Review Article

Focused review on management of the difficult paediatric airway

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ABSTRACT

Management of the difficult paediatric airway management may be associated with a high rate of complications. It is important that clinicians understand the patient profiles associated with difficult airway management, and the equipment and techniques available to effectively manage these children. The goal of this focused review is to highlight key airway management concepts when managing the paediatric difficult airway. This includes understanding the advantages and limitations of various airway equipment designed for children and reviewing the difficult airway algorithm with its unique considerations for the paediatric patient. Early recognition of known risk factors and thorough preparation may be helpful in reducing the risk of complications during difficult airway management in children.

Key words: Airway devices, airway, complications, difficult, pediatric

INTRODUCTION

One of the major reasons for anaesthesia-related cardiac arrest, death, and brain injury in healthy children is owing to difficulties in airway management.[1,2] The presence of a difficult airway has been identified as a significant patient factor associated with increased morbidity and mortality.[3] The paediatric airway can rapidly become a disaster situation. Airway management of the paediatric patient is a critical skill to have. Fortunately, the incidence of unexpected difficult paediatric airway is very low. Understanding how to predict the presence of a difficult airway, and being up to date on the latest algorithms, along with the knowledge of various equipments, will significantly increase the probability of successful airway management of the difficult paediatric airway.

ANATOMY AND PHYSIOLOGY

The anatomical differences between the airway of the paediatric patient and the adult patient are more pronounced in children under 2 years of age. The occiput is large relative to the rest of the body, and flexion of the cervical spine can cause obstruction. The larynx is more cephalad and thus seems more anterior. The small child's tongue takes up more room in the oral cavity, causing an obstruction and making it harder to sweep during direct laryngoscopy (DL). The baby's large floppy omega-shaped epiglottis is more likely to obstruct views of the vocal cords.

Major physiological differences also occur in children 2 years and younger. Oxygen consumption is much higher, and they have a smaller functional residual capacity, which results in more rapid desaturation compared to adults. They have more type 2 respiratory fibers, which are prone to fatigue, and when sedated can lead to decreased muscle tone and collapse of the small airways. The younger the child, the shorter the apnea time to reach SpO_2 of 90%.[4] Gastric distension may occur because of prolonged bag-mask ventilation or bowel obstruction and can cause further difficulty

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in ventilation due to cephalad displacement of the small child's very compliant diaphragm.

Defintions-A difficult airway is defined as an airway in which there is difficulty with face mask ventilation, direct or indirect laryngoscopy [e.g., videolaryngoscopy (VL)], tracheal intubation, supraglottic airway device (SAD) use, or FONA (e.g., surgical airway). Difficult face mask ventilation occurs when multiple manipulations are required, such as the use of two hands and adjustment of head and neck.[5] Difficult laryngoscopy occurs when there is a failure to visualise the vocal cords. Difficult tracheal intubation has been defined as multiple attempts; more than one provider required; the use of adjuncts; the need for an alternative device after primary attempts have failed.[5] A significant principle of airway management is oxygenation. Failed oxygenation is, thus, the worst result of a difficult airway, in which the patient cannot be oxygenated due to failed face mask, failed tracheal intubation, and failed SAD use.

The Pediatric Difficult Intubation (PeDI) registry[3] includes standardised data from 13 paediatric centers worldwide. Their definition of the difficult airway includes

1. Failure to visualise vocal cords on DL by an experienced provider
2. Impossible DL because of abnormal anatomy
3. Failed DL within the last 6 months
4. DL felt to be harmful in a patient with suspected difficult laryngoscopy.

