Management of the Difficult Airway in the Pediatric Patient

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J Pediatr Intensive Care 2018;7:115–125.

Abstract

Loss of airway control in children, if not resolved quickly, will lead to devastating consequences. Successful management of the pediatric difficult airway, both anticipated and unanticipated, is facilitated by preprocedure assessment and preparation. Accessibility of and continued hands-on training with modern airway instruments, familiarization with difficult airway guidelines, and collaboration with multidisciplinary airway teams can aid in the management of the difficult pediatric airway. This review outlines the importance of airway assessment and advanced airway equipment for children. It also discusses difficult airway management techniques and algorithms for the management and rescue of the pediatric difficult airway.

Keywords

- difficult pediatric airway
- ventilation
- laryngoscopy

Introduction

The act of securing the airway in pediatric patients is a crucial element of care in the perioperative setting, pediatric intensive care unit, and pediatric emergency room. Due to anatomical and physiological differences, the technique of mask ventilation, direct laryngoscopy, and endotracheal intubation is relatively more difficult in children. In addition, the time available to accomplish these tasks is lesser in pediatric patients than in adults. Even among pediatric anesthesiologists and intensive care physicians, who are trained in pediatric airway management, failure to manage the airway is one of the primary events leading to morbidity and mortality. The closed claims database of the American Society of Anesthesiologists (ASA) and the Perioperative Cardiac Arrest Registry demonstrate that respiratory complications are one of the most common causes for perioperative morbidity and mortality in children.^{1,2} Many of the catastrophic outcomes during airway management may be preventable, occurring due to improper assessment, planning, and execution.³ The following article outlines the techniques of airway assessment in children with a discus-

sion of the physical features that may identify a difficult airway. This is followed by a description of advanced airway equipment and techniques, with suggested algorithms for the management and rescue of the difficult airway in children.

Airway Assessment in Children

In children and adults undergoing anesthesia or sedation, the evaluation of the airway remains an integral part of the preoperative assessment.⁴ The airway-focused history may help identify issues that were encountered in previous perioperative or intensive care unit (ICU) admissions. Medical records from previous encounters should be reviewed to determine the ease of mask ventilation, need for airway adjuncts, type of laryngoscope used, the number of attempts at direct laryngoscopy, and the direct laryngoscopic view achieved. The latter is generally classified using the Cormack and Lehane scale (► **Table 1**). This should be followed by an assessment of the airway including an evaluation of the symmetry of head, face and neck, degree of mouth opening, presence or absence of oral pathology, oral hygiene,

received

October 19, 2017

accepted after revision

December 8, 2017

published online

January 28, 2018

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Verlag KG, Stuttgart · New York

DOI <https://doi.org/10.1055/s-0038-1624576>.
ISSN 2146-4618.

Table 1 Cormack and Lehane scale

Grade 1	Full view of glottic structures
Grade 2	Only posterior commissure is visible (rest of the glottic structures are invisible)
Grade 3	Only the tip of epiglottis is visible (rest of the glottic structures are invisible)
Grade 4	None of the glottic structures are visible

measurement of mentohyoid and thyromental distance, adequacy of neck flexion/extension, and neck circumference.^{5,6} Concerns in one or more of these parameters may indicate the potential for difficulties with airway management (► **Table 2**). The Mallampati score is commonly used in adults to predict difficulties with endotracheal intubation (► **Table 3**) and may also be applicable in cooperative children.⁷ Unlike adult patients, neck circumference and body mass index have not been shown to be independent predictive factors in children.^{6,8}

In general, patients with a higher ASA physical status (III and IV), Mallampati airway score of III or IV, infants, and those undergoing oromaxillofacial, otolaryngologic, and cardiac surgery are more likely to have airway management issues.^{9–11} Additionally, there is a higher incidence of airway difficulties in patients with anomalies of the external ear (microtia), micrognathia, and certain congenital anomalies and syndromes including Pierre Robin sequence, Treacher Collins syndrome, and Goldenhar syndrome.^{12–14} Another unique and increasingly common co-morbid condition, obstructive sleep apnea (OSA), may be associated with airway management issues.¹⁴

