

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

Before anesthesia, surgical procedures were difficult and dangerous. They were usually performed only as a last resort. In the 1840s, physicians discovered that substances like ether and chloroform effectively rendered patients unconscious, which launched the practice of anesthesia. A detailed history of anesthesia is available [here](#).

While the discovery transformed surgery, patients still suffered complications from anesthesia, especially children, mostly because of dosage regulation. Pediatric patients have **unique anatomical differences** from adults, and therefore require customized care.

Dr. Charles H. Robson, from Toronto's Hospital for Sick Children, is considered the first pediatric anesthesiologist. His techniques, which included **open-drop ether** and **cyclopropane administration** with **tracheal intubations**, inspired pioneering

research which made anesthesia safer for children.

By the 21st century, there were pediatric anesthesia subspecialties, including **congenital cardiac anesthesia, neurosurgical pediatric anesthesia,** and **pediatric pain medicine.**

Airway of a Child

The differences between a child's and an adult's airway can be summarized as follows:

| Organ/system | Characteristics in the 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 the 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 premature infants, C3-4 in newborns, C5 in adults |
| The 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 | A 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, per **Poiseuille's law**, as well as decreased residual lung volume, higher minute ventilation, and increased oxygen consumption. In children, the oxygen reserve is tenuous, with **underdeveloped respiratory drives.** These factors are important in pediatric mechanical ventilation and airway management.

Differences in other systems in the pediatric population, when compared to adults, are tabulated 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 the need for the utmost attention to fluid administration. |
| Liver function | Naïve; prolonged drug clearance |
| Glucose stores | Immature glucose stores and high glucose consumption predispose children to hypoglycemia. |
| Neuromuscular junction | Immature; prolonged drug action |

| | |
|-------------|---|
| Muscle mass | Lower than adults; predisposing the pediatric population for longer action of drugs and increased risk of toxicity. |
|-------------|---|

Equipment for Pediatric Anesthesia

Airway devices for pediatric anesthesia must be designed **specifically for children**.

Endotracheal tubes (ETT)

The characteristics of endotracheal tubes designed especially for the 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: $\text{Size} = 3.5 + \text{age}/4$
- Another 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. License: Public Domain

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

- Smaller-sized 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.

The fiberoptic laryngoscope, such as the Bullard and Glide fiberoptic laryngoscopes, has its own advantages.

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 post-ductal pulse oximeters** in neonates (simultaneous oximetry measurements in either upper extremity and a lower extremity).

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

Anesthesiologists 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. There are unique concerns in the pediatric population. Some of the more eminent ones are discussed below.

Temperature regulation in children

Temperature regulation in children is a crucial aspect of pediatric anesthesia. Children are prone to **hypothermia**. Because of their relatively larger body surface in relation 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.

A few prominent reasons for this predisposition include:

- Greater heat loss: thin skin, low-fat content, high surface area/weight ratio
- Lack of shivering in children under 12 months old
- **Thermogenesis** by brown fat
- Greater risk of iatrogenic hypo-/hyperthermia.

Temperature monitors are commonly used, and **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 the child's weight, **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 hour: replace half of the deficit
- In the next hour: replace one quarter
- Replace the remaining one quarter in the third hour.

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

Blood loss in surgery is inevitable most of the time.

Pediatric anesthesia requires calculating the patient's approximate blood volume, subsequent estimated allowable loss, and consequent calculation of replacement to be given. The total blood volume in children can be estimated as follows:

| Age | Estimated total blood volume |
|----------------|------------------------------|
| Premature 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 kg*estimated blood volume* (starting Hct- allowable Hct)/ avg Hct

In the 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**, or **coagulation abnormalities**. In certain circumstances, such as cardiothoracic surgeries, **invasive monitoring** is essential, which requires expertise and caution. A central venous line, with frequent cannulation of the IJV or femoral vein, is used. The arterial line is most often cited in the right radial artery.

Pain management in children

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

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

| |
|--|
| Regional anesthesia: alternatives practiced in adults are also feasible in children. Epidural/ spinal anesthesia are used. Caudal is the most prevalent |
| Acetaminophen |
| Ketorolac |
| Opioids: Morphine, Hydromorphone, Fentanyl |

Perioperative concerns in children

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

Preoperative measures: a 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. A preoperative workup should be elaborate enough to help the anesthetist anticipate any specific difficulties that may be encountered during the procedure.

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

| Food supplement | To be administered safely before/following surgery |
|-----------------|--|
| 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 permit **parental presence until induction**.

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

Intravenous access is challenging secondary to the 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 the use of anesthetic agents.

Children generally require **larger doses** of induction drugs and maintenance drugs than adults. **Meticulous calculation** of drug dosages is obligatory. In emergent circumstances, one can estimate a child's weight using the following formulation:

Weight (estimate) = 2*age + 9

Inhalation induction is rapid, and neonates' and infants' blood pressure is more sensitive to the **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 of the important anesthesia drug-related etiologies prevalent in the pediatric community are:

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

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

Malignant hyperthermia is characterized by an acute hypermetabolic state in muscle tissue. The incidence of malignant hyperthermia in the 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. Succinylcholine and volatile agents are often triggering factors.

Manifestations include **tachycardia**, **hyperkalemia**, and **dysrhythmias**. The specific sign is the **rapid rise in EtCO₂**. Contrary to expectations, a rapid increase in body temperature is a rather late sign.

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

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

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