PEDIATRIC ANESTHESIA MANUAL

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Introduction

The purpose of the pediatric anesthesia rotation is to provide an initial exposure to a variety of pediatric cases. The length of this rotation, 4 weeks, is enough to allow participation in the care of about 100 patients. Residents on this rotation should be able to develop skills for setting up OR's for pediatric patients of different ages and should master skills in mask ventilation and intubation of pediatric patients including neonates. Topics for discussion should include neonatal emergencies, pediatric airways, ENT cases, general surgical cases, and questions from written and oral boards. One of the goals of this rotation is to prepare residents for routine "bread and butter" cases, to be safe with pediatric patients, and to be able to identify situations in which he or she might need help.

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OR set up for pediatric cases/Shands Hospital/

For pediatric cases, the OR should be warmed, as high as 85 F for neonates and especially premature patients. Warming lights, a circulating water warming blanket on the OR table, and an infant forced air warming blanket ("Bair Hugger") may be helpful. The anesthesia machine should be preset for ventilation of small patients. Pressure controlled ventilation may be the best choice- since it will deliver whatever volume will generate the set pressure (such as 20 mm Hg). Be SURE the ventilator is NOT set to deliver an adult volume (which could cause pneumothorax in an infant). Monitors should be changed appropriately, to neonatal or pediatric, with alarms adjusted. All tools for intubation should be appropriate size including blades (Miller or WH), masks and ETT. ETT size should be 4 + (age in years/4). You can confirm that the ETT size is appropriate by comparing the tube to the external nare or the diameter of the little finger. Normal newborns can accommodate a 3.5 ETT. {The marking that should appear at the lips should be 12 plus [age in years/2]. For tiny infants the distance should be 6 plus the weight in kg.} You should have a stylet in the ETT you plan to use, and have available two other ET tubes, one size larger and one size smaller. You will need a selection of different size airways and a tongue blade. The wrong size artificial airway can obstruct the child's airway. An oral airway that is too small can indent the tongue and push it back into the hypopharynx, effectively preventing air exchange. An oral airway that is too long can touch the tip of the epiglottis and cause laryngospasm. When measuring the oral airway on the outside of the jaw, make sure that the tip will not extend past the angle of the mandible. A pulse oximeter should be the first monitor placed on the child, followed by a precordial stethoscope. The pulse oximeter will count the heart rate and also confirmation that each beat generates a pulse. When left to right shunting may occur (as in all infants), two oximeters (one on the right arm or right ear) and another on one of the other three extremities will reflect the amount of shunting occurring. The precordial stethoscope will tell you that air is moving in the trachea, the patient is not having laryngospasm (hopefully!), and the heart tones are not muffled. (Cases of previously unsuspected cardiomyopathy have been diagnosed by alert residents using precordial stethoscopes!) Also- the precordial stethoscope is an excellent monitor for transporting the patient to the Recovery Room when the pulse oximeter must be disconnected, unless clinical conditions necessitate a portable transport monitor. ECG leads should be appropriately positioned considering the location of the surgery as well as patient position. Suction should be checked and working. Suction tubing should be connected to a suction catheter of appropriate size. Be careful not to have a suction catheter that is too small.

On the anesthesia cart you should have succinylcholine, atropine, and a syringe with a mixture of succinylcholine and atropine. If you put 4 cc of succinylcholine (80 mg) with 1 cc atropine (0.4 mg) in a 5 cc syringe you will have the intramuscular dose for a 20 kg child. Half the syringe (2.5 cc) will be the dose for a 10 kg child (usually about a one year old), and ¼ of the syringe (1.25 cc) will be the dose for a 5 kg child. Use of this syringe will be necessary extremely rarely- in the instance where a child develops laryngospasm during inhalation induction before intravenous access has been achieved. However- if it is needed, it will be needed emergently. Succinylcholine is only given in the most life-threatening circumstances in children because some children may have an undiagnosed muscular disorder that could result in hyperkalemic cardiac arrest, or MH. Propofol and paralyzing agent should also be available. Pediatric patients are more likely than adults to require dextrose in their intravenous fluids. Almost all adults will react to the stress of surgery with a rise in their serum glucose. Unfortunately, at least 15% of toddlers will react to the stress of surgery with a FALL in their serum glucose.

NICU patients may have almost no glucose stores, and generally should receive dextrose in maintenance infusions. Other patients with increased glucose requirements are children with FTT (failure to thrive- weights lower than expected on the basis of age), liver failure, or sepsis. A normal newborn should weigh about 3 kg. They should double their birthweight by 3 months of age, and triple it by one year. A normal 4 year old should be 40 pounds and 40 inches.
For a simple procedure like hernia repair, simply adding 40 cc of D5LR to the buretrol (and adding an equal amount of LR from the hanging bag to create 80 cc of D2.5 LR) should be adequate. Never use dextrose containing solutions for fluid boluses or to replace third space or intravascular volume losses. If there is any concern about procuring the airway, dextrose administration should be deferred until this has been accomplished as dextrose infusions have been associated with worsening the outcomes of hypoxic episodes.

Preoperative evaluation

Meeting pediatric patients and parents prior to induction is very important.
The preoperative interview should meet the following objectives:

1. to obtain essential details of the child's present illness and medical history
2. to assess potential anesthetic risk factors and discuss their likelihood and treatment with the patient and family
3. to initiate an anesthetic plan that is acceptable to the patient and family
4. to discuss recovery, postoperative analgesia and discharge planning
5. to allay anxiety and to establish trust and confidence with the patient and family
6. to find topics of interest to the child (pets, sports, games, TV shows)
7. to offer play therapy and tours of operating, induction and recovery rooms (if you are having the luxury of seeing the patients prior to the day of surgery)

Prematurity

Infants are considered premature if they are born before 38 weeks of gestation or weigh less than 2500 g at birth.

Age definitions: the term **newly born** is used to describe the infant in the first minutes to hours after birth; the term **neonate** describes infants in the first 28 days/first month/ of life; the term **infant** includes the neonatal period and up to 12 months.

Chronic respiratory dysfunction with risk of apnea is the most common sequela of prematurity. Controversy persists regarding at what age former premature infants are no longer at risk for postoperative apnea, with ages ranging from 44 weeks PCA to 60 weeks PCA. Common problems of prematurity:

Respiratory distress syndrome/RSD/
Meconium aspiration syndrome
Apnea
Bronchopulmonary dysplasia/BPD/
Persistent pulmonary hypertension
Patent ductus arteriosus
Congenital heart disease
Necrotizing enterocolitis/NEC/

Gastroesophageal reflux
Jaundice
Anemia
Hypoglycemia
Hypocalcemia
Congenital infections/STORCH/
Group B streptococcal infection
Intraventricular hemorrhage
Neonatal seizures
Retinopathy of prematurity

Common problems of prematurity. Respiratory distress syndrome – absence or deficiency of surfactant; characterized by hypercarbia and hypoxia with resultant acidosis; may be complicated by pneumothorax, pneumomediastinum, and pulmonary interstitial emphysema.

Meconium aspiration syndrome – characterized by respiratory insufficiency, pneumonia, and asphyxia.

Apnea – absence of breathing for 15 to 30 sec, often accompanied by bradycardia and cyanosis.

Bronchopulmonary dysplasia – chronic obstructive lung disease of neonates exposed to barotraumas and high inspired oxygen concentration; characterized by persistent respiratory difficulty and radiographic evidence of diffuse linear densities and radiolucent areas.

Persistent pulmonary hypertension – pulmonary hypertension and vascular hyperreactivity with resultant right to left shunting and cyanosis; associated with cardiac anomalies, respiratory distress syndrome, meconium aspiration syndrome, diaphragmatic hernia, and group B streptococcal sepsis. Treatment: oxygen, mechanical ventilation, high-frequency oscillatory ventilation, vasodilator drugs such as tolazoline, nitric oxide, and ECMO/extracorporeal membrane oxygenation/.

Patent ductus arteriosus/PDA/ - left-to-right shunt from the aorta to the pulmonary artery through the ductal remnant of fetal circulation; commonly found in premature infants with RDS; the shunt can result in congestive heart failure and apnea.

Necrotizing enterocolitis /NEC/ - ischemic injury to intestinal mucosa, often complicated by bowel necrosis and perforation, causing abdominal distention, bloody diarrhea, apnea, acidosis, and septic shock.

Gastroesophageal reflux – involuntary movement of stomach contents into the esophagus; physiologic reflux is found in all newborns; pathologic reflux can result in failure to thrive, recurrent respiratory problems/aspiration, bronchospasm, and apnea, irritability, esophagitis, ulceration and gastrointestinal bleeding.

Jaundice – hyperbilirubinemia from increased bilirubin load and poor hepatic conjugation/unconjugated, physiologic/ or abnormalities of bilirubin production, metabolism, or excretion/non-physiologic/.

Hypoglycemia – blood sugar less than 40 mg/100ml, characterized by lethargy, hypotonia, tremors, apnea, and seizures.

Hypocalcemia – total serum calcium concentration less than 7 mg/100ml or ionized calcium less than 3.0 to 3.5 mg/dl; characterized by irritability, jitterness, hypotonia, and seizures.

Intraventricular hemorrhage/IVH/ - periventricular-intraventricular hemorrhage associated with immaturity and hypoxemia. Characterized by bradycardia, respiratory irregularity, apnea, seizures, and hypotonia. Treatment – shunting and supportive care.

Retinopathy of prematurity /ROP/ - vasoproliferative retinopathy seen in premature infants exposed to high concentrations of oxygen for prolonged periods. Treatment – cryotherapy or laser to the avascular retina.

Premedication

The primary goals of premedication in children are to facilitate a smooth separation from the parents and to ease the induction of anesthesia. Other effects that may be achieved by premedication include:

Amnesia
Anxiolysis
Prevention of physiologic stress
Reduction of total anesthetic requirements
Decreased probability of aspiration
Vagolysis
Decreased salivation and secretions
Antiemesis
Analgesia

Children greater than 10 months usually receive midazolam 0.5 mg/kg/max10-15 mg/. These medications should be given about 15-20 min prior to entering the OR.

Dose: midazolam 0.5 mg/kg PO
0.3 mg.kg intranasal
0.08 to 0.5 mg/kg IM
0.2 mg/kg OT
1 mg/kg PR

Midazolam is commonly administered in Ibuprofen, 10 mg/kg to provide postoperative pain relief.

Barbiturates: pentobarbital or secobarbital.
Opioids: morphine or meperidine, fentanyl; sufentanyl.
Dose: morphine 0.1 to 0.2 mg/kg IM
Meperidine 1 to 2 mg/kg IM
Fentanyl 10 to 15 mcg/kg OT
Sufentanyl 1.5 to 3 mcg/kg IN

Clonidine is an alpha-2 agonist that given in combination with atropine produces satisfactory preoperative sedation, easy separation from parents and mask acceptance within 30-60 min.

Dose: clonidine 4 mcg/kg PO
Atropine 0.03 mg/kg PO administered together

Hypnotics: Chloral hydrate 25 to 75 mg/kg and triclofos 70 mg/kg PO.

Anticholinergics: atropine 0.02 mg/kg IM, PO
scopolamine 0.02 mg/kg IM
glycopyrrolate 0.01 mg/kg IV, IM

Antihistamine : hydroxyzine 0.5 to 1 mg/kg PO, IM

Premedication/induction: methohexital 1%-10% solution to 20-30 mg/kg PR
Thiopental 1 to 2 mg/kg IV
Propofol 2-4 mg/kg IV (over 1 year)
Ketamine 2 to 5 mg/kg IM
6 mg/kg PO
3 mg/kg IN
8 to 10 mg/kg PR

Equipment and monitoring

Airway equipment

Circuits commonly used for children under 12 to 15 kg include Mapleson D, Bain, Jackson-Rees modification of Ayre's T-piece and pediatric circle.

The circuits used for pediatrics were traditionally designed specifically to decrease the resistance to breathing by eliminating valves; decrease the amount of dead space in the circuit; and in the case of the Bain circuit, decrease the amount of heat loss by having a coaxial circuit with warm exhaled gas surrounding and warming the fresh gas flow.

The reservoir bag should contain a volume similar to that of the child's vital capacity.

Airways: To determine whether an oral airway is the proper size, hold the airway beside the patient's face with the top of the airway beside the mouth. The bottom of the airway should end just before the angle of the mandible. If the airway is too long, it may touch the epiglottis and trigger laryngospasm. If the airway is too short- it can indent the tongue and push the posterior portion of the tongue into the hypopharynx, CAUSING (rather than alleviating) upper airway obstruction.

Laryngoscopes: The use of small pediatric handle is recommended. It is less bulky, allowing laryngoscopy to be performed while cricoid pressure is applied with the fifth finger of the same hand.

In general straight blades/Miller/ are used in infants to facilitate picking up the elongated epiglottis and exposing the vocal cords.The wider-phlanged Wis-Hippel or Robert-Shaw blades are sometimes preferred for ease of exposure.

The oxyscope has a separate port to which oxygen tubing can be attached. The light wand facilitates blind intubation of the trachea . The Bullard laryngoscope consists of a rigid blade with a fixed fiberoptic bundle. The Shikani optical stylet is a combination of a lightwand, stylet and fiberoptic scope.

Endotracheal tubes: small-diameter endotracheal tubes increase airway resistance and work of breathing. The anesthesiologist should calculate ideal tube size and have available one size larger and one size smaller.

Age/yr/+16/4 or wt/kg/+35/10

Cuffed tubes are generally not used for patients under age 8. Ultimately the proper tube size is confirmed by the ability to generate positive pressure greater than 30 cm H2O and by the presence of a leak at less than 20 cm H2O.

A stylet should be placed in the ET or be readily available to facilitate tracheal intubation.

The tube should be secured so that the second mark at the tip just passes through the cords. Extending the neck decreases tube depth ("EX"tension tends to "EX"tubate); flexing the neck deepens the tube position within the trachea.

Laryngospasm is defined as approximation of true vocal cords or both true and false cords. It is caused most often by inadequate depth of anesthesia with sensory stimulation /secretions, manipulation of airway, surgical stimulation/. Treatment includes removal of stimulus, 100% oxygen, continuous positive pressure by mask, and muscle relaxants. Usually laryngospasm will break under positive pressure but on the rare occasion that this fails, only a very small dose of succinylcholine is required for relaxation of the vocal cords, which are quite sensitive to muscle relaxation. While 1-2 mg/kg maybe required for complete relaxation, only one tenth of this will generally relax the vocal cords.

Laryngeal mask airway/LMA/ consists of a silicone tube fused to a spoon-shaped mask with an inflatable cuff. It is manufactured now in following sizes: 1. 11/2, 2. 21/2, 3. LMA is indicated in patients who are candidates for inhalation anesthesia who do not require intubation; LMA is useful in children with possibility of difficult intubation; for neonatal resuscitation; for anesthesia outside OR. Elective LMA placement may not be recommended for children under 2 years; LMA may increase dead space. ProSeal LMA available now in pediatric sizes starting from 1 ½.

ECG: the T waves in infants are much larger, because the electrodes are situated much closer to the heart; the most prominent P wave in infants is seen in lead 3, because of R axis shift.

Blood pressure monitoring: Cuff size can be determined using the following criteria: cuff bladder width should be approximately 40% of the arm circumference; bladder length should be 90 to 100% of the arm circumference. Placement of two BP cuffs on upper and lower extremities may be recommended when there is no arterial line.