Unfortunately, there is no single screening test or combination of tests that can be applied universally. Many of the suggested measurements, scales, and scores for airway evaluation that are used commonly in adults, have not been validated in children. Despite these limitations, the majority of children with a difficult airway can be identified by obtaining a detailed history and performing a thorough

Table 3 The Mallampati scoring system^a

Class	Anatomical features seen
Class 1	Complete visualization of the soft palate, uvula, and tonsillar pillars
Class 2	Complete visualization of the soft palate with partial visualization of the uvula and tonsillar pillars
Class 3	Visualization of only the base of the uvula and the soft palate. No visualization of the distal uvula or tonsillar pillars
Class 4	No visualization of the soft palate, uvula, or tonsillar pillars

^aApplicable in cooperative children. However, typically, children may not cooperate for a proper oral airway exam, and an isolated class 3 or 4 score in an uncooperative child with otherwise normal airway exam may not indicate a potential difficult airway.

physical examination. The ultimate goal of any airway assessment exercise is to identify the problematic airway and then devise a management plan including rescue and alternate pathways for children in whom mask ventilation, direct laryngoscopy, and endotracheal intubation of the trachea may be difficult (► **Table 4**).

Advanced Equipment for Airway Management

When encountered with a difficult pediatric airway, the chances for effective management and a successful outcome can be tilted favorably with proper preparation and development of a management plan. The latter frequently requires access to advanced airway equipment.

Supraglottic Airways

Supraglottic airways (SGAs) are commonly used during the management of a difficult airway in children.^{15,16} They can relieve upper airway obstruction by displacing the tongue

Table 2 Physical features suggestive of a difficult pediatric airway

Physical feature/action	Clinical finding predictive of difficult airway
Upper incisor length	Longer–lesser available space for laryngoscope blade and endotracheal tube
Alignment of incisors	Overriding of maxillary incisors or underriding of mandibular incisors
Protrusion of mandible	Inability to protrude the mandibular incisors in front of maxillary incisors
Mouth opening	Distance between upper and lower incisors with full mouth opening: less than two fingerbreadths. ^a Mallampati grade 3 or 4 view (see ► Table 4)
Palate	High arch or narrow
Submandibular space	Narrow, indurated, or firm
Thyromental distance	Decreased to less than 3 finger breadths ^a
Length of neck	Short
Neck size	Increased circumference
Head and neck range of motion	Limited mobility (flexion, extension, and lateral rotation)

^aFor evaluation in a child, one should use the child's own fingers.

Table 4 Questions to consider during the airway evaluation

1. Does this patient have a potential difficult airway?
a. Past medical history
b. General appearance of face, mandible, and maxilla
c. Is there an identifiable syndrome?
d. Assessment by the Mallampati and other airway scoring systems
2. Can ventilation be maintained with a bag-valve-mask device?
a. Will an oral or nasal airway be needed to maintain and/or improve bag-valve-mask ventilation?
3. Can the glottic structures be visualized using direct laryngoscopy?
a. Will I need indirect laryngoscopy?
b. Should I have the difficult airway cart on hand
4. What if I fail to achieve bag-valve-mask ventilation?
a. Can a supraglottic device be placed?
b. If needed, can an emergent surgical airway be established?
5. Will I get help if needed?
a. Operating room personnel to summon help
b. Additional anesthesiologists to provide assistance or advanced airway management
c. Surgeon to establish a surgical airway

and the soft tissue of the posterior pharynx. By forming a seal in the periglottic area, they may allow effective oxygenation and ventilation even when bag-valve-mask ventilation has failed. Safe use of SGAs in children is well established and has a lower reported failure rate than in adults (0.86% or 102 of 11,910 children versus 1.1% or 170 of 15,795 adults).^{17,18} SGAs are also frequently used as the primary device to secure the airway during perioperative period in the recognized difficult airway when endotracheal intubation is not required.¹⁹ However, similar to the oral and nasal airways, they do not relieve airway obstruction at the level of the glottis (laryngospasm) or in the lower airway (pathologies such as laryngomalacia, tracheobronchial tumors, and bronchomalacia).

