Management of the Difficult Pediatric Airway: Current Strategies and Clinical Approaches

Mohamed Ashraf Ahmed Kadry Mohamed, Ahmed Mohamed Salama, Manal Salah El Din Farmawy, Rehab Abd-Allah Wahdan

Anesthesia, Intensive Care and Pain Management Department Faculty of Medicine, Zagazig University

Corresponding Author: Mohamed Ashraf Ahmed Kadry Mohamed

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Abstract

Background: Management of the difficult pediatric airway remains a major challenge in anesthesia and critical care because children possess unique anatomical and physiological characteristics that increase the risk of airway obstruction, hypoxemia, and failed intubation. Limited oxygen reserve, higher oxygen consumption, and anatomical variations such as a relatively large tongue, anterior larynx, and narrow airway contribute to rapid deterioration during airway manipulation. Repeated intubation attempts may further worsen airway edema, bleeding, and ventilation difficulty. Recent advances in airway devices, structured algorithms, and ultrasonographic assessment have improved the safety and success of pediatric airway management.

Aim: To review current strategies and clinical approaches used in the management of the difficult pediatric airway, with emphasis on airway assessment, preparation, advanced airway techniques, rescue strategies, and the emerging role of ultrasound in pediatric airway practice.

Methods: A narrative review of literature was conducted using recent and validated references focusing on pediatric difficult airway management. Data from clinical studies, airway registries, practice guidelines, and review articles were analyzed to discuss anatomical considerations, airway evaluation, preparation and planning, videolaryngoscopy, flexible bronchoscopy, supraglottic airway devices, oxygenation strategies, and airway ultrasonography.

Conclusion: Successful management of the difficult pediatric airway depends on early recognition, careful preparation, maintenance of oxygenation, and timely escalation to advanced airway techniques when needed. Modern airway strategies emphasize minimizing repeated attempts, improving first-pass success, and integrating technologies such as videolaryngoscopy and ultrasound into routine practice. A structured, multidisciplinary, and evidence-based approach remains essential to reduce complications and improve outcomes in pediatric airway management.

Keywords: Difficult Pediatric Airway, Clinical Approaches, Pediatric anatomical considerations

Introduction

Management of the difficult pediatric airway represents a critical domain in anesthesia and intensive care, where both technical skill and physiological understanding directly influence patient outcomes. Unlike adults, pediatric patients exhibit distinct anatomical configurations and physiological responses that make airway control more complex and less tolerant to error. These differences are particularly significant in neonates and infants, where even minor deviations in airway structure or technique may rapidly lead to compromised ventilation and oxygenation.[1]

From an anatomical perspective, the pediatric airway presents a combination of structural features that predispose to difficulty during both mask ventilation and tracheal intubation. The relatively large occiput promotes passive neck flexion when the child is placed supine, which can lead to airway obstruction unless appropriate positioning is applied. In addition, the larynx is situated higher and more anterior in the cervical region, making direct alignment of the oral, pharyngeal, and tracheal axes more challenging during laryngoscopy. The tongue, being proportionally larger within a smaller oral cavity, further contributes to obstruction and limits visualization of the glottis. These combined factors often result in suboptimal laryngoscopic views and increased reliance on advanced airway techniques.[2]

Physiological characteristics further amplify