Invasive monitoring (intraarterial catheters); Smaller catheters provide greater accuracy in monitoring, but larger are more practical for blood sampling. Generally neonates and infants will need 24G.

Temperature monitoring. The consequences of thermal stress include cerebral and cardiac depression, increased oxygen demand, acidosis, hypoxia, and intracardiac shunt reversal.

Oximetry. Use of the oximeter is particularly important in pediatrics because of the greater tendency of the infant to develop rapid desaturation and hypoxemia. The goal of neonatal oxygen monitoring is to maintain saturation in the low 90s to minimize risks of oxygen toxicity. In infants, two probes/preductal (right ear or right arm) and postductal (left arm or either leg) will reflect the amount of right to left shunting occurring.

Gas monitoring. The ASA lists capnometry as a monitoring standard. Indeed it may be THE most important monitor, especially in patients being sedated, particularly if supplemental oxygen is being administered. Extra oxygen will be stored in the FRC, meaning that a patient can be apneic for a while before there will be a drop in oxygen saturation. Constant monitoring of ETCO2 will guarantee that apnea is

identified promptly. Also, while a patient may become noticeably cyanotic when the sat drops below 90%, there is no level of hypercarbia that is reliably clinically evident. In the recovery area, hypercarbia itself acts as a sedative and will contribute to delayed emergence. Patient pathophysiology may contribute to an increased gradient between end-tidal and arterial CO2 measurements, usually by increasing shunt and increasing dead space. ETCO2 will not accurately reflect arterial CO2 if something is interfering with delivery of CO2 to the lungs, such as pulmonary embolism (clot or air). Decreased cardiac output of any etiology will decrease CO2 deliver to the lungs. ETCO2 shows adequacy of cardiopulmonary resuscitation. Factors that increase West's Zone I of the lungs (where alveolar pressure surpasses arterial pressure) will increase gradient. Such factors include hypovolemia (decreasing arterial pressure) and increased mean airway pressure (increasing alveolar pressure). In children with cyanotic heart disease, end-tidal underestimates arterial CO2.

Neuromuscular blockade. Infants will not display head lift or respond to commands, even with full return of neuromuscular function. Lifting both legs may indicate that the patient can generate adequate negative inspiratory force. Nerve stimulation is recommended at the superficial ulnar nerve and posterior tibial nerve. The facial nerve is not recommended as the orbicularis oculi muscle is more resistant to blockade and if one successfully blocks this muscle, the patient's neuromuscular blockade may be unreversible. Also, direct muscle stimulation in this area may result in the administration of excessive amounts of relaxant.

Intravenous equipment. Small-gauge catheters are available for venous cannulation: 24G, 22G; a 25 or 27-gauge for very small premature infants. Use of a T-piece connector with stop-cock is recommended in children. It speeds delivery of medication by limiting tubing dead space. Most infants are going to have a patent foramen ovale. Because of the possibility of an intracardiac shunt, all IV's should have air bubbles scrupulously removed. Tubing with built-in stopcocks is notorious for trapping air. It will be much easier to administer medications and remove air from the intravenous system by using a separate stopcock and attaching it to a plain piece of extension tubing. In children who weigh less than 10kg a burette/150cc/ should be used for fluid administration. For children weighing over ~15kg minidrop /60gtt/ml/ is useful. Extensions for intravenous systems are particularly advisable as intravenous access is sometimes obtained in lower extremities.

Fluids, electrolytes and transfusion therapy

Preterm and small infants have a relatively high percentage of total body water/85% in a preterm and 75% in a full-term infant/.The minimum amount of water required to meet ongoing insensible losses is 60 to 100 ml/kg/day. Preoperative assessment of the child's fluid status is important to determine intraoperative needs. Dehydration is classified by its tonicity according to the concentration of serum sodium.

Replacement of fluid deficits: "easy- to- use" formula – 4-2-1; 4ml for first 10kg. 2ml for second 10kg and 1ml for the rest per hour. Generally either lactated Ringer's or normal saline is used for routine intraoperative fluid administration.

When acute intravascular volume loss has occurred, the rapid administration of 10 to 20 ml/kg of lactated Ringer's or normal saline may be warranted.

Glycogen stores in the neonatal liver are limited and are rapidly depleted within the first few hours of life. Preterm infants may be hypoglycemic without demonstrable symptoms, necessitating close monitoring of blood glucose levels. Full-term neonates undergo a metabolic adjustment after birth with regard to glucose. **Hypoglycemia** is defined in full-term infants as a serum glucose concentration less than 30mg/100ml in the first day of life or less than 40 mg/100ml in the second day of life. The routine intravenous replacement solution for normal neonates contains 5- 10% dextrose.

Transfusion of blood components is indicated to increase oxygen-carrying capacity or to improve coagulation. Fresh whole blood may also be chosen for trauma patients, transplant patient, or infants needing exchange transfusion or having open heart surgery.

Transfusion reactions: Acute hemolytic reactions are usually the result of clinical errors. Extravascular hemolysis is usually seen when antibodies other than ABO are present. Nonimmune hemolysis is caused by mechanical or osmotic factors. Febrile reactions occur when antibodies against leuckocytes or platelets are transfused. Anaphylaxis is seen in patients with IgA deficiency who have anti-IgA antibodies as a result of previous transfusion.

Emergence and recovery

The primary goal of the postanesthesia care unit/PACU/ is to provide a safe environment, where patients can return to their preanesthetic homeostasis. The most important aspect of awakening is the return of cardiorespiratory reflexes: the ability to gag and cough to protect the airway, the return of baroreceptor reflexes to support perfusion, and the return of chemoreceptor responses to hypercapnia and hypoxia.

Ventilation: Upon the patient's arrival in the recovery room, attention should be focused on patency of the airway and adequacy of ventilation.

Oxygenation: Children recovering from general anesthesia are at greater risk for hypoxia; continuous administration of oxygen during monitoring of SpO2 has been advocated for children. It may be necessary to administer oxygen and monitor SpO2 in the transfer from OR to PACU.

Normothermia: Both hypothermia and hyperthermia are common intraoperative problems, particularly in infants.

Neuromuscular Blockade: Reversal of neuromuscular blockade in toddlers and school-age children can be assessed by the same clinical indices as in adults: full train-of-four and sustained tetany on NMB monitor, inspiratory force greater than –20 cm H2O and a vital capacity of at least 15 ml/kg. Brisk flexion of the hips and knees is an indication of return of adequate peripheral muscle strength in infants. Leg lift in children may be an equivalent of head lift in adults.

Analgesia: Preverbal children cannot convey their perception of pain. Prompt treatment of pain is urged. Crying is not always an indicator of pain but may represent anxiety, hunger, thirst or nausea. Intravenous opiates are used most commonly to treat moderate to severe pain.

Control of nausea and vomiting: Nausea and vomiting occur frequently after eye and ear surgery but can occur after any procedure or anesthetic. Control of nausea and vomiting begins in the selection of agents/techniques used for anesthesia. Pretreatment with ondansetron 0.1mg/kg has been very successful in reducing nausea and vomiting for patients at higher risk/tonsillectomy, strabismus repair, or chemotherapy./ Metoclopramide is less preferred for post operative nausea and vomiting since it has a 10% incidence of dystonic reactions. { Metoclopramide 0.3 mg/kg remains useful in children who have sustained trauma (at which time gastric emptying ceases). The important time interval is the time between the last ingestion and the time the trauma occurred. In other words, if a child fell off his bicycle at 7 pm and hadn't had anything to eat since 11 AM, he would not be considered to have a full stomach. On the other hand, if he had just eaten dinner at 6 pm- he will continue to have a full stomach for many hours (possibly even more than 24 hours). This latter child is one who might benefit from metoclopramide ("chemically emptying the stomach"). However, the risk of dystonic reactions must be considered.}

Newborn physiology and development

Circulatory changes at birth: Expansion of the lungs, increased Po2 to 60 mm Hg, and release of vasoactive substances and arachidonic acid metabolites lead to an 80% decrease in the PVR. As a result, both pulmonary circulation and oxygenation increased dramatically. Amputation of the placenta results in an increase of systemic vascular resistance. The ductus arteriosus will constrict in 90% of term neonates in the first three days of life as Po2 increases, pH becomes less acidotic, and the placental contribution of prostaglandin/PGE2/ ceases. The increase in pulmonary blood flow will result in increased blood volume in the left atrium and subsequent closure of the flap of the foramen ovale. The cardiac output of the neonate is dependent upon heart rate and left ventricular filling pressure. Infant ventricular myocytes can not increase contractility, so heart rate and volume status determine output. The neonate can achieve twice the cardiac output of the fetus with volume loading and heart rate increases. At birth, the lungs undergo the transition from a fluid-filled organ to an air-filled organ for gaseous exchange. In order to overcome surface active forces and fully expand the lungs, the neonate must generate negative intrathoracic pressures of up to 70 cm H2O.

Tidal volume is the same for neonates and adults/7 to 10 ml/kg/. Because neonatal oxygen consumption is two to three times that of the adult, respiratory rate must be increased proportionally. The high minute ventilation/FRC ratio may result in rapid desaturation in the neonate during periods of apnea or airway obstruction. Neonatal closing volumes are higher than for adults.

In infants less than 3 weeks of age, hypoxia initially stimulates ventilation, followed by a decrease in ventilation. After 3 weeks, hypoxia causes sustained hyperventilation.

Large surface area, poor insulation, a small mass from which heat is generated, and inability to shiver place newborn at a disadvantage for maintaining temperature. Catecholamine-stimulated nonshivering thermogenesis (brown fat metabolism) may cause such complications as elevated pulmonary and systemic vascular resistance and higher O2 consumption with resultant stress on the newborn heart.

General principles of anesthetic management for airway procedures

The anesthesiologist must share the airway with the surgical team. The technique selected for airway control/mask, ETT, LMA/ must protect the airway from blood and obstruction and not hinder surgical visualization. Securing the airway may also involve a cooperative effort between the surgeon and the anesthesiologist. The anatomic location of the surgical procedure has direct anesthetic implications. For nasal procedures the airway can be secured orally. Oropharyngeal lesions may increase the difficulties of intubation or maintaining mask ventilation. Throat packs may help to decrease aspiration of blood and secretions. Be SURE they are removed at the end of the case, after which they can cause obstruction of the airway in the Recovery Room. To avoid fires, delivered oxygen concentration should be kept as low as possible when electrocautery is being used. Procedures involving the larynx, trachea and bronchi necessitate the greatest anesthetic depth to prevent airway hyperreactivity. Spontaneous ventilation may also be required.

Induction techniques. Inhalation inductions are commonly used in children undergoing otolaryngologic procedures. Brief procedures such as myringotomy and tube placement often can be completed safely with mask and inhalation anesthesia without IV placement.

In children with airway edema or foreign body, inhalation agents may improve bronchodilation and decrease airway reactivity. In children with airway emergencies an inhalation induction allows for continuous maintenance of spontaneous ventilation and delivery of high concentration of oxygen. An intravenous induction is appropriate for removal of esophageal foreign body or airway lesions without airway compromise but with high risk of aspiration. Intravenous induction may also be used for upper airway obstruction when mask ventilation may be very difficult but uneventful intubation is anticipated. Intravenous agents such as propofol may also be beneficial adjuncts to primarily inhalational anesthetics.

Commonly anticipated complications include airway edema or obstruction, bleeding, and nausea and vomiting.

Anesthesia for otolaryngologic surgery

Diagnostic procedures: radiographs, CT, MRI; transnasal flexible fiberoptic bronchoscopy; direct laryngoscopy and rigid bronchoscopy.

For direct laryngoscopy and rigid bronchoscopy a gentle inhalation induction may be preferred. An FiO2 of 1.0 is used if respiratory insufficiency or airway compromise is present. A careful incremental IV induction with propofol may also maintain spontaneous ventilation. Spontaneous ventilation is important if there is a suspicion of tracheomalacia or laryngomalacia. Otherwise, muscle relaxation during rigid bronchoscopy is an excellent method of preventing coughing or bucking on the bronchoscope which could cause the life-threatening complication

of bronchial rupture. Primary intubation can be performed before bronchoscopy when the airway must be rapidly secured. Intravenous atropine or glycopyrrolate/10 to 20 mcg/kg/ may be useful as an antisialogue. Topical lidocaine spray to the vocal cords will help to minimize reactivity. The rigid bronchoscope is placed under direct vision by the surgeon. An oxyscope may be useful. Sometimes by closing the pop-off valve on anesthesia machine you may create PEEP in the airway. The anesthesia circuit can be connected to the rigid bronchoscope from a proximal side port. Use of 100% oxygen while the bronchoscope is in the trachea offers a margin of reserve against possible hypoxia. Hypercapnia frequently occurs because passive ventilation is difficult with the high airway resistance caused by the narrow bronchoscope. High flows may be necessary if there is much discrepancy between the size of the bronchoscope and the size of the trachea. On the other hand, if there is a tight fit, air trapping and "stacking" of ventilation (lungs unable to completely deflate prior to the next inflation) can lead to pneumothorax or impede venous return. For children spontaneous or assisted ventilation through a ventilating bronchoscope is preferred to jet ventilation because of the risk of barotraumas and air trapping. If jet ventilation is used, limit delivered pressure and place a hand on the chest to detect "stacking". At the end of procedure an anesthesia mask can be used for emergence but intubation is preferred in the presence of airway compromise, edema, blood or secretions.

Laser excision of lesions in the lower airway is accomplished under direct vision using the carbon dioxide laser. Shavers may be used as well, in which cases more blood loss and secretions may occur.

Anesthetic for laser microsurgery of the airway :

A small ETT is used. If it is a cuffed tube, the cuff is filled with methylene blue so that if the balloon is lasered it will be immediately obvious. Laser safe tubes should be used. PVC tubes are not recommended as they burn easily and release hydrochloric acid. Muscle relaxants are used. The patient's eyes are protected with moist pads. The use of flammable O2 and N2O is minimized. Air decreases fire hazards. A combination of helium and oxygen may be used to improve flow characteristics. PEEP may be added to the breathing circuit during laser operation to decrease the risk of airway fires. The use of highly reflective instruments is avoided in the surgical field. If a fire occurs, the flow of O2 is discontinued, the ETT removed, the fire extinguished with saline, and tissue damage is assessed with bronchoscopy.

The difficult airway

Awake intubation is used most commonly for neonates with complicated airways but some sedation/IV versed/may be required. An oxyscope is useful. The lightwand or LMA may assist in blind or fiberoptic tube placement if direct laryngoscopy is not successful. In older children an inhalation induction with maintenance of spontaneous ventilation is usually advocated. Topical anesthesia may help to decrease anesthesia requirements during laryngoscopy.

The lightwand is useful for blind intubations in older children in whom a tube which will fit over the lightwand can be used.

The LMA has been advocated for use in children with difficult airways. A blindly placed LMA serves as an easy guide for the fiberoptic bronchoscope, and may be helpful if mask ventilation unexpectedly becomes difficult. Don't forget that if laryngospasm is the cause of difficult mask ventilation it will not be relieved and may be exacerbated by an LMA. However, constant positive pressure or a small dose of lidocaine or propofol may correct the problem. Cricothyrotomy may become necessary in emergent situations (such as a foreign body inextricably stuck partly through the cords). This procedure may be quite difficult in the infant, whose trachea is small.

