



Pediatric Anesthesiology

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Pediatric Anesthesiology

- Children are not little adults!
 - Neonates: 0-30 days old
 - Infants: 1 month to 1 year
 - Children: older than 1 year
- Special pediatric considerations
- Pediatric anesthesiology on call
- Malignant hyperthermia



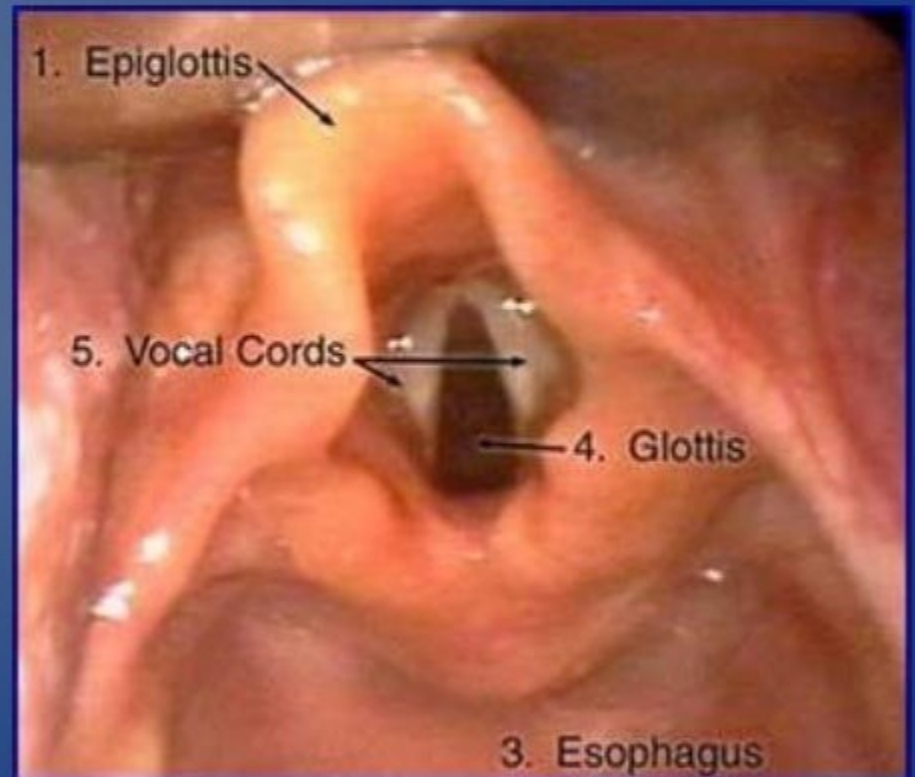
Airway

- Head large
 - $\frac{1}{3}$ size of adult head
 - $\frac{1}{9}$ height of adult
 - $\frac{1}{27}$ weight of adult
- Tongue large
- Nasal passages narrow
- Obligate nose breathers until 5 mo



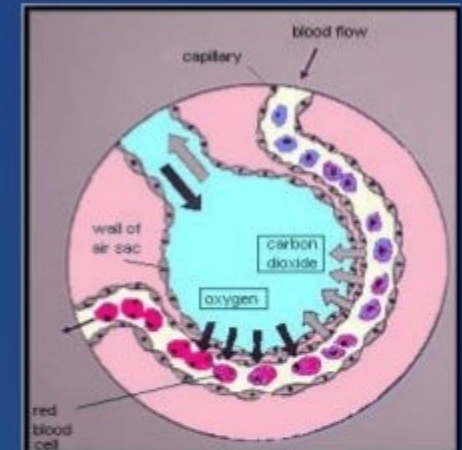
Airway

- Larynx
 - Anterior
 - Cephalad
 - C 4 level
- Epiglottis long & U shaped
- Trachea short
 - Neonates → 2 cm cords to carina
- Cricoid → Narrowest point until 10 yo



Breathing

- Alveoli small & limited number
 - Lung compliance decreased
- Cartilaginous rib cage
 - Chest wall compliance increased
- Chest is circular shaped with horizontal ribs
- Diaphragm easily fatigued
 - Fewer type 1 muscle cells
- Abdominal muscle strength undeveloped
- Airway resistance increased → Poiseuille's Law

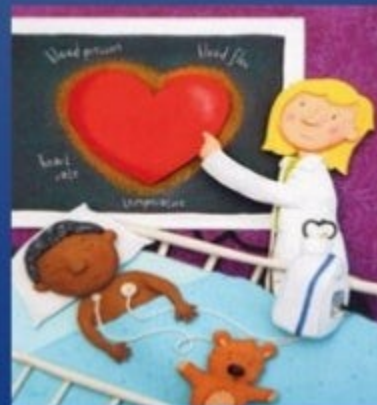


Breathing

- Low residual lung volumes at expiration (FRC)
 - FRC overlaps closing capacity → atelectasis
- Hgb P50 19 mm Hg contrasts to 26 Hg adults
- Increased oxygen consumption → 7 ml/kg/min
 - Higher minute ventilation
 - Higher blood flow to vessel rich group
- Hypoxic/hypercapnic respiratory drives not well developed
- Oxygen reserve is limited

Circulation

- Equalization of biventricular pressures
- Stroke volume fixed
- Cardiac output dependent upon heart rate
- Immature sympathetic and baroreceptor response
 - Lack of tachycardia to hypovolemia/hypotension
- Dysrhythmias
 - Bradycardia
 - Hypoxemia

