

## Pediatric Anesthesia — Airway Management, Equipment and Management

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**Children are not little adults. With a prologue to pediatric anesthesia, this article focuses on the airway of a child and equipment for pediatric anesthesia, and concludes with a final touch on other anesthetic considerations for children.**



### Origin of Pediatric Anesthesia

Pediatric anesthesia as a **subspecialty** has come a long way. The humble origins can be traced back to 1842 when the rural physician **Dr Crawford Long**, rendered first documented **ether anesthesia** to an 8-year-old boy for a toe amputation.

Necessity is the mother of invention. The rise of pediatric surgery in the able hands of **Dr Ladd**, “the father of pediatric surgery” demanded a parallel development of refined pediatric anesthetic skills in **Children’s Hospital of Boston**.

**Dr. Charles H. Robson from Toronto’s Hospital for Sick Children** was the first pediatric anesthesiologist. His techniques of **open-drop ether** and **cyclopropane administration**, use of **tracheal intubations** in children in the 1930s fuelled pioneering research in pediatric anesthesia.

The **golden era** of pediatric anesthesia dates back to the 1980s and '90s.

The 21st century has witnessed the emergence of **congenital cardiac anesthesia** and **pediatric pain medicine** as subspecialties within pediatric anesthesia.

## Airway of a Child

Pediatric patients are not little adults. They have **unique anatomical differences** from adults which necessitate customized care. The airway of a child is not a miniature replica of its adult counterpart. The differences can be summarized as follows:

Organ/system	Characteristics in pediatric population
Breathing	Obligate nasal breathers
Tongue	Proportionately larger tongue
Head size	1/3rd of adult head
Occiput	Larger occiput
Larynx and trachea	Funnel shaped
Trachea	Short, neonates: 2 cm from cords to carina
Larynx	Anterior, cephalad, located higher in the neck (at C4 vs. C6 in adults)
Vocal cords	Slant anteriorly
Glottis opening	Glottis location different in prematures, C3-4 in newborns, C5 in adults.
Narrowest part of the airway	At cricoid cartilage (until age 6); in adults the narrowest part is at the vocal cords.
Epiglottis	Elongated and U-shaped
Diaphragm	Meager amount of type I muscle fibers with easy fatigability
Cartilaginous rib cage	Enhanced chest compliance
Chest	Circular with horizontal ribs
Abdominal muscles	Immature strength
Alveoli	Diminished size and number; reduced lung compliance

All these factors culminate in increased airway resistance as per **Poiseuille's law**, decreased residual lung volume, higher minute ventilation and increased oxygen consumption. In children, the oxygen reserve is tenuous with **underdeveloped respiratory drives**.

All these factors have a bearing in pediatric mechanical ventilation and management of airway.

Differences in other systems in pediatric population when compared to adults are tabulated as below for easy recall:

System	Differences
Circulation	Cardiac output is a function of heart rate. Absence of tachycardia to hypovolemia/hypotension Subnormal underdeveloped sympathetic and baroreceptor response
Renal function	Decreased creatinine clearance, sodium/glucose excretion, decreased diluting/concentrating ability: these facts attest to need for utmost attention to fluid administration.
Liver function	Naïve; drug clearance is prolonged
Glucose stores	Immature glucose stores and high glucose consumption predispose children to hypoglycemia.

Neuromuscular junction	Immature; drug action is prolonged
Muscle mass	Less as compared to adults; predisposing the pediatric population for longer action of drugs and increased risk of toxicity.

## Equipment for Pediatric Anesthesia

Airway devices for pediatric anesthesia have to be created **specifically for children**.

### Endotracheal tubes (ETT)

The characteristics of endotracheal tubes specially designed for pediatric population are as follows:

- Absence of cuff on the endotracheal tubes
- Smaller sized tubes

#### Size determination of endotracheal tubes:

- In neonates and infants, 3-4 size ETT suffices.
- For older children, the appropriate ETT size can be determined by the following formulae:
  - For uncuffed ETT:  $\text{Size} = 4 + \text{age} / 4$
  - For cuffed ETT:  $\text{Size} = 3.5 + \text{age} / 4$
- Other important factor is how deep the tube should be inserted to facilitate adequate ventilation.
- For cuffed tubes:  $\text{Depth in cm} = 3 * \text{internal diameter in mm}$

### Laryngoscope



**Image:** "Infant laryngoscope with AA battery for size comparison." by Erich Schulz, en:User:Erichgasboy - [http://en.wikipedia.org/wiki/Image:Infant\\_laryngoscope.jpg](http://en.wikipedia.org/wiki/Image:Infant_laryngoscope.jpg). License: Public Domain

The modifications in laryngoscope to suit the pediatric community are as follows:

- Smaller size of blades and handle
- Prevalence of straight blades to deal with the short, stiff epiglottis
- Straight blades: Miller, Phillips and Wis-Hipple
- Curved tubes are also available.

