

**Research Article**

Pediatric Airway Management: Steps through the Time

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Introduction

Perioperative morbidity and mortality are still high among pediatric patients undergoing anesthesia. The incidence of perioperative critical events is 5,2% [1]. Out of which, respiratory complications related to the airway management are one of the main causes with the incidence of 3,1% [1]. Firstly, laryngospasm and bronchospasm, prolonged unsuccessful intubation, all of that is leading to hypoxia, and hypoxia to cardiac arrest, major disability, neurologic deficit or death. Other main causes for high incidence of perioperative morbidity and mortality undergoing anesthesia are cardiac (hypotension and bradycardia), allergic and neurological complications [1]. These complications are not dependant on the type of anesthesia, as the major risk factor is actually age [1]. APRICOT study revealed evidence supporting the beneficial effect of years of experience of the most senior anaesthesia team member for respiratory and cardiac critical events, rather than the type of health institution or providers [1]. In addition, NECTARINE study showed that perioperative complications in infants associated with increased risk of morbidity and mortality are mainly hypotension (>30% decrease in blood pressure), reduced oxygenation ($SpO_2 < 85\%$), and anemia [2]. Risk of those critical events increases by congenital anomalies, prior neonatal medical conditions, patients requiring intensive care, and postmenstrual age [2].

Reviewing data shows us that the real progress in the management of pediatric airway, and changes in pediatric anesthesia altogether, started in the first decade of the 21st

century with EXIT (ex uteri intrapartum treatment) intubation, and fiberoptic bronchoscopy and videolaryngoscopy as golden standards in daily practice for management of difficult airway. Then, over the following years, the guidelines were, at first, a modification of adult based approaches, and only later were the guidelines made specially for pediatric patients. Over the following years, the neuromuscular blocker was added to the guidelines, and the ultrasound started being used in airway management. The next step was ECMO (Extracorporeal membrane oxygenation) incorporation in protocols of resuscitation. Later on, the Vortex protocol was implemented, and the latest addition was apneic oxygenation. Nowadays, during this pandemic, there are special airway management protocols which define the standard of care for COVID-19 patients [3].

Discussion

Based on past history (data about previous prolonged intubation), physical changes (recently upper airway respiratory infections, bronchial hypersensitivity, sleep apnea, snoring, chronic cough or sudden onset cough, stridor) and anatomical abnormalities (facial end ears dysmorphism, limited neck mobility, big tongue, limited mouth opening and recessive mandible) pediatric airway is classified into normal airway, altered difficult airway (suspected, impaired, acquired, unanticipated or unexpected as mentioned frequently in literature) and anticipated difficult airway (expected, known abnormal, as mentioned frequently in literature) [3-8]. Normal airway is a healthy airway without past history of physical and anatomical disorders and routine airway management is normally easy [3,8]. But even the normal, healthy

pediatric airway could become difficult during the anesthesia. Reasons could be anatomical, such as: upper airway collapse, adenoid/tonsils hypertrophy, and/or functional: laryngospasm and bronchospasm caused by inadequate depth of anesthesia, gastric hyperinflation, or muscle rigidity [6,8]. These situations are time critical and demand fast recognition and treatment in order to avoid hypoxia and prevent other serious consequences.

Altered difficult airway is previously healthy and normal airway but due to the foreign body, trauma, burns, allergies, and inflammation (epiglottitis, croup, submandibular/perimandibular abscessus) they require complete management of difficult airway with adequate personal and minimum standard equipment [3,8]. Children with congenital abnormalities and syndromes are pediatric patients with anticipated difficult airway and should be handled and observed in special centers with experienced pediatric anesthesiologists and high standard equipment appropriate for managing difficult pediatric airway [3,8]. When speaking of complications in airway management, it is important to mention the NAP4 Major Complications of Airway Management in the United Kingdom study, which provided detailed information about the factors contributing to poor outcomes associated with airway management in adult patients [9]. Those same claims could be applied to pediatric patients as well.

Thanks to NAP4 study we have realized how problematic it is to make multiple attempts at intubation, inappropriately use SADs (Supraglottic airway devices) and when AFOI (Awake fiberoptic intubation) is indicated but not performed [9]. There must be a limit to direct laryngoscopy attempts in children. Most often, more than two tries should not be performed. The pediatric airway is sensitive to trauma and swelling and we should be thinking about switching to indirect laryngoscopy much sooner, if we run into trouble [8]. Success rates of first attempts in the pediatric difficult airway population were found to be substantially higher in video than in direct laryngoscopy (55% vs 3%) [8].