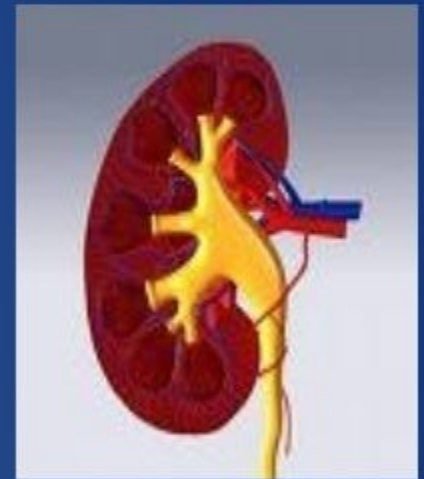


Normal vital signs

Age	Heart rate	SBP	Resp rate
Newborn	110-170	> 60	30-50
1 year	100-160	> 80	< 40
5 years	80-130	> 90	< 30
> 10 years	< 90	> 90	< 20

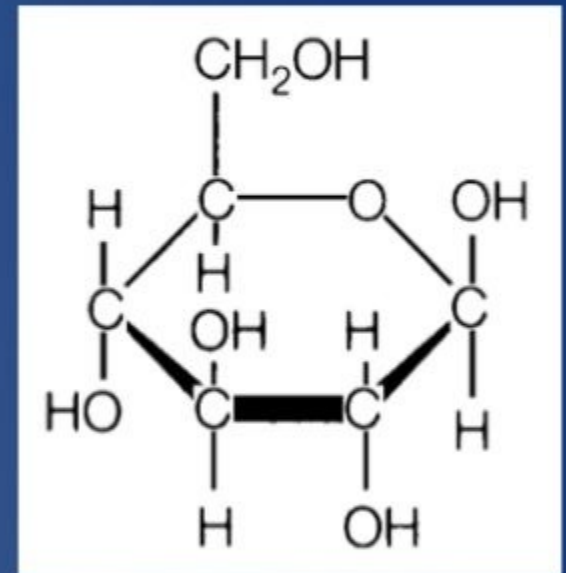
Renal

- Decreased glomerular filtration rate
 - Decreased creatinine clearance
 - Decreased sodium excretion
 - Decreased glucose excretion
 - Decreased bicarbonate resorption
 - Decreased diluting capability
 - Decreased concentrating ability
 - 600 mosm
- Meticulous attention to fluid administration



Glucose management

- High glucose utilization
 - Premies 5-6 mg/kg/minute
 - Neonates 3-4 mg/kg/minute
- Low glycogen stores
 - Predisposes to hypoglycemia
 - Neonates < 30 mg/dl
 - Infants < 40 mg/dl
 - Increased risk with prematurity and/or hyperal
- Options at maintenance rate
 - D5LR, D5 ½ NS, D5 ¼ NS



Thermoregulation

- Greater heat loss
 - Thin skin
 - Low fat content
 - High surface area/weight ratio
- No shivering until 1 yo
- Thermogenesis by brown fat
- More prone to iatrogenic hypo/hyperthermia



Pharmacotherapy

- Weight “guesstimate” = $2 \times (\text{age}) + 9$
- Total body water content increased (70-75%)
 - Large volume of distribution for water soluble meds
 - Increased dose/kg
- Hepatic biotransformation immature
- Protein binding decreased
- Neuromuscular junction immature
- Muscle mass in neonates smaller
 - Termination of action by redistribution prolonged

Volatile anesthetics

- Minute ventilation to FRC ratio increased
- Blood flow to vessel rich groups increased.
 - Rapid rise in alveolar anesthetic concentration
- Blood-gas coefficients lower in neonates
- Inhalation induction rapid
 - BP of neonates and infants more sensitive to hemodynamic effects of volatile agents
 - Caution against overdose



MAC

Agent	Neonate	Infant	Children	Adults
Halothane	0.87	1.1-1.2	0.87	0.75
Isoflurane	1.6	1.8-1.9	1.3-1.6	1.2
Sevoflurane	3.2	3.2	2.5	2
Desflurane	8-9	9-10	7-8	6

IV/IM Anesthetics

- Ketamine mg/kg → 1-2 IV, 3-5 IM, 5-8 PO
- Benzodiazepines
 - Midazolam mg/kg → 0.3-0.7 PO, 0.05-0.2 IV, 0.2-0.5 IN
- Propofol
 - Larger doses/kg
 - Propofol infusion syndrome
- Opioids
- Muscle relaxants



Propofol infusion syndrome

- Higher incidence in pediatrics than adults
- 90 mcg/kg/minute for as little as 8 hours
- Metabolic acidosis
- Hemodynamic instability
- Hepatomegaly
- Rhabdomyolysis
- Multiorgan failure

