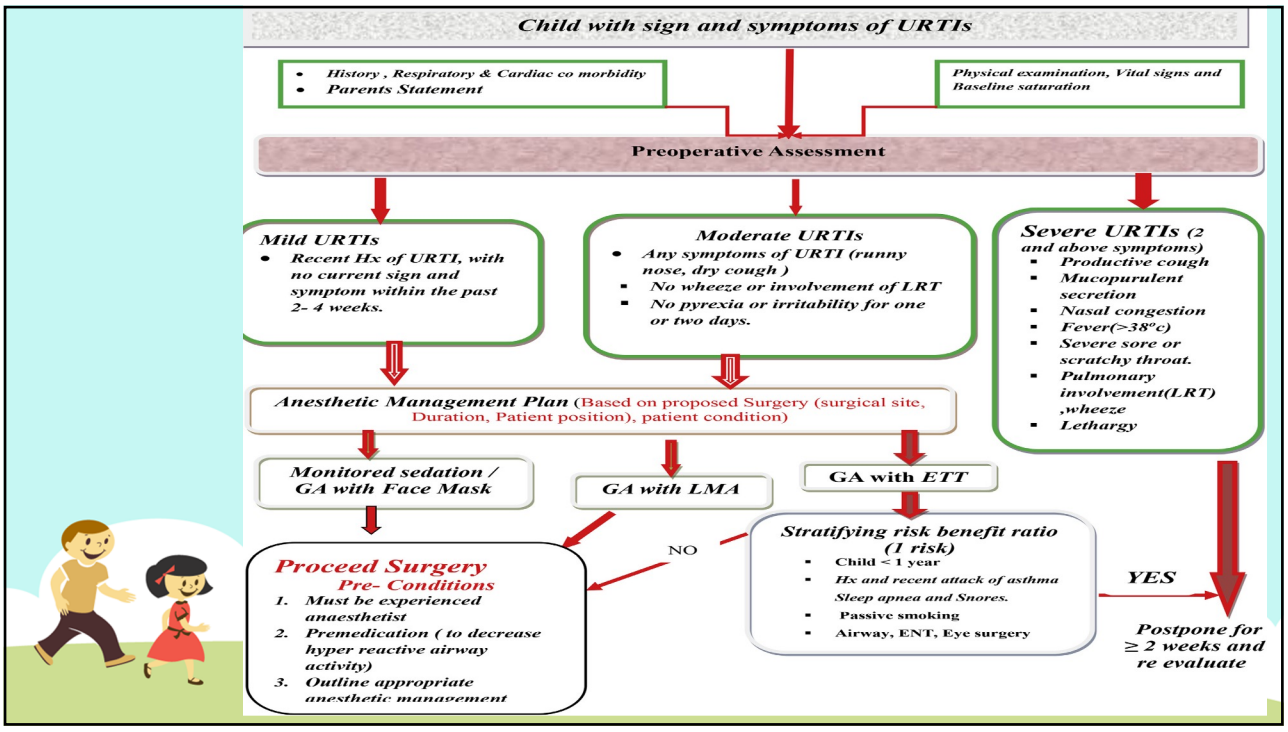

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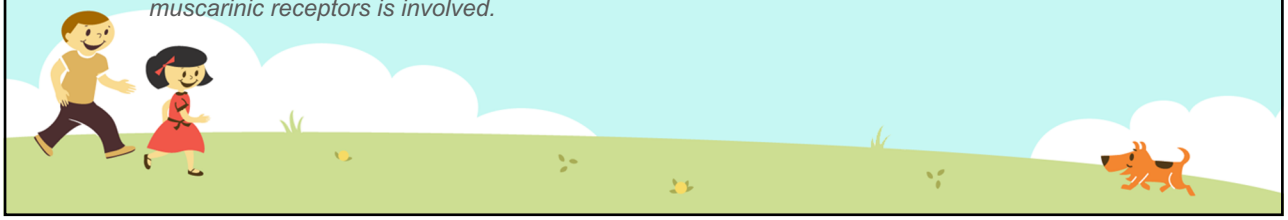
Perioperative Management