Percutaneous transtracheal jet ventilation is frequently advocated as the system of choice for emergency ventilation. Remember that the lungs must have some route for deflation. The rapid delivery of high-pressure oxygen to the lungs of an infant could result in barotrauma and pneumothoraces. It may be safer to ventilate more gradually using anesthesia circuit despite the risk of hypercapnea, until tracheostomy can be performed.

Indications for **tracheostomy** in children include chronic airway obstruction/laryngomalacia, bilateral vocal cord palsy, pulmonary toilet when chronic ventilator support is required, as part of major head and neck surgery, to urgently secure airway after cricothyrotomy, rarely for prolonged ventilation. When caring for children with tracheostomies, there should always be an extra tracheostomy tube available since tubes with such small lumens can easily become obstructed by tenacious secretions. Tracheostomy in infants is performed as a last resort since it is associated with such a high mortality.

Congenital disorders of the airway

Choanal atresia (obstruction of nares- if bilateral, infants can't feed since normally they breathe through their nose while eating), tracheomalacia (stridor on inspiration due to collapse of the trachea which usually responds well to positive pressure distending the airway or intubation, children tend to out grow this), laryngomalacia (where inspiration pulls laryngeal structures down over the vocal cords effectively obstructing them, ENT surgeons trim supraglottic area to treat this), laryngeal atresia and webs (problems at birth), and cleft lip and palate (which can cause feeding difficulties and failure to thrive). Difficulty of ventilation and intubation may be encountered in the presence of micrognathia and dysmorphic syndromes, subglottic hemangiomas , cysts, and subglottic stenosis.

Tonsillar hypertrophy

Children with this diagnosis may have obstructive sleep apnea. Here history is important- Does the child have daytime drowsiness, difficulty concentrating, noisy breathing, apnea ended by a snorting or gasping breath? A preoperative sleep study may document hypoxia, hypercarbia, apnea. Echocardiography may demonstrate the presence of right heart dilation or failure. Children with right heart failure are particularly susceptible to postobstructive /negative-pressure

pulmonary edema and to volume overload. Premedication should be used judiciously, if at all, in children with sleep apnea. A mask inhalation induction is usually preferred although with extreme hypertrophy, IV induction might be less hazardous.

In patients with sleep apnea, intraoperative opioids should be probably avoided. Patients with sleep apnea must be completely awake with intact reflexes and normal ventilatory pattern before tracheal extubation.

Postoperative problems include vomiting, pain, bleeding, and airway obstruction.

Overnight observation with apnea monitoring and oximetry is recommended for patients with T&A who have documented obstructive sleep apnea or meet any of the following criteria: less than 2 years old, craniofacial abnormalities, failure to thrive, hypotonia, cor pulmonale, morbid obesity, history of airway trauma, or concomitant uvulopalatopharyngoplasty.

Foreign body aspiration

Any recent aspiration is considered urgent. A peanut, because it releases inflammatory mediators, may cause **pneumonitis** and should also be urgently removed.

Most foreign bodies lodge in the right mainstem bronchus. A greater degree of obstruction can result in a ball-valve phenomenon, leading to gas trapping and hyperinflation. Most foreign bodies are radiolucent. Chronic cough and recurrent pneumonia are often the manifestations of a foreign body when there is no known history of aspiration.

Inhalation induction with maintenance of spontaneous ventilation is the induction of choice. Avoidance of N2O is advised. IV atropine, lidocaine spray and IV propofol also help to maintain anesthesia depth. Foreign bodies are usually removed by surgeons using rigid bronchoscopy. The patient may be intubated or masked following removal.

Epiglottitis

Epiglottitis is an acute, life-threatening infection of the supraglottic area, usually due to H. influenzae. There is sudden onset of sore throat, fever, inspiratory stridor, and respiratory distress. The child will be leaning forward to breathe, drooling, and appearing quite toxic. The patient should be kept calm and comforted by the parents as agitation worsens the ventilatory state. A physician with the ability to perform emergent cricothyrotomy/tracheostomy in children should always be in attendance. The induction may be performed with the child sitting upright, possibly on a parent's lap. Inhalation anesthesia is induced with halothane/sevoflurane and oxygen. Spontaneous ventilation is maintained regardless of the patient's oral intake status. Yankauer suction should be readily available. After a deep plane of anesthesia is obtained, an IV cannula is placed and atropine administered.

Direct laryngoscopy and oral endotracheal intubation are performed using an endotracheal tube one size smaller than normal. Spontaneous ventilation should always be maintained and muscle relaxants avoided. (Lateral radiographs of the airway may help in diagnosis, showing a "thumb-like" swelling of the epiglottis,

but children must never be sent to the radiology area unaccompanied by a practitioner skilled in airway maintenance.)

Laryngotracheobronchitis/croup/

Symptoms include an insidious onset of low-grade fever, a croupy or seal-bark cough, inspiratory stridor, retractions, and sometimes cyanosis. Differentiation from epiglottitis may be difficult. Similar presentations include bacterial tracheitis, laryngeal foreign body, retropharyngeal abscess, and diphtheria. In croup subglottic edema appears as a “steeple” sign (narrowing) on AP radiographs. Basic guidelines for care include keeping the patient calm and providing oxygen in a cold steam/croup tent/. Racemic epinephrine may temporarily improve symptoms but one should always remember rebound obstruction often occurs 4-6 hours later. The use of steroids remains controversial. The need for intubation is unusual.

Peritonsillar abscess

This problem tends to occur in older children or young adults. Incision and drainage are required if response to antibiotic therapy is inadequate. Severe pharyngeal swelling, trismus, distortion of pharyngeal anatomy and airway obstruction can occur.

Rapid-sequence induction is performed in young children if no airway difficulty is suspected. If significant trismus or difficult intubation is anticipated, an **inhalation induction with spontaneous ventilation** can be performed. An extremely critical airway might require tracheostomy under local anesthesia.

Myringotomy with placement of tubes helps to control recurrent otitis media in children and may improve hearing loss. The very short duration of this procedure often precludes the need for IV catheter placement. General anesthesia is usually provided using mask. Ketorolac/IV/ or acetaminophen/PR/ or postoperative oral ibuprofen (if not given preoperatively with midazolam) can be used for analgesia without prolonging discharge.

Trauma. Lacerations, bleeding, edema, and fractures of the maxillofacial area make airway management extremely difficult. Awake intubation is preferred. Open or closed injuries to the larynx and trachea can occur from direct trauma but are unusual in children. Subcutaneous emphysema, dyspnea, hoarseness, cough, hemoptysis and in particular, voice changes indicate the possibility of laryngeal damage. Cricoid pressure is not used with laryngeal or tracheal trauma. One of the safest approaches to securing the airway is the use of fiberoptic broncoscopy. **Tracheostomy** under local anesthesia may be necessary.

Anesthesia for ophthalmic surgery

The presence of an ocular abnormality always should alert the anesthesiologist to the possibility of other associated anomalies. Inhalation agents cause dose-

related decreases in intraocular pressure. Narcotics, barbiturates, propofol and etomidate all lower IOP, assuming that normocapnia is present.

Asphyxia, hypoventilation or administration of carbon dioxide will raise IOP, while hypothermia, nondepolarizing muscle relaxants, ganglionic blockers or hypertonic solutions such as dextran, urea, mannitol, or sorbitol will reduce IOP.

Succinylcholine raises IOP as much as 8 mm Hg; the efficacy of pretreatment with nondepolarizing muscle relaxants to prevent increases in IOP caused by succinylcholine is still questionable. Nondepolarizing agents will lower IOP as long as hypercapnea is avoided.

Strabismus surgery

Strabismus surgery is associated with an increased incidence masseter spasm and of MH. The oculocardiac reflex has trigeminal/V/ afferent and vagal/X/ efferent pathways. It is triggered by pressure on the globe or traction of the extraocular muscles, the conjunctiva, or orbital structures. The most common manifestation is sinus bradycardia. Different arrhythmias may occur. For strabismus surgery routine prophylaxis with atropine 0.02mg/kg IV or glycopyrrolate 0.01 mg/kg can be administered.

Treatment depends upon its nature and severity. Severe bradycardia or hypotension is treated by asking the surgeon to stop ocular manipulation. If the heart rate does not return to normal, atropine/0.01mg/kg/ should be given.

Oculocardiac reflex prophylaxis is advised before intubation. Postoperative nausea and vomiting are common. Antiemetics include droperidol 0.075 mg/kg IV, metoclopramide 0.25 mg/kg IV, ondansetron 0.05 to 0.15 mg/kg IV/max dose 4 mg/, and lidocaine 1 to 2 mg/kg IV.

Open-eye and full-stomach situations

Trauma is the typical cause of an open globe. Any unnecessary stimulation should be avoided because coughing or vomiting can raise IOP as much as 40 mm Hg. The use of a slightly larger mask will help to avoid pressure on the eyes. Aspiration prophylaxis with an H2-receptor antagonist is advised. After pretreatment with a nondepolarizing agent, rapid-sequence induction is generally the method of choice. Rocuronium may be a useful drug in this setting.

Anesthetic implications of topical ocular drugs

Systemic absorption occurs from either the conjunctiva or nasal mucosa. Topical ocular drugs with systemic toxicity to which the anesthesiologist should be alert are found among commonly used mydriatics/atropine, scopolamine, cyclopentolate/as well as antiglaucoma agents/echothiophate iodide,epinephrine, timolol, betaxolol/, and vasoconstictors/cocaine, phenylephrine/. One drop of 4% cocaine solution contains 2 mg of cocaine;phenyephrine 2,5% – one drop – 1,25 mg. Cocaine should not be administered in combination with epinephrine because of the facilitation of dysrhythmias (especially in the presence of halothane). Cocaine is contraindicated in patients with hypertension or those receiving drugs which modify the adrenergic nervous system.

Anesthesia for children with musculoskeletal disorders

Scoliosis is defined as lateral deviation of the spine. Severity is determined by the degree of angulation measured by the Cobb method.

Cardiorespiratory effects of scoliosis include ventilation/perfusion abnormalities, decreased total lung volume, decreased PaO2, blunted ventilatory response to CO2, and pulmonary hypertension.

The main anesthetic management concerns are positioning and blood loss, which can be minimized by hyperventilation/vasoconstriction, hemodilution, autologous storage, and controlled hypotension. Cell saver is often helpful.

Hyperventilation with hypotension may lead to spinal cord ischemia.

Monitoring spinal cord function is done by either an intraoperative "wake-up" test or SSEP.

Dwarfism – The most common disorder is **achondroplasia.** Anesthetic management mandates suspicion of an abnormal airway. Preoperative sedation should not be given in order to avoid upper airway obstruction. Antisialagogues are particularly useful. Both awake intubation and mask inhalation induction with spontaneous ventilation have been used successfully. Muscle relaxants may be best avoided until the airway is secured. Succinylcholine is avoided if muscle wasting is present. (Succinylcholine is best avoided in all children under the age of 12).

Juvenile rheumatoid arthritis is an autoimmune disease associated with chronic nonsuppurative inflammation of synovium and connective tissue. Anesthetic management necessitates evaluation of glottic position; cervical spine x-rays for evaluation of atlanto-axial joint stability, cardiac exam (auscultation, ECG, and possibly echocardiogram). Perioperative stress steroid coverage is indicated if the patient is on chronic steroid therapy or if there is a history of recent steroid use. Hydrocortisone 4 to 8 mg/kg/day in 3 divided doses should suffice. All pressure points should be padded carefully.

Neuromuscular disorders

Von Recklinghausen disease/ neurofibromatosis/: The hallmark of the disease is café-au-lait spots/more than 6 that are greater than 1,5 cm in diameter/ and neurofibromas.

Associated conditions are laryngeal and tracheal compression, a high incidence of kyphosis and progressive scoliosis, an increased incidence of neural tumors, compression of spinal roots, and an increased incidence of cancer. Anesthetic considerations: Airway abnormalities may lead to difficulties with intubation. Patients may have increased intracranial pressure or a prolonged response to nondepolarizing muscle relaxants.

Tuberous sclerosis is an autosomal dominant disease with cutaneous and neurological manifestations. It consists of a triad of mental retardation, epileptic seizures, and facial angiofibromas. Anesthetic considerations include respiratory compromise in the presence of scoliosis, antiepileptic medications, and considerations for patients with seizure disorders.

Myotonic dystrophy is an autosomal dominant trait affecting primarily the limb muscles but it may also involve extraocular and facial muscles. Clinical features include poor sucking and swallowing, muscle atrophy, facial weakness, ptosis, cataracts, frontal baldness, gonadal atrophy, endocrine failure, and mental retardation. These patients are predisposed to aspiration, atelectasis, and pneumonia, bradycardia and intraventricular conduction delays, and hypoxemia and hypercapnia. Myotonia worsens with hypothermia. Succinylcholine may precipitate a myotonic crisis. Nondepolarizing agents can be used safely but reversal with neostigmine and an antimuscarinic can precipitate contracture. The trachea should not be extubated until the patient has completely recovered.

Muscular dystrophy, Duchenne is an X-linked recessive trait that usually presents with waddling gait in a child between the ages of 3 and 5 years. The hallmark of the disease is muscle degeneration. Death is usually secondary to CHF, cardiomyopathy or pneumonia by 20 years of age. Succinylcholine may cause hyperkalemia, myoglobinemia and cardiac arrest, or at least rhabdomyolisis. Sensitivity to nondepolarizing agents is common. As the disease progresses patients are unable to protect their airways from secretions, pneumonias occur, kyphoscoliosis occurs, and cardiac muscle degenerates. Muscular dystrophy may be associated with **MH** therefore atropine and scopolamine should be avoided. These patients have an increased risk of aspiration. There was report about propofol infusion causing rhabdomyolisis in patient with Duchenne muscular dystrophy. Remifentanyl infusion may be anesthetic of choice.

Myasthenia gravis is an autoimmune disorder that results in a decrease in the number of acetylcholine receptors at the neuromuscular junction. Antibodies to the receptors may be present. Affected individuals suffer weakness and fatigability of voluntary muscles. The treatment is oral neostigmine and pyridostigmine. In the perioperative period anticholinesterase therapy should be continued. Premedication may be best avoided. If nondepolarizing agents are needed they should be used in 1/20 of the usual dose and titrated to effect. Reversal may be ineffective. Hypothermia and hypokalemia can further decrease respiratory function. Narcotics must be titrated carefully. Patients should be extubation only after meeting strict criteria.

Myastenic syndrome/Eaton-Lambert/ primary involves proximal limb muscles. There is decreased of acetylcholine available at the end plate. This syndrome is associated with leukemia, neuroblastoma, SLE, rheumatoid arthritis, hypothyroidism and hyperthyroidism. Anesthetic considerations are similar to those for myasthenia gravis.

Anesthesia for children with congenital heart disease

Congenital lesions of the heart are generally classified according to the physiologic problems: **left-to-right** shunt: single connection between the venous and arterial systems; children display right-sided failure because of increased pulmonary blood flow; **right-to-left** shunt: a connection between the venous and arterial systems with obstruction to outflow on the right side will shunt blood right to left; venous blood is ejected systemically by the left ventricle and these children are

cyanotic; **complex**: complex shunts or mixing lesions are cardiac defects where all venous and arterial blood is mixed before being ejected from the heart; **obstructive**: obstructive lesions such as valvular stenosis or coarction of the aorta, can prevent ventricular outflow from either side of the heart, diminishing cardiac output and causing ventricular failure.