INCIDENCE

The incidence of difficult airway in healthy children is low. For unexpected difficult bag-mask ventilation, one study found the incidence to be almost 7%.[6] The only significant risk factor identified was decreasing age. There was no association between difficult bag-mask ventilation and difficult tracheal intubation. The incidence of difficult DL ranges from 0.06% to 3%.[7,8] The incidence is highest in children under the age of one. One study found the incidence of difficult direct laryngoscopic intubation in children to be 0.25%, with the majority being anticipated. The rate of unanticipated difficult intubation was 0.03%, confirming that unanticipated difficult intubation in children is rare. The most common risk factors were narrow inter-incisor distance and mandibular hypoplasia.[9]

In the PeDI registry study of 1018 children with difficult airways, 2% resulted in failed intubation, and 20% had complications. Of those complications, 2% resulted in cardiac arrest.[3]

RISK FACTORS

It is very important to know the risk factors for encountering the child with a difficult airway. The most common physical finding in children with difficult airways is a short thyromental distance or micrognathia. Presence of this physical finding is an independent risk factor for increased adverse events during airway management.[9] The tongue lies against the posterior oropharyngeal wall causing upper airway obstruction. In these patients, DL is possible, but visualization of the laryngeal inlet is poor because the limited submandibular space is unable to accommodate the displaced tongue during DL.

Remember that most difficult airways are rarely unanticipated. Syndromic and dysmorphic features (such as midface hypoplasia and mandibular hypoplasia) can usually be identified in the preoperative evaluation, especially in the lateral profile. If the patient has been diagnosed with a syndrome, be aware that each syndrome or abnormality presents its own functional or anatomic challenge. Craniofacial syndromes are the most common reason for difficult airways in the paediatric population.[10]

See Table 1 for syndromes associated with difficult airway.

The PeDI registry study found four independent risk factors associated with the risk of complications:[3]

- Weight less than 10 kg
- Micrognathia (mandibular hypoplasia)
- Greater than two tracheal intubation attempts
- Three DL attempts before an indirect technique.

PRINCIPLES

It is important to remember the fundamental principles of airway management – oxygenation, not intubation, is life-saving. Limit the number of DL attempts, and proceed to more advanced devices sooner than later. Always have a SAD available because it is useful as a rescue device in every difficult airway algorithm when mask ventilation and tracheal intubation has failed. From the beginning of airway management, consider various methods of providing passive oxygenation to the

Table 1: Syndromes in children associated with difficult airways with key airway features observed

Syndrome	Airway Features
Pierre Robin sequence	Micrognathia; glossoptosis (backward displacement of tongue); airway obstruction at rest; and improves with age
Treacher Collins	Micrognathia; limited mouth opening; airway obstruction at rest; and worsens with age (in spite having mandibular distraction)
Goldenhar syndrome	Micrognathia; hemifacial macrosomia; occipitalization of atlas; and limited mouth opening
Mucopolysaccaridoses (Hunter's and Hurler's syndromes)	Accumulation of mucopolysaccharides in various tissues, including airway; short, immobile neck; cervical instability, airway obstruction at rest; difficult mask ventilation and tracheal intubation; and worsens with age
Apert syndrome	Midface hypoplasia; possible choanal stenosis; progressive calcification of cervical spine; and airway obstruction
Down syndrome	Macroglossia; atlantoaxial instability; and pharyngeal hypotonia
Crouzon syndrome	Midface hypoplasia; maxillary hypoplasia; short neck; and restricted neck movement
Pfeiffer syndrome	Midface hypoplasia and airway obstruction
Klippel-Feil syndrome	Fusion of variable number of cervical vertebrae and limited neck movement
Beckwith-Wiedemann syndrome	Macroglossia
Freeman-Sheldon syndrome	Circumoral fibrosis and microstomia

patient. Studies have shown that transnasal humidified rapid-insufflation ventilatory exchange delays hypoxia in children who are apneic. The prolongation of time to oxygen desaturation would be very advantageous because hypoxemia is a leading cause for perioperative morbidity and mortality in children.[11,12]

ALGORITHMS

Compared to the long-established adult difficult airway algorithms, the paediatric algorithm has been coming more into focus only in the past several years. Various airway and anaesthesia societies around the world have created and recommended algorithms for difficult paediatric airway.[13,14] All of them have something in common – limiting the number of attempts. However, one major difference, for example, is that awake intubation is rarely discussed in paediatrics beyond the anecdotal success of neonates and older children. The algorithms presented below are separated into two categories: the anticipated and unanticipated difficult airway. Figure 1 represents anticipated and unanticipated management of the paediatric difficult airway.