When managing a difficult airway, an SGA can be used as a rescue device, allowing time to prepare other airway maneuvers. An SGA can also facilitate placement of an endotracheal tube (ETT), aiding in navigation and visualization of the glottis with a fiberoptic bronchoscope (FOB). The SGA restores oxygenation and ventilation while acting as a conduit for passage of the FOB loaded with an ETT. Once the FOB is navigated through the SGA and into the trachea, the ETT can then be advanced off the bronchoscope and into the trachea. The Difficult Airway Society website located at (https://www.das.uk.com/files/AIC_abbreviated_Guide_Final_for_DAS.pdf) provides a detailed description of the technique. Of the various brands and modifications of SGAs, the air-Q disposable masked laryngeal airway is particularly

suited for this technique as it has a shorter and wider shaft as well as a removable 15-mm airway adaptor that facilitates passage of the ETT.

When the ETT is placed through the supraglottic device into the airway, the distal end of the ETT may extend for only a short distance beyond the distal tip of the SGA. When the SGA is removed, the ETT may be inadvertently dislodged from the trachea. Multiple options to prevent dislodgement of the ETT, when the supraglottic device is removed, include using another ETT tube as a pusher or specifically designed ETT advancing stylets, holding the end of the ETT with forceps, leaving the bronchoscope in the trachea, or use of a specially designed ETT (microlaryngoscopy tube, which is available only in sizes 4.0, 5.0, and 6.0 mm) which is a few centimeters longer than a standard ETT.

Video Laryngoscopes

Video laryngoscopy uses the principles of indirect laryngoscopy. Unlike direct laryngoscopy, alignment of the oral, pharyngeal, and laryngeal axes is not required for successful visualization of the glottis.^{20–22} These devices have been extensively utilized, with varying degrees of success, in the anticipated difficult endotracheal intubation scenario and in rescue scenarios when conventional direct laryngoscopy has failed.^{22–24} Several of the indirect laryngoscopic devices have been introduced with modifications that facilitate their use in children, including neonates and infants.^{23–25} These devices are frequently the first option when conventional laryngoscopy fails and have become an important part of the armamentarium when approaching the difficult airway in both adults and children.

Our clinical practice and experience has primarily involved two of the earliest devices in this category, the GlideScope and the Storz C-MAC. The GlideScope has specially designed blades that are slightly different from conventional commonly used laryngoscope blades and hence require an altered technique of blade insertion and manipulation of oral structures to enable glottic visualization when compared with direct laryngoscopy.^{20–22} The Storz C-MAC is equipped with blades that are similar in size and shape to standard direct laryngoscopy blades with a similar insertion technique to direct laryngoscopy.^{20–22} With both, the primary challenge is directing the ETT toward the glottis opening, which is not in one's direct line of sight. Various techniques and modifications of the ETT with use of a stylet have been suggested to facilitate the process.²⁰

Flexible Fiberoptic Bronchoscope

The flexible FOB remains a useful tool in management of the difficult airway in children in elective procedures. It is a valuable tool in patients with limited mouth opening when direct and indirect laryngoscopies are not feasible.²⁶ It is also frequently used in the management of pediatric patients with a known or suspected unstable cervical spine.²⁷ When placement of an ETT is required in these patients, it has advantages over other techniques to more reliably ensure the stability of the cervical spine. Although awake fiberoptic endotracheal intubation is commonly performed in adults,