Left-to-Right Shunts

Simple left-to-right shunts include the defects which connect the arterial and venous circulation resulting in increased pulmonary blood flow: atrial septal defect; ventricular septal defect; patent ductus arteriosus; atrioventricular canal;aortopulmonic window.

Long standing left-to-right shunts can eventually cause **pulmonary hypertension**; if pulmonary hypertension becomes severe PVR may exceed SVR resulting in shunt reversal – **Eisenmenger's syndrome**. Anesthetic considerations: premedication should be used judiciously; endocarditis prophylaxis; meticulous removal of all air bubbles; induction of anesthesia may include intravenous or inhalation techniques; positive pressure ventilation increases PVR; low FiO2 limits pulmonary blood flow; inhalation agents-reduce SVR; ketamine- increases both PVR and SVR, which may increase left-to-right shunt; opiates-in the failing heart--high-dose fentanyl techniques have the least effec on myocardial performance.

Right-to-Left Shunts

Lesions that produce a right-to-left shunt contain not only a connection between the right and left heart, but also must offer increased resistance to blood flow through the pulmonary vasculature. Patients have marked hypoxemia and cyanosis: tetralogy of Fallot; tricuspid atresia; pulmonary atresia; Ebstein's anomaly. Anesthetic management: infusions of prostaglandin E1 will help to maintain patency of the ductus arteriosus to increase pulmonary blood flow; palliative shunts are usually placed to provide additional pulmonary blood flow; endocarditis prophylaxis is recommended; inhalation induction is prolonged; IV induction is more rapid; the goal of induction is to improve pulmonary blood flow to reduce hypoxemia and cyanosis; oxygen is the cornerstone of intraoperative management; hydration helps to maintain adequate right filling pressures; spontaneous ventilation or gentle assisted ventilation is recommended; ketamine raises both PVR and SVR and is ideal for fixed pulmonary obstructions; morphine is also useful, it may lowers both PVR and SVR; fentanyl decreases mortality in infants undergoing open-heart surgery; b- blockade has been used in children over 6 m to relax infundibular spasm; halothane offers similar effects to beta blockade therapy-slow heart rate and negative inotropy to relax infundibular spasm.

Right-to-Left shunts usually slow inhalation induction; Left-to-Right shunts do not affect induction significantly, may attenuate Right-to-Left shunts.

Tetralogy of Fallot

This disease complex comprises about 10% of all CHD and is the most common R-to-L shunt. Four anomalies: RV outflow tract obstruction; subaortic VSD; overriding aorta; RVH. Primary pulmonary artery reconstruction with complete repair at any earlier age is now more common. Treatment of hypercyanotic spells: high FiO2; hydration; morphine; ketamine; phenylephrine; propranolol; halothane; thiopenthal; squatting, abdominal compression. Anesthetic agents contraindicated: atropine; N2O; isoflurane; epinephrine; dopamine.

Drugs of choice for induction are: halothane, ketamine/IV or IM/.

Anesthetic management of noncardiac surgery in children with CHD

A current cardiac physiology profile is critical for determining shunt direction and therefore anesthetic management. It is important to remember that postoperative pain can increase catecholamines and will affect vascular resistance and shunt direction. Most of these patients are not candidates for outpatient surgery. Important is: obtain history and physical; review most recent Echo and cath data; antibiotic prophylaxis; plan induction based upon primary shunt flow; anticipate severe conduction disturbances; plan postoperative ICU stay.

Cardiomyopathies

Cardiomyopathies in children – primary/idiopathic and secondary, when they occur in association with an underlying disorder. They also may be classified as dilated, hypertrophic or restrictive.

Dilated cardiomyopathy in many cases is result of viral or inflammatory process. The functional profile includes decreased ejection fraction and stroke volume, increased ventricular volume and filling pressures and normal or decreased ventricular compliance.

Combinations of diuretics, inotropics and vasodilators may improve symptoms and clinical status. Another important cause of dilated cardiomyopathy in children is the anthracycline anticancer agents, such as doxorubicin, adriamycin.

Goals of anesthetic management: preserving ventricular filling and intravascular volume status, minimizing drug-induced myocardial depression, and avoiding significant increases in afterload.

Hypertrophic cardiomyopathy is often hereditary, transmitted as an autosomal dominant trait. It usually occurs as asymmetric hypertrophy of the interventricular septum. Left ventricular outflow tract obstruction and diastolic dysfunction are common. Ventricular tachycardia or fibrillation is the most frequent cause of sudden death in these patients.

IHSS : symptoms of dyspnea, angina on exertion, and orthionea are most consistently present; sudden death occurs in 3% to 4% of cases.

The mainstays of treatment are beta blockade/negative inotropy to reduce outflow stenosis and slow heart rate/ and maintenance of adequate preload and afterload. Filling volumes must be monitored so that hypovolemia, hypotension, reflex tachycardia, and vasodilation can be avoided. Sinus rhythm should be maintained. Primary fentanyl techniques help to maintain a slow heart rate with few hemodynamic changes. Halothane helps to relax dynamic ventricular outflow and maintain a slow rate. One should remember about its negative inotropic properties.

Anesthetic management of children with hematologic and oncologic disorders

In the normal newborn b-chain production shifts from Hb F to Hb A; over the first few weeks of life, Hb levels fall to an average nadir of 11 g/dl. The lowest levels are usually seen between 8 and 12 weeks of age. It is rare for infants to develop any clinically significant symptoms from physiologic anemia of the newborn.

Sickle cell disease

The single-gene amino acid substitution of valine for glutamic acid at position 6 in the b-hemoglobin chain results in the production of Hb S. About 10% of the African-American population has the Hb S gene, with increased prevalence also noted in those of Middle Eastern, Indian or Mediterranean descent.

Hb S, when deoxygenated, can polymerize with itself, leading to damage to the red cell that causes it to assume the sickled shape. Vasoocclusive symptoms predominate after the first year of life.

SCD: organ system dysfunction - hemolysis, anemia, leukocytosis, jaundice; renal-loss of concentrating ability; splenic autoinfarction, immunoincompetence; pulmonary – diminished function due to recurrent infarcts; cardiac-cor pulmonale; neurologic-stroke, seizures; chronic leg ulcers; growth retardation, delay in sexual maturity; skeletal – osteomyelitis/femoral head/; genital-priapism; cholelithiasis, bowel infarcts.

Anesthetic management: should be designed to minimize the possibility of hypoxia, vascular stasis, hypothermia and catecholamine production, which can trigger vasoocclusive episodes. Ideally it is recommended that the percentage of Hb S be decreased below 50% and if it is possible to about 30% before operation. Aggressive hydration with crystalloid or colloid is recommended. Intraoperative normothermia is maintained. Preoxygenation and an increased delivered FiO2 minimize the opportunity for hypoxia. Spinal anesthesia has been avoided traditionally. Tourniquet use is avoided. Postoperative pain should be managed aggressively to avoid vasoconstriction and hypoventilation.

Hemophilia

Hemophilia is the most common of the inherited coagulation disorders. They are inherited as X-linked disorders. Patients with hemophilia A have deficiency in factor VIII while those with hemophilia B are deficient in factor IX. Symptoms: usually normal hemostasis with minor cuts; bleeding with circumcision as a neonate; joint and muscle bleeding by age 1 year; spontaneous hemorrhage into deep tissues. Diagnostic tests: normal PT, prolonged PTT, normal platelet count, normal bleeding time, reduced amounts of factor VIII or IX. Anesthetic management: IM injections should be avoided; replacement with factor VIII or IX 15 to 20 min before invasive procedures.

Von Willebrand Disease

VWD is an autosomal dominant coagulation defect caused by deficiency of von Willebrand factor found in platelets, plasma and endothelial cells. There is variable penetrance of the defective gene, considerable variability in clinical manifestations classified into types I, II and III. The majority of patients have type I with prolonged bleeding time and PTT.

Clinical manifestations: history of abnormal bleeding that dates back to early childhood; epistaxis, mucosal and gum bleeding, bruising and menorrhagia are common.

Anesthetic management: consultation with the hematologist; many patients can achieve adequate plasma level of vWF after administration of DDAVP alone; patients with type II b vWD should not receive DDAVP; DDAVP is given as 0.3 mcg/kg IV over 20 min in 50 ml of normal saline; if more than three doses of DDAVP are required in 48 hr, the risk of hyponatremia and fluid retention is increased.; cryoprecipitate or fresh frozen plasma can provide a source of vWF if DDAVP is contraindicated or ineffective.

Oncology

Leukemias accounts for about 50% of pediatric malignancies; varying degrees of pancytopenia are common; DIC may be seen in children with AML; massive hepatosplenomegaly or cervical adenopathy may exert mass effect; electrolyte abnormalities may be present; renal function may be significantly compromised; treatment of leukemias/chemotherapy/ should be taken into consideration.

Mediastinal masses: masses may occur in all of the anatomic compartments of the mediastinum, but those of the anterior mediastinum are the most challenging to the anesthesiologist; compression of the trachea and larger bronchi by tumor mass has contributed to anesthetic difficulty or poor outcome. In those cases it is prudent to avoid muscle relaxants. In patients with severe airway/respiratory compromise, preanesthesia radiation therapy has been advocated. Preoperative assessment should include CT or MRI.

Wilms tumor is the most commonly occurring childhood abdominal malignancy/1:15000 live birth/; is usually diagnosed when a large intraabdominal mass is discovered; complete surgical resection remains the mainstay of treatment usually followed by chemotherapy and radiation.

Neuroblastoma – the most common tumor of infancy, usually diagnosed in children less than 2 years of age. Most commonly found in the abdomen/adrenal medulla/ it is not uncommonly found in the mediastinum/usually posterior/; intracranial tumors also occur. Staging is the major determinant of survival. Conventional treatment remains surgical excision followed chemotherapy and radiation. Mass effect of the tumor place most patients at risk for aspiration. Rapid-sequence induction with cricoid pressure may be indicated. Large fluid shifts should be anticipated; heat loss from surgical exposure and fluid infusions; nitrous oxide should be avoided.

Intracranial tumors – the preoperative assessment should include documentation of any neurologic deficits and signs of elevated ICP. The induction technique

selected should consider the presence of increased ICP from the mass. Invasive monitoring is recommended/a-line/; CVP monitoring is useful; Foley catheter is necessary for fluid management.

Chemotherapy in children: pancytopenia; anorexia, nausea, vomiting; stomatitis, alopecia; all patients are immunocompromised; prophylactic AB and antiviral agents; treatment with high-dose corticosteroids-stress dose coverage.

Complications: cyclophosphamide-hemorrhagic cystitis; methotrexate-hepatitis, nephrotoxicity, pulmonary fibrosis; doxorubicin, daunorubicin-cardiomyopathy; bleomycin-pulmonary fibrosis.

HIV – infection with HIV has become the leading cause of immunodeficiency in children. Greater than 90% of cases of HIV infection in children are caused by perinatal transmission. Primary HIV infection usually causes an acute illness resembling mononucleosis. The acute phase is followed by the clinical latency period, which can last for several years. Ultimately, CD4 T lymphocytes are depleted with onset of opportunistic infections or malignancies.

Delivery room resuscitation

Fetal monitoring: monitors for uterine activity; fetal heart rate monitors. An external transabdominal Doppler probe monitors fetal heart rate. Early decelerations-compression of fetal head, causing vagal tone; variable decelerations-compression of umbilical cord; late decelerations-occurs if fetal hypoxia is present prior to stress of contractions.

Fetal acid-base monitoring: normal pH 7.25 to 7.35; preacidotic 7.20 to 7.25; acidotic < 7,20.

Treatment of fetal compromise: O2 to mother; left uterine displacement; maternal volume expansion/without dextrose/; discontinuation of oxytocin.

Goals of newborn resuscitation: assuring airway patency; maintaining ventilation/oxygenation; maintaining cardiac output; reducing metabolic requirements.

Airway: light suction; airway patency-bag-and-mask ventilation of the newborn can be difficult, use of LMA may be advised; positioning: placing a rolled towel under the shoulders will improve airway patency and make bag mask ventilation easier; ventilation-after 3-4 min of apnea acidosis will cause a drop in cardiac output; treatment of neonatal asphyxia includes basic techniques; **cardiac output**-cardiac output of the neonate is largely rate and preload dependent; the normal heart rate is greater than 120; heart rate 80-100 required assisted ventilation with 100% O2; heart rate 60-80 – chest compressions should begin; a newborn who required chest compressions should be intubated; if volume loss is suspected 10 ml/kg of NS or LR can be administered repeatedly;

Metabolic requirements: heat is produced in the newborn by metabolism of brown fat/nonshivering thermogenesis/; hypothermia causes hypoxia, hypercapnia, acidosis and hypoglycemia.

Basic resuscitation in the delivery room: Apgar scores are useful; documentation of the 1-, 5-, and 10- min Apgar scores is important; drugs used in neonatal resuscitation: epinephrine 0.01 mg/kg, atropine 0.01-0.03 mg/kg, bicarbonate

1mEq, calcium chloride 10mg/kg, glucose D10 5-10 ml, naloxone 0.1 mg/kg; endotracheal route – epi, atropine, naloxone.

Pediatric Advanced Cardiac Life Support 2006

Airway adjuncts. Endotracheal intubation remains the 'gold standard' approach to secure the airway of a pediatric victim of cardiopulmonary arrest. Only properly trained individuals must attempt endotracheal intubation. Bag-mask ventilation has been shown to be very effective means of ventilating and oxygenating children when properly trained personal is not available. Confirmation of initial endotracheal placement of the tube is very important. Detection of exhaled carbon dioxide using either a capnograph or colorimetric device is strongly recommended. The **LMA** well known to anesthesiologists as an effective ventilating device used in the OR, has not been studied sufficiently to allow an evidenced-based recommendation for its use in pediatric CPR. The opinion of resuscitation experts recommends that the LMA be considered as a potentially useful adjunct device for airway control when bag-valve-mask ventilation is inadequate or airway cannot be secured by endotracheal intubation.

The suggested AHA mnemonic for making the differential diagnosis when an intubated patient deteriorates is to think, **"DOPE"**: **D**isplacement of the tube, **O**bstruction of the tube, **P**neumothorax, and **E**quipment failure. Cricothyroidotomy is an effective way to provide secure airway in a child when airway cannot be obtained by endotracheal intubation.

Vascular access in pediatric patients may be problematic. The CPR goal is to establish vascular access as rapid as possible. The intraosseous space is a noncollapsible venous plexus and its cannulation takes 30-60 sec. The recommended cannulation sites include the anterior tibia, distal femur, medial malleolus and anterior superior iliac spine. Intraosseous vascular access should be used for all age children.

Pharmacological agents. Epinephrine continues to be a mainstay of CPR pharmacology. Its a-adrenergic vasoconstrictive effect is key to successful CPR. The use of high-dose epinephrine in pediatric ACLS has been de-emphasized in the current PALS protocol.

The recommended dose for epinephrine for the unconscious, asystolic, pulseless cardiopulmonary arrest patient: initial dose 0.01 mg/kg IV/IO; 0.1 mg/kg, tracheal route; subsequent doses/every 3-5 min/ - repeat initial dose; may consider high – dose protocol, 0.1 mg/kg IV.