LMA is a useful and powerful supraglottic airway device for the management of both, routine and difficult pediatric airway. Over the years, various designs (1st, 2nd, and 3rd generation) and insertion techniques have been: described, accepted widely, and incorporated into difficult pediatric airway algorithms. Awake fiberoptic intubation is an invasive difficult airway management technique acceptable for adult patients. However, due to inadequate cooperation, it cannot be applied to children. Intubations in children are performed under general anesthesia or deep sedation. Remember that fiberoptic intubation is considered as the gold standard of difficult pediatric airway management and needs practice [8]. But, the primary goal of pediatric airway management is to ensure oxygenation and ventilation, not intubation [7,8].

Do not forget that bag-mask ventilation is the cornerstone for successful oxygenation and ventilation. But good bag-mask

ventilation technique requires daily practice. Difficult face mask ventilation in healthy children is very rare (incidence is 0.02%) [8]. There are two techniques of bag-mask ventilation: one-person bag-mask ventilation technique, performed with the left hand gripping E-C (third, fourth and fifth fingers lift the jaw up, thumb and index fingers hold mask tight against the face) and with the right hand bagging, and two-persons face mask ventilation technique which means E-C is gripped with both hands of one provider and the other provider does bagging [8].

During ventilation the patient's head needs to be in a specific position. With pediatric patients, the positioning depends on the child's age. In infants and toddlers occiput is relatively large and airway management should be performed with a small towel under the shoulders to avoid flexion of the neck. Sniffing is the optimal head position to open the upper airway for preschool and school children. In teens and adults for optimal head position to open the upper airway, recommendation is to put a pillow under their head and shoulders. Just like the adequate size of a face mask (large enough to cover the mouth and nose) is important, different sizes of oropharyngeal and nasopharyngeal airway are also very important for successful ventilation and oxygenation.

Predictors of a difficult pediatric airway include: younger age (particularly < 1 year old), congenital malformations, and emergencies (1-5). One of the very useful tools for prediction of difficult airway assessment is mnemonic LEMON [8]:

L look externally (facial trauma, large incisors, large tongue, short neck, micrognathia)

E evaluate the 3-3-2 rule (incisor distance/mouth opening - 3 child's finger breadths, hyoid-mental distance - 3 child's finger breadths, thyroid-hyoid distance - 2 child's finger breadths),

M Mallampati (Mallampati score > 3; in children we are using modified Mallampati score performed with pressing the base of tongue with wooden spatula)

O obstruction (presence of any condition like epiglottitis, edema, peritonsillar abscess, trauma...)

N neck mobility (limited neck mobility)

Mnemonic **DOPES** is useful to exclude and treat unexpected tracheal tube (TT) ventilation problems [8]:

D displacement of TT

O obstruction of TT (secretions, blood, tracheal wall, punch, tracheal foreign body)

P pneumothorax

E equipment problems

S stomach (increased intraabdominal pressure)

Poor airway assessment leads to poor planning, poor planning leads to poor outcomes [9]. Great example of how important assessment, planning, education, training, and practice combined are in helping with proper airway management of pediatric patients is the multidisciplinary program of Johns Hopkins Hospital. This program includes: Pediatric Difficult Airway Response Team, Pediatric Difficult Airway Consultant Service, and biannual multidisciplinary pediatric airway management educational course with the goal to create a service to optimize patient safety, eliminate morbidity associated with pediatric airway management and mitigate stress among providers [10]. The first algorithm dedicated to handling difficult pediatric airway, which guides me in my daily practice, was a modification of DAS guidelines for management of difficult airway in adult patients [4,6,7] (Figure 1).