- Impact of location and provider experience.
- Benzodiazepine premedication associated with increased rates of PRAEs.
- A2 adrenergic agonists may lead to fewer PRAEs
  - RCT among children undergoing cardiac cath with recent URI, dexmedetomidine halved the incidence of oxygen desaturation with SGA devices compared to placebo.
  - Presynaptic inhibition of acetylcholine release resulting in reduction of bronchial hyperactivity and airway tone.
  - Clonidine has been shown to not affect carbon dioxide response curve in anesthetized children.
- B2 adrenergic agonists cause acute smooth muscle relaxing effects, stabilize mast cells, inhibit release of inflammatory mediators and coughing reflex.
  - *Anticholinergics like inhaled ipratropium or IV glycopyrrolate at induction has not been shown to reduce PRAEs despite evidence that airway stimulation of bronchial smooth muscle via M3 muscarinic receptors is involved.*



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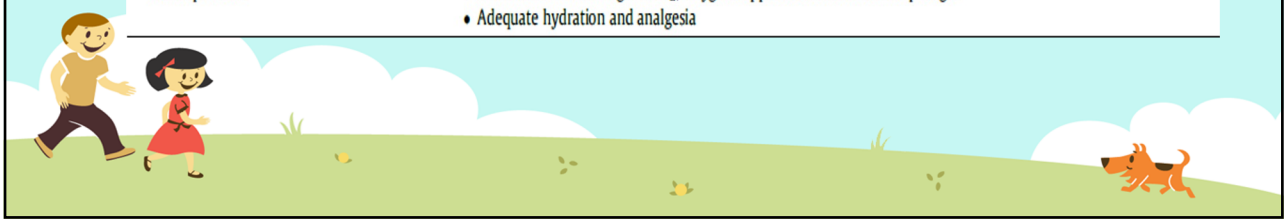
Perioperative Management

Evidence-based perioperative management of children with URTIs undergoing Elective Surgery.

Premedication	*Salbutamol (inhalational)*	• Salbutamol puff 10–30 min before induction. • 2.5 mg if weight <20 Kg. • 5 mg if weight >20 kg
	Lidocaine (IV), 1.5 mg/kg	• To suppress airway reflexes either before intubation or extubation
Anaesthetic agents	*Propofol*	• Propofol has good airway reflex blunting properties with mild bronchodilator effect
	Volatile anaesthetic agents	• Volatile anaesthetic agents have good bronchodilator properties but limited effects in suppressing airway reflexes. • When using volatile anaesthetic agents **sevoflurane** followed by **halothane** anaesthetic agents. • In high-risk children, IV induction with propofol over inhalational induction. • Optimal depth of anesthesia during intraoperative period
Extubation		• Adequate suctioning under optimal depth of anesthesia. • Awake extubation. • Immediate oxygen supplementation and CPAP
Post operative		• Meticulous monitoring of SPO_2, Oxygen supplementation via nasal prongs. • Adequate hydration and analgesia



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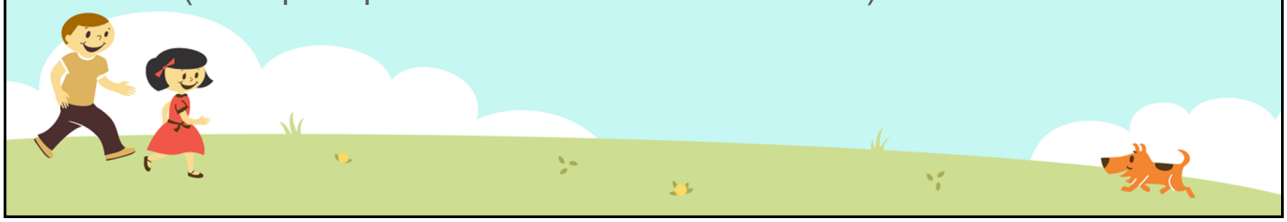
Maintenance