Amiodorone/5mg/kg/ may be considered in the treatment algorithms for supraventricular and ventricular arrhythmias. Adenosine /0.1mg/kg up to 6 mg/ remains the first choice medication for treatment of supraventricular arrhythmias.

Non-pharmacological treatment of arrhythmias. Vagal maneuvers have been added to the treatment protocol for supraventricular tachycardia for children who are hemodynamically stable and/or being prepared for cardioversion. Utilization of vagal maneuvers must not delay cardioversion or administration of adenosine for children with poor perfusion state. The most effective vagal stimulant in infants and children is the application of a bag with ice/ice water to the face. Carotid massage and Valsalva maneuver are effective treatments in older children. Current recommendations for AED therapy in the pediatric population include use of: an adult AED for pediatric patients > 8 years of age, 150-200 joule shock/6-8 joules/kg for the average weight 8 years old/ and an AED with

pediatric paddles delivering a ~50-75 joules for children <8 years old. There is little evidence to justify use of the AED for children <1 year of age.

Ambulatory anesthesia for the pediatric patient

About 70% of all pediatric surgical cases are done on ambulatory basis. Children are very good candidates for ambulatory surgery because majority of them are healthy, surgical procedures are simple and recovery period is short. Avoiding hospitalization for children is very beneficial – minimal separation from parents, less risk of exposure to hospital infections.

Patient selection criteria: the most important for selecting a child for ambulatory surgery are the physical status of the patient, and the type of surgical procedure. These factors should be also combined with how well facility is equipped and the ability to deal with complications.

The child preferred to be in good health or any systemic disease must be optimized or under good control.

For example, **the premature infant** is not a good candidate for ambulatory surgery because of immaturity of respiratory center, temperature control, and gag reflex. The age at which a former premature infant (ex-preemie) is no longer at increased risk for postoperative apnea is controversial and should be considered individually. Many anesthesiologists will admit all ex-preemies to a hospital for 23 hr who are younger than 50-55 weeks of PCA.

The child with a runny nose may have benign condition like allergic rhinitis or URI without fever and when child does not look toxic in which case surgeon should be informed and elective surgery may be performed. The preanesthetic exam should include history and physical exam, including auscultation of child's chest to rule out lower respiratory infection and possible pneumonia. When the pediatric patient looks toxic, has fever and you can not rule out lower respiratory infection and possible pneumonia elective cases should be postponed, surgeon informed; chest x-ray may be advisable and ambulatory treatment by primary pediatrician should be instituted. Elective cases may be rescheduled in 4-6 weeks.

Asthma is common chronic disease of childhood, and many pediatric patients with asthma being scheduled for ambulatory surgery. The decision to proceed with each case depends on severity of asthma and patient's condition (control of disease). Children with moderate asthma who do require daily medications to control their symptoms should be instructed to continue their medications until the morning of surgery. A beta agonist (albuterol) may be administered by nebulizer. Sometimes glycopyrrolate (robinul) or small dose of steroids (for patients who are on steroid containing inhaler) may be beneficial in these patients, specifically when they have some respiratory infection symptoms. If patient with history of asthma on daily medications is wheezing, has co-existing URI on the day of surgery it is best to reschedule procedure. The choice of anesthetic technique depends on procedure. The use of LMA may decrease risk of bronchospasm; if endotracheal tube is used sufficient depth of anesthesia should be established first. ETT may allow better control of secretions in patients with URI. Deep extubation may be recommended.

Most ambulatory surgical centers do **screen** their patients before surgery. It may be visit for preoperative anesthesia evaluation or even a phone interview. Information is sought concerning past or present risk factors like prematurity, chronic cardiac or pulmonary conditions and so forth. Assessment of current health status is performed, acute illness is ruled out and NPO status reinforced (2 hr for clear liquids, 4 hr for breast milk, 6 hr for

formula and 8 hr for heavy meal in teenagers). On the day of surgery, all patients getting physical exam, screen for acute illness and NPO status, allergies are checked. Vital signs are evaluated. Many ambulatory centers have presurgical orientation programs when pediatric patients coming few days before surgery to facility and getting a tour with explanations.
Pharmacologic **premedication** usually includes oral midazolam in dose of 0.5-1 mg/kg and rarely exceeds 10-12 mg; Parents presence during induction is another option and use of induction rooms in some institutions is helpful. For uncooperative child IM injections of ketamine, nasal midazolam may be a viable option.
Inhalation induction is a popular choice for ambulatory surgery in children and sevoflurane is induction agent of choice. Sometimes after induction with sevoflurane anesthesia provider may switch to isoflurane for maintenance. Maintenance of anesthesia with sevoflurane too possible but risk of emergence delirium should be entertained.
Intravenous induction with propofol in children is an option in older pediatric population when IV access may be established in preoperative area. Combination of propofol with lidocaine is recommended to decrease pain on injection. Propofol infusion may be combined with inhalation agent and may prevent nausea and vomiting, specifically in strabismus surgery. Other antiemetic drugs may include: zofran, low dose of dexametasone, phenergan, compazine.
Postoperative analgesia: preference for acetaminophen, total daily dose should not exceed 100 mg/kg. Rectal dose varies between 10-30 and more mg/kg. NSAID, ketorolac have proved to be effective in children but side effects should be taken in consideration – renal complications and effect on platelet function. Potent narcotic analgesics: short acting should be preferred (fentanyl is drug of choice often). Nasal fentanyl may be used for BMT surgery. Regional analgesia like field block and other peripheral blocks provide excellent postoperative pain relief and early ambulation and extremely important in pediatric ambulatory surgery.
Rapid recovery and ambulation are must for ambulatory surgery. In certain cases patients may bypass PACU (fast-tracking) and stay with parents right after surgery; it is quite beneficial in majority of cases. Other pediatric patients being discharged home after they meet certain criteria. Every child must have an escort home.

Analgesia and sedation for children outside of the operating room

Analgesia and sedation outside of the operating room also in offices and free standing medical facilities becoming more prevalent for pediatric patients and requires special approach and protocol. Sedation for children may be required in the ER, for CT and MRI studies , GI exams, bronchoscopy, cardiac evaluations (echocardiography, catheterizations), in burn unit (dressing change), and others (chest tube removal, et cet.). These procedures may require various depth of sedation. Some procedures are associated with loss of airway reflexes and are at increased risk of complications. Anesthesiologists may not be directly involved in the care of these patients but their input is very significant in organization and training sedation team/service.
The JCAHO regulations have recommendations made by the ASA. The definition of the four levels of sedation and anesthesia are:
Minimal sedation (anxiolysis): A drug induced state during which patients respond normally to verbal commands. Although cognitive function and coordination may be impaired, ventilatory and cardiovascular functions are unaffected. This level of sedation

is rarely adequate for diagnostic or therapeutic procedures in children.
Moderate sedation: A drug induced depression of consciousness during which patients respond purposefully to verbal commands, either alone or accompanied by light tactile stimulation. No interventions are required to maintain a patient airway and spontaneous ventilation is adequate. Cardio-vascular function is usually maintained.
Deep sedation: A drug induced depression of consciousness during which patients cannot be easily aroused but respond purposefully following repeated or painful stimulation. Reflex withdrawal is not considered a purposeful response. The ability to independently maintain ventilatory function may be impaired. Patients may require assistance in maintaining a patent airway and spontaneous ventilation may be inadequate. CV function is usually maintained.
Anesthesia: General anesthesia is a drug induced loss of consciousness during which patients are not arousable, even by painful stimulation. The ability to independently maintain ventilatory function is often impaired. Patients often require assistance in maintaining a patent airway and positive pressure ventilation may be required because of depressed spontaneous ventilation or drug induced depression of neuromuscular function. CV function may be impaired.
Those terms were not specifically designed for children. Some children are developmentally delayed or too young to understand and follow verbal commands. Clear examples of the stages of sedation for different age groups would be very helpful in clarifying any misconceptions. There is also the assumption that there is a consistent correlation between different levels of sedation and the ability to maintain a patent airway.
Most hospitals have sedation policy and sedation flow sheet. The updated regulations require similar standards for moderate and deep sedation as are used for patients having general anesthesia. Qualified individuals must have competency based education, training, and experience: in evaluation of patients, in performing sedation, to "rescue" the patient from **the next** level of sedation/anesthesia.
BLS certification is required for practitioners of moderate sedation. PALS certification is required for practitioners of deep sedation. PALS training should provide airway and cardiovascular support training and thus allow rescue from general anesthesia.
Risks of sedation: all sedatives and narcotics have caused problems even in "recommended doses", all areas using sedation have reported adverse events, children 1-5 yr of age are at most risk (most had no severe underlying disease), respiratory depression and obstruction are the most frequent causes of adverse events, adverse events involved – multiple drugs, drug errors or overdose, inadequate evaluation, inadequate monitoring, inadequate practitioner skills, and premature discharge.
There obvious need for uniform, specialty-independent guidelines for monitoring children during sedation both inside and outside of the hospital setting.
Sedation techniques: Local anesthetics play very important role in analgesia during painful procedures. Application of local anesthetics to skin and mucosal membranes as well as local and regional blocks usually easily to perform. Maximum doses (lidocaine 5 mg/kg – 7 mg/kg with Epi, tracheal lidocaine 2 mg/kg, marcaine 2 mg/kg – 3 mg/kg with Epi, cocaine 3 mg/kg, tetracaine 1.5 mg/kg) should be calculated. The toxic effects of local anesthetics are additive. The cocaine component can cause arrhythmias and CV collapse if given mucosally.
Chloral hydrate is one commonly used sedative inj infants and children. Doses range from 25-100 mg/kg with maximum of 1.0 g per dose (2 g per day). It may be given orally or rectally. It has slow onset time – 30-60 min and prolonged duration (1/2 life 10 hr in toddlers). It may cause airway obstruction.
Midazolam has amnestic effect, short duration (half-life 100 min) and easily being

administered; reversibility (flumazenil 0.1 mg/kg IV) make it very useful. The doses are: oral 0.5-0.75 mg/kg – 10-30 min onset time; rectal 0.3-0.5 mg/kg – 20-30 min; IV doses start at 0.05-0.1 mg/kg. Sedation doses may cause mild respiratory depression. Severe respiratory depression can occur when narcotics are combined with midazolam.
Fentanyl is potent opioid (100 times more potent than morphine) with rapid onset, intermediate duration (30-45 min) and reversibility (naloxone 0.1 mg/kg IM or IV). The respiratory depressant effect is much longer (4 hr) than its analgesic effect. Can cause apnea and chest wall rigidity when given rapidly. Doses start at 0.5-1.0 mcg/kg and should be titrated to effect with maximum of 5 mcg/kg.
Nitrous oxide used alone in concentrations less than 50% is a useful mild anxiolytic, sedative agent which causes analgesia. Verbal contact must be maintained with the patient.
Ketamine is an excellent analgesic and amnesic which can be given intravenously (0.25-0.5 mg/kg), orally or rectally (6-10 mg/kg) or intramuscularly (2 mg/kg). It increases HR, BP, and ICP. It can cause copious secretions and lead to laryngospasm; it can also cause vivid dreams. Ketamine in large doses can cause an incompetent gag reflex, deep sedation or general anesthesia.
Propofol has sedative and hypnotic effect, fast onset and extremely short duration time. Propofol administered by anesthesiologists as a continuous infusion of 50-200 mcg/kg/min IV is extremely useful in non-painful pediatric deep sedation procedures (for example MRI) where a quick wake up is desirable. Its antiemetic effect makes it particularly useful for outpatient procedures. Currently general ASA recommendation is that propofol should be used for sedation by an anesthesiologist.
MRI – sedation service for MRI should be supervised by an anesthesiologist. Small children (newborn, 1-2 m of age) may undergo study without sedation. Sometimes sedation with IV midazolam (0.1 mg at a time) in controlled situation is feasible alternative. Longer studies (1hr or more) may require secured airway (intubation). Many anesthesia practitioners comfortable with LMA in small children. If MRI compatible anesthesia machine is available so general anesthesia or sedation may be provided using inhalation agent. If not – propofol infusion with proper monitoring (CO_2, pulse oxymetry) is reasonable choice. Ideally it should be holding area next to MRI scanner which is properly equipped (similar to OR), and recovery space with nursing staff available so pediatric patient may be discharged home without going to main recovery.

Pediatric pain management.

The treatment of pain is a basic in medicine and applicable to every patient regardless of age. Children frequently receive no treatment, or inadequate treatment for pain and for painful procedures. The newborn and critically ill children are especially vulnerable to no treatment or under-treatment. Children less than 3 years of age or critically ill children may be unable to adequately verbalize when or where they hurt. They may be afraid to report their pain. Fears of opioid addiction are also causal factors in the under treatment of pediatric pain. Pain management in children is often dependent on the ability of parents to recognize and assess pain and on their decision to treat pr not to treat it. This is very much true in patients who are too young or developmentally delayed to self report pain. Pediatric pain service should provide the pain management for acute, post-operative, terminal, neuropathic and chronic pain.
Non-opioid analgesics. Acetaminophen (Tylenol), salicylated (aspirin), ibuprofen, naproxen, diclofenac acid are the classic examples, comprise a group of non-steroidal anti-inflammatory drugs (NSAID) and non-opioid analgesics. They provide pain relief mostly by blocking peripheral prostaglandin production. These agents are administered

enterally: oral, or rectal route and are very useful for inflammatory, bony, or rheumatic pain. Ketorolac (Toradol) may be administered parenterally. Regardless of dose, the non-opioid analgesics reach a “ceiling effect” above which pain can not be relieved by these drugs alone. Aspirin has been abandoned in pediatric practice because of its possible role in Reye’s syndrome, its effects on platelet function, and its gastric irritant properties. Acetaminophen works mostly centrally and has minimal anti-inflammatory activity. Rectal doses for acetaminophen being recommended by some authors are as high as 30-40 mg/kg as loading dose. Follow-up doses are 10-20 mg/kg every 4-6 hr. Regardless of route of delivery, the daily maximum acetaminophen dose in the preterm, term, and older child is 60, 80, 90 mg/kg respectively.

Opioid drugs. Factors to consider when opioids are appropriate are: pain intensity, patient age, co-existing disease, potential drug interactions, prior treatment history, physician preference, patient preference, and route of administration. All opioids are capable of treating pain regardless of its intensity if dose is adjusted appropriately and at equipotent doses most opioids have similar effects and side effects.