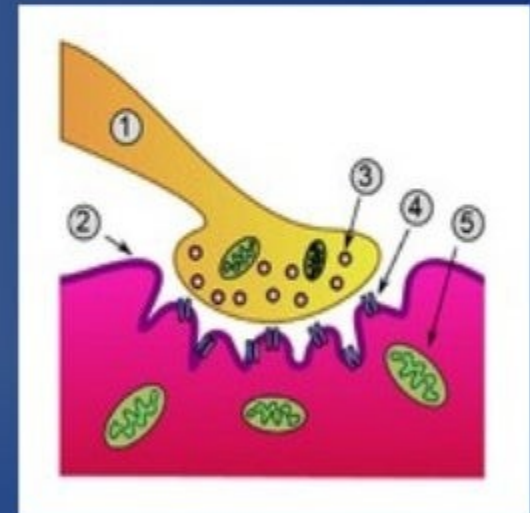


Opioids

- More potent in neonates than children or adults
 - Easier across blood:brain barrier
 - Decreased metabolic capability
 - Increased sensitivity of respiratory centers
 - Caution in neonates
 - Hepatic conjugation decreased
 - Cytochrome P 450 pathways mature by 1 mo
 - Renal clearance of morphine metabolites is decreased
- Children have high rates of hepatic blood flow
 - Increased biotransformation and elimination

Neuromuscular blockers

- Shorter onset time (as much as 50%)
 - Shorter circulation time
- Depolarizing agent
 - Succinylcholine
- Nondepolarizing agents
 - Rocuronium
 - Cisatracurium
 - Vecuronium



Succinylcholine

- Fastest onset → 30-60 secs
- Children → 1-1.5 mg/kg IV, 4-6 mg/kg IM
- Infants → 2-3 mg/kg IV, 4-6 mg/kg IM
- Dysrhythmias
 - Bradycardia and sinus arrest
 - Atropine 10-20 mcg/kg
- Hyperkalemia
- Masseter spasm

Nondepolarizing NMB

Rocuronium

- Drug of choice for intubation
 - 0.6 mg/kg IV
 - RSI 0.9-1.2 mg/kg IV
 - May last 90 min
- May be given IM
 - 1-1.5 mg /kg
 - Onset 3-4 min

Cisatricurium

- Consistently intermediate duration
- 0.05-0.06 mg/kg IV

ED 95 for muscle relaxants

(Rapid intubating dose is 1.5-2 x ED 95)

Agents	Infants mg/kg	Children mg/kg
Succinylcholine	0.7	0.4
Rocuronium	0.25	0.4
Cisatricurium	0.05	0.06
Vecuronium	0.05	0.08

Reversal

- Monitor NMB
- Neostigmine 0.03-0.07 mg/kg
- Edrophonium 0.5-1 mg/kg
- Coadministered with anticholinergic
 - Glycopyrrolate 0.01 mg/kg
 - Atropine 0.01-0.02 mg/kg

Preoperative considerations

History and physical

- Comorbid illness
- Recent URI
- Murmur
 - Innocent
 - New
 - Symptomatic
- Anesth problems
- Labs → none routine

NPO

- Clears → 2 h
- Breast milk → 4 h
- Formula → 6 h
- Solids → 8 h

Separation anxiety

- Anxiolysis
- Premeds
- Parental presence

URI



- Symptoms new or chronic?
 - Infectious vs allergic or vasomotor
- Viral infection within 2 - 4 weeks of GA with intubation increases perioperative risk
 - Wheezing risk increased 10x
 - Laryngospasm risk increased 5x
 - Hypoxemia, atelectasis, recovery room stay, admissions and ICU admissions all increased
- If possible, delay nonemergent surgeries

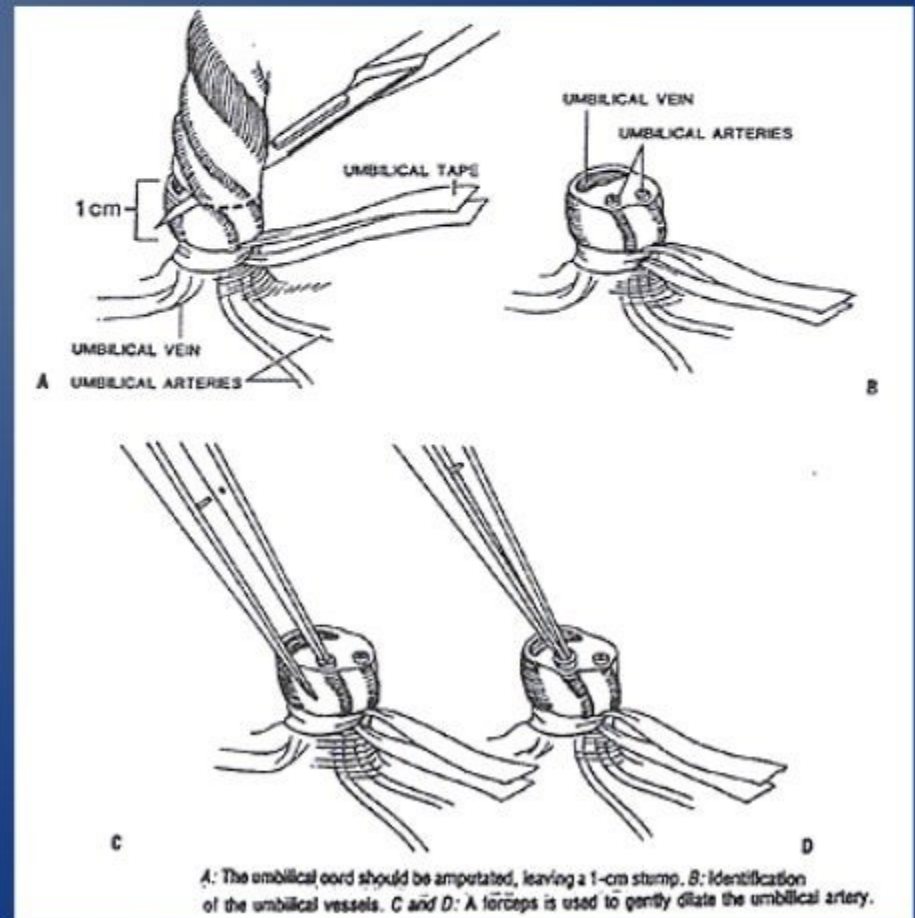
Monitoring

- Age & size appropriate standard monitors
- Precordial stethoscope
 - Heart rate, heart tones, respiratory quality
- Preductal pulse oximetry in neonates
 - Right extremity or earlobe
- EtCO₂ monitor
 - Main-stream less accurate in < 10 kg
 - Side-stream may falsely elevate iCO₂ and falsely lower EtCO₂.
- Temperature

