Pediatric Airway

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Case Study

Steven is a CRNA at a community hospital, and in his practice, he rarely provides anesthesia for children. This evening, he's been called into the operating room to care for a small child with a surgical bleed following a recent tonsillectomy. Luckily for Steven, he recently completed the objective that you're working on right now, so he's armed with the basic knowledge of how to manage this child's airway when he arrives to the operating room.

By the end of this objective, you should have a working understanding of pediatric airway anatomy, the difficult pediatric airway, and an appreciation of the potential airway problems that commonly arise in the care of pediatric patients.

Pediatric Airway Anatomy

A thorough understanding of pediatric airway anatomy helps us to better understand the technical challenges associated with airway management in children. In this video, we're going to do a comparative analysis between the adult and the pediatric airway with a focus on the clinical relevance of these differences.

Until about 5 months of age, infants are preferential nose breathers. Obstruction of the nasal passages, such as bilateral choanal atresia, can impair ventilation and may necessitate emergency airway management if the infant is unable to convert to mouth breathing.

The infant has a larger occiput, and this flexes the neck when the infant is placed supine on a flat surface. Placing a roll under the shoulders will help to align the oral, pharyngeal, and laryngeal axes during laryngoscopy. The sniffing position is avoided, as it tends to move the laryngeal opening further from the line of site during laryngoscopy.

Most sources say that the infant's tongue occupies a relatively larger volume of the mouth, which increases the risk of upper airway obstruction and makes laryngoscopy more difficult.

In the adult, the glottis resides at about C5. In the full-term newborn, it's higher at about C4 and in the premature newborn it can be as high as C3. A higher glottic opening can be described as more superior, cephalad, or rostral, but it's a misnomer to describe the infant larynx as "anterior." A more cephalad larynx, coupled with a larger tongue, creates a more acute angle between the oral and laryngeal axes. For this reason, a straight blade is preferred as it helps to lift the tongue to better expose the pediatric larynx.

The adult epiglottis is shorter, floppier, and resembles a leaf or "C" shape. By contrast, the infant epiglottis is longer, stiffer, and resembles an Omega shape. Additionally, the epiglottis is angled away from the tracheal axis. Taken together, these differences make it more difficult to displace the epiglottis during laryngoscopy.

The adult vocal cords run perpendicular to the trachea, but the infant's vocal cords slant anteriorly. This explains why the endotracheal tube is more likely to get stuck at, or even injure, the soft tissue of the anterior commissure, particularly during

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nasotracheal intubation or when a blind technique is used.

In the adult, the larynx resembles a cylinder shape, where the laryngeal inlet is the narrowest region of the airway. By contrast, classic teaching suggests that the pediatric airway resembles a funnel shape, where the narrowest region is the nondistensible cricoid ring. There is, however, some data that challenges these classic teachings. For instance, newer research suggests that the laryngeal inlet is the narrowest region of the pediatric airway. So, which is it and, more importantly, why do we care?

Logically, we want to know the narrowest region of the pediatric airway, as this diameter determines the maximum size endotracheal tube that the airway can accommodate. Although some studies conclude that the laryngeal inlet is the narrowest region, we must recognize that the size of the laryngeal inlet is dynamic (that is to say that it changes) depending on a variety of physiologic circumstances such as if the patient is anesthetized or awake, spontaneously ventilating or apneic, or if the study was conducted on a living or cadaveric subject. Furthermore, the soft tissue of the vocal folds is highly pliable allowing it to be actively opened without risk of harm to the patient. Conversely, the cricoid ring is nondistensible. This means that it's functionally the smallest cross-sectional area of the pediatric airway. Therefore, the diameter of the cricoid ring limits the size of the endotracheal tube. Indeed, resistance to endotracheal tube insertion beyond the level of the vocal cords is likely at the cricoid ring. In this situation, a smaller endotracheal tube should be used.

Difficult Airway: Literature Part 1

The value of closed claims analysis is that it examines trends, and these trends can be used to identify mechanisms and patterns of patient injury. Such information can be used to assess the way that care is delivered and to determine if there are areas where improvement can be achieved. Let's examine the most recent (2007) closed claims analysis of pediatric anesthesia liability.

- There were over 500 independent cases of children under the age of 16 years.
- Death occurred in 41% of the cases.
- Brain damage occurred in 21% of the cases.
- Half of the claims involved children 3-years-old or younger.
- Twenty percent of the patients were classified as ASA 3 – 5.
- The most common events were cardiovascular (26%) or respiratory (23%) in origin. Compared to previous data, these findings reflect a downtrend in respiratory complications likely as a function of better monitoring capabilities.
- Respiratory events not preventable by monitoring (e.g., end-tidal CO_2 monitoring, pulse oximetry, etc.) included failed intubation, airway obstruction, aspiration, premature extubation, and airway trauma.

The authors noted that understanding the mechanisms that lead to pediatric patient injury provide an opportunity to develop strategies to prevent them from occurring in the future (1).