Anticipated difficult airway

Preoperative considerations

The anticipated difficult airway allows the anaesthesia provider to be adequately prepared with an airway plan and to guarantee that help (anaesthesiologist, ENT specialist) will be available if needed. Obtaining advanced airway equipment such as a VL and/or flexible fiberoptic bronchoscope is critical, as the goal is to increase the probability of success on the first tracheal intubation attempt (if tracheal intubation is indicated). An analysis of the Multicenter PeDI registry found that fiberoptic intubation using supraglottic airway device (FOI-SAD) technique resulted in the first attempt success rate of 59%. For VL it was 51%.[15]

Key questions to ask before airway management:

1. How old is the patient?
   a. Analysis of the PeDI registry data showed that in children less than 1 year of age, FOI-SAD had a higher rate of first attempt success than VL.[15]
2. Will this patient have potential difficult mask ventilation after anaesthetic induction?
   a. Evaluate the patient while lying supine at rest and look for signs of upper airway obstruction, such as paradoxical chest wall movement or stridor
   b. Does positioning (lateral/prone) or use of a nasopharyngeal airway improve this airway obstruction? This may help predict difficult mask ventilation under anaesthesia.
3. Does the patient require awake intubation?
   a. High-risk difficult mask ventilation
   b. Full stomach potential
   c. Rapid sequence intubation scenarios
   d. Severe airway obstruction with no evidence of relief.

Execution

Patients with an expected difficult airway should have intravenous access prior to induction of general anaesthesia. If it has been determined during the preoperative assessment that awake intubation is not necessary, proceed with the induction of general anaesthesia while maintaining spontaneous ventilation. Remember the aphorism: "It is difficult to kill a spontaneously breathing patient."

Scenario: Difficult bag-mask ventilation (BMV)

If during execution, BMV is found to be difficult, consider the following steps: insert an oropharyngeal airway; optimise the patient's position utilizing chin lift,[16] jaw thrust, lateral position,[17] and shoulder roll; use two hands; and provide continuous positive airway pressure. Make sure that there is an adequate depth of anaesthesia and that the difficult BMV is not due to laryngospasm. Similar to the adult world, there is no consensus on whether to administer paralysis during difficult BMV. The association of paediatric anaesthetists of great Britain and Ireland (APAGBI) favors the use of succinylcholine as the first-line relaxant to facilitate ventilation and intubation;[18] however, it is not clear in which scenarios. Most would agree that paralysis would be best if difficult BMV is due to laryngospasm; however, if it is because of an airway or mediastinal mass, or mucopolysaccharidosis buildup (Hunter, Hurler), paralysis could potentially worsen difficult BMV. Ensure that gastric distension is not to blame and treat if necessary. If difficult mask ventilation persists, insert a SAD.

If the SAD allows for adequate ventilation, determine if the SAD is a safe alternative to tracheal intubation for the duration of the surgery. If the SAD allows for adequate ventilation, but tracheal intubation is required, use the SAD as a conduit for FOI (the SAD allows for the advantage of passive oxygenation during airway management). If the SAD had failed to allow for adequate ventilation, the next step is dependent on the SpO_2 – if declining SpO_2, the scenario is heading to the Can't Intubate Can't Oxygenate (CICO); if SpO_2 is not in rapid decline, consider waking the patient up.

The CICO scenario is rare and frightening. Immediately call ENT specialist (who may not be available, or there may not be time to wait for their arrival owing to rapid clinical deterioration of the patient) for assistance and consider surgical tracheostomy or rigid bronchoscopy. Paediatric algorithms from the Difficult Airway Society, Association of Anaesthetists of Great Britain and Ireland, and the All India Difficult Airway Association recommend that in absence of an ENT specialist the anaesthesia provider perform percutaneous cannula cricothyroidotomy as the first option for the front-of-neck access (FONA) (e.g., surgical airway).[13,14] Practicing for this very rare event is difficult – it is impossible to replicate the real child's airway with simulators and manikins. The fourth National Audit Project (NAP4) found 12 out of 19 narrow-bore cannula cricothyroidotomy failed in adults during anaesthesia (65% failed).[19] This procedure in children would be even more challenging. In one study, 22 out of 30 physicians were unable to successfully cannulate the trachea within 4 min of an 8 kg piglet model.[20]