**Fiberoptic laryngoscope** has its own advantages. The examples include Bullard and Glide fiberoptic laryngoscopes.

**Special devices** have been built for children. They are as follows:

- **Precordial stethoscope:** for assessment of heart rate, heart tones and respiratory quality
- **Pre- and postductal pulse oximeter** in neonates (measurement of oximetry in either upper extremity and a lower extremity simultaneously).

State of the art technological advances in pediatric anesthesia include:

- Pulse oximetry-based hemoglobin determination
- Continuous cardiac output monitoring
- Anesthesia information management systems.

## Other Considerations for Children

Anesthesiologist providing care to premature babies, children requiring cardiac surgery, neurosurgery, burn surgery, thoracic surgery or other specialized and high risk procedures should have completed a **pediatric anesthesia fellowship** in addition to normal specialty training. Concerns in the pediatric population are unique. Some eminent ones are discussed below.

### Temperature management in children

Temperature regulation in children is a very crucial aspect of pediatric anesthesia. Children are prone to **hypothermia**. Because of their relatively larger body surface in relationship to their body mass, they lose heat much more rapidly than adults, hence it is very important to **maintain normal body temperature** in the OR and recovery room.

Few prominent reasons for this predisposition can be summarized as follows:

- Greater heat loss: thin skin, low fat content, high surface area/weight ratio
- No shivering until 1 year
- **Thermogenesis** by brown fat
- More prone to iatrogenic hypo-/hyperthermia.

**Temperature monitors** are commonly used. **Warmers** ensure normothermia.

### Fluid management in children

It is very easy to overload a child, so care with IV fluids and blood products is critical. Based on weight of the child, **maintenance fluid** can be estimated as follows:

- For 1st 0-10 kg: 4cc/kg/hr
- For next 10-20 kg: 2cc/kg/hr
- Above 20 kg: 1cc/kg/hr

The **optimum maintenance fluids** for children are: **D5LR, D5 with 1/2 NS and D5 with 1/4NS**.

One must calculate the **preoperative deficit** and replace the same using the following

protocol:

- In the first 1 hour: replace half of the deficit
- In next 1 hour: replace one quarter
- Replace the remaining one quarter in the third hour.

One must remember to add **additional 2cc/kg/hr for minor surgeries**. Additional maintenance fluid requirement can **escalate up to 10 cc/kg/ hr in case of major surgeries**. The same needs to be customized accordingly.

**Blood loss in surgery** is most of the times inevitable.

Pediatric anesthesia requires calculation of approximate blood volume of the patient, subsequent estimated allowable loss and consequent calculation of replacement to be given.

Total blood volume in children can be estimated as follows:

Age	Estimated total blood volume
Pre-mature baby	95 ml/kg
Term neonate	90 ml/kg
Up to 1 year	80ml/ kg
1 year	70ml /kg

**Estimated allowable blood loss** is calculated as:

Estimated allowable blood loss =  $Wt \text{ kg} \times \text{estimated blood volume} \times (\text{starting Hct} - \text{allowable Hct}) / \text{avg Hct}$

In pediatric population, blood loss replacement protocols are largely based on institutional practice and experience. A rough algorithm is as follows:

**After initial replacement with 3\*BSS or 1\*colloid; blood products are used in the following formulations:**

- Packed RBC: 10cc/kg
- Fresh frozen plasma (FFP): 10cc/kg
- Cryoprecipitate: 1U/10kg

**Fluid overload** in a child can manifest as **pulmonary edema**, **circulatory overload** and **coagulation abnormalities**. In certain circumstances, such as cardiothoracic surgeries, **invasive monitoring** is essential. It requires expertise and caution. Central venous line, with frequent cannulation of the IJV or femoral vein is used. Arterial line is most often sited in the right radial artery.

## Pain management in children

Earlier beliefs that neonates cannot experience pain have been demolished. Pain management is of equal significance in pediatric population when compared to adults. Pain management must be **customized to the personality, size and condition** of the child.

The various modalities of pain management available for children are summarized as follows:

<b>Regional anesthesia:</b> alternatives practiced in adults are also feasible in children. Epidural/ Spinal anesthesia are used. Caudal is the most prevalent
<b>Acetaminophen</b>
<b>Ketorolac</b>

## Perioperative concerns in children

**Enhanced recovery protocol** establishes optimal perioperative care in order to ensure better postoperative results. The salient features of perioperative care in pediatric anesthesia are mentioned below:

**Preoperative measures:** thorough history and physical examination form the keystone of successful patient care.

A special mention of any co-morbid illnesses; recent infections such as upper respiratory tract infection (URTI), however trivial, should be documented. Pre-operative work-up should be elaborate enough to help the anesthetist anticipate any specific difficulties he is likely to encounter during the procedure.