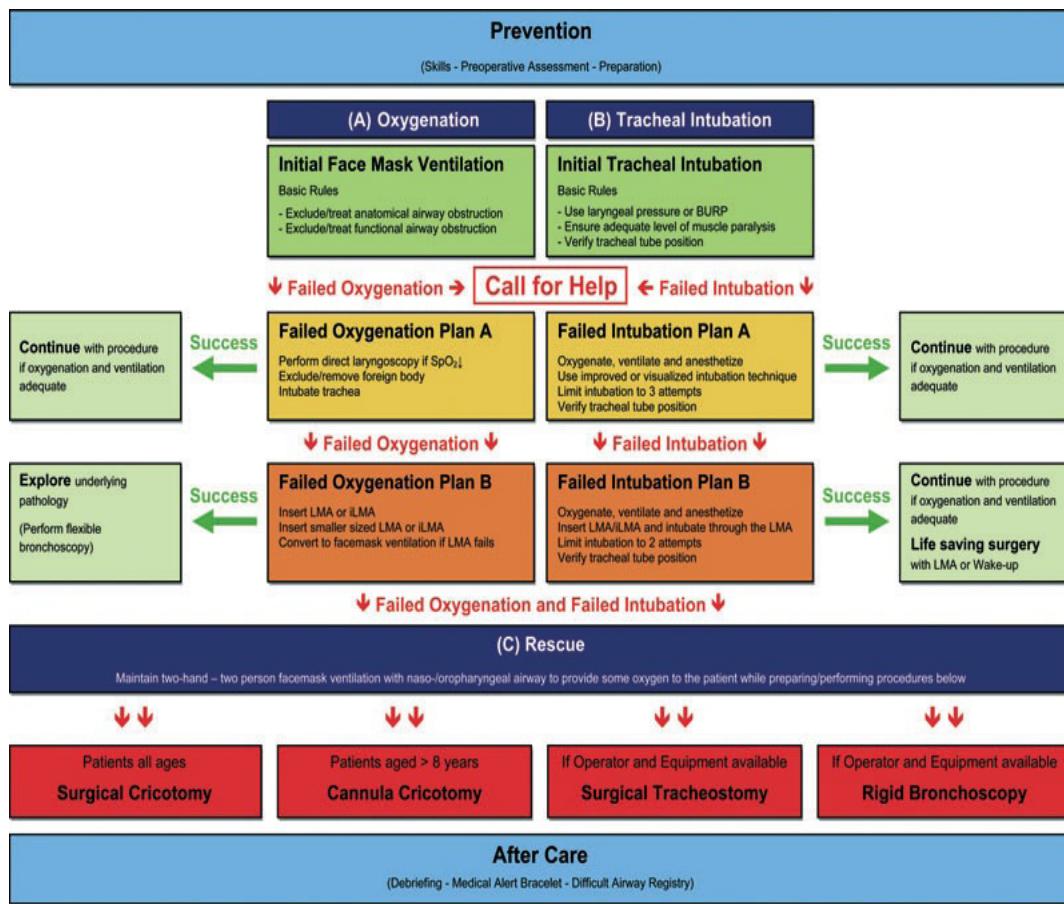


Figure 1: Unanticipated difficult pediatric airway algorithm [Adapted from Difficult Airway Society].

