Airway management in pediatric patients: an update

Surender K. Malhotra¹, Zahid Hussain Khan²

ABSTRACT

One of the crucial responsibilities of an anesthesiologist is to secure the airway for anesthesia or resuscitative purposes. The patients of pediatric age group differ from adults, both anatomically and physiologically. This is the basic reason that an anesthesiologist has to carefully evaluate and use specific devices and methods to safely manage the airway in pediatric patients. There are various syndromes that pose challenges in children due to distinctive pathology leading to difficult airway. In the present scenario in the field of anesthesia, many gadgets and tools are available that may assist in airway management in pediatrics. Though these devices resemble the ones used in adult age group but specific changes in methods may be employed to overcome the anatomical differences. This article deals with the perfect evaluation of airway as well as specific problems and their solutions in pediatric age group. The advances in simulation technology are quite helpful in providing training in the field of difficult pediatric airway. Following the recommended guidelines and algorithms would go a long way in securing a safe airway in pediatrics.

Key words: Pediatric airway; Difficult intubation; Airway, anatomy; Airway, Physiology; Abnormal airway

INTRODUCTION

Anesthesiologists have to learn a variety of skills to conduct anesthesia, particularly in the pediatric age group. Securing the pediatric airway is one of the tasks that require skill and dexterity. It is of vital importance that the pediatric anesthesiologist should have in-depth understanding of anatomy and physiology of the pediatric patient, especially the neonate and the infant. In addition, he/she should be familiar with the pathological aspects of pediatric airway. The knowledge of various devices and techniques currently prevalent is a must to manage the airway safely. Fortunately, the incidence of difficult airway is less common in pediatric age group as compared to the adults.¹,²

Most anesthesiologists are well trained to manage airway in the adult age group but children are not small adults. The methods and procedures required in pediatric patient are not similar, due to developmental differences. If the concerned anesthesiologist is prepared beforehand to manage the difficult airway, better results would follow. The present article underlines the vital dissimilarities in anatomy and physiology of an adult and a child. The congenital pathological conditions that may complicate the pediatric airway are described. The currently available devices, gadgets and procedures to manage airway in pediatrics have been considered in detail. The awareness of basic concepts, current guidelines, as well as, algorithms is vital to minimize complications related to pediatric airway management.³

MANAGEMENT OF PEDIATRIC AIRWAY

It is vital that the skill of managing pediatric airway should be regularly practiced. The recent advances in technology have led to safe and secure management of airway in pediatric age group. Current devices
have made a significant shift in advancement in this field. Though, technology has improved but we must be acquainted with the minute details of pediatric airway to achieve a successful outcome. The ASA Closed Claim Database has provided details regarding advancement in airway management of pediatric population. Till about two decades ago, the main concern was ventilation and oxygenation but the respiratory events have been on the decline in the last few years. In pediatric age group, the incidence of difficult airway that includes difficult ventilation and intubation is 0.25 to 3%, much less than that in adults.\(^1\) It has been observed that more than two attempts may lead to unsuccessful intubation or problems like hypoxia or even cardiac arrest.

**ANATOMY OF PEDIATRIC AIRWAY**

Securing the airway in pediatric age group is not similar is not similar to adults, as the anatomy differs considerably. The anatomical differences are more pronounced in newborns, neonates and infants. This results in difficulty in visualization of larynx during laryngoscopy.\(^4\) The child's head is relatively larger with a prominent occiput. Facial structures are smaller in size compared to the head size as the paranasal sinuses are absent.\(^5\) When the child is under anesthesia the airway gets obstructed easily as a result of flexion of neck. If a small pillow is placed under the shoulders, neutral position the neck becomes neutral and the airway obstruction is minimized (Figure 1).\(^6\)

Since the axis of trachea, oral cavity and larynx are not aligned due to larger size of head, occiput and a short neck laryngoscopy in pediatric patients becomes difficult.