- TIVA vs. Inhalational agents
- Desflurane - Adverse changes in airway and respiratory tissue mechanics
- Lung-protective ventilation strategies:
  - Low tidal volumes (<10 mL/kg)
  - Peak inspiratory pressures <30 cm H20
  - Avoidance of high FIO2
  - Moderate PEEP
  - Regular recruitment maneuvers to avoid atelectasis with cuffed ETT (avoid peak pressures in excess of 40 cm H20)



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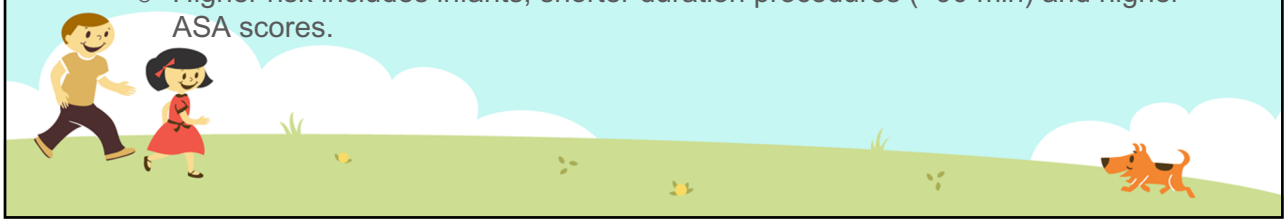
Neuromuscular Blockade

- Controversial
- Neuromuscular drugs improve quality and success of intubation with better hemodynamic stability.
- Children have markedly variable sensitivities to NMB drugs due to immaturity of neuromuscular transmission and volume of distribution differences.
- Residual blockade decreases respiratory control resulting in hypoventilation, aspiration, and fatigue = hypoxemia and hypercapnia.
  - Higher risk includes infants, shorter duration procedures (<90 min) and higher ASA scores.



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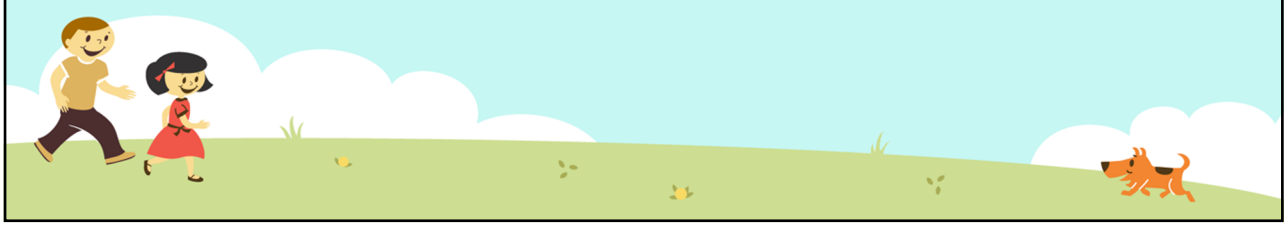
LMA vs ETT

- Children with URIs undergoing surgery under GA with ETT had the highest probability of suffering PRAEs than those managed by LMA or facemask.
- Children with URIs had a 2 to 7 times increased risk of suffering PRAE during anesthesia and 11 times increased risk if intubated.
- Incidence of laryngospasm increased in intubated patients and with airway surgery.



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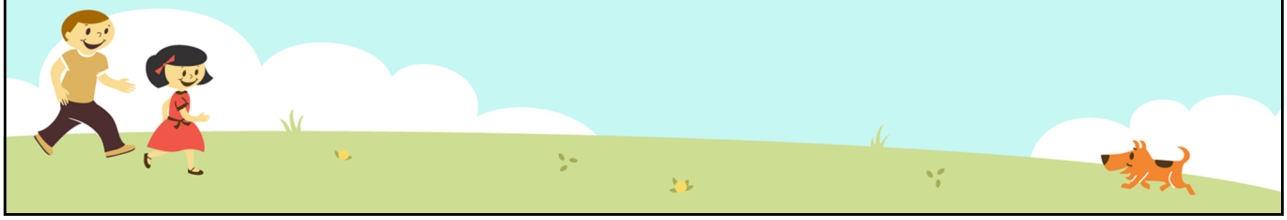
Extubation Techniques

- RCT by Tait and Malviya found that there is no difference in the incidence of complications in either awake or deep.
- Increased incidence of coughing in children extubated awake versus deep (60% in awake vs 35% in deep).
- Incidence of airway obstruction in deeply anesthetized patients were more frequent.