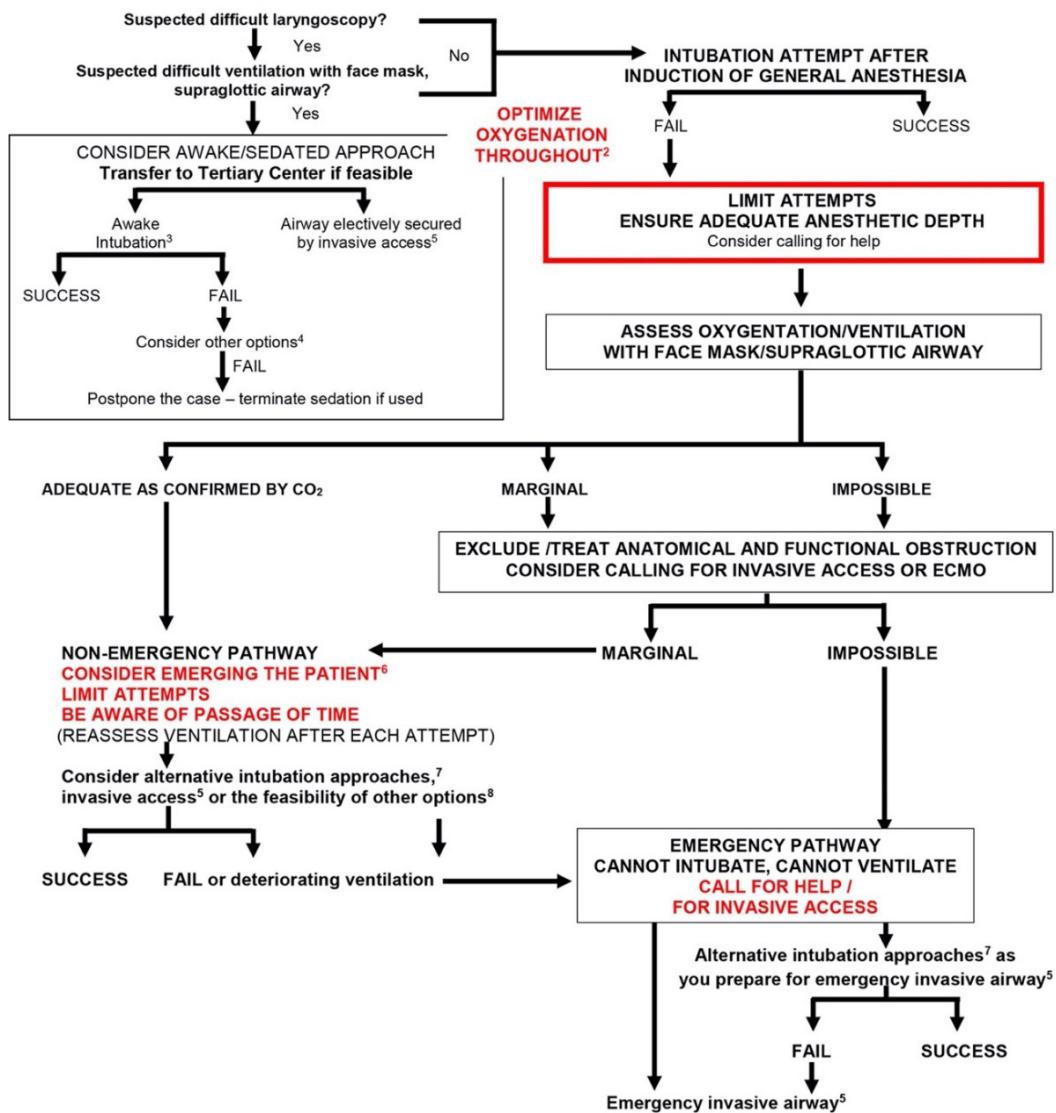
Afterwards, DAS guidelines were made especially for the management of difficult airway in children aged 1 to 8 years, there were three guidelines in total (<https://www.das.uk.com/guidelines>):

- Difficult mask ventilation during routine induction of anaesthesia in a child aged 1 to 8 years
- Unanticipated difficult tracheal intubation during routine induction of anaesthesia in a child aged 1 to 8 years
- Cannot intubate and cannot ventilate (CICV) in a paralysed anaesthetised child aged 1 to 8 years.

Next is the Vortex protocol, created by consultant anesthesiologist in Australia. It consists of a funnel visual schematic airway management guidelines, using three of four life lines: facial mask, supraglottic devices and endotracheal intubation³. This protocol allows clinicians the freedom of flexibility in handling airway management using whichever lifeline is felt to be the most appropriate in maintaining the patient in the green safety zone, with adequate oxygenation and ventilation. The fourth lifeline neck access is activated when the previous modalities have failed (<http://vortexapproach.org>) [3].

ASA DIFFICULT AIRWAY ALGORITHM: PEDIATRIC PATIENTS

Pre-Intubation: Before attempting intubation, choose between either an awake or post-induction airway strategy. Choice of strategy and technique should be made by the clinician managing the airway.¹



Finally we have American Society of Anesthesiologists Practice Guidelines for Management of the Difficult Pediatric Airway, the newest one, with purpose to guide the management of children with difficult airways, optimize first attempt successes, improve patient safety during procedures, and minimize/avoid adverse effects [11] (Figures 2, 3).

Figure 2: ASA Difficult Airway Algorithm: Pediatric Patients.