Difficult Airway: Literature Part 2

There is surprisingly little robust data available about the difficult pediatric airway in large, unselected groups of patients. What is clear is that a certain 'triple' relationship exists among very young age, a higher ASA score, and higher Mallampati airway assessment score. Of note, a child being overweight was not found to be associated with difficult intubation. Let's examine a few papers that help us provide context to this topic.

Recent work in Europe investigated the incidence and predictors of difficult laryngoscopy in over 11,000 pediatric patients undergoing general anesthesia with endotracheal intubation (1). The overall incidence of difficult laryngoscopy (defined by a Cormack and Lehane grade III/IV) was 1.4%. When the authors took age into consideration, the incidence of difficult laryngoscopy was 5% in children less than 1 year old and 0.7% in children over 1 year of age. Other findings strongly associated with a difficult airway included ASA III – IV status, low BMI (underweight), Mallampati score of III – IV, and those undergoing cardiac or oromaxillofacial surgery.

A more recent paper from the United States examined the incidence of difficult tracheal intubation in pediatric intensive care units using the National Emergency Airway Registry for Children (2). Here, difficult intubation was defined as a failed direct laryngoscopy or an intubation that required more than two attempts by experienced specialists. The clinician-researchers found an incidence of difficult intubation in 9% of the children. Strong association for difficulty was observed in children who were the youngest, those with a history of a difficult airway, and those with signs of airway obstruction. Both studies remind us that difficult intubation in the child is something that we must be prepared to deal with every pediatric patient that we encounter.

Difficult Airway: Practice Considerations

The response to a difficult pediatric airway must be preplanned, with the appropriate resources at the ready should the need arise. Iatrogenic injury can occur, and most likely will occur, if the same, repeated direct laryngoscopy maneuvers are performed. Case reports and retrospective reviews suggest that surpra-glottic edema and bleeding can occur in the child, even with attempts that appear to be gentle and atraumatic in nature. Because no single intervention (procedure or device) has been shown to be universally superior in all circumstances, it's important to have a preplanned approach that optimizes local resources, including personnel, devices, and processes. The benefit of this approach is detailed in an investigation of anesthesia-related deaths in over 100,000 pediatric patients in a highly resourced, tertiary care center with experienced pediatric anesthesia providers. Deaths related to issues of difficult airway management approached zero (1, 2). Simulation based education compliments clinical teaching, and experience and has shown that this improves technical skills and teamwork in managing the airway (3).

Airway Obstruction

A recent paper proposed an algorithm-based approach for managing the pediatric airway. Let's review the essential elements of these teachings, where the approach to care is based upon the fundamental underlying problem of anatomical, functional, and mechanical obstruction of the airway.

The most likely causes of anatomical airway obstruction are inadequate head position, poor facemask technique, and airway collapse, where the latter is quite common in the obese child or one with adeno-tonsillar hyperplasia. Generally, these problems can be overcome by repositioning the head, a gentle chin lift and jaw thrust, insertion of an oropharyngeal airway, and continuous positive airway pressure on the breathing bag. In some circumstances, a two-person facemask technique may be required.

Causes of functional airway obstruction include inadequate depth of anesthesia, laryngospasm, and opioid-induced glottic closure, opioid-induced chest wall rigidity, bronchospasm, and gastric distention that compresses the lungs.

Due to a higher oxygen requirement, children are less tolerant of inadequate oxygen delivery, where hypoxemia can lead to bradycardia and cardiovascular collapse. The use of a muscle relaxant to relieve unrelenting glottic closure unresponsive to positive pressure and Larson's maneuver is warranted, particularly when the patient is symptomatic (1, 2). Likewise, treatment of opioid-induced glottic closure or chest wall rigidity is typically unresponsive to positive pressure and therefore requires treatment with a muscle relaxant. Although there's a black box warning for succinylcholine in children, intramuscular succinylcholine is indicated for emergent use in the child without IV access. Acute bronchospasm can be treated with epinephrine, sevoflurane, albuterol, and even ketamine. Recall that the bronchioles are smooth muscle, so they won't respond to a neuromuscular blocker.

The possibilities (and realities) of objects that can cause a mechanical obstruction span the imagination. Chewing gum, batteries, small toys, coins, pins, regurgitated material, blood, peanuts, and virtually anything a child can fit into his mouth can lead to mechanical obstruction of the airway. The presentation can range from no signs or symptoms to coughing, hoarseness, stridor, or complete airway obstruction. In the absence of signs or symptoms or a witnessed event, the recognition of a foreign body in the airway may be delayed, not uncommonly for many days, and may result in worsening lung pathology.