Codeine, oxycodone (Tylox, Percocet) and hydrocodone (Vicodin, Lortab) are opioids which are frequently used to treat pain in children and adults. They are most commonly administered in the oral form, usually in combination with acetaminophen or aspirin. In equipotent doses, codeine, oxycodone, and morphine are equal as analgesics and respiratory depressants. They all cause sedation, respiratory depression, and nausea. Nausea is particularly true for codeine. The analgesic effects for codeine and oxycodone occur in ~ 20 min following oral intake and reach maximum at 60-120 minutes. The plasma half-life of elimination is 2.5-4 hr. Approximately 10% of codeine is metabolized into morphine and is responsible for analgesic effect. Approximately 10% of the patients and most newborns cannot metabolize codeine into morphine so codeine has little analgesic effect in these patients. Morphine is effective given orally but only 20-30% of an oral dose reaches the systemic circulation. **Codeine** is usually prescribed 0.5-1 mg/kg in elixirs which contain 120 mg acetaminophen and 12 mg codeine per teaspoon (5 ml). Codeine and acetaminophen also available as tablets – Tylenol number 1, 2, 3, or 4. The number refers to how much of codeine is in every tablet. Tylenol 4 has 60 mg of codeine, and number 1 has 7.5 mg. In all combination drugs be aware of hepatotoxic acetaminophen doses (in adults, 7.5-10 g daily for 1-2 days, children 60-420 mg/kg/day for 1-42 days). **Hydrocodone** is prescribed in a dose of 0.05-0.1 mg/kg. The elixir is available as 2.5 mg/5 ml combined with acetaminophen 167 mg/5ml. As a tablet it is available in doses between 2.5-10 mg, combined with 500-650 mg acetaminophen. **Oxycodone** is prescribed in a dose of 0.05-0.1 mg/kg. In tablet form oxycodone is commonly available as a 5 mg tablet or as Tylox (500 mg acetaminophen and 5 mg oxycodone) or Percocet (325 mg acetaminophen and 5 mg oxycodone). Oxycodone is also available in sustained-release tablet for use in chronic pain. It must not be crushed and cannot be administered via gastric tube**. Oral morphine** is available as a liquid in different concentrations, a tablet (MSIR 15 and 30 mg) and as a sustained-release (MS Contin and Oramorph tablets, “sprinkle capsules”).

Patient controlled analgesia. Intravenous boluses of morphine may need to be given at intervals of 1-2 hr based on pharmacokinetics of the opioids. Continuous intravenous infusions may provide steady analgesic levels. Rational pain management requires some form of titration to effect whenever any opioid is administered. In order to give patients some measure of control over their pain demand analgesia or PCA devices have been developed. Usually morphine (20 mcg/kg), hydromorphone (4 mcg/kg) or fentanyl (o.5 mcg/kg) per bolus at a rate 5 boluses/hr with a 6-8 min lock-out interval between each bolus been prescribed. Most PCA allow low continuous infusion (morphine, 20-30 mcg/kg/hr, hydromorphone 3-4 mcg/kg/hr, fentanyl 0.5 mcg/kg/hr) in

addition to boluses. PCA requires a patient with enough intelligence to operate the pump. The lower age limit in whom this treatment modality can be used continues to fall. Some authors suggesting that any child able to play Nintendo can operate a PCA pump. All opioids can produce some unwanted side effects, such as pruritis, nausea and vomiting, constipation, urinary retention, cognitive impairment, tolerance, and dependence.

Written exam questions

What is prematurity?

Infants are considered premature if they are born before 38 weeks of gestation or weigh less than 2500 g at birth. Intrauterine asphyxia is common. Anesthetic considerations: **impaired temperature regulation** – increased surface-to-volume ratio; lack of fat insulation; fewer brown fat cells/cells stimulated by norepinephrine to increase heat production/ than in full-term infants; thin skin, resulting in heat and water loss; hypothermia may cause: hypoglycemia, apnea, bradycardia, and/or metabolic acidosis; **respiratory distress syndrome**/ hyaline membrane disease/ **–** RDS occurs more often in those born by cesarean section; prenatal risk factors-maternal diabetes and perinatal asphyxia; is caused by a deficiency in surfactant; pneumothorax should be considered if oxygenation deteriorates abruptly; immediate treatment with surfactant has reduced mortality associated with RDS; **bronchopulmonary dysplasia/BPD/ -** continued oxygen requirement at 28 days of life in an neonate with a history of RDS; the more severe the RDS, the greater the degree of BPD; risk factors associated with BPD include increased FiO2, positive-pressure ventilation, infection, patent PDA and fluid overload in the first 5 to 6 days of life; pulmonary hypertension and cor pulmonale can result from severe BPD;

apnea – cessation of breathing that lasts for 15 to 20 sec or produces cyanosis and bradycardia; risk of apnea spells is increased postoperatively especially in preterm infants less than 44 weeks postconceptual age/risk is reduced after 44 to 60 weeks PCA/; in hospital monitoring is recommended for at least 12 hr after surgery;

patent ductus arteriosus – may result in congestive heart failure and respiratory distress; PDA results in a left-to-right shunt, LVH and increased pulmonary blood flow; first line of treatment-indomethacin;

infection – is a threat to premature infants; sepsis can develop in the absence of a positive blood culture, elevated WBC or fever;

necrotizing enterocolitis /NEC/ - primarily a disease of small preterm infants; hypoperfusion of the GI tract, resulting in ischemia; initial signs are abdominal distention and bloody feces; shock may develop; patients are often hypovolemic and require fluid resuscitation before anesthesia; rapid fluid administration may cause in preterm neonates intracranial hemorrhage or reopening of ductus arteriosus; nitrous oxide should be avoided;

retinopathy of prematurity/ROP/ - is inversely related to birth weight; although the role of oxygen as risk factor is controversial, it remains prudent to minimize

oxygen exposure in premature infants less than 44 weeks old; it is recommended that PO2 be maintained between 60 and 80 mm Hg whenever possible;

intracranial hemorrhage – subdural, primary subarachnoid, periventricular-intraventricular/most common/, intracerebral; newborn immaturity is the single most important factor; intracranial hemorrhage is unusual after 10 days of life; it is prudent to avoid hypoxemia and hypercapnia and to avoid cerebral hyperperfusion/BP in normal range/; hyperosmolarity is a contributing factor.

What is Down syndrome?

Trisomy-21/Down's syndrome/ - is the most common chromosomal abnormality/1:700/; is associated with mental retardation/IQ below 65/; many features of the **airway** are abnormal: narrow nasopharynx, large tonsils and adenoids; tongue becomes progressively larger; intubation is usually not difficult;

cervical spinal malformations – cervical spinal stenosis/10%/, atlantoaxial subluxation/31%/; lateral cervical spine radiographs in flexion and extention may be useful;

congenital heart disease – VSD/25%/, TF, ASD.PDA; increased incidence of respiratory complications following cardiac surgery; patients are predisposed to the development of pulmonary hypertension;

other findings: obesity, laxity of the skin and joints, duodenal atresia, hearing loss, hematologic malignancy.

Anesthetic implications: potentially difficult airway, select ETT one size smaller than anticipated. Decreased CNS catecholamine stores, may decrease MAC. Exaggerated response to muscle relaxants. Consider obtaining C-spine films prior to neck manipulations. Preoperative cardiac evaluation required ; may require prophylactic antibiotics.

What is omphalocele and gastroschisis?

Omphalocele and gastroschisis – anesthetic management is essentially the same; knowledge of the associated anomalies may influence decisions; omphalocele and gastroschisis are congenital defects of the anterior abdominal wall permitting external herniation of abdominal viscera; **gastroschisis** is not midline, has normally situated umbilical cord/**not covered** with a hernia sac / and is rarely associated with other congenital anomalies, does have an increased incidence of prematurity; **omphalocele** has a 75% prevalence of other congenital defects, including cardiac anomalies/VSD most common/, trisomy 21 and Beckwith-Wiedemann syndrome/omphalocele, organomegaly, macroglossia and hypoglycemia/; epigastric omphaloceles are associated with cardiac and lung anomalies, hypogastric – exstrophy of the bladder and other genitourinary anomalies; **preoperative care** – limit heat loss, deficits of fluid and electrolytes, correct hypoglycemia, decompress the stomach;

intraoperative management – general endothracheal anesthesia; N2O should be avoided; preoxygenation followed by awake or rapid sequence intubation. Elevated intraabdominal pressures, high ventilatory pressures and inferior vena cava compression can cause low BP, desaturation and lower limbs

hypoperfusion – if this is a case, abdomen should be reopen and surgery converted to silo procedure.

What is NEC?

Necrotizing enterocolitis/NEC/ - disease of small preterm infants, multifactorial etiology with the common feature of hypoperfusion of the GI tract, resulting in ischemia; initial signs-abdominal distention and bloody feces; shock may develop from multiple bowel perforations; patients often are hypovolemic; NEC is often associated with DIC and thrombocytopenia; N2O should be avoided and preoperative pressure maintained.

Anesthetic management: most infants are hypovolemic with a metabolic acidosis requiring fluid resuscitation; blood and blood products should be ordered; awake intubation is intubation of choice; anesthetic agents-opioids and ketamine; hypothermia is common problem.

What is pyloric stenosis?

Pyloric stenosis – incidence is higher in males; common in first-born males of parents who had pyloric stenosis; presentation: persistent, bile-free vomiting; the infant is dehydrated and lethargic; vomiting may be projectile, causing loss of hydrogen, chloride, sodium, and potassium ions from stomach; this results in hypokalemic, hypochloremic metabolic alkalosis. Olive-sized mass may be palpated in the mid-epigastrium; noninvasive diagnostic tests include ultrasound; pyloric stenosis is a **medical emergency** not a surgical emergency. Management of anesthesia: patients are at risk for pulmonary aspiration; the stomach should be emptied as completely as possible; induction of anesthesia may be variable-rapid sequence or modified rapid sequence , an awake oral intubation; NG tube should be inserted and left in place during procedure; narcotics are seldom necessary, rectal tylenol can be given.

When should you expect difficulty in managing a pediatric airway?

Congenital pediatric airway problem. Anatomically pediatric airways are narrower, resulting in greater resistance to air flow, and the tongue is relatively larger; all patients can be divided into those who will be difficult to intubate but can be ventilated by mask and those who are difficult or impossible to ventilate by mask. The latter group poses a more difficult anesthetic challenge and may require emergency tracheostomy; if child can be ventilated by mask, then a number of options-fiberoptic intubation, blind nasal intubation or use of a retrograde transtracheal wire can be attempted.

Hurler's syndrome /mucopolysaccharidosis type 1H/-associated with severe mental retardation, deafness, stiff joints, dwarfism, pectus excavatum, hepatosplenomegaly and severe valvular and early coronary artery disease; upper airway obstruction and difficult intubation are common, getting worse with age.

Pierre Robin syndrome-cleft palate, micrognathia, glossoptosis, CHD; early significant airway problems; intubation may be very difficult and should initially be

attempted awake; tracheostomy should be considered early; positioning patient prone, pulling the tongue forward, nasopharyngeal airway may be helpful.

Treacher Collins syndrome – the most common of the mandibulofacial synostoses; features: micrognathia, aplastic zygomatic arches, microstomia, choanal atresia, and CHD; fiberoptic intubation may be intubation of choice.

Goldenhar's syndrome – unilateral facial hypoplasia, mandibular hypoplasia, CHD and eye, ear and vertebral abnormalities; difficulty of tracheal intubation may be variable.

Crouzon's syndrome – congenital craniofacial synostosis, wide, towering skull with proptosis, maxillary hypoplasia and a beaked nose; maxillary hypoplasia can make mask ventilation difficult.

Cleft lip and palate – associated with more than 150 syndromes; risk for pulmonary aspiration; large defects can cause difficulty with intubation; postoperative airway problems are also common.

Anesthetic management: preservation of spontaneous ventilation is strongly recommended; H2 blockers preoperatively; several intubation approaches should be considered-awake, blind nasal, fiberoptic; with alternative methods immediately available/emergency bronchoscopy, cricothyrotomy or tracheostomy; variety of laryngoscopy blades, ETT, stylets; preoxygenation is recommended; all equipment should be also available before extubation.

What is tracheoesophageal fistula?

Tracheoesophageal fistula – type C, esophageal atresia with a distal TEF, is the most common/90%/ type; maternal polyhydramnios; diagnosis-excessive drooling, cyanotic episodes, coughing, inability to pass a soft catheter into the stomach. Associated conditions: prematurity, CHD, other midline defects, VATER syndrome. Pulmonary complications of TEF will not resolve until the fistula is ligated; often a preliminary gastrostomy may be performed. Intraoperative management: induction-inhalation, rapid sequence and awake intubation; avoid nitrous oxide; avoid intubating the fistula; optimal position of ETT-above carina but below fistula; attempt spontaneous ventilation to avoid gastric distention until fistula has been ligated, then controlled ventilation. Postoperative complications-tracheal compression, gastroesophageal reflux, esophageal stricture.

Fluid management in infants-normal daily water consumption in the infant is 10% to 15% of body weight; estimated fluid requirements may be calculated using formula"4-2-1" for weight less than 10kg – 4 ml/kg/hr, 10-20kg - 2ml/kg/hr. more than 20kg add 1 ml/kg/hr. When patient is NPO replacing one-half of the deficit in the first hour and one-fourth in the second and third hours in addition to maintenance requirements has been suggested. The sodium deficit/in mEq/ can be calculated as normal sodium – measured sodium x 0.6 x weight/kg/; for metabolic acidosis give one-half of the HCO3 calculated requirement/base deficit x weight/kg/ x 0.3/0,4 for infants/; potassium replacement is initiated only after adequate urinary output has been established. Blood replacement: estimated blood volume ranges from 90 ml/kg in neonates to 65 ml/kg in teenagers; the decision to transfuse depends on preoperative hemoglobin level, estimated surgical loss, the patient cardiovascular response.

Approximately 4 ml of PRBC per kg of body weight is required to increase the hemoglobin level by 1 mg/dL. Generally anything less than one-third acceptable

blood loss/ABL/ is replaced with 3 to 4 ml of crystalloid per ml of blood loss. Above ABL replace the total blood loss with red blood cells. Glucose management: one point of view is to give glucose containing solution to only infants and younger children/0-6m/; the easy way to prevent hypoglycemia and hyperglycemia is to use a D5LR solution at a maintenance rate.

What is persistent pulmonary hypertension in the neonate?

Persistent pulmonary hypertension in the neonate – leads to respiratory failure and death unless treated. It may be primary or secondary; secondary causes: meconium aspiration syndrome, hyaline membrane disease, neonatal sepsis with pneumonia, CDH, certain congenital heart defects. The key in this syndrome is increased PVR which induces a R-to-L shunt/PFO,PDA/. Treatment: mechanical ventilation, tolazoline, prostaglandin E2 and prostacyclin, isoproterenol, ECMO, nitric oxide.

How does croup differ from epiglottitis?

Croup versus epiglottitis – both present with evidence of airway obstruction; in 80% of all pediatric patients with acquired stridor, infection is the etiology. Of these 90% are due to laryngotracheobronchitis. Other causes of respiratory distress-foreign body, subglottic stenosis, tracheitis, retropharyngeal abscess.

	Acute epiglottitis	**Croup**
	3-7 years	6m-5 years
prodrome	none, or sore throat	usually URI
onset	abrupt, 6-24 hr	gradual
clinical course	rapid, may progress to cardioresp. arrest	usually self limited
hoarseness	no	yes
dysphagia	yes	no
dyspnea	severe	no
appearance	toxic, anxious, sitting upright	nontoxic
anteroposterior radiograph	tracheal narrowing	subglottic narrowing
WBC	marked elevation with left shift	variable
bacteriology	H. influenza	viral etiology, parainfluenza

Croup – in mild cases humidified air, fever control, hydration; racemic epinephrine; rarely is intubation or tracheostomy needed.

Acute epiglottitis – child must be disturbed as little as possible; transport to OR in the sitting position with airway equipment and skilled physician; do not attempt to visualize the pharynx; OR should be set for direct laryngoscopy, bronchoscopy and tracheostomy; inhalation induction with oxygen in sitting position; establish IV line; atropine may be given; perform laryngoscopy and intubate with tube smaller than predicted for age; extubation after AB therapy in 12 to 36 hr when air leak has developed around ETT.