Invasive monitoring

- Require expertise and caution
- CVL most often IJ or femoral
- A-line most often right radial artery
 - Preductal
 - Mirrors carotid & retinal

UA/UV may be considered

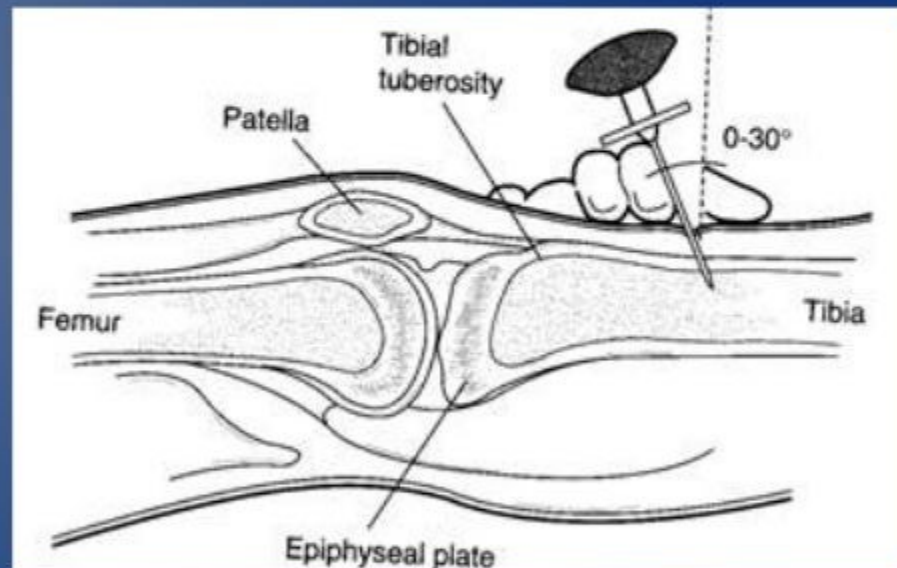


Induction

- Inhalation
 - Sevoflurane
 - Halothane
- Intravenous
 - Propofol
 - Thiopental
 - Ketamine
- Intramuscular
 - Ketamine
- Intravenous access
 - Challenging
 - Small veins
 - Subcutaneous fat
 - Multiple sticks
- Saphenous
- Intraosseous

Intraosseous

- IO kit or bone marrow bx needle
- 1-2 cm below tibial tuberosity
- Insert with screwing motion until lack of resistance
- Aspirate marrow to confirm placement
- Secure needle
- Volume replacement
- Labs
- Drug administration



Airway management

- Mask
- LMA
- Intubation



- Neonate – 1 y
 - 3 – 4 ETT
- Uncuffed ETT
 - 4 + age/4
- Cuffed
 - 3 ½ + age/4
- Depth
 - 3 x tube size

- Blades

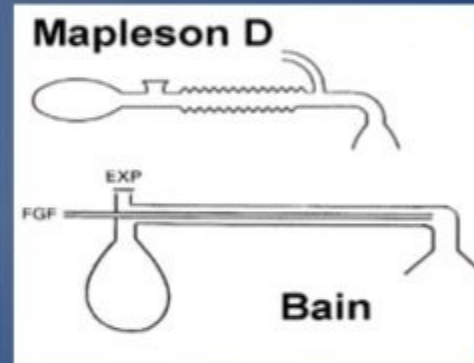
- Straight most common



- Miller
- Phillips
- Wis-Hipple
- Curved available
- Fiberoptic
 - Bullard
 - Glide

Maintenance

- Balanced anesthetic most common
- Semiopen circuits traditional
 - Low resistance
 - Light weight
 - Mapleson D, Bain
- Circle systems with new machines
 - VT 8-10 ml/kg
 - PC/PS 15-18 cm H₂O



Perioperative fluid replacement

- 1st 0-10 kg → 4 cc/kg/hr
- 2nd 10-20 kg → 2 cc/kg/hr
- > 20 kg → 1 cc/kg/hr
- Calculate preoperative deficit
 - Replace 50% first hour
 - Replace 25% second hour
 - Replace 25% third hour
- Minor surgery → additional 2 cc/kg/hr
- Major surgery → up to additional 10 cc/kg/hr

Estimated allowable blood loss

- Blood volume
 - Premies → 95 ml/kg
 - Term neonates → 90 ml/kg
 - Up to 1 year → 80 ml/kg
 - > 1 year old → 70 ml/kg
- EABL → $\text{wt kg} \times \text{est blood vol} \times (\text{starting Hct} - \text{allowable Hct}) / \text{ave Hct}$