Scenario: Easy BMV, difficult DL

If initial DL is found to be difficult, consider transitioning to indirect technique (VL and FFB) sooner than later. It is important to limit the number of unsuccessful attempts – multiple attempts increase the risk of serious complications.[3] Consider using airway adjuncts such as a bougie and even ultrasound.[21] If still unsuccessful tracheal intubation, place SAD and continue same algorithm for post SAD placement.

Unanticipated difficult airway

This clinical scenario is likely to be encountered after induction of anaesthesia or after initial or subsequent attempts with tracheal intubation. When faced with an unanticipated difficult airway, it is important to remember that smaller children can rapidly become hypoxemic and bradycardic, leading to cardiac arrest. Therefore, providing passive oxygenation during all periods of airway management, especially during apneic episodes is very important. This can be accomplished with a nasal cannula (high-flow and transnasal humidified rapid-insufflation ventilatory exchange) or other devices (nasal trumpet and SAD) and may reduce oxygen desaturations and repeated attempts at intubation.

Key questions to ask while managing the unexpected difficult airway after induction of anaesthesia:

1. Is mask ventilation adequate after initial airway interventions?
2. Was neuromuscular given prior to realization of a difficult airway?
    - If rocuronium given, know the reversal dose of sugammadex: 16 mg/kg.
3. How many attempts have been made to intubate the trachea already?
    - Limit the number of unsuccessful attempts.

Steps can then be separated into (1) difficult BMV; and (2) easy BMV and difficult DL/tracheal intubation. Algorithm becomes the same as the anticipated difficult airway. For all difficult airway scenarios in the paediatric patient, it is important to remember that functional causes, such as laryngospasm, is the most common cause of adverse airway events.[1,22,23] Therefore, recognizing and treating functional causes would be essential early on in every algorithm.

EQUIPMENT AND DEVICES: [SEE TABLE 2]

Direct laryngoscopy

DL is the most utilised initial technique for tracheal intubation in children. Studies comparing Macintosh and Miller blades have found similar rates of optimal views in healthy small children.[24] In children with difficult airways, the decision to proceed with DL must be according to the provider's own expertise and comfort level. The PeDI registry found that greater than two attempts at DL in pediatric patients with difficult airways were associated with greater rates of failure and severe complications (cardiac arrest, persistent hypoxemia, bronchospasm, esophageal intubation, and severe airway trauma).[3] The results of the study should encourage every provider to minimise the number of DL attempts and to transition to an indirect technique VL, fiberoptic) sooner than later.

The "paraglossal"/retromolar technique can be considered for the micrognathic child, in which the tongue cannot be compressed further into the submandibular space. This technique involves avoiding the tongue altogether by using a straight blade along the buccal mucosa and lifting the epiglottis from the side of the mouth. This technique should be practiced in the elective setting with a healthy patient, before being utilised in the difficult airway of a small child.

Videolaryngoscopy

Small children have a higher incidence of difficult laryngoscopy than the adults because of difficulty in obtaining an adequate view of the glottis.[7] VLs have more angled blades that can obtain indirect glottic views without having to align oral, pharyngeal, and tracheal axis. They have been shown to significantly improve glottic views[25,26] and are effective in paediatric patients with known difficult airways.[15] The VL can be characterised by the shape of their blade or the existence of a tracheal tube channel. The available paediatric options are diverse – they include the GlideScope™ Video Laryngoscope (Verathon, Bothell, Washington, USA), Storz DCI™, C-MAC® Video Laryngoscope (Karl Storz, Tuttlingen, Germany), Truview PCD™ Infant (Truphatek, Netanya, Israel), Airtraq™ Disposable Optical Laryngoscope (ProdolMeditec, Vizcaya, Spain), and Pentax-AWS™ (Pentax Corporation, Tokyo, Japan).