In infants and younger children, the size of mandible is smaller and the tongue is relatively larger. For a few months after birth a child breathes through the nose. Around the age of 5 years, a child may develop enlargement of tonsils and adenoids. All these features may lead to difficulty in breathing and ventilation with a face mask, as well as, difficult laryngoscopy. Further obstruction of airway is likely while inducing general anesthesia since various anesthetics may reduce the tone of airway muscles. The hypo pharynx in a child is short and narrow, while the airway of adult is oblique and oval in shape.\(^7\)

**PHYSIOLOGY**

The pediatric age group, especially infants and neonates have specific physiological considerations
that may lead to hypoxemia and other consequences. The consumption of oxygen in infants is 6 ml/kg/min as compared to adults (3ml/kg/min) at rest.\textsuperscript{18}

Even after preoxygenation, the saturation may deteriorate during induction of anesthesia since FRC in infants is relatively smaller. The preoxygenation also does not provide enough safe period to avert desaturation in case of short duration apnea.\textsuperscript{19}

The production of carbon dioxide is raised in infants i.e. 130 mL/kg/min while in adults it is 60 mL/kg/min. To counter this larger production of carbon dioxide and removal, respiratory rate is higher. Since resistance to air flow is inversely proportional to the radius of pediatric airway, decrease in diameter due to inflammation or edema may lead to unwarranted respiratory complications. There are various pathological conditions that may increase the narrowing of pediatric airway. These may be congenital such as tracheomalacia or clefts in larynx or lesions like papilloma’s or hemangiomas within the trachea. Also, acquired problems like subglottic stenosis and vocal cord paralysis may add to the airway compression.\textsuperscript{20} In these conditions, any edema or inflammation may lead to further airway deterioration.

Laryngospasm may be total or partial. If total there is no chest movement, noise or bag movement. Mask ventilation is also not possible. In partial laryngospasm, chest movement, stridor and bag movement are present. Mask ventilation is possible to some extent.\textsuperscript{21} Various risk factors of laryngospasm include recent upper respiratory tract infection, secretions in the airway, and multiple attempts at intubation, upper airway surgery and inexperienced anesthesiologist.\textsuperscript{22}

**EVALUATION OF AIRWAY**

The outcome of anesthesia in pediatric patients depends on anticipating an airway problem and to plan accordingly. There is no single test for preoperative assessment of pediatric airway which is reliable or unanimously accepted.\textsuperscript{23}

Various diagnostic techniques to assess the pediatric airway include MRI and CT scan.

Routine clinical assessment of the airway may not be feasible in pediatric patients since they usually do not cooperate. MRI is superior to CT scan as it uses non-ionizing radiation. Moreover, MRI provides better soft tissue contrast and generates an image through each body-plane. For anesthesia purposes, ultrasound is appropriate to assess airway as it is easily available in modern anesthesia set-up. Though in adults, there are several studies assessing epiglottis, glottis, and cricoid cartilage and tracheal rings using ultrasound, there is scarcity of literature related to pediatric airway. Ultrasound is also helpful in measuring correct tube size as well as accurate placement of tracheal tube but routine practice is yet to be clinically established.\textsuperscript{24-26}

In pediatric age group, one must obtain history from parents pertaining to events that may lead to possible airway problems. Any history of difficulty in speech, breathing or feeding is important. If the parents narrate any event of sleep apnea, snoring or day time sleepiness would be informative regarding a difficult airway.

**Congenital syndromes and anomalies related to pediatric airway:**\textsuperscript{27}

There are various congenital syndromes that may have impact on management of airway in pediatric patients. In Goldenhar syndrome, cervical problem and micrognathia may complicate the airway. Pierre Robin syndrome is another well-known disorder that comprises of large tongue, cleft palate and micrognathia that may pose a serious situation in laryngoscopy and visualization of larynx. Treacher-Collins syndrome includes small mouth opening, underdeveloped zygoma and micrognathia. All three syndromes described above are related to oropharynx and oral cavity (Table 1). Apert syndrome includes large tongue, limited cervical movements, midface hypoplasia and micrognathia. Klipple-Feil syndrome presents with fusion of cervical spine. Microstomia is the highlight of Hallermann-Streif syndrome. The Down syndrome may pose difficult pediatric airway because of large tongue, small oral cavity and atlanto-occipital disorders.

As in case of adults, evaluation parameters are pertinent and relevant in children, too. Out of numerous factors that predict complex airway; decreased mandibular space, large tongue and restricted extension of head are dependable factors.\textsuperscript{28} A few scoring systems have also been described in literature .These are based on facial measurements and correlated to laryngeal view but are clinically not practical. Some of the studies have shown correlation between lip to chin distance and length of mandible with Cormack and Lehane grading of laryngoscopic view of the larynx.\textsuperscript{29} Hemifacial microsomia and congenital microtia have

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<tr>
<th>Site</th>
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<td>Oral cavity</td>
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<td>Mandible/Mandible</td>
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**Table 1: Congenital syndromes related to pediatric airway**
also been associated to difficult laryngeal view in a few studies.\(^{30,31}\)