Blood product replacement

- Age appropriate Hct
 - Premies and sick neonates Hct 40-50%
 - Nadir at 3-6 months of 30%
- Comorbid conditions
- Replace initially with 3 x BSS or 1 x colloid
- Usual starting dose of PRBC is 10 cc/kg
- EBL ~ 1.5 blood volumes give FFP/platelets
 - FFP 10 cc/kg
 - Platelets 1 unit/10 kg raises platelets by 50K
 - Cryo 1 U/10 kg

Laryngospasm

Etiology

- Involuntary spasm of laryngeal musculature
 - Superior laryngeal nerve stimulation
- Risk increased
 - Extubated while lightly anesthetized
 - Recent URI
 - Tobacco exposure

Treatment

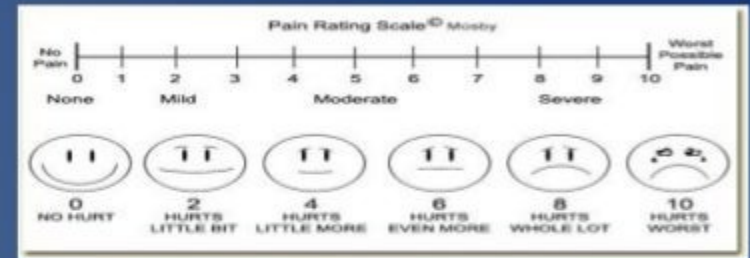
- Positive pressure ventilation
- Laryngospasm notch
- Propofol
 - 0.5–1 mg/kg IV
- Succinylcholine
 - 0.2-0.5 mg/kg IV
 - 2-4 mg/kg IM

Postintubation stridor

- Glottic or tracheal edema
- Associated with
 - Large ETT
 - Repeated intubation attempts
 - Prolonged surgery
 - ENT procedures
 - Excessive tube movement
- Preventive dexamethasone
- Racemic epi neb

Perioperative pain control

- Regional
- Acetaminophen
 - PO 10-15 mg/kg, PR 40 mg/kg
- Ketorolac 0.5-0.75 mg/kg IM/IV
- Opioids
 - Morphine 50-100 mcg/kg
 - PCA 20 mcg/kg 10 min lockout
 - Hydromorphone 10-20 mcg/kg
 - PCA 5 mcg/kg 10 min lockout
 - Fentanyl 0.5-0.75 mcg/kg



Regional

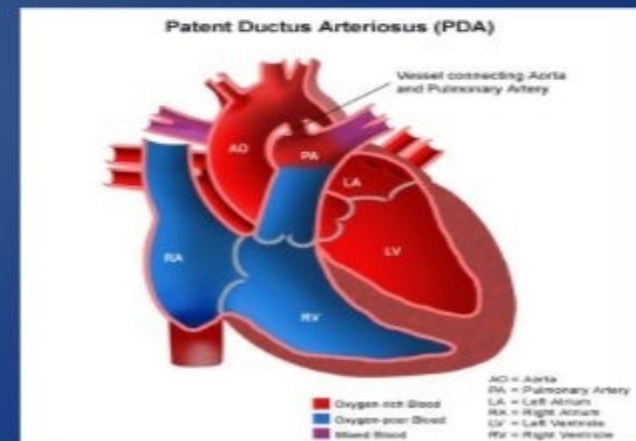
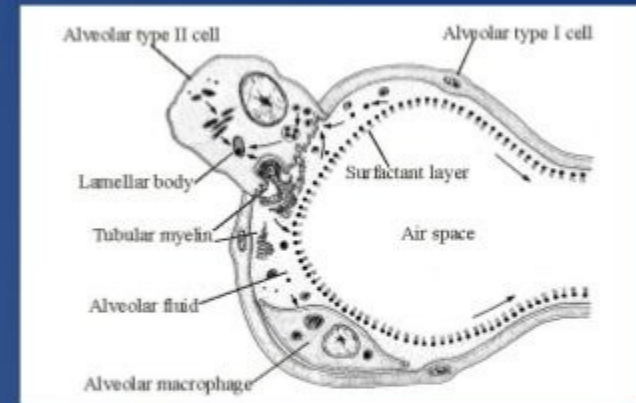
- Operative and postoperative utility
- Caudal is most common
- Options in adults available for children
 - Peripheral blocks and catheters
- Epidural
 - 0.2-0.3 cc/kg/hour covers ~ 4 dermatomes
 - T wave changes may indicate toxicity
- Spinal
 - Short duration even with tetracaine

Caudal

- Perioperative analgesia
 - Ropivacaine 0.2% 1 cc/kg (up to 2 mg/kg)
 - Bupivacaine 0.25% 1 cc/kg (up to 2.5 mg/kg)
 - Opioids
 - Duramorph 25-50 mcg/kg
 - Hydromorphone 5-10 mcg/kg
 - Clonidine 2 mcg/kg
- Minimal epidural fat
 - May advance catheter to thoracic region

Prematurity

- Birth before 37 weeks gestation
 - Pulmonary
 - Hyaline membrane disease
 - BPD
 - Apneic spells
 - 44 wks for minor surgery
 - 52 wks for major surgery
 - Cardiac → PDA
 - GI → NEC
 - Neurologic
 - Intracerebral hemorrhage
 - ROP



Trisomy 21: most common pattern of human malformation

- Down's facies
- Short neck
- Irregular dentition
- Mental retardation
- Hypotonia
- Large tongue
- Narrow nasal passages
- Cervical spine → atlantooccipital instability
- Cardiac defects → endocardial cushion defects