**Just adequate optimum starvation** is advocated. A simple algorithm is as follows:

<b>Food supplement</b>	<b>To be administered safely before following hours of the surgery</b>
Clear liquids	2 hrs
Breast milk	4 hrs
Formula feeds	6 hrs
Solid food	8 hrs

**Separation anxiety** is inevitable in children. The same can be alleviated with **anxiolysis** and **premedications**. Some ORs have the provision of **parental presence until induction**.

**Needle phobia** is common in children, so **inhalation induction** is more common.

**Intravenous access** is challenging secondary to presence of small veins and subcutaneous fat. Multiple sticks are discouraged.

## Risk of laryngospasm

Children often develop laryngospasm when recovering from anesthesia.

**Viral infection** in the preceding 2-4 weeks of [general anesthesia](#) increases the risk 5 times. It involves **involuntary spasm of laryngeal musculature** often secondary to **superior laryngeal nerve stimulation**. Recent URTI, tobacco exposure and extubation attempts when lightly anesthetized predispose a patient to laryngospasm.

### Treatment options

- Positive pressure ventilation
- Laryngospasm notch
- Propofol: 0.5-1 mg/kg/iv
- Succinylcholine 2-4 mg/kg im.

## Drug management in children

**Immature and underdeveloped drug scavenging systems** in the pediatric population predispose them to adverse effects secondary to use of anesthetic agents. Children generally require **larger doses** of induction drugs and maintenance drug compared to adults. **Meticulous calculation** of drug dosages is obligatory. In emergent

circumstances, one can estimate weight of a child using the following formulation:

**Weight (estimate) = 2\*age + 9**

Inhalation induction is rapid and blood pressure of neonates and infants is more sensitive to **hemodynamic effects of volatile agents**. Of record, opioids are more potent in neonates with escalated sensitivity to respiratory centers. **Neuromuscular blockers** demonstrate shorter circulation time.

One must exercise **caution against overdose**. Two important anesthesia drug related etiologies mainly prevalent in pediatric community are:

**Propofol infusion syndrome** is more prevalent in pediatric population. It can occur following 90 mcg/kg/min administration for as short as 8 hours. Manifestations include:

- Hemodynamic instability
- Hepatomegaly
- Metabolic acidosis
- Rhabdomyolysis
- Multiorgan failure.
- **Emergent detection and treatment** is essential to prevent untoward consequences.

**Malignant hyperthermia** is characterized by acute hypermetabolic state in muscle tissue. The incidence of malignant hyperthermia in pediatric population is estimated to be approximately 1:15,000 as opposed to 1:40,000 in adults. **Familial predisposition** and increased incidence in certain syndromes like **muscular dystrophies** exist. Succinyl choline and volatile agents are often the triggering factors.

**Manifestations** include **tachycardia**, **hyperkalemia** and **dysrhythmias**. The specific sign is **rapid rise in EtCO<sub>2</sub>**. Contrary to the expectations, rapid increase in temperature is rather a late sign.

**Treatment options** comprise of immediate discontinuation of the triggering agents, **Dantrolene** administration, cooling the patient and supportive symptomatic treatment as needed.

## Summary

Pediatric anesthesia has come a long way since its inception. Children, not being the same as adults, need modified attention and care in accordance to their physiological makeup, needs and pathologies.

Airway of a child is not the same as in an adult. The intricate differences have to be kept in mind while managing a pediatric patient.

Necessity encourages invention. The armamentarium of a pediatric anesthetist is well equipped of technologically sound, well formulated and customized devices to satisfy the specific unique demands of the pediatric population.

Temperature regulation, drug management, fluid management, pain management, perioperative concerns are other important factors considered in children.

# Review Questions

The correct answers can be found below the references.

## 1. Which is the narrowest part of the airway in a 3-year-old child?

1. Vocal cords region
2. Subglottis
3. Epiglottis
4. Cricoid region

## 2. Which of the following does not represent specialized equipment for pediatric anesthesia?

1. Uncuffed endotracheal tubes
2. Large laryngoscopes
3. Curved laryngoscopes
4. Fiberoptic laryngoscopes

## 3. Which of the following is not a true statement regarding fluid management in children?

1. For minor surgery, additional 2cc/kg/min fluid need to be added to the maintenance fluid calculation.
2. Packed RBC are administered at the rate of 10cc/kg.
3. One must calculate preoperative deficit and administer fluid accordingly.
4. One can give clear liquids only 4 hours prior to surgery.

## References

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Christine L. Mai, M.D. Myron Yaster, M.D. Courtesy: Pediatric Anesthesia: A Historical Perspective. Wood library museum.

**Correct answers:** 1D, 2B, 3D

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