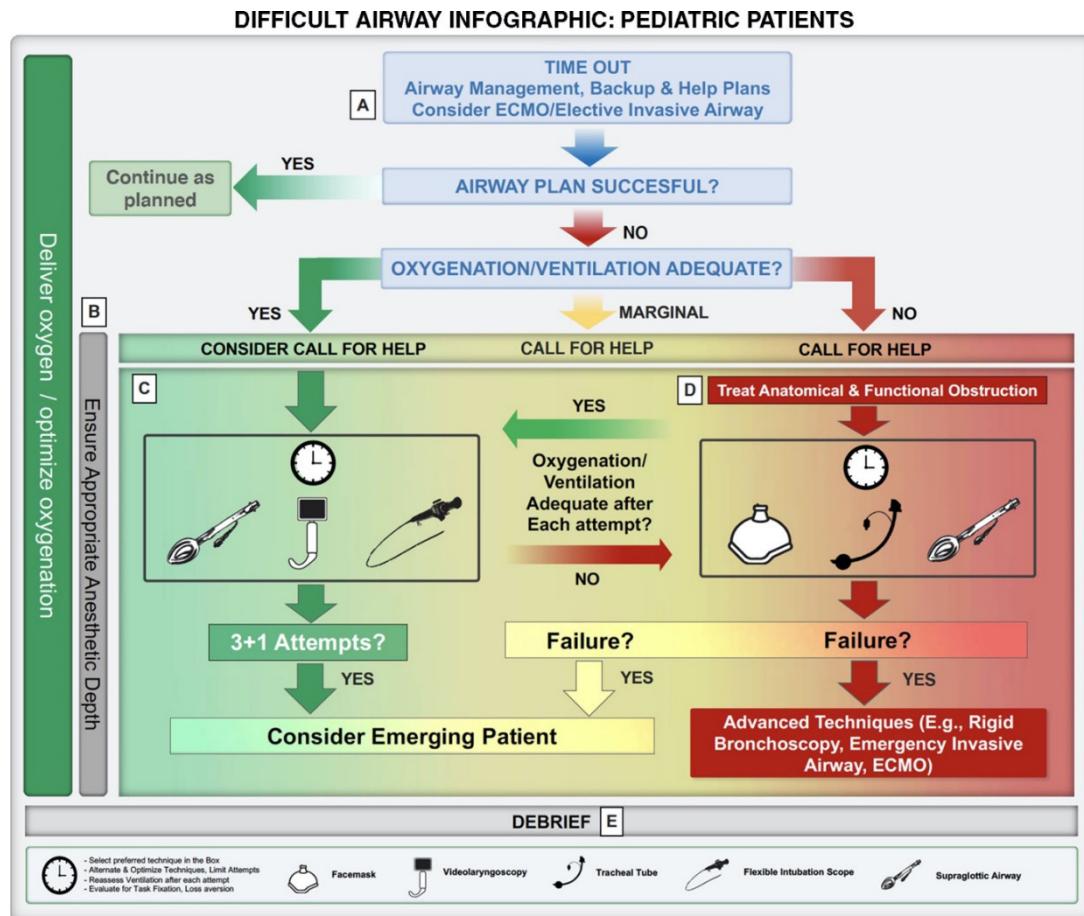


Figure 3: Difficult Airway Infographic: Pediatric Patients.

Interestingly, we see that rigid bronchoscopy has returned as part of the algorithm. This merely shows its importance in practice, as it is present in both the first, and the last guideline. As for the American guidelines, appropriate choice of medication and techniques depends greatly on experience and training of practitioners, medical issues of the patient, the type of procedure, and environment in which airway management takes place [11]. However, the appropriate choice may as well be limited by state/municipality regulations in a way that not every country's economical status allows equipment befitting of every patient. As we know, pediatric patients require different sizes of equipment according to their age, which is all in all much more costly than the adults'. As we can see, all guidelines recommend emergency invasive airway/FONA if all our attempts to oxygenate the patient fail, but it is still controversial whether this is useful or not, especially in very young children. The reason being very high incidence of complications and failed procedures with increased inhospital mortality, due to issues such as location of the cricothyroid membrane and incorrect approach [3,8,12,13].

Conclusion

The best framework to guide us through safe and secure airway management is a combination of: good knowledge of anatomical and physiological pediatric airway specificity, good airway assessment, planning, minimum standard of equipment, and implementation of difficult airway algorithms along with personnel dedicated to teaching, training and practice.

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