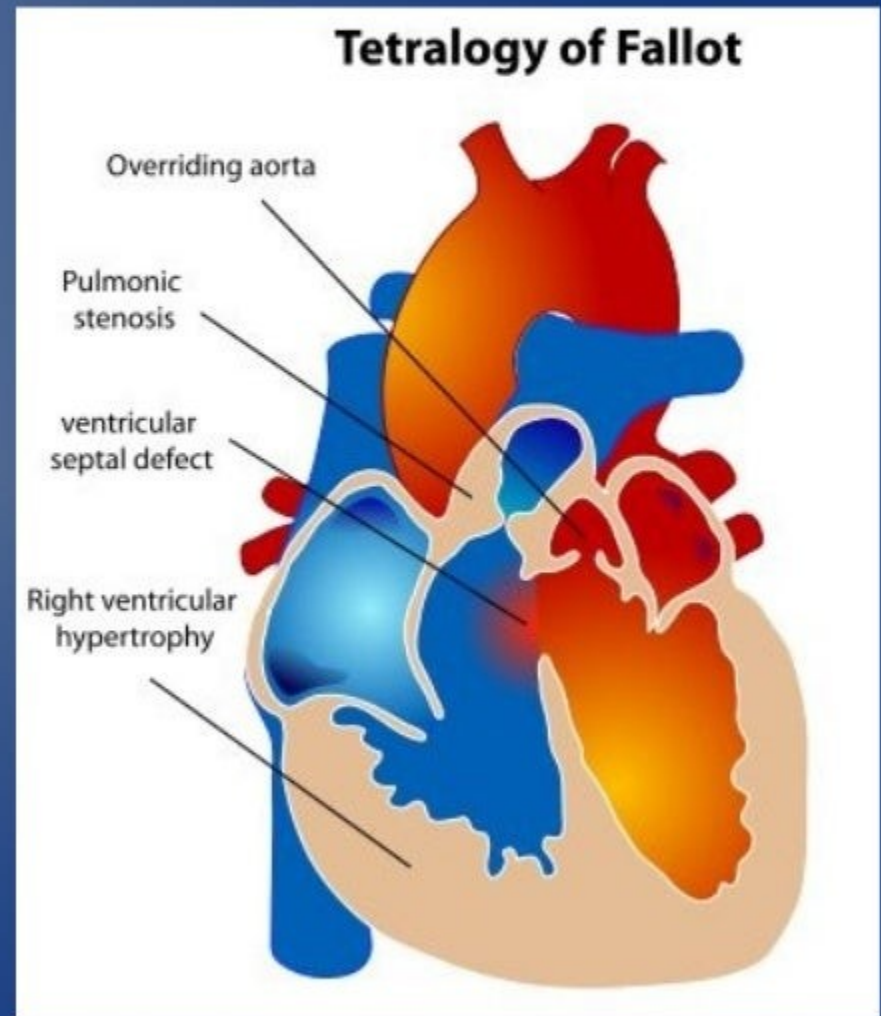
Trisomy 21 anesthesia

- Difficult airway
- Postop intubation stridor and apnea common
- Neutral neck position
 - Atlantooccipital dislocation risk
 - Congenital laxity
- Bradydysrhythmias
 - Atropine pretreatment

Tetralogy of Fallot

Characteristics

- Overriding aorta
- Infundibular pulmonary stenosis
- VSD
- RV hypertrophy



Hypercyanotic “Tet” spell

Etiology

- Infundibular spasm
- Decreased pulmonary blood flow

Treatment goal

- Reduce right to left shunt

Treatment

- 100% oxygen
- Volume administration
- Increase SVR
- Increase pulm blood flow
- Phenylephrine
- Relax infundibulum

Pediatric anesthesia on call

- Omphalocele and gastroschisis
- Congenital diaphragmatic hernia
- Intestinal malrotation and volvulus
- Pyloric stenosis
- Foreign body ingestion/aspiration



Omphalocele and gastroschisis

Omphalocele

- Base of umbilicus
- Hernia sac
- Other assoc defects
 - Trisomy 21
 - Cardiac
 - Diaphragmatic hernia
 - Bladder malformation

Gastroschisis

- Lateral to umbilicus
- No hernia sac
- Not associated with other defects
- Increased risk of infection

Omphalocele and gastroschisis

- Decompress stomach
- Muscle relaxant to assist reduction
- Criteria for closure
 - Intragastric or intravesical pressure < 20
 - PIP < 35
 - EtCO₂ < 50
- Silo possible