There may be an important airway issue in craniopagus twins i.e. the conjoined twins who are fused at the cranium. Incidence of the condition is 10-20 children in every million births. The maintenance of airway in such twins is a challenge in its own way.\(^{32,33}\)

Some clinical conditions and systemic diseases, such as cardiothoracic surgery, individuals with low BMI, patients with Mallampati class III/IV, ASA grade III and IV and infants have been associated with difficult laryngoscopic view in up to 1.3% cases.\(^{34}\)

**TECHNIQUES AND DEVICES FOR PEDIATRIC AIRWAY**

An experienced anesthesiologist usually finds no difficulty in securing airway in routine pediatric patients. In some cases, problem in airway management may lead to hypoxemia, cardiac arrest or even mortality.\(^{35,36}\) In the long-term, the effects of hypoxemia during anesthesia are not well studied and documented.

Classification of pediatric airway problems: The difficulties faced in managing pediatric airway are classified into three categories:

A: Normal (anatomically and physiologically)

B: Impaired Normal (earlier normal airway but presently affected by swelling, trauma, burns etc.)

C. Known Abnormal (due to syndromes and congenital causes).

In straight-forward cases, securing the airway should not be a problem but in difficult airway the approach and strategy should be based on algorithms.\(^{37}\)

Problems and emergency situations: The basic aim of airway management in children is to ensure oxygenation and ventilation. Adequate ventilation with facemask is the key to the successful airway management and calls for regular practice and training. An experienced anesthetist never has a problem in ventilating a normal child.

Various tools and techniques to manage perioperative pediatric airway may include mask ventilation, oral and nasopharyngeal airways, various laryngoscopes, supraglottic devices, video-laryngoscopes, fiberoptic bronchoscopes and as a last resort surgical airway techniques. There are many options for induction of anesthesia in case there is anticipated difficult airway.

Mask ventilation: The basic skill in management of pediatric airway is adequate ventilation of the child with face mask using one or two hands. In case there is difficulty in mask ventilation following obstruction, it may be overcome by lifting the chin, extending the head, thrusting the jaw forward or using CPAP.\(^{38}\) Moreover, keeping the child in 'tonsillar position' i.e. left lateral position, lifting the chin and extending the head would help in maintaining the airway.\(^{39}\) Ventilating via face mask may add to the anatomical dead space which is a detrimental factor in infants.\(^{40}\)

Problems in mask ventilation may occur when head positioning is not adequate, child is obese or a foreign body is present in upper airway. Other causes may include laryngospasm due to light plane of anesthesia, bronchospasm, over-inflation of stomach and closure of glottis due to opioids. In a difficult situation following an obstruction due to anatomical or functional causes, an easy to remember algorithm should be followed to prevent hypoxemia (Figure 2).

Oral and Nasal airways: The oral airway may be helpful when mask ventilation is undertaken both in spontaneous or controlled ventilation since it helps in preventing the tongue fall. The suitable size of airway may be estimated by measuring the distance from angle of mandible to corner of the mouth.\(^{41}\) The nasal or nasopharyngeal airways may also be employed when any obstruction to airway occurs while ventilating with a face mask. These airways are also recommended for compromised airway to
insufflate oxygen or monitor EtCO2 while using fiberoptic bronchoscope.42

Supraglottic devices: These are relatively newer devices to manage airway. There are numerous devices available commercially and each device has indications advantages and disadvantages. Various considerations in using supraglottic devices are seal pressure, aspiration port, single or multiple use and material used for the cuff. Other factors include the learning curve and ability to insert a tracheal tube through the device. In pediatric age group, Classic as well as ProSeal laryngeal mask airway (LMA) have been found to be more useful and safe for ventilation, with success rates up to 98 percent.43,44 In a large study of 1400 patients, the difficulties and morbidity was as low as 11.5 percent.45 The ProSeal LMA has been used successfully even in infants in procedures such as laparoscopic surgery.46 In case of upper respiratory infection in pediatric age group, the use of supraglottic devices, have an edge over tracheal intubation. The use of LMA results in less respiratory problems than tracheal intubation.47 However, the use of LMA may lead to more respiratory complications in children with recent upper respiratory infection when compared with those with no history of such infection.48 The cuff pressure of LMA should be monitored intraoperatively so that it does not exceed 60 cmH2O. The higher cuff pressure may cause injury to mucosa due to higher perfusion pressure.49

It is ideal to keep the intra-cuff pressure around 40 cmH2O to prevent leak as well as pain in throat in immediate postoperative period. Several newer supraglottic devices, such as Fastrach, air-Q and I-gel are available through which tracheal tube may be directly placed with success rates of more than 95 percent.50-52

2.4.6. Endotracheal tubes: The skill of intubating the trachea is part of the basic training of anesthesiologists. The main goal is to avoid hypoxemia and not the intubation of trachea. Hence it is generally advised that it is the ventilation that may save the patient and not the intubation.