The child who presents with mechanical obstruction of the airway is typically anxious, crying, and even combative. The great majority of literature suggests that general anesthesia is the safest method to retrieve a foreign body, where clear communication between the anesthesia provider and the surgeon/endoscopist is critical. The choice between maintenance of spontaneous ventilation and controlled ventilation is more often made based on personal preference and does not appear to affect the outcome of the care provided. A foreign body above the vocal folds can often be retrieved during direct laryngoscopy, however a foreign body below the vocal folds must be retrieved via bronchoscopy. Radiographic imaging, such at CT, may be required to determine the exact location of a foreign body.

LMA

Although a comprehensive review of all of the airway devices that can be used in the care of children is beyond the scope of this objective, we'd like to spend a few minutes discussing the role of the supraglottic airway in this patient population.

Since its widespread availability in the later half of the 1980s, the LMA has become widely regarded as an established alternative to mask ventilation and endotracheal intubation. Since then, a variety of new supraglottic airways and device modifications have emerged. Many of these are specifically designed to overcome issues associated with aspiration, oro-laryngeal injury, the ability to employ positive pressure ventilation, and general stability in the airway. One of the major concerns raised about this line of work was that, instead of crafting devices specifically manufactured with the unique aspects of the pediatric airway in mind, simple downsizing of adult devices was the general approach taken by the manufacturers. As a result, many reports have emerged that voice concerns that, in the context of pediatric use, these devices are difficult to place with a higher chance of them being malpositioned or even dislodged (3 – change number and add reference). Furthermore, additional reports documented concerns about cuff over-inflation leading to mucosal injury, sore throat, and failure to seal the child's airway.

Supraglottic airways have also secured a well-defined role in caring for the patient with an anticipated or unanticipated difficult airway. An unintended consequence of their widespread use is that prolonged mask ventilation is rarely employed in contemporary practice, with some voicing concern that the anesthesia provider's skillset regarding traditional mask management is eroding. In fact, the supraglottic airway typically appears early in various difficult airway algorithms, as they can often overcome supraglottic airway obstruction and can usually create a good seal when it's otherwise difficult to do so with a mask. The latter can be particularly problematic if there is trauma to the face, anatomical/pathophysiological facial deformity, a large tongue, or redundant tissue in the oropharynx. Additionally, many supraglottic devices (such as the Fastrach LMA) can serve as a conduit for tracheal intubation. Furthermore, the fiberoptic bronchoscope can be used to assist tracheal intubation when the LMA is used as a conduit (5 – need reference and new number). Key to using any supraglottic airway is gaining experience in doing so, either through simulations or their deployment in the routine, uncomplicated airway scenario.

Success with the LMA is highly dependent upon pharyngeal tone, head and neck position, shape of the oropharynx, and depth of anesthesia during placement. The cuff volume of the LMA is rarely given enough attention, and it should be titrated to the minimum volume required to achieve an airtight seal. Selecting the correct size device for the child is essential. Overinflating the cuff to compensate for a device that's too small can increase the risk of patient injury. LMAs have established utility in bypassing supraglottic pathology and in facilitating emergency oxygenation and ventilation for complex or difficult airway scenarios. Complications are more likely when using the LMA in infants and small children, particularly sizes 1 and 1.5.

Extubation

There's a surprising lack of recent literature examining the process of extubating the pediatric patient after routine (noncardiac) surgery. There is, however, some work examining extubation in the setting of tonsillectomy and adenoidectomy with respect to the incidence of laryngospasm. The key takeaway from this paper was that using a "no touch" approach (i.e. no stimulation until the patient spontaneously woke up) during anesthetic emergence was associated with a zero incidence of laryngospasm, desaturation, and severe coughing (1). Key limitations of this report were its observational design and small sample size of only 20 patients.

Other work recommends a variety of adjuncts at the end of anesthesia to smooth the extubation phase, including the use of propofol, dexmedetomidine, and lidocaine (among other drugs). But carefully controlled, large trials are absent and thus the extubation phase of care is managed in a wide-ranging manner based on the individual provider's preference and experience. It has been suggested that the incidence of laryngospasm and other adverse issues is reduced by either extubating patients in a deep plane of anesthesia or what essentially amounts to the patient being wide-awake.

One potential advantage of "deep" tracheal extubation as opposed to awake extubation is the avoidance (or lessening) of coughing and straining, either of which can provoke laryngospasm and oxyhemoglobin desaturation. The flip side of deep extubation revolves around concerns of aspiration risk and compromised airway reflexes during this phase of care. The literature is fairly conclusive that in a child whose airway was difficult to manage, the child should be awake for extubation, and a team of providers experienced with difficult airway management experience in the child, along with supporting equipment, should be immediately available.

Key Points

A comprehensive appreciation for what makes the pediatric airway different from the adult is essential.

Unexpected airway problems in children are common and require a pre-planned strategy.

Early muscle relaxation should be considered to resolve most functional airway problems.

Ideally, experienced pediatric providers in dedicated centers should manage the most complex difficult pediatric airways. For the occasional pediatric provider, acquisition and retention of airway management skills can be challenging.

Simulation based education compliments clinical teaching, and experience and has shown that this improves technical skills and teamwork in managing the airway.

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