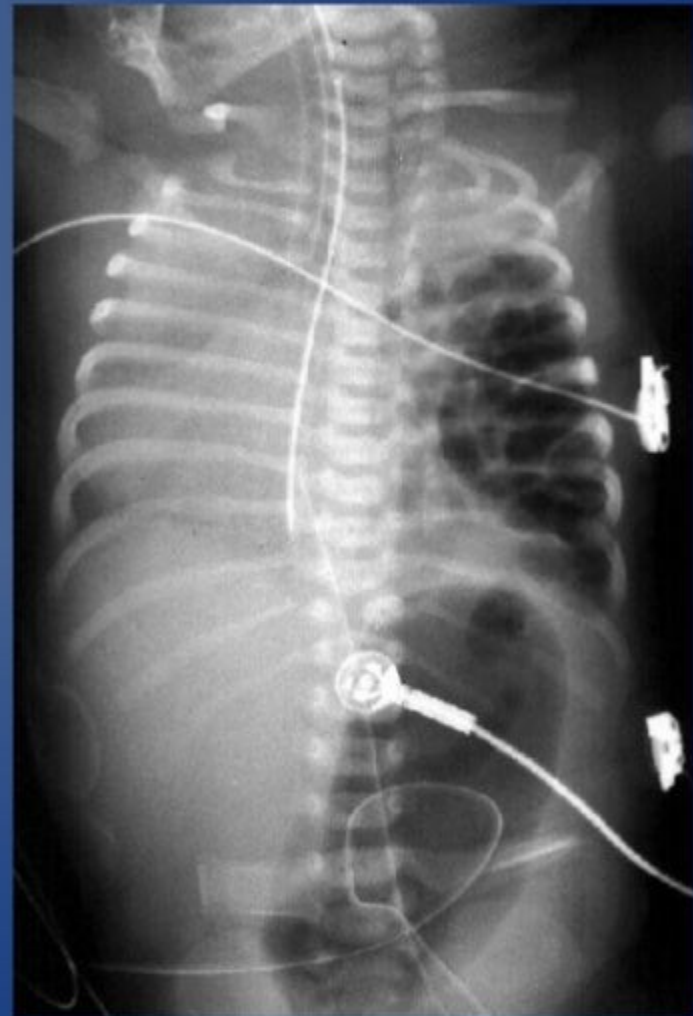


Congenital diaphragmatic hernia

- Gut herniates into chest
 - Left (most common ~ 90%) or right posterolateral foramen of Bochdalek
 - Anterior foramen of Morgagni
- Hallmarks
 - Hypoxia
 - Scaphoid abdomen
 - Bowel sounds in chest
- Respiratory support
- ECMO

Congenital diaphragmatic hernia

- NG tube
- Avoid high PPV
- Intubate
- $PIP < 30$
- Avoid aggressive lung reexpansion
- Consider PTX if sudden change in compliance

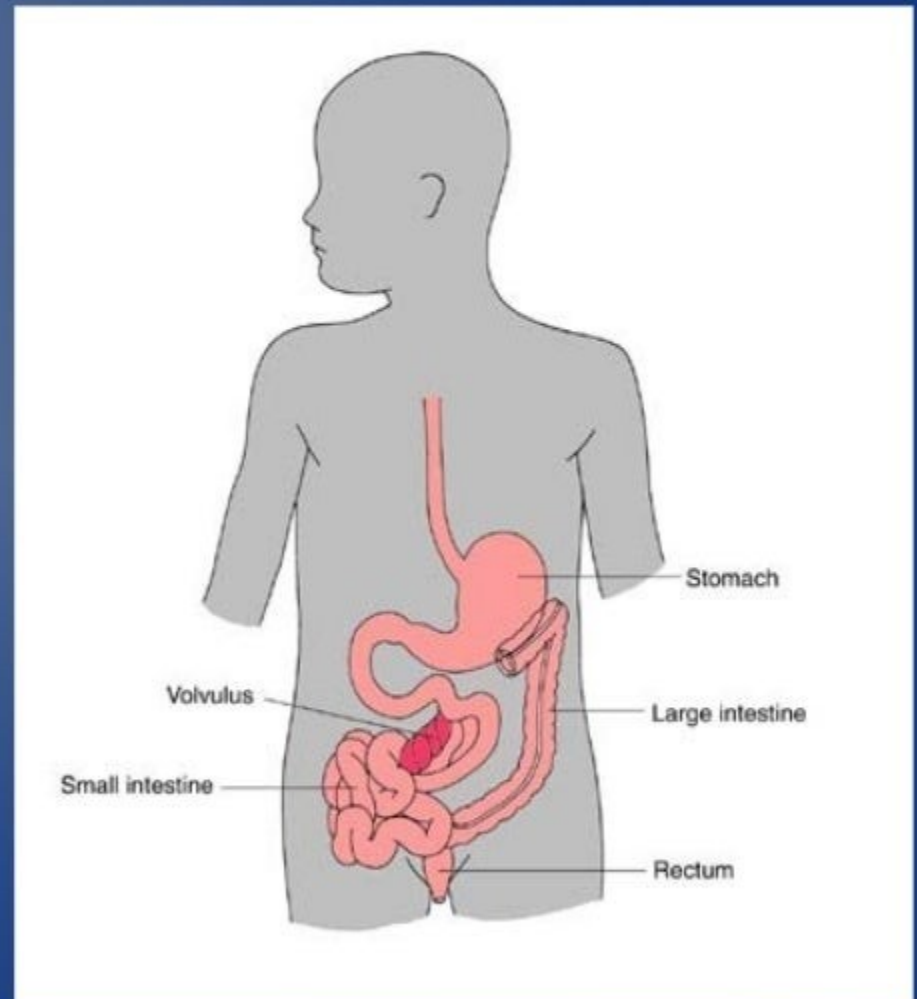


Intestinal malrotation and volvulus

- Developmental abnormality
 - 1:500 live births
- Spontaneous rotation of midgut around mesentery (SMA)
- Presentation
 - Acute or chronic obstruction
 - Bilious vomiting
 - Abdominal distention and tenderness
 - Metabolic acidosis

Midgut volvulus

- True surgical emergency
- Compromised intestinal blood supply
- 1/3 occur in 1st week of life
- Bloody diarrhea → bowel infarction