What are some differences between pediatric and adult airways?

The Infant airway - position: larynx is more cephalad, rima glottitis is opposite the interspace of the C3 and C4; larynx is more anterior in infants. Epiglottis: is longer and stiffer, it tends to be U- or V-shaped, where the adult epiglottis is flatter and more flexible. Tongue: is relatively larger and more bulky. Laryngeal exposure: blade may have to be passed perpendicularly with the head in the neutral position; lifting an infants upper back and shoulder area is helpful in obtaining proper neck extension; gentleness in manipulation of the laryngeal tissues is important. Vocal cords: as the cartilaginous portion is angled down the trachea and inward, the infantile cords are concave, whereas concavity is minimal in the adult. The concavity of the cords in the infant may impede passage of a curved endotracheal tube. Pushing the tube slightly posteriorly with the blade will aid advancement. Cricoid ring: the narrowest point of the infant larynx is at the level of the cricoid cartilage, whereas the rima glottides is the narrowest point of the adult upper respiratory tract.

Selection of **endotracheal tube** size: 1-2-3/7-8-9 rule/1kg infant: 7cm at lip/; Idx3 gives the approximate position at the lip, add 2-3 cm for nasotracheal ETT; term newborn-3,0 or 3,5 ETT; 6-12m – 4,0 ETT; after 2 y/o – 16 + age/years divided by 4. Tubes one size smaller and larger should be immediately available during intubation. Confirmation of tube placement: suprasternal notch palpation/balloon/; condensation in ETT; ET CO2; bilateral breath sounds; O2 saturation.

How is temperature regulated in neonates ?

Four mechanisms of heat loss: radiation, convection, conduction, evaporation.

Factors that increase heat loss in infants: relatively larger body surface area, less keratin in skin/preemies/.

There are three mechanisms by which heat can be produced: increased physical activity, shivering – ability to shiver not present until~3 m old, nonshivering thermogenesis – the only means of heat production in anesthetized neonate, a result of brown fat metabolism. Cold body temperature - increase in norepinephrine production: 1.peripheral vasoconstriction, 2. pulmonary vasoconstriction/R-to-L shunting with hypoxia/, 3. brown fat metabolism, energy and heat production.

Very important is to keep OR temperature high; you may use warming lights, warming mattress, fluid warmer, warming blanket.

What is meconium aspiration?

Meconium aspiration pneumonitis is the leading cause of respiratory death in the full-term newborn. Meconium staining is present in 12% to 13% of all live birth and 36% of postdate pregnancies have meconium-stained fluid.

The immediate tracheal suctioning of infants born through meconium was first suggested in 1960. Recently the value of routine intratracheal suctioning has been questioned. Conditions associated with meconium staining: uteroplacental

insufficiency/late decelerations/, post-term pregnancies, maternal hypertension, placenta previa, maternal pulmonary disease, placental abruptions, cord prolapse and cord compression.

Meconium is the sterile breakdown product of swallowed amniotic fluid, gastrointestinal cells and intestinal secretions. Mechanical airway obstruction by particles of meconium plays the most important role in meconium aspiration syndrome. With complete obstruction atelectasis of distal alveoli occurs , causing R-to-L intrapulmonary shunt. Radiologic findings: infiltrates, hyperexpansion, and extra-alveolar air. Meconium aspiration may increase risk for persistent pulmonary hypertension after birth.

Current recommendations include the early suction of fetal mouth and pharynx before the delivery pf the shoulders. Intubation and tracheal suctioning are reserved only for depressed infants or exposed to thick particulate matter on emergence. The best treatment is the prevention of meconium aspiration.

What is Tetralogy of Fallot?

Tetralogy of Fallot consists of: pulmonary stenosis, VSD, overriding aorta and RVH. Physiology of TET spell: increase in right to left shunting via VSD, cyanosis. Management of TET spells: hyperventilate with 100% O2, decrease pulmonary resistance; phenylephrine IV – increase in SVR and SVR>PVR; L to R shunting, best used for acute treatment; fluid bolus; propranolol-best used for prevention.

Anesthetic management: must consider what will cause R to L shunting-decrease SVR, increase in PVR, increase in myocardial contractility. Factors that decrease SVR: volatile agents, histamine-releasing drugs, ganglionic blockers, a-blockade. Anesthetic factors that increase PVR: acidosis, hypercarbia, hypoxia, positive pressure ventilation/PEEP/, loss of negative intrapleural pressure when chest is open, nitrous oxide. Preoperative management: hydrate, continue b-blockers, avoid noxious stimuli/crying/. Induction – consider ketamine/increases SVR/; inhalation technique/halothane/.

What is CDH?

CDH most commonly presents shortly after birth as a true surgical emergency with respiratory distress and cyanosis. The primary problem in CDH is hypoplasia of the lung parenchyma and pulmonary vasculature with pulmonary hypertension. Left-sided hernias/left foramen of Bochdalek/ occur five times more often. Associated congenital problems: polyhydramnios, CNS anomalies, GI anomalies, genitourinary abnormalities, congenital heart defects. Clinical presentation: shifted cardiac sounds, scaphoid abdomen, diminished breath sounds on the affected side. The primary cause of death is progressive hypoxia and acidosis. The immediate therapy is endotracheal intubation along with placement of nasogastric tube.

Anesthetic management: most infants are urgently intubated in the delivery room. Positive-pressure ventilation with bag and mask should be avoided. The usual technique is oxygen/narcotic/relaxant. Nitrous oxide is contraindicated. Contralateral pneumothorax should be suspected if sudden changes in heart rate, blood pressure, PaO2 happening. The postoperative care of infants with CDH is critical. High frequency ventilation, ECMO, nitric oxide may be utilized

pre- or postoperatively. Selection criteria for ECMO may include hemodynamic instability, persistent acidosis, severe barotrauma. ECMO may be veno-venous or arterio-venous; in latter case there is possibility to support BP in patient. ECMO requires some degree of anticoagulation.

How is inhalation induction in children different from adults?

Anesthetic levels in the brain depend on anesthetic levels in the alveolus. The speed of induction depends on the speed at which alveolar concentration approaches the inspired concentration [rate of rise of Fa/Fi]. Factors speeding the rate of rise Fa/Fi : high gas inflow rates; high alveolar ventilation; high concentration of inspired gas; augmented alveolar ventilation; the concentration effect; the second gas effect; anything that reduces uptake of agent.

Factors affecting uptake of inhaled agents: 1. solubility: quantified by blood/gas partition coefficient, 2. cardiac output, 3. uptake by tissues, 4. intracardiac shunts - a R-to-L shunt will slow induction; L-to-R shunt have little effect on speed of induction, they can reduce effect of R-to-L shunts a little bit.

Inhalation induction is faster in children because: 1. smaller FRC, proportionately more alveolar ventilation, 3. organs are better perfused, 4. disproportionately large amount of blood flow to the vessel-rich group of organs/the brain/.

How does one provide neonatal resuscitation ?

Fetal assessment at delivery is via the Apgar score: Appearance/color/, Pulse, Grimace/reflexes/, Activity/muscle tone/, Respirations. Management of the abnormal Apgar: 7-10 – warm the baby, nasal/oral suction only; 4-6 – stimulate baby, suction airway, bag-mask ventilation with FiO2 1,0; if heart rate stays < 60, intubate; if heart rate remains < 80, begin compressions; additional resuscitation as needed.

Differential diagnosis for neonatal depression: drug addiction, perinatal drugs, hypovolemia, hypocalcemia, hypoglycemia, hypermagnesemia/treat with calcium/. Neonatal effects of hypermagnesemia: hypotonia, ventilatory depression, hypotension, increased sensitivity to muscle relaxants.

Neonatal resuscitation drugs: volume expansion, epinephrine 10-30mcg/kg, naloxone 10mcg/kg, $NaHCO_3$-rarely indicated, dose 1-2 mEq/kg; effects of administration-hypercarbia, hypotension, intravascular volume overload and intracranial hemorrhage, decreased hematocrit.

What are pediatric breathing circuits ?

The T-piece was used initially for spontaneous ventilation during anesthesia for infants. FGF of only 1.5 to2 times the minute volume is required to prevent rebreathing or dilution of inspired gases, minimal airway resistance and improved humidification are advantages of this system.

Mapelson added overflow valves and reservoir bag to the T-piece for better controlled ventilation. Mapelson D circuit: fresh gas enters at the patient end, and the overflow valve is near the reservoir bag. With inspiration, the patient inspires a mixture of fresh gas, alveolar gas and deadspace gas. The fresh gas flow determines the gas mixture in the corrugated tube. Because of rebreathing, all of

these systems require relatively high fresh gas flows to prevent hypercarbia. In general with infants FGF that is three times the minute ventilation can be used.

The Bain circuit places the fresh gas flow coaxial to the expiratory limb. The Bain circuit functions identically to the Mapelson D circuit. Advantages are: less equipment, less likelihood of kinking the endotracheal tube, ability to mount the Bain circuit on the anesthesia machine. The resistance in the pediatric circle systems is low, less than 0.3 cm H2O at flow rate of 10 L/min.

How is respiratory function different in infants as compared to adults ?

Infants must generate negative pressure 40-60 cm H2O for first few breath of life. Work of breathing more than in adults due to increased chest wall compliance and decreased lung compliance. Ribs are horizontally situated allowing less chest expansion than the angled ribs of the adult. The chest muscles are ineffective in assuming any work of breathing. Diaphragm is main muscle of respiration and is comprised of easily fatigued fibers. Neonates are at risk for respiratory failure whenever there is increased respiratory work..

Pulmonary parameters: TLC in infants/60cc/kg/ is less than adults/80cc/kg/; FRC is equal to adult on cc/kg basis; closing capacity constitutes ~ 50% of infant TLC whereas adult is only~35%; tidal volume is equal to adult/6-7 cc/kg/; O2 consumption is 2 to 3 times adult values; alveolar ventilation must be at least twice as much as adult value and this is achieved by an increased respiratory rate. Children have more alveolar ventilation and dead space ventilation than adults but their Vd/Vt is the same as for adults.

Factors that contribute to rapid desaturation in infants: high O2 consumption and smaller total volume at FRC; FRC is less than closing capacity, therefore during tidal exhalation they have airway closure occurring before they reach FRC/shunting during tidal breathing/; the elastic recoil of the lung exceeds the expansive forces of the chest wall; infants set their FRC by auto-PEEPing, ceasing their exhalation above the lung relaxation volume; in the apneic infant there is a smaller store to obtain oxygen from than in the apneic adult.

Causes of hypoxemia in neonates: intrapulmonary shunting secondary to unexpanded areas of lung; extrapulmonary shunting through patent foramen ovale or ductus arteriosus; undiagnosed congenital heart disease; high resting O2 consumption; hypothermia-increases O2 consumption.

Perioperative desaturation in neonates: /see above/ plus- airway obstruction; apnea; hypoventilation due to incomplete reversal of neuromuscular blockade, anesthetics; decreased FRC due to general anesthesia.

Factors predisposing neonates to postoperative apnea: prematurity/44-60 weeks PCA/; immaturity of central respiratory drive centers; hypothermia; hypoglycemia; hypocalcemia; acidosis; hypoxia.

What is a patent ductus arteriosus?

Most common cardiovascular anomaly that presents in the neonatal period. Common causes of PDA in newborns: prematurity, neonatal sepsis, pneumonia, acidosis, hypoxemia. Initial medical management involves digitalis, diuretics, and fluid restriction. Indomethacin can be given to stimulate closure of the ductus. Nitrous oxide, fentanyl, and ketamine in some combination are well tolerated in most of these infants. A fluid bolus at the start of the case improves tolerance to

anesthetics. Prostaglandin E2 can be infused in these patients to maintain ductal patency if necessary.

In shunt lesions the PVR-SVR ratios can be altered to improve ventricular workloads. High doses of narcotics and deep level of anesthesia can attenuate some pulmonary vascular responses. Vasopressors, usually a-agents, can be used to reduce R-to-L shunting and maintain coronary perfusion. Manipulations that alter PVR: increase PVR –

Hypoxia, hypercarbia, acidosis, hyperventilation, atelectasis, sympathetic stimulation, high hematocrit level, surgical constriction; decrease PVR – oxygen, hypocarbia, alkalosis, normal FRC, blocking sympathetic stimulation, low hematocrit level.

How do neuromuscular blockers act in neonates ?

The neuromuscular system is incompletely developed at birth and matures throughout the first year of life. The neonatal diaphragm is paralyzed simultaneously with peripheral muscles, in contrast to the resistance to diaphragmatic relaxation seen in adults. Infants have a greater extracellular fluid and blood volume in proportion to skeletal muscle weight than older children and adults, resulting in increased drug requirements. The reduced glomerular filtration rate in neonates is responsible for slower elimination of agents excreted by the kidneys. The neonatal myoneural junction is more sensitive to neuromuscular blockade and has less neuromuscular reserve when exposed to titanic stimulation.

Succinylcholine: neonates have a decreased sensitivity to its effects/50% less response than an adult to an equivalent dose/;the duration of muscle paralysis from succinylcholine is shorter in neonates. Masseter spasm can occur after succinylcholine administration. Inability to open patient's mouth may be a reason to cancel a case. Controversy exists as to the actual incidence of malignant hyperthermia/MH/ associated with masseter spasm. Bradycardia can occur with an intravenous bolus of succinylcholine.

Factors prolonging neuromuscular blockade: deficient pseudocholinesterase; abnormal variant of pseudocholinesterase;anticholinesterase-containing drugs; phase 2 block; hepatic dysfunction; hypermagnesemia; hypothermia; respiratory acidosis; hypokalemia; antibiotics-aminoglycosides, tetracyclines; lincomycines; polymyxines; other drugs – inhalation agents, local anesthetics, lithium, dantrolene, certain chemotherapeutic agents.

How can blood volume be calculated ?

An estimation of circulating blood volume should be made before induction of anesthesia. The blood volume of a premature infant /90 to 100 ml/kg/ constitutes a greater portion of body weight than that of full-term newborn/ 80 to 90 ml/kg/, an infant 3 m to 1 year old/70 to 80 ml/kg/, or an older child/70 ml/kg/. In an obese child the blood volume would be 60 to 65 ml/kg. From the estimated blood volume/EBV/, the initial hematocrit and the minimum acceptable hematocrit an estimation can be made of the maximum allowable blood loss/MABL/.

$$MABL = \frac{EBV \times (\text{pt's Hct} - \text{minimum accepted Hct})}{\text{Pt's Hct}}$$

What are toxic effects of local anesthetics ?

The major toxic effects of local anesthetics are on the cardiovascular and central nervous systems. Local anesthetics readily cross the blood-brain barrier to cause alterations in CNS function. Sequence of symptoms can be observed as plasma local anesthetic concentrations progressively increase, although this may not be readily apparent in infants and small children. With bupivacaine, cardiac toxicity and neurotoxicity may occur virtually simultaneously in pediatric patients, or cardiac toxicity may even precede neurotoxicity. The risk of cardiac toxicity may be increased by the concomitant use of volatile anesthetics and the CNS effects of the general anesthetic may obscure any signs of neurotoxicity until devastating cardiovascular effects are apparent.