VL may have limitations in children with very limited mouth opening or airways with trauma and/or bleeding. VLs can also pose challenges with tracheal tube insertion because of its indirect course in spite an optimal view. This is consistent with the repeated finding of prolonged time for successful intubation across various VLs.[18,26-29] A clockwise rotation of the tube, external laryngeal manipulation, and stylet withdrawal are suggested techniques to optimise tube placement with VL.

Supraglottic airway devices

The SAD has been a significant part of airway algorithms (adult and paediatric) all over the world.[13,14,30,31] It is used when there is difficulty ventilating, when there has been failed intubation, or both. Older SADs (e.g., LMA Classic and LMA

Table 2: Pros and Cons of various airway techniques/equipment

Device	Pros	Cons
Direct laryngoscopy	Widely available	Requires alignment of axis to obtain laryngeal view; requires degree of mouth opening; multiple attempts are associated with increased complications; greater workforce needed to displace tissue vs. other techniques
Video laryngoscopy	Easy to acquire skill; portability; less force; panoramic and/or wide magnified view; and proven efficacy in the difficult airway	Requires moderate degree of mouth opening; the view can be easily obstructed with blood, secretions; time to intubate typically longer than DL
Supraglottic airway	Rescue device; conduit for tracheal intubation; can be used as a primary airway; and strong evidence base in difficult airways	Requires some degree of mouth opening; risk of pulmonary aspiration when used in patients with a "full stomach"
Flexible fiberoptic bronchoscope	Can be used in limited mouth opening; nasal or oral route; and can be used in conjunction with SAD	Steep learning curve to be proficient with its use; expensive; and suboptimal view in airway with blood, secretions
Optical stylet	Shorter learning curve than the FFB	Cannot use for nasal intubations and suboptimal view in airway with blood, secretions

Unique) have been successfully used for many years in children. However, limitations of older SADs include mask displacement, poor airway seal, and epiglottic downfolding causing airway obstruction. Newer SADs (e.g., air-Q, Ambu Aura-I) have design features meant to address these limitations and be a more efficient conduit for fiberoptic-guided tracheal intubation. Multiple studies have shown that SADs are safe for use in children with difficult airways[32] and are effective conduits for tracheal intubation in children with difficult airways.[33-36] It also may be more effective than VL in children less than 1 year of age.[15] It is important to note that blind intubation through a SAD should not be routinely attempted.

Flexible fiberoptic bronchoscope

Flexible fiberoptic bronchoscope (FFB) is considered the gold standard of difficult airway management in paediatric patients. Intubation can be achieved through a number of different routes – the mouth, nose, or through a SAD. It allows the operator to maneuver the tip around and bypass distortions in airway anatomy. Limitations include lack of patient cooperation; significantly distorted airway anatomy; and small amounts of blood and secretions can easily obscure views from its small camera.

The scope comes in numerous sizes, down to a 2.2 mm outer diameter to accommodate even very small endotracheal tubes. Other advantages are the ability to use a FFB through a SAD either as a planned adjunct or in a rescue situation. FFB is recognised as having a steep learning curve for the operator. To be a viable option in the paediatric difficult airways, providers must be proficient.[35,36] Familiarity with FFB in adults does not equate to proficiency for FFB in children. There are technical challenges in navigating an ultra-thin FFB with a small camera, along with inherent small airway size.[37,38]

Optical stylet

The Shikani Optical Stylet (SOS; Clarus Medical) is a malleable fiberoptic stylet with a distal eyepiece that can either be connected to a video or used on its own. It combine features of a fiberoptic bronchoscope and a lightwand. In some case series, it has been shown to be effective in children with difficult airways.[39,40] Its possible advantage over the FFB is a shorter learning curve.[39] The paediatric SOS can accommodate tubes as small as 2.5 mm ID. The Bonfils (Karl Storz) optical stylet also comes in paediatric sizes. Some limitations are the inability to use the device for nasotracheal intubation. Similar to paediatric bronchoscopes, the small lens is easily obscured with secretions or blood. The rigidness of the scope also does not allow it to be passed beyond the vocal cords any significant distance.