Malro and volvulus anesthesia

- Obstruction present without obvious volvulus
 - Stabilize coexisting conditions
 - Insert NG
 - Broad spectrum abx
 - Fluid and electrolyte management
- To OR ASAP
- Cautious induction and anesthesia if unable to be preoperatively stabilized

Malro and volvulus anesthesia

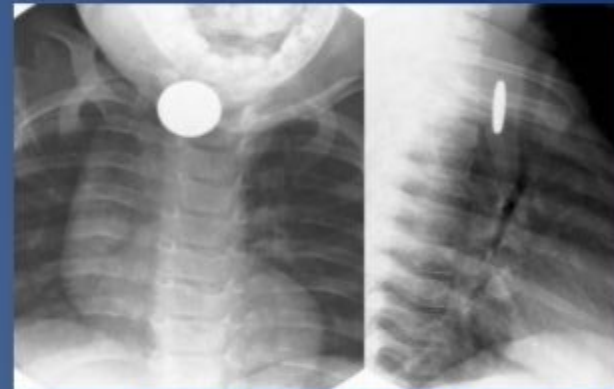
- Usually hypovolemic and acidemic
 - Aggressive fluid management
 - Consider bicarb
- Full stomach precautions
 - RSI → ketamine?
 - Awake intubation
- Opioid based anesthetic
- Post op intubation common
 - Significant bowel edema → Silo

Foreign body aspiration/ingestion

Aspiration

- Acute onset
- Supraglottic/glottic
 - Stridor
 - Inhalation induction
- Subglottic
 - Wheezing
 - Inhalation induction
 - RSI

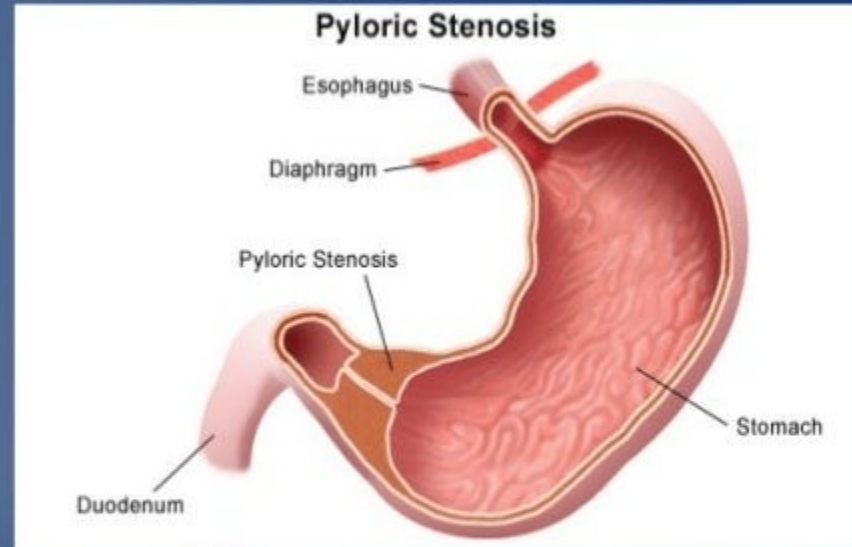
Ingestion



- Inhalation induction
- RSI
- Intubation
- Don't turn esophageal FB into airway FB!

Pyloric stenosis

- 4-6 weeks old
- Male > female
- Persistent vomiting
- Metabolic disarray



- Hypochloremic metabolic alkalosis
 - Vomiting depletes hydrogen ions
 - Kidney compensates by excreting NaHCO_3
 - Hyponatremia and dehydration worsen
 - Kidney conserves sodium at expense of hydrogen $\rightarrow$ paradoxical aciduria
- Correct metabolic issues prior to surgery

Pyloric stenosis anesthesia

- Empty stomach
 - Supine, lateral and prone
- RSI
 - Propofol or thiopental + NMB or remi
- Awake intubation
- Laparoscopic vs open
- Post op
 - Increased risk for respiratory depression
 - Persistent metabolic or CSF alkalosis

Malignant hyperthermia

- Acute hypermetabolic state in muscle tissue
- Triggering agents
 - Volatile agents
 - Succinyl Choline
- Incidence
 - 1:15,000 peds
 - 1:40,000 adults
- MH may occur at any point during anesthesia or emergence
- Recrudescence despite treatment

MH anesthesia

- Family history
 - Muscle bx → caffeine contracture test
 - +/- Ryanodine receptor abnormality
- High flow O₂ flush circuit x 20 min
- Nontriggering
 - TIVA, Nitrous

Increased risk of MH

- Duchenne's muscular dystrophy
- Central core disease
- Osteogenesis imperfecta
- King Denborough syndrome

Classic signs of MH

Specific

- Rapid rise in EtCO₂
early sign
- Rapid increase in temp late sign
- Muscle rigidity +/-
- Rhabdomyolosis
 - Increase CK
- Myoglobinuria

Nonspecific

- Tachycardia
- Tachypnea
- Acidemia
 - Metabolic
 - Respiratory
- Hyperkalemia
- Dysrhythmias

MH treatment

- Discontinue triggering agents
- Hyperventilate with 100% FiO₂
- NaHCO₃ 1-2 mEq/kg IV
- Dantrolene 2.5 mg/kg IV
- Cool patient
- Support as indicated → intropes, dysrhythmias
- Monitor labs
- Consider invasive monitoring
- 1 800-MH-HYPER



Questions?



Children's Hospital of Pittsburgh