Numerous devices have been recommended to secure airway by intubating the trachea. The use of laryngoscope for tracheal intubation is a standard technique and various designs as well as sizes of blades are commercially available. For older pediatric age group, Macintosh laryngoscope is still widely used. The tip of the Macintosh blade is placed in glaso-epiglottic fold and larynx is visualized by lifting the epiglottis indirectly. In younger age group i.e. less than five years old, the epiglottis is relatively larger in size and not in same axis as trachea, it is difficult to lift the epiglottis indirectly. Hence, it is recommended to use the straight blade e.g. Miller blade or semi- curved blade to lift the epiglottis directly to visualize the larynx.53,54

In the past, uncuffed tracheal tubes were preferred in infants and younger patients, so to reduce the chances of subglottic trauma. Currently, there is increasing trend to use cuffed tracheal tubes in this age group, as now it is considered that conditions for ventilation are better with cuffed tubes. The frequency of laryngospasm is more with uncuffed tube than the cuffed one.55 The uncuffed ETT may lead to pressure damage to mucosa in the subglottic area even if the leak pressure is within normal range.56

It has been suggested that if the air leak can be heard with airway pressure < 20cm H2O, over-inflation of ETT cuff cannot be avoided. In a study, cuff pressures were found to be 40-60 cm H2O on an average while it should not exceed 30 cm H2O.57

Induction technique: When a difficult airway is anticipated, there are numerous anesthetic choices to induce the patient. Though induction with volatile agents has the advantage of spontaneous breathing but in case of increased depth of anesthesia, laryngeal and pharyngeal reflexes are depressed adding to the obstruction of upper airway.

Figure 3: Unanticipated difficult Intubation algorithm
A simple and easy to follow algorithm using the best available local facilities should be followed\(^5\) (Figure 3).

Still it is the most popular technique for difficult airway in children as revealed by many surveys.\(^5\) Regarding choice of narcotics, fentanyl and remifentanil are ideal for perfect intubating conditions and are widely preferred. For neuromuscular blockade, the choice of relaxant is between suxamethonium and rocuronium. The latter may be easily reversed with sugammadex though it has the limitation of not reversing other anesthetic agents that have been administered, concurrently.

**Fiberoptic bronchoscope:** For anticipated difficult airway in adult patients awake intubation using fiberoptic bronchoscope is the technique of choice, since it allows longer period of time to intubate, while the patient is breathing spontaneously.\(^6\)

Since cooperation is lacking in pediatric age group the choice of awake intubation is not practical. There are techniques that may be employed using supraglottic devices to achieve fiberoptic intubation. In one technique, supraglottic device is placed and fiberoptic is used through an exchange catheter or Aintree. After entry into the trachea, fiberoptic bronchoscope and supraglottic device is removed and exchange catheter or Aintree is left in trachea over which tracheal tube is advanced.\(^6\)

Alternatively, fiberoptic bronchoscope is passed through an already placed supraglottic device to enter trachea. A guide wire is passed through the drug port of the scope and left in trachea. Both fiberscope and supraglottic device are removed and a bougie or exchange catheter is advanced over the wire followed by placement of tracheal tube over the bougie or catheter.\(^6\)

**Video-laryngoscope:** This is a useful device that makes laryngoscopy much easier and successful. Various video-laryngoscopes in the market are C-MAC, King Vision, Glidescope McGrath among others.\(^6\) An improved view of larynx can be achieved when it is difficult or impossible to do so by direct laryngoscopy, as revealed by various trials using the video-laryngoscopes.\(^6\)

A video-laryngoscope cannot replace the practice of standard direct laryngoscopy since they may not be available all the times and may not be suitable for all clinical situations. Efficiency in skill of mask
ventilation and direct laryngoscopy is the basic of pediatric airway management.