sedation or general anesthesia is frequently required in pediatric patients. In children requiring fiberoptic bronchoscopy, spontaneous ventilation should be maintained even during sedation or general anesthesia. Given its limited impact on respiratory function, dexmedetomidine has become a useful sedative agent during elective pediatric fiberoptic bronchoscopy-aided difficult endotracheal intubation.²⁷ Alternatively, general anesthesia can be induced and spontaneous ventilation maintained with inhalational anesthetic agents, with or without supplementation of intravenous anesthetics such as propofol. A nasal trumpet connected to the anesthesia circuit through a 15-mm adaptor off an ETT or an endoscopy mask with a self-sealing diaphragm (the mask is equipped with a slit-diaphragm in the anterior aspect, which enables the insertion of the FOB without compromising the seal created by the mask) can be used to continue the administration of an inhalational agent while fiberoptic intubation is performed through the nares or mouth.

Despite its utility in the nonemergent scenario, the role of the fiberoptic bronchoscopy is debatable in the management of the emergent and unanticipated difficult airway. Secretions or blood in the airway frequently impede visualization. Set-up and procedure performance times are generally longer than those of an indirect video laryngoscope. Additionally, with the introduction of indirect video laryngoscopes, experience and competence with fiberoptic bronchoscopy have diminished. However, fiberoptic bronchoscopy is still frequently used for indirect visualization and placement of an ETT through a SGA.

Difficult Airway Cart

A dedicated pediatric difficult airway cart can facilitate quick and organized equipment retrieval and is recommended for any institution caring for children.^{28,29} The difficult airway cart should be stored adjacent to locations where airway management is occurring including the operating room, ICU, or emergency department. At our institution, we also have a difficult airway bag that we can carry easily to remote locations in the hospital and a standardized difficult airway cart modeled on the suggestions from the Difficult Airway Society (https://www.das.uk.com/files/Difficult_airway_trolley_DAS.pdf) for use in operating rooms. Although the cart can be tailored based on individual preferences, it usually contains different sizes of FOBs, indirect video laryngoscopes, airway adjuncts (including nasal airways, oral airways, stylets, intubating guides, tube exchangers, and gum elastic bougies), ETTs (conventional uncuffed, cuffed, microlaryngoscopy, and armored), laryngoscope blades (curved, straight, and hybrid), laryngoscope handles (regular and short), SGAs including laryngeal mask airways (LMAs, classic LMAs as well as intubating and other LMA hybrids), anesthesia masks, lung isolation devices (bronchial blockers and double lumen ETTs), surgical airway access kits, and accessory equipment (end-tidal carbon dioxide [ETCO₂] detector, artificial manual breathing unit (AMBU), and self-inflating anesthesia bags, suction catheters, forceps, and local anesthetic agents).

Management of the Difficult Pediatric Airway

Categorization of the pediatric difficult airway can be divided into two scenarios: the anticipated and the unanticipated difficult airways. They both have common goals and pathways of management; however, there are important differences in the preparation and management. The anticipated difficult airway can be carefully prepared for while the unanticipated difficult airway will require a quick evaluation and rapid setup of advanced airway equipment and rescue efforts.

The Anticipated Difficult Pediatric Airway

Patients with a known or anticipated difficult airway should not be sedated or anesthetized in centers that do not have the expertise or multidisciplinary teams dedicated to management of the difficult airway in children (►Fig. 1). The anticipated difficult airway can further be classified into difficult to mask, difficult to intubate, or both. Faced with a difficult pediatric airway in the preoperative assessment, the management plan can be guided by a series of questions (►Table 5).

Given the inability of children to cooperate, the potential to use awake airway techniques is limited. Multiple alternative strategies have been used to create a humane, but safe environment to secure the airway including the use of a sedated or anesthetized fiberoptic intubation. The common critical factor is to ensure an unobstructed airway to allow the maintenance of spontaneous ventilation. Intravenous sedation with a medication, such as ketamine, dexmedetomidine, and/or midazolam, that has limited effects on the respiratory drive can be used. General anesthesia with an inhaled agent such as sevoflurane or an intravenous infusion with propofol while maintaining spontaneous ventilation may be also feasible.

Difficult airway patients with a proven history of easy mask ventilation are relatively easier to treat than those known to have problems during mask ventilation. The subset of difficult airway patients with a past history of easy mask ventilation may, under controlled conditions, receive sedation or anesthesia prior to securing the airway. However, airway control can be lost before the airway is secured, and preparation and rescue plans should always be in place. Once the patient is adequately sedated or anesthetized, the airway can be secured using an advanced technique, preferably one that was successful in the past. Attempts at direct laryngoscopy should be avoided if they were unsuccessful in the past, as it may make conditions unsuitable for advanced techniques or result in the loss of effective bag-valve-mask ventilation. Advanced techniques to secure the airway may include, but are not limited to:

1. indirect video laryngoscopy
2. FOB-guided endotracheal intubation
3. endotracheal intubation through an SGA

Pediatric patients with known difficult mask ventilation are more difficult to manage. Awake fiberoptic intubation

Fig. 1 Summary of guidelines for the management of a difficult pediatric airway in nonpediatric tertiary care locations. When presented with unanticipated difficult endotracheal intubation during elective procedures in these locations, if bag-valve-mask ventilation is easy, it may be prudent to awaken the patient. The patient should then be referred to a tertiary care pediatric center. *Advanced airway techniques should be attempted only if the provider has adequate experience with the advanced airway techniques and easy access to such equipment.

Table 5 Preparation for an anticipated difficult airway

1. Is the procedure or surgery elective or urgent or emergent?
2. In the event of failure to secure the airway, can the patient be awakened and can an alternative airway strategy be planned for a later time?
3. Are any further evaluations necessary to define the airway?
4. Can the airway be optimized further before anesthesia or sedation?
5. What is the level of sedation that will be required: awake (rare in pediatric patients), sedated, or anesthetized?
6. If sedation or anesthesia is attempted, can a patent airway and spontaneous ventilation be preserved?
7. Should a surgical airway be electively performed?
8. What is the preferred route for endotracheal intubation: oral or nasal?
9. What is the method of securing the airway: FOB intubation, use of a supraglottic airway (e.g., LMA) or indirect video laryngoscopy?
10. Is the difficult airway cart accessible and what equipment will be utilized to secure the airway?
11. If there is a loss of airway control at any point, what is the rescue route and pathway?
12. Is there a need for emergency surgical access? If so, would it be prudent to have an ENT surgeon in the room?
13. Is there a need to be prepared for complex advanced rescue procedures, such as emergency tracheostomy, emergency sternotomy, or vascular access for extracorporeal membrane oxygenation?

Abbreviations: ENT, ear, nose, and throat; FOB, fiberoptic bronchoscope; LMA, laryngeal mask airway.

may be considered in rare circumstances in pediatric practice if there is no other safe option. This plan is usually used in neonates and infants when there is a severe airway abnormality associated with anticipated or proven difficult mask ventilation. Anecdotal reports demonstrate the possibility of awake placement of a supraglottic device to aid in awake fiberoptic intubation.³⁰ Alternatively, we have also used awake airway adjuncts to demonstrate effective mask ventilation prior to the administration of sedative or general anesthetic agents in these difficult scenarios.

In those patients where awake airway adjuncts or SGAs have been unsuccessful or failed, airway blocks to prepare the airway for advanced awake endotracheal intubation techniques are an option in older and cooperative children.³¹ In younger children and in uncooperative patients, when direct airway blocks are not feasible, nebulization with a local anesthetic agent can be used with attention to dosing recommendations to avoid toxicity.³¹ Anticholinergic agents (e.g., glycopyrrrolate) may decrease secretions and improve visualization.³¹

The Unanticipated Difficult Pediatric Airway

Unanticipated airway difficulties in pediatric patients can also be classified into difficult to mask or difficult to intubate.³² These guidelines can be summarized using various flow diagrams (→ **Figs. 2–4**).

Unanticipated difficulties with mask ventilation (→ **Fig. 2**) in pediatric patients usually result from dynamic airway obstruction and respond favorably to prompt and appropriate interventions. These dynamic obstructions can be broadly categorized as supraglottic, glottic, and infraglottic.

Supraglottic dynamic obstructions are the easiest to manage and also the first issue that should be ruled out when unanticipated difficulties with mask ventilation are noted. Optimizing head position in addition to traditional airway maneuvers, including a chin lift or jaw thrust, may improve ventilation. In patients less than 2 years of age, the larger head size may flex the neck and occlude the patency of the airway. Airway exchange in such patients may improve with the insertion of a shoulder roll. Other maneuvers suggested include adjusting cricoid pressure if used and using the two-person bag-valve-mask technique. If unrelieved, airway adjuncts (oral or nasal airway) can be used.

Obstruction at the level of the glottis or laryngospasm may impair ventilation during mask ventilation. During laryngospasm, there is a dynamic glottic closure of the vocal cords due to a laryngeal reflex, which is meant to protect the airway from aspiration in the awake state. In the sedated or anesthetized patient, during laryngospasm, the reflex becomes sustained and impairs ventilation.³³ A light plane of anesthesia, turbulent air flow, airway secretions, aspiration, stimulation, instrumentation of the airway, a recent respiratory tract infections and/or passive smoke exposure can increase the risk of laryngospasm. The incidence of laryngospasm is higher in younger than in older children and adults, with the highest incidence among preschool aged children.^{33–35} Laryngospasm can be severe enough to cause complete airway obstruction leading to severe hypoxemia. If

not resolved quickly, hypoxia can precipitate cardiovascular effects such as bradycardia and cardiac arrest. The management goal when dealing with laryngospasm is to ensure ventilation and restore oxygenation. The initial treatment includes applying continuous positive airway pressure (CPAP) using the anesthesia mask and deepening the level of anesthesia with propofol. Although subhypnotic doses (0.25–0.5 mg/kg) of propofol may be successful, a larger dose (1–2 mg/kg) is generally recommended and may be more effective.^{36–38} If unrelieved, succinylcholine is recommended, and generally considered the gold standard for the treatment of laryngospasm.³⁸ It may be used as the initial intervention especially if there is complete laryngospasm resulting in no air movement, or when intravenous access is lacking. A succinylcholine dose of 0.1 mg/kg intravenously is effective in treating laryngospasm without impacting spontaneous ventilation, but a higher dose (0.5 mg/kg) is generally recommended for reliably treating laryngospasm.^{33,39} If intravenous access is lacking, a larger dose of 4 to 6 mg/kg can be given intramuscularly. The onset time of an intramuscular dose for relieving laryngospasm is slower compared with the intravenous route, but is still effective if administered quickly before bradycardia, and decreased cardiac output lead to diminished drug delivery due to poor drug circulation.^{40,41} Administration into the deltoid muscle is generally more efficacious than administration into the thigh while others have suggested intralingual or submental administration due to the increased vascularity of these regions.^{40,41} In rare circumstances, especially when cardiovascular resuscitation is needed, there are reports of intraosseous administration (dose and onset time are similar to intravenous route).^{42,43} Atropine or epinephrine may be needed if there is associated cardiovascular collapse due to prolonged bradycardia or when succinylcholine is repeated.^{42,43} In patients in whom succinylcholine is contraindicated, a two to three times the ED₉₅ dose of rocuronium (0.9–1.2 mg/kg intravenously) is a reasonable choice for a rapid onset.⁴⁴ Previously, the duration of neuromuscular blockade could be expected to be prolonged following the administration of rocuronium. However, sugammadex can now be used for rapid restoration of normal neuromuscular function.⁴⁵ The importance of considering laryngospasm and effectively treating it have recently been emphasized by an editorial written by Drs. Weiss and Engelhardt.⁴⁶ These authors suggest that after excluding upper airway obstruction, the use of airway maneuvers, and the placement of airway adjuncts, unanticipated difficulties with mask ventilation in a pediatric patient should be considered functional obstruction (i.e., laryngospasm). This is the rationale for their advocating the recent algorithm of “cannot (mask) ventilate → paralyze!”⁴⁶

Unanticipated difficulties with mask ventilation may rarely be due to lower airway diseases such as bronchospasm. Severe bronchospasm to the extent of impeding mask ventilation is rare, but should be considered in the algorithm when faced with the unanticipated difficulties with ventilation (“cannot ventilate”) scenario. Treatment includes epinephrine intravenously or subcutaneously when there is no

Fig. 2 Guidelines for the management of an unanticipated difficult pediatric mask ventilation. CPAP, continuous positive airway pressure.

intravenous access. The use of inhaled bronchodilators is ineffective when there is no effective gas exchange for delivery of these agents.

Another consideration while evaluating the reason for unanticipated difficult mask ventilation is that gastric distension may be impeding ventilation. In smaller patients, even when airway patency is reestablished, gastric distension, if severe, can be sufficient to impair ventilation by causing cephalad movement of the diaphragm and limitation of lung expansion. Decompression with an oral gastric tube will generally alleviate gastric distention and improve respiratory compliance. However, gastric distention may reoccur with bag-valve-mask ventilation.

When bag-valve-mask ventilation becomes difficult, if the issue cannot be promptly resolved, additional help should be

sought immediately. The difficult airway cart should be brought to the patient's bedside. Patients will desaturate quickly and become bradycardic with a subsequent decrease in cardiac output, thereby further impairing oxygen delivery. These physiological responses to hypoxemia also impair the ability of intravenous medications to aid in resuscitation, as the delivery time to target organs will be prolonged.

Unanticipated difficult endotracheal intubation can occur even following a thorough preoperative assessment. However, *as long as ventilation by mask is feasible*, various options can be considered including securing the airway with an SGA, advanced endotracheal intubation techniques (indirect laryngoscopy), or awakening the patient (–Fig. 3). Care should be taken not to convert the situation from a “cannot intubate but can ventilate” to a “cannot intubate and cannot

Fig. 3 Guidelines for the management of an unanticipated difficult pediatric endotracheal intubation. *Although the consensus group of Black et al recommended limiting the number of direct laryngoscopies to four, a latter recommendation suggested only two attempts.^{15,33} Fiberoptic placement of an ETT via a SGA is the preferred method; however, if fiberoptic bronchoscope is unavailable, blind advancement with caution to avoid damage to laryngeal structures, through the SGA may be feasible. ETT, endotracheal tube; SGA, supraglottic airway device.

ventilate (CICV)” condition by repeated attempts at direct laryngoscopy. In their recent guidelines, Black et al recommend limiting the number of direct laryngoscopy attempts to four and placement of supraglottic device attempts to three.³² Although indirect video laryngoscopy was not included in these guidelines, a side note stated that indirect video laryngoscopy could be considered if the practitioner was experienced in its use. A large multicenter experience with the difficult pediatric airway found that more than two direct laryngoscopy attempts with difficult intubation were associated with a high rate of failure and complications even among pediatric anesthesiologists.¹⁴ Based on these data, other authors have recommended that the number of direct

laryngoscopy attempts should be minimized, and that when direct laryngoscopy fails, an indirect technique such as video laryngoscopy or fiberoptic bronchoscopy should be attempted.⁴⁷ They also recommended that during these critical tracheal intubation attempts, a means for oxygenation of the lungs should be ensured via a nasal cannula or SGA to avoid complications.^{29,48} The risk of airway trauma increases with each attempt. If the airway structures become swollen or bloody, it may likely decrease the chances for successful indirect video laryngoscopic- or fiberoptic-assisted endotracheal intubation. Furthermore, it may turn the “cannot intubate, but can mask ventilate” scenario into a “cannot intubate, cannot ventilate” event. After failed direct

Fig. 4 Guidelines for the management of a "cannot intubate–cannot ventilate scenario." *Sugammadex can be considered if rocuronium or vecuronium has been administered. However, it should not delay other rescue techniques. #Use of the Combitube is included in the American Society of Anesthesiologists' algorithm for patients weighing more than 40 kg.

laryngoscopy, common options include the use of indirect video laryngoscopy or placement of an SGA. After placement of an SGA, the FOB can be used to guide the ETT through the SGA into the trachea.

The "CICV" scenario is a rare, but emergent and potentially fatal event during airway management in children. A management algorithm has been summarized in **Fig. 4**. The odds of a successful outcome decrease with the younger and smaller child. The time available and the ease of surgical airway intervention decrease as the age of the child decreases. Four independent risk factors were found to be associated with an increased risk of serious complications:

(1) more than two endotracheal intubation attempts; (2) weight less than 10 kg; (3) short thyromental distance (micrognathia); and (4) three direct laryngoscopy attempts prior to an indirect technique.¹⁴ After exclusion of upper airway obstruction, there may be a role for the use of neuromuscular blockade to relieve undiagnosed laryngospasm (see above). This can be combined with epinephrine to relieve an undiagnosed or coexistent bronchospasm. When these rescue attempts and alternative airway devices fail, invasive airway access is the next option. As open surgical access is beyond the realm of most pediatric anesthesiologists, a surgeon is the preferred candidate to perform an open

surgical airway, and surgical help should be immediately requested for invasive airway access. Severe complications may result from improperly performed emergent surgical airway access or high-pressure rescue jet ventilation through a wrongly positioned tracheostomy tube.^{49–51}

When surgical consultation is not readily available, needle cricothyrotomy may be the technique of choice.^{47,52} However, the success rate is only 60 to 70% on the first attempt, and there is a risk of perforation of the posterior tracheal wall and other structures in the neck.^{49,52} Several commercial kits are available with special modifications for pediatric patients. Alternatively, a 14, 16, or 18 intravenous cannula with continuous gentle aspiration to identify tracheal entry can be used. The 15-mm adapter from a 3.0-mm ETT can be connected to the intravenous cannula to provide the delivery of oxygen. Alternatively, a low-pressure oxygen supply attached to an Enk Oxygen Flow Regulator (Cook Medical, Bloomington, IN, United States) can restore and maintain oxygenation for a brief period of time.⁵³ The risks of jet ventilation include subcutaneous emphysema, tension pneumothorax, tension mediastinum, and air embolism.

Conclusion

Many patients with a difficult airway can be identified prior to the induction of anesthesia or sedation. These patients should be cared for only in a tertiary care facility with qualified caregivers, including pediatric anesthesiologists and appropriate surgical support. Current practice guidelines and recommendations should be reviewed and practiced so that the individuals and institution can be ready to act quickly when problematic airway scenarios arise. Skills with rescue airway techniques, including indirect video laryngoscopy, SGA-assisted fiberoptic bronchoscopy, and needle cricothyrotomy should be acquired and maintained using simulation or clinical practice in the nonemergent scenario. The needed equipment should be readily available in a portable difficult airway cart.

As the study of the management of the pediatric difficult airway progresses, there will be ongoing improvements in clinical care. Ultrasound has recently been used to visualize airway structures and endotracheal intubation in real time.⁵⁴ Simulation and interactive computer-based learning modules such as virtual reality may also allow for increased realistic opportunities to develop and maintain necessary skills. Future multicenter studies are needed to identify risk factors, evaluate treatment algorithms, and determine outcomes in the difficult pediatric airway.

Conflict of Interest

None.

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