Front-of-neck access

FONA includes all cannula and scalpel rescue techniques through the cricothyroid membrane or anterior tracheal wall. It may be required when there is an inability to intubate the child's trachea and an inability to oxygenate the patient's lungs (even after insertion of a rescue device) – leading to the CICO scenario. There are few case reports and even fewer clinical studies – most are limited to animal models. When CICO emergency does occur, it results in poor survival.[41]

It is ideal to have ENT perform a tracheostomy and/or rigid bronchoscopy with pressure-limited jet ventilation (assuming there is enough time prior to hypoxic cardiovascular collapse). If ENT is not available, there is insufficient evidence to promote one FONA technique over another.[42] Although surgical cricothyrotomy is recommended in the Difficult Airway Society algorithm for adults, there is insufficient evidence for its recommendation in small children. A rabbit study showed significant complication rates of posterior tracheal wall damage.[43] The size of the cricothyroid membrane is much smaller and the surrounding cartilage is much softer. The thyroid cartilage is also underdeveloped in children compared to adults.

The combined Association of Paediatric Anesthetists (APA) and Difficult Airway Society (DAS) guidelines, along with the All Indian Difficult Airway Association recommend a cannula as the first FONA technique in the absence of an ENT surgeon.[31] A rabbit model of the infant airway demonstrated a high success rate of cannula tracheotomy, however, it was also associated with perforation of the posterior tracheal wall.[44,45]

Needle cricothyrotomy does not require a scalpel incision, but rather involves a catheter over a needle. The cricothyroid membrane is palpated, and the catheter over needle assembly is advanced through the membrane until the syringe aspirates air into a 3 mL saline-filled syringe, signaling entrance into the trachea. The needle is then withdrawn, and the catheter is connected to an oxygenating and ventilating source.