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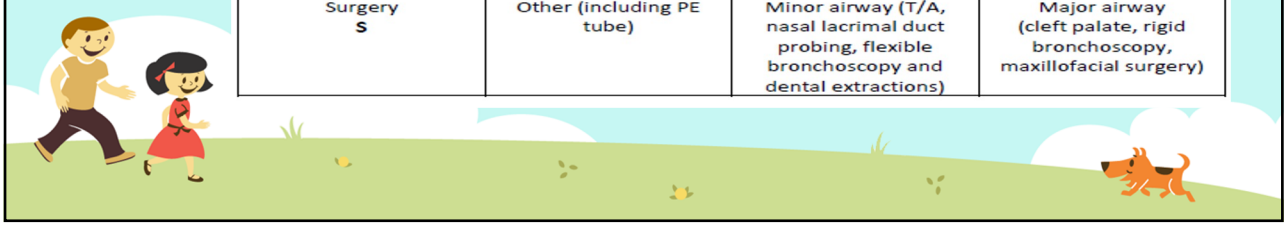
The COLDS Score

	1 point	2 points	5 points
Current signs and symptoms **C**	None	Mild (Parents confirm URI and/or congestion, rhinorrhea, sore throat, sneezing, low fever, dry cough)	Moderate / Severe (purulence, wet cough, abnormal lung sounds, lethargy, toxic appearance, or high fever)
Onset of symptoms **O**	>4 weeks ago	2 – 4 weeks ago	<2 weeks ago
Presence of lung diseases **L**	None	History of RSV, mild intermittent asthma, Bronchopulmonary dysplasia if >1 year old, loud snoring, or passive smoker.	Moderate / severe (moderate, persistant asthma, infant with Bronchopulmonary dysplasia, Obstructive sleep apnoea or pulmonary hypertension)
Airway device **D**	None or facemask	LMA or supraglottic airway	Endotracheal tube
Surgery **S**	Other (including PE tube)	Minor airway (T/A, nasal lacrimal duct probing, flexible bronchoscopy and dental extractions)	Major airway (cleft palate, rigid bronchoscopy, maxillofacial surgery)



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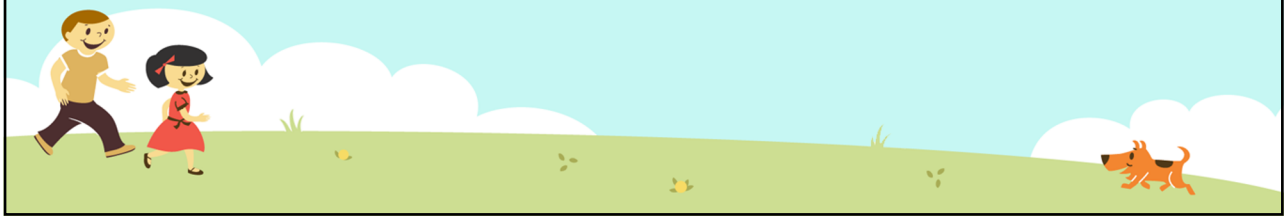
Timing of Elective Surgeries in SARS-CoV-2

The American Society of Anesthesiologists (ASA) and the American Patient Safety Foundation (APSF) released a joint statement in March of 2021 (recently updated in February 2022) with recommendations advising clinicians of the appropriate timing of elective surgeries in SARS-CoV-2 infected patients. Based on the accumulated data at that time, the statement issued the following recommended waiting times for infected patients:

- 4 weeks for asymptomatic patients or recovered from mild nonrespiratory symptoms
  - 6 weeks for symptomatic patients who did not require hospitalization
- 8–10 weeks for a symptomatic patient who is diabetic, immunocompromised, or hospitalized
  - 12 weeks for patients admitted to the Intensive Care Unit due to COVID-19 infection.



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