In adults the earliest symptom reported is circumoral paresthesia, which is followed by the prodromal CNS symptoms of lightheadedness and dizziness, which progress to both visual and auditory disturbances/difficulty in focusing and tinnutis/. Objective signs of CNS toxicity during this time are shivering, slurred speech and muscle twitching. If plasma level of local anesthetic continue to rise CNS excitation causes generalized seizures.

Bupivacaine appears to have particular affinity for the fast sodium channels and perhaps also for the calcium and the slow potassium channels in the myocardium why it is so difficult to resuscitate patients after toxic dose. Ropivacaine is safer in relation to cardiac toxicity.

Careful observation of the ECG during test dose administration may be a sensitive indicator of unintended intravascular injection in the child. The significantly higher levels of free lidocaine and bupivacaine that result in infants are due primarily to the decreased level of a –1 – glycoprotein, which is the primary binding protein of these drugs.

There may be differences in the susceptibility of the neonate to the toxic effects. Plasma levels of lidocaine that produce cardiovascular and respiratory depression are about half of those causing toxicity in adults. Seizures and cardiovascular collapse have been reported in human infants at normal adult bupivacaine levels.

Caution should be exercised in the use of local anesthetics in infants. Infants and children may develop signs of systemic toxicity, including dysrhythmias, seizures and cardiovascular compromise from accumulation of epidural infusions of bupivacaine. Some recommend that both bolus and infusion doses of bupivacaine and lidocaine be reduced by 30% for infants under 6 m of age to decrease the risk for toxicity.

Treatment of toxic reactions. Inhaled anesthetics may actually raise the threshold for seizures and delay the detection of toxicity until cardiovascular collapse occurs. The progression from prodromal signs to frank cardiovascular collapse may be very rapid and the initial definitive therapy in some cases may need to be directed at re-establishing circulation and normal cardiac rhythm. Initial management – establishing and maintaining patent airway and providing supplemental oxygen. Administration of a CNS depressant that alters the seizure threshold /midazolam 0.05-0.2 mg/kg, thiopental 2-3 mg/kg, propofol 1-3 mg/kg/

may prevent seizures. Initial stage of cardiovascular toxicity consists of peripheral vasodilation so treatment should consist of IV fluid loading/10-20 ml/kg LR or NS/, titration of phenylephrine. Bretylium has been reported to be useful in restoring normal cardiac rhythm and perfusion. A report in infants found that phenytoin/5 mg/kg/ was particularly effective even when all other agents had failed.

Excretion of local anesthetic agents is hastened by hydration and alkalization of the urine by intravenous administration of sodium bicarbonate. Successful resuscitation of bupivacaine-induced cardiac toxicity was achieved by prolonged resuscitation or by placing the patient on cardiopulmonary bypass.

Oral exam questions

1. 5 year old boy had tonsillectomy done 2 days ago, developed bleeding from his mouth earlier today; pale, HR 110. How would you induce this patient?

Problems: hypovolemia, full stomach, blood in airway/difficult intubation/

Answer: I would start IV; give bolus of fluids and perform rapid sequence induction with cricoid pressure; would have suction with Yankauer tip ready. IV may be started under different conditions including cut down, central line. Patient may be positioned on a side for induction so blood will be coming out.

2. 6 years old coming to a hospital for BMT; has running nose fever with t-37.8 C; no significant PMH; family lives 50 m away from hospital.

Would you intubate this patient?

Problems: chronic otitis media; respiratory infection.

We have to distinguish between upper and lower respiratory infection/pneumonia/; physical exam will be helpful/ chest auscultation/; can we relate fever to chronic otitis media ? Proceed with acute PNA will be not safe; risk of complications much higher when you

intubate a patient as oppose to masking a patient; but you should be ready for intubation if you have to.

Answer: I would do physical exam, listen to patient's chest, rule put pneumonia; if there no PNA I would do this case and after premedication will mask this patient; will start IV if I have to/suspect possibility for difficult intubation, significant cardiac or lung history/.

3. 15 m old boy is scheduled for orchiopexy; there is strong family history of MH; no significant PMH; patient's weight is 10 kg.

How would you induce this patient?

Problems: family history of MH; should not use inhalation induction.

Patients with family history of MH may not develop MH on first exposure to inhalation agents but safety is always first so avoiding inhalation induction will be a good

choice. Other option will be starting IV and use propofol infusion alone or with combination with O2+N2O or narcotics/remifentanyl/. Premedication with versed/ 0.5 mg/kg/is a good choice and then IM injection of ketamine /5-8 mg/kg with robinyl /5-10 mcg/kg will make possible to start IV. Proper preparation of OR and anesthesia machine/vaporizers off/; flashing machine with high flows for ~ 20 min/ is very important. Proper observation of this patient in PACU; dantrolene is not given these days as prophylaxis.

First signs of MH will be unexplained hypercarbia and tachycardia.

4. 12 m girl with Tetralogy of Fallot scheduled for inguinal hernia repair; cardiac surgery not performed yet; O2 sat on RA ~ 90%; good physical tolerance. Otherwise no significant PMH.

How would you induce this patient?

Problems: TF/intracardiac shunt/; risk of air embolus. LV function?

TF: RVH, RV outflow tract obstruction; ASD/VSD; overriding aorta. Ideal agent for inhalation induction is halothane /decrease in myocardial contractility, relieve of RV outflow obstruction, bradycardia/; ketamine is also drug of choice; volume resuscitation is important before induction; avoid N2O; gentle ventilation; deair IV lines; for maintenance isoflurane may be used. Your actions should not decrease pulmonary blood flow. Antibiotic prophylaxis may be considered.

5. You are called to help with induction of a child. On your arrival to OR you see 4 year old boy with monitors on, colleague of yours is attempting mask ventilation; O2 sat is 60 and going down; ventilation with oral airway, LMA been attempted – unsuccessfully, DL – unable to intubate; as you approach OR table O2 sat is 50.

What would you do?

Obviously this is can not intubate, can not ventilate situation. Using difficult airway algorithm the only choice is left – cricothyrotomy. It is helpful to separate all airway tools and options in a way you can use them above or below vocal cords: above- oral airway, ETT, LMA, lightwand, Shikany stylet; below – tracheostomy or cricothyrotomy.

6. 6 y/o boy aspirated foreign body into a trachea; had full meal 2 hr ago; otherwise healthy; currently not in respiratory distress; no IV access.

How would you induce this patient?

Problems: foreign body in airway/may loose ability to ventilate/; full stomach

This is not a win - win situation. Mask induction may cause vomiting so it is very important to be prepared for that and have suction ready. Foreign body can move and obstruct airway and cause inability to ventilate so bronchoscope and a surgeon should be in OR. Option number one. You may bring parent in OR, keep child calm and start inhalation induction with 100% O2 and sevoflurane. In case of vomiting – put patient in lateral position, use suction. Start IV, then – propofol infusion and let a surgeon to do

bronchoscopy and remove foreign body. In case when during induction you are loosing ability to ventilate surgeon should perform bronchoscopy and either remove foreign body or push it forward below carina so you can ventilate at least one lung. Other option is to use IM injection of ketamine first and be prepared for possible complications.

7. 12 m old swallowed coin 4 hr ago; last meal ~ 4 hr ago; term baby, no significant PMH.

How would you induce this patient?

Problems: full stomach.

Ideally it should be rapid sequence IV induction with cricoid pressure. You may attempt to start IV when patient is awake. Other option will be slow inhalation induction with cricoid pressure, start IV and intubate. Suction with Yankauer tip should be readily available.

8. 8 years old autistic boy is scheduled for dental procedure. Refusing to drink oral versed, aggressive, combative; normal pediatric airway; no other significant PMH.

How would you approach this patient?

Problem here is to make transition from preoperative area to OR. There are several ways to do it. Oral premedication with versed is common practice and dose varies between 0.5-1.0 mg/kg. Additionally ketamine, atropine can de added to oral meds. Ketamine dart/IM injection/ 5-8 mg/kg alone or in combination with robinul/5-10 mcg/kg/ works fast and provides good condition even to start IV. Parents presence is always comforting for a child but not always helpful.

9. Term baby born in respiratory distress; cyanotic; breath sounds diminished on left side; flat abdomen.

Would you mask this baby with 100% of O2?

With this minimal information we should suspect possibility of CDH so this baby needs emergent intubation; mask ventilation is contraindicated because air in stomach will deteriorate respiratory status even more. This patient needs endotracheal intubation which should be performed by experienced person; “gentle” ventilation/low PIP pressures/, no N2O. Main problem is pulmonary hypertension which can compromise cardiac function as well. These patients may need nitric oxide, high frequency ventilation, ECMO and cardiac inotropic support.

10. 12 year old brought to ER, status post MVA, combined trauma, head trauma, bleeding out of his mouth; vital signs: BP-100/60 mm Hg, HR-120, O2 Sat on RA – 92%; mental status – obtunded. You are called to ER to help trauma team.

What would you do?

With combined trauma including head trauma and compromised mental status “A,B,C” sequence will be very much applicable for this situation. Patient most probably will go for CT study so securing his airway beforehand will be advisable.

How would you secure his airway?

Intubation with ETT is best choice. But head trauma and oral bleeding may make intubation difficult. One of the options may be DL after some sedation.

You did DL of this patient, he is still breathing spontaneously; you can see blood in his mouth but can not see epiglottis; O2 Sat is going down.

What would you do next?

In this situation further attempts to intubate patient or use LMA would only compromise patients status. You should proceed to emergency tracheostomy, under local anesthesia when other MD is masking this patient.

11. 1500g premature baby /ex 29 week, now 7 d old/ brought to OR for exploratory laparotomy, possible NEC; baby is currently on RA, no inotropic support; BP-45/28 mm Hg/mean 30/, HR 145.

How would you induce and intubate this patient?

Problems: low weight premature baby, possible NEC what may by lethal for this particular patient.

For this case “A,B,C” rule is very much applicable and there is not much room for mistake. OR set up and preparation is very important; temperature control also/OR temp, warming lights, warming blanket on OR table/. After all monitors applied baby may be intubated using 100% + sevo/5-6%/, breathing spontaneously; ETT size 3.0 should be appropriate; adequate IV access/2 IV lines/ is must; air and oxygen, no N2O; blood in OR and resuscitation drugs/including epi /- all should be available; inotropic drugs/dopamine, epi, dobutamine infusions/ should be prepared.

12. 3 weeks old term baby with history of vomiting for one week scheduled for pyloromyotomy.

Would you do this case today? And if yes how would you induce this patient?

Pyloric stenosis is medical emergency, not surgical. So patient first should be resuscitated with fluids and when electrolytes are in safe range/K >3.0; Cl >88, HCO3 < 30/ patient may be taken to OR. Pyloric stenosis causes hypokalemic hypochloremic metabolic alkalosis. Patient’s stomach should be suctioned/x 2/ when patient is awake; rapid sequence induction with cricoid pressure /STP or propofol + succinylcholine/ is advisable. Patient is usually extubated by the end of procedure after muscle paralysis is reversed.

13. 2 years old girl with Down syndrome scheduled for BMT and hearing test; patent ductus arteriosus; running nose, cough, no fever; never had general anesthesia before; weight 16 kg; NPO for 12 hr.

Would you do this case? If yes would you intubate this patient?

Problems: upper respiratory infection; difficult intubation; cardiac status; can we flex her neck?/atlanto-axial instability/

Mother tells that there is no other cardiac problems present as per pediatrician. On physical exam-lungs clear; as usually we have to differentiate between upper and lower /pneumonia/ respiratory infection. If we have strong suspicion for pneumonia CXR may be done. Baby sits in mothers lap and extends and flexes her neck significantly without any problem. Intubation in patients with Down syndrome is usually not difficult.

Anesthetic concerns in patients with Down syndrome: poor IV access; mental retardation; obesity; airway: large tonsils, large tongue, small subglottic area; cervical spinal stenosis, atlantoaxial subluxation; cardiac: VSD, ASD, TF, pulmonary hypertension.

After oral versed inhalation induction is method of choice; will start IV and place LMA; robinul may decrease secretions.

14. Two days old baby scheduled for TEF repair; he is in NICU, on RA, has PIV, weight 3,5 kg.

How would you induce this patient?

Problems: this patient has a high risk for developing pneumonia/TEF/ also we should look for possibility of VATER syndrome.

VATER syndrome: Vertebral defects, Anal malformation, Tracheo-esophageal fistula/TEF/, Radial and Renal dysplasia. Complete and intensive workup is necessary with special attention to cardiac and renal function. Type C, esophageal atresia with distal TEF is the most common/90%/ type. Sometimes gastrostomy under local anesthesia is done first.

Induction techniques include inhalation, rapid sequence and awake intubation. Avoid nitrous oxide; avoid intubating the fistula. You may attempt spontaneous ventilation to avoid gastric distention. Tip of ETT should be above carina but below fistula.

15. Term baby is born with omphalocele and transported to OR; PIV started in LD and baby received bolus of NS.

What problems you may encounter during this case?

Problems: other associated anomalies/cardiac, trisomy 21, Beckwith-Wiedemann syndrome-omphalocele, organomegaly, macroglossia, and hypoglycemia/; heat loss; dehydration; infection; hypoglycemia.

Anesthetic management is practically the same for omphalocele and gastroschisis. They are congenital defects of the anterior abdominal wall permitting external herniation of

abdominal viscera. Gastroschisis is not midline, has normally situated umbilical cord/not covered with a hernia sac/, and is rarely associated with other congenital anomalies.

The exposed viscera must be covered with a sterile plastic bag or film to limit evaporative heat loss. Deficit of fluid should be replaced aggressively; decompress the stomach. Awake or rapid sequence intubation is preferred.

Elevated intra-abdominal pressures, high ventilatory pressures and IVC compression can cause circulatory stasis in lower limbs – you have to open abdomen!

16. 12 years old boy with foreign body in left eye/open eye/ brought to OR; had full dinner 1,5 hr ago; no significant PMH. Has PIV.

How would you induce this patient?

Problems: open eye; full stomach.

Methods and agents useful in protecting against aspiration of gastric contents must be balanced against potential to increase IOP.

Simultaneous injuries need to be excluded before operation. Any unnecessary stimulation should be avoided because coughing or vomiting can raise IOP as much as 40 mm Hg or more. Avoid any external pressure/by mask/. Aspiration prophylaxis with an H2-receptor antagonist is advised.

After pretreatment with a nondepolarizing agent, rapid-sequence induction is generally the method of choice. Patient may be extubated in lateral position. Rocuronium may be a useful drug in this setting.

In case where possibility of difficult airway may be present succinylcholine may be used in combination with thiopental.

17. 16 years old girl, 260 lb, with history of fever for 2 m, cough, unable to lie flat scheduled for lymph node biopsy; short neck, otherwise fits criteria for easy airway; peripheral IV.

How would you induce this patient?

Problems: obesity, possible mass in mediastinum

You have to be very careful with patients if you suspect anterior mediastinal mass. Ideally imaging study (CT or MRI) should be performed before procedure. If you have results you should look and assess relationship between trachea and the mass. Clinical sign when patient is unable to lie flat points to tracheal compression. Induction with paralysis of such patient may cause complete tracheal obstruction and inability to ventilate. If you are already in this situation you may try to reposition this patient – put her on a side or even prone and this maneuver may relive obstruction. Small chances for success may be offered by placing patient on CPB.

Ideally lymph node biopsy should be performed under local anesthesia with some sedation (ketamine) and chemo- or radiation therapy should be done first. In response mass may shrink and tracheal compression may become less prominent.

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