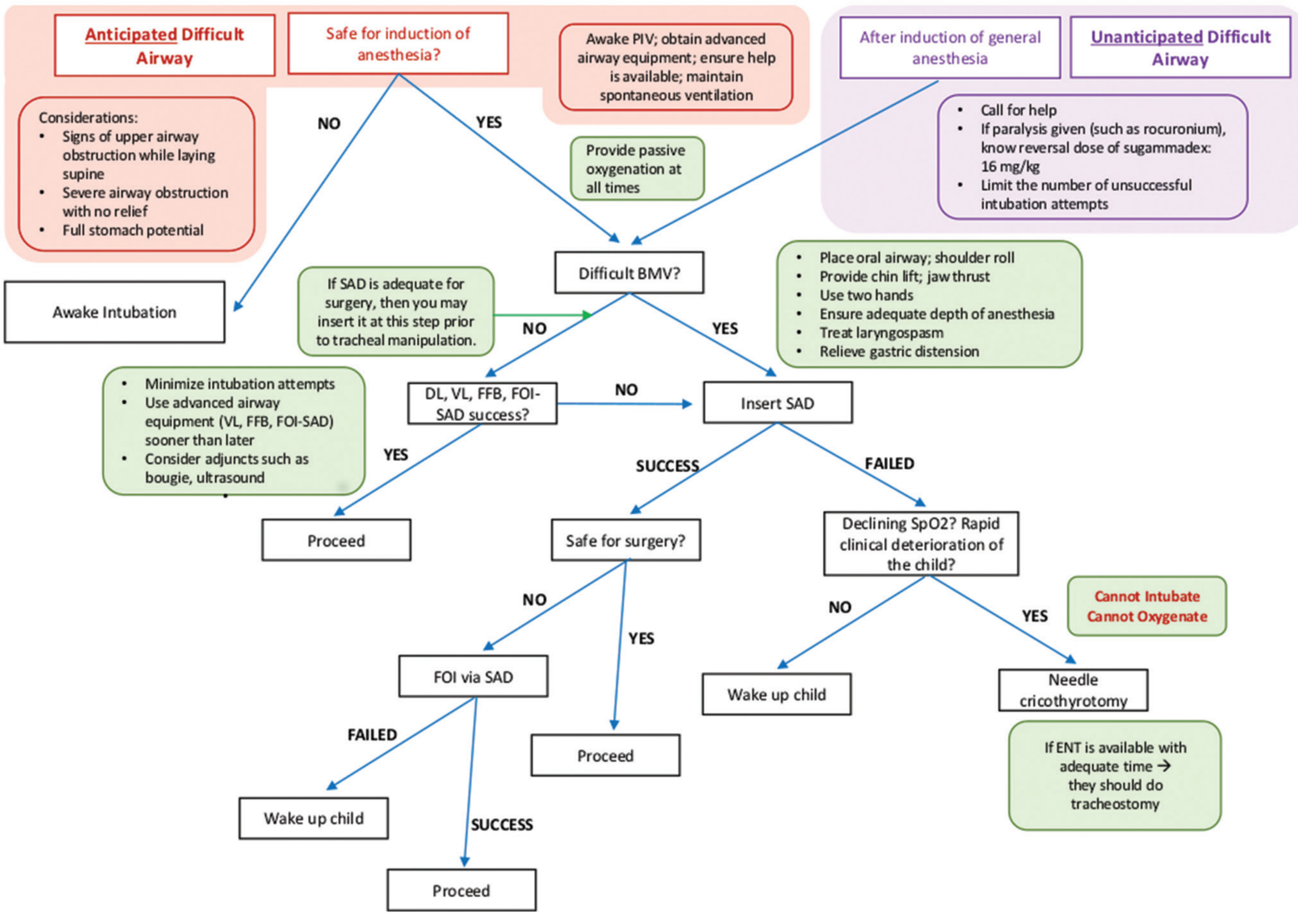

Figure 1: Paediatric difficult airway management algorithm

It is recommended to use commercially available, purpose-specific equipment. Commercially available cricothyroidotomy kits for children and infants include the Quicktrach Child (VBM Medizintechnik GmbH, Sulz am Neckar, Germany); Quicktrach Baby (VBM Medizintechnik GmbH, Sulz am Neckar, Germany), Melker kit (Cook Medical; Bloomington, IN USA), and Arndt Emergency Cricothyroidotomy Kit (Cook Medical; Bloomington, IN USA).

In spite lack of clinical human evidence, simulation training and persistent practice are necessary in the rare event; a CICO scenario is encountered. Adequate preparation of one technique is more important than which specific technique is employed. The goal is oxygenation rather than ventilation.

OTHER OPTIONS

Awake intubation

Unlike the adult patient population, awake intubations are not practical for the majority of paediatric patients owing to their inability to cooperate. There are case reports of it being safely done in children with difficult airways.[36,46,47] One example is the newborn with Pierre Robin, in which the baby is at high risk of aspiration, has severe upper airway obstruction at rest and is at high risk of being a difficult airway.[36] Keeping the baby awake allows him/her to maintain his/her own life-saving oxygenation and ventilation and is more able to protect themselves from aspiration of regurgitated gastric contents.

Awake extubation with exchange catheters

The American Society of Anesthesiologist Difficult Airway Algorithm recommends the use of an airway exchange catheter upon tracheal extubation in an adult patient with a difficult airway. This should also apply to the paediatric population.[30] Cook Critical Care supplies airway exchange catheters made for endotracheal tube with 4 ID mm or larger; their smallest size is the 11 Fr catheter.

CONCLUSION

Fortunately, the unanticipated difficult airway in a child is extremely rare. With multiple studies, we now know the major risk factors for encountering a difficult airway in a child. Studies have also enlightened us to strategies that will increase our success in managing these airways, while preventing further harm to the child. The devices designed for children continue to grow; however, use of these devices requires the provider to maintain a high level of proficiency. Ongoing and future studies will be required to determine an effective algorithm for the youngest of our patients, those less than 1 year of age.

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