**Surgical Airway:** The challenges in management of airway may be either due to inadequate ventilation with face mask or failure to secure airway by tracheal intubation. These two factors may sometimes lead to the development of “cannot ventilate, cannot intubate” scenario. In 2015, APAGBI Pediatric Difficult Airway have suggested Guidelines for this situation (Figure 4).

In case, oxygen desaturisation occurs following both an unsuccessful mask ventilation and tracheal intubation, needle cricothyroidotomy is recommended. This emergency technique may be more difficult in pediatric age group. The needle may cross-puncture the elastic trachea and pierces the esophagus. The hazards of cricothyroidotomy in younger children below 5 years of age are greater than in adults; hence direct surgical cricothyroidotomy is a preferred choice in younger children. On the other hand, it is documented that cricothyroid membrane in neonates is of small, hardly measuring 3 mm in size. Moreover, in infants, laryngeal prominence is not appreciated so it is difficult to detect thyroid cartilage. Therefore, percutaneous puncture between the tracheal cartilages should be preferred to secure emergency airway and ventilation.

**Extubation of pediatric airway:** Extubation in pediatric patients is a risky situation. The decision to extubate the child in deep plane or awake with adequate respiratory efforts lies with the concerned anesthesiologist. In case the intubation was difficult, it is recommended to extubate when the child is fully awake, respiratory efforts are adequate and airway reflexes are appropriate. Some anesthesiologists are in favour of extubation in deep plane of anesthesia to minimise the extubation response but it may be associated with respiratory complications. In case the child has undergone surgery in prone position, the extubation should be done more carefully so as to avoid accidental extubation.

**Rapid Sequence Induction in pediatric patients**

There has been a controversy regarding Rapid Sequence Induction and intubation (RSII) in pediatric age group. It is established that RSI prevents regurgitation and aspiration in patients with full stomach. This includes preoxygenation for a few minutes followed by administration of hypnotic agent and depolarising muscle relaxant accompanied by Sellick's manoeuvre or application of cricoid pressure. At the same time, problems associated with RSI such as hypoxia, difficult intubation and bradycardia have to be considered. The concept of “Controlled rapid sequence induction and intubation (cRSII)” has been advocated which includes administration of hypnotic agent followed by nondepolarising muscle relaxant. A gentle mask ventilation is carried out without the use of Sellick’s manoeuvre. This study by Neuhaus et al using cRSII involving over one thousand children found no hazardous conditions for tracheal intubation while administering general anesthesia in full stomach pediatric patients. The contraindications of administering succinylcholine in RSII still remain the same i.e. children with muscular disorders.

**CONCLUSION**

One of the major responsibilities and expertise an anesthesiologist should possess is the successful management of airway, particularly in pediatric age group. There are considerable differences in airway management in children when compared to those in adults. The anesthesiologist should have thorough understanding of anatomy, physiology and various congenital and complicating syndromes before making a successful strategy for securing a pediatric airway. With thorough knowledge of basic concepts, proper use of various devices and suitable algorithms, the hypoxemia in children can be avoided perioperatively. In the past few years, there has been considerable evolution in pediatric airway. There has been a significant change in anesthesia training in this age group. The cricoid ring that was believed to be the narrowest part of pediatric airway is less likely as shown by the recent studies. Further research is needed to assess the airway in pediatric population. Through, regular practice and training, morbidity and mortality related to pediatric airway can be significantly minimized.

**Conflict of interest:** The authors declare no conflict of interest involved.

**Authors’ contribution:** Both authors contributed equally in preparation of this manuscript.
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HONORS & AWARDS

RICHARD ‘HARRY’ HARRIS AND CRAIG CHALLEN HONORED

Cave rescue divers Australian Anesthetist Richard ‘Harry’ Harris and his colleague Craig Challen have both been named 2019 Australian of the Year for their heroic efforts in saving 12 boys from a flooded cave in Thailand. “Richard Harris and Craig Challen led a heroic rescue under the spotlight of the world’s media. They placed the safety of others above their own and inspired hope when hope seemed lost,”

Dr Harris’s medical expertise was instrumental in the plan to safely evacuate the children.

After swimming through the narrow cave system to assess the health of those trapped and giving the medical all-clear for each child, he administered an anesthetic to each to enable their rescue and remained underground until the last evacuee was safe.

Dr Challen’s technical expertise was critical to the rescue and he worked 10 to 12 hours each day in perilous conditions to swim the children one-at-a-time through the dark and narrow flooded caves.

The pair had been about to leave for a cave-diving holiday when they received the call for help with the delicate rescue mission.