Current Update in Pediatric Anesthesiology

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What is Special about Pediatric Anesthesia?

- Small Babies
- Difficult Airways
- Congenital Heart Disease
- Cardiac Arrest

THE PEDIATRIC AIRWAY

- Larynx situated at the level C3/4 instead of C5/6
- Obligate nasal breathing
- Large tongue with a small mandible
- Large occiput flexes the head, causing airway obstruction
- “Floppy” epiglottis
- Short trachea
- Narrowest at the cricoid ring

The Pediatric Lung

- Lung is less compliant
- Less elastin equals less recoil/more collapse
- Closing capacity close to FRC
- Greater airway resistance
- Smaller airway caliber
- Greater work of breathing
- Improves at age 5

The Pediatric Lung

- Pediatric chest wall shape
- Mechanically less efficient
- Box-shaped chest with ribs at right angles to vertebral column
- Chest wall is highly compliant resulting in increased chest wall collapse

The Pediatric Lung

- Neurologic development differences
- Incomplete development of medullary respiratory centers in infants
- Accentuated in premature infants
- Biphasic response to hypoxia
- Initial increase in ventilation followed by a decrease
**Lateral Decubitus Position**

- Compliant chest wall in infants and children
- Decreased FRC and other V/Q mismatch worsened by chest wall collapse
- Limits increase in ventilation of dependent lung to match increased perfusion
- Collapse of non-dependent/surgical lung helps to restore V/Q matching

**Gas Exchange in Infants: Postural Effects**

- Heaf et al. and Davies et al. Studied the effects of body position on gas exchange in infants
- Ventilation is preferentially distributed to the uppermost lung which is opposite to adult physiology
- Oxygenation best with the healthy lung in the superior position

**Peri-Op Respiratory Events**

- 755 Swiss children aged 1-14 years
- 40% < 2 years
- Patients with URI excluded
- Adverse Events: 28% incidence total

**Risk Factors**

- Non-Pediatric anesthesiologist (1.7 X)
- Mask or LMA
- Young age
- 8% increase per year (below 14 years)
- ENT surgery (2.7 X)
A “New Syndrome”: Pediatric Obesity
16% prevalence of overweight children
Girls > increase than Boys
>95th %ile BMI (determine BMI adjusted for age)
Triple the rate during the 1980s
<5% due to a unique medical cause
i.e. Endocrine, Prader-Willi, Cushing's

Help with the Difficult Pediatric Airway

Equipment

Shikani Optical Stylet
- 19 m/o Pierre Robin
- 2 m/o Treacher Collins
- 8 y/o Goldenhar
- 7 y/o Rigid spine
- 2.5 mm ETT
- Maneuverability
- Light Wand
- Video Capability

Storz Video Laryngoscope

Difficult Airway Rescue
- Neonate unable to be intubated by direct laryngoscopy
- Pediatric Video-Laryngoscope used to provide grade 1 view and intubation as a rescue maneuver

Wald, et al, Pediatric Anesthesia, 2008
**Verathon Glidescope**

- Integrated high resolution camera
- Patented 50 to 60-degree blade angulation designed to view anterior glottis without need for direct line of sight
- Requires less force than traditional laryngoscopes
- Slim blade profile helps create working space for quick tube placement
- Patented anti-fogging mechanism resists lens contamination

1.5-20 Kg

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**Fiberoptic Bronchoscopes**


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**Dexmedetomidine Infusion**

- Alpha-2 Adrenoreceptor Agonist
  - Highly selective (1620:1)
  - Clonidine 250:1
- Sedation and analgesic without respiratory depression
- Adult loading dose 0.5-1 mcg/kg over 10 minutes
- Infusion of 0.2-0.7 mcg/kg/hr
- Consider Adjunct Agent to Increase HR
- Spontaneous Ventilation
- Rapid Onset
- Decreases Secretions
- IV Administration
- Bradycardia
- Hypotension
- Slow Offset
- Unfamiliar
- Not Amnestic

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**Dexmedetomidine Fiberoptic**

- Two 10 y/o with spinal cord impingement
  - Dexmedetomidine
  - Nebulized Lidocaine
  - Glycopyrrolate pre-treatment
  - Midazolam 0.1 mg/kg
  - Uneventful with no recall
  - No Bradycardia/hypotension

- 6 year-old
- Treacher Collins
  - Dexmedetomidine plus low dose Ketamine
  - Successful Fiberoptic with topicalization

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**Neonatal Glidescope**

- Report of 5 Neonatal Intubations
  - 0.5-3.5 Kg
- 3/5 success rate
- Fogging occurred
- Resistance to advancement of ETT
- Excellent definition

LMA with ETT

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Removing the LMA

Neonatal Physiology

- Transition from fetal to neonatal circulation
- Lungs are ventilated and perfused and PVR changes from high to low resistance
- Ductus Arteriosus closed
- Patent foramen ovale closed
- Increasing pulmonary pressures (hypoxia, hypercarbia, acidosis) may lead to persistent fetal circulation

Infant Physiology

- Neonatal myocardium is significantly less compliant than in an adult
- Noncompliant ventricle is very sensitive to volume increase and stroke volume is restricted
**Congenital Heart Disease**

- Affects Other Organs
  - Impaired Neurologic Development
  - Pulmonary Hypertension
  - 8.5% have associated syndromes
  - 25% have an extra-cardiac anomaly: abnormal airway

**Symptoms of Heart Failure in Infants and Children**

- Poor weight gain and feeding (FTT)
- Tachypnea
- Tachycardia
- Poor exercise tolerance
- Diaphoresis – pediatric equivalent of PND or orthopnea

**Signs of Heart Failure in Infants and Children**

- Pallor/poor capillary refill
- Hepatomegaly by physical examination
- Cardiomegaly on chest x-ray
- Poor function by echocardiogram

**Cardiac Lesions**

- Left-to-right
- Right-to-left
- Complex
- Surgical palliation

**Cardiac Lesions: Left-to-Right**

- **Left-to-right** shunt is an arterial to venous connection without cyanosis
- Increase in pulmonary blood flow leads to Pulmonary HTN
- Right-sided failure occurs secondary to increased pulmonary blood flow
- FiO2 affects pulmonary blood flow
- ASD, VSD, AV Canal, PDA

**Cardiac Lesions: Right-to-Left**

- **Right-to-left** shunt
- Venous and arterial connection with outflow obstruction on the right side
- Venous blood is ejected systemically and patients are cyanotic
- TOF, Pulmonary Stenosis/ Atresia, Tricuspid Atresia

**http://embryology.med.unsw.edu.au/Notes/heart2.htm**
Complex

- Hypoplastic left heart syndrome
- Total or partial anomalous venous circulation
- Transposition of the great vessels

Surgical Palliation to Supply Blood to the Lungs

- Central Shunt
  - Aorta connected to Pulmonary Artery
- Blalock-Taussig (B-T) Shunt
  - Subclavian Artery to Pulmonary Artery
- Glenn Shunt
  - Superior Vena Cava connected to Pulmonary Artery
- Fontan Procedure
  - All systemic venous flow is connected to the pulmonary arteries

Blalock-Taussig Shunt

Glenn/Fontan

Pre-operative Considerations

- Determine the anatomy with a pre-operative echo report
- Cyanosis and polycythemia are correlated with the severity of disease

Pre-operative Considerations

- Exercise tolerance is an excellent indicator of cardiac function
- Pre-load dependent lesions (outflow obstruction) and shunted (palliated) lesions may require hydration pre-induction
- Identify abnormal airways and heart failure
Is a Mask Induction Safe in a Patient with CHD? Inhalation Anesthetic vs. TIVA

- 30 patients (4-12 months) with single ventricle received sevoflurane or fentanyl-midazolam induction plus pancuronium for cardiac surgery
- Transthoracic echo of myocardial performance index showed no significant difference from baseline in either group

Ikemba et al, Anesthesiology, 2004

Outcomes of Non-cardiac Surgical Procedures with CHD

- Mayo Clinic retrospective review of non-cardiac procedures 1987-1992 for morbidity and mortality in 276 patients under 50
- 5.4% (n=15) had a perioperative complication
  - CHF, Seizures, Bronchospasm, Pneumonia, Arrhythmia, Cardiac Arrest
  - 3 Deaths


Non-cardiac Surgical Procedures

- Association with perioperative complications included
  - Young age especially under 2 years
  - Cyanosis (SpO2<90%)
  - CHF medications
  - Inpatient procedures
  - High ASA status
  - Pulmonary HTN 3X likelihood of complications (15% vs. 4.7%)
  - Pulmonary and Neurologic Procedures


Peri-op arrest considerations for the pediatric patient

Local Anesthetic Toxicity

- 1992 Case series of 3 patients: Newborn, 4 year-old and 8 year-old
- Continuous infusions of bupivacaine via caudal catheter
- Seizures in all 3 patients
- 4 Kg neonate had cardiac toxicity
- Bradycardia/hypotension->CPR
- Successfully resuscitated

McCloskey Anesth Analg 1992

Local Anesthetics

- Unintentional Intravascular injection of local anesthetic
- Most commonly during Caudal med bolus
- Often negative aspiration and test dose followed by bolus of entire dose
- Recommendation: Incremental doses of local anesthetic
- Consider: Ropivacaine (2mg/kg) which has less cardiac toxicity
Local Anesthetic Cardiotoxicity

- Comparison of Local Anesthetic overdose resuscitation in 40 dogs
- Bupivacaine/Ropivacaine more difficult to resuscitate than Lidocaine toxicity
- Secondary to myocardial depression rather than arrhythmia
- EPI beneficial with Lidocaine toxicity
- Epinephrine may induce VF with Bupivacaine and Ropivacaine toxicity
- Ropivacaine better tolerated than Bupivacaine

Groban et al, Anesth Analg 2001

Therapy: Local Anesthetic Cardiotoxicity

- Information is only available from animal or adult studies
- ACLS guideline for Vasopressin
- Consider epinephrine, norepinephrine, amiodarone or lidocaine
- Calcium channel blockers are contraindicated and will exacerbate toxicity

Intralipid Rescue: Animal Study

- Bupivacaine 10 mg/kg isoflurane general anesthesia, n=6 per group
- Resuscitation by 10 minutes of internal cardiac massage followed with either saline or 20% lipid infusion, administered as a 4-mL/kg bolus followed by continuous infusion at 0.5 mL/kg/min for 10 minutes
- Survival after 10 minutes of unsuccessful cardiac massage was successful for all lipid-treated dogs but with no survivors in the saline controls

Weinberg et al, Reg Anesth Pain Med 2003

Intralipid Rescue: Human Case Reports

- Intralipid 20% 100 ml IV administered after suspected Bupivacaine toxicity
- All successfully treated
- 75 y/o seizures and CV collapse-no arrest
- 58 y/o with asystole
- 18 y/o during C-section with seizures

Hypovolemia

- Cardiac arrest due to hemorrhage
- Failure to secure adequate access
- Failure to keep up with blood loss
- Cardiac arrest due to massive transfusion and hyperkalemia
  - K+ leakage accelerated in irradiated blood
- Recommend:
  - Measure potassium in blood
  - Consider washing cells for high-risk patients such as infants requiring > 1 blood volume
- Avoid irradiation if possible

Central Line Complications

- ASA closed Claims Database
- 110 claims 1978-1999
- Most Common:
  - wire/catheter embolus
  - cardiac tamponade
  - carotid artery puncture/cannulation
  - hemothorax
  - pneumothorax
Central Line Complications

- Ultrasound guidance, pressure waveform analysis and/or CXR would have prevented >50% complications

PALS vs ACLS

- Airway/Hypoxia
- Pulse check
- Child-Carotid
- Infant-Brachial
- 100 compressions/min 1/3 to 1/2 A-P diameter
- Asystole and PEA are much more common in children
- VF/Pulseless VT
  - 2 J/kg (Gutgesell et al Pediatrics 1976, n=27)
  - 2nd round all 4 J/kg

PALS vs ACLS

- Ventricular Fibrillation is an UNCOMMON pediatric arrhythmia
- 1914 Garrey -critical mass hypothesis which has been confirmed in multiple studies
- Small hearts are unable to sustain VF
- Smallest dog or rabbit able to sustain VF -3kg

PALS vs ACLS

- Inadequate data to draw conclusions on monophasic vs. biphasic waveform
- Infant paddles recommended for patients less than 10kg
- AED should probably not be used in children younger than 1 year
  - Current will probably be greater than 2-4J/kg
  - Pediatric attenuator system may be used ages 1-8 years

OUTCOME OF PEDIATRIC IN-HOSPITAL VF/VT

National Registry of CPR (159 hospitals)
1005 Children with Cardiac Arrest
27% VF or VT during arrest (initial or subsequent rhythm)
- 35% with initial VF or VT survived to discharge
- 27% without VF or VT survived to discharge
- 11% with subsequent VF or VT survived to discharge

Patients with VF or VT had more likely cardiac disease, trauma, renal insufficiency

Samson et al NEJM 2006

HIGH DOSE EPI?

- Comparison of high vs standard dose Epi in children (mean age 7 years) for cardiac arrest
- Double-blind randomized over 2 years in 68 children received 10 mcg/kg or 100mcg/kg for cardiac arrest
- 24-hour survival and Hospital Discharge
- High-dose: 1/34 and 0/34
- Standard-dose: 7/34 and 4/34

Perondi et al NEJM, 2004
Chest Compression in Infants

- 30 adults positioned by AHA guidelines on 30 infants
- 3 adult fingers exceeds distance from nipple-line to xiphoid
- All infants had lower sternum <4 cm
- Shortest adult 3 finger breadth was 4 cm
- Places compression at xiphoid or abdomen

Clement and McGowan Resuscitation 2000

Chest Compression in Infants

- Method using sternal anatomy should be used
- Recommendation of one finger breadth up from lower sternum
- Two Thumb Technique also studied on simulator and thought to improve hemodynamics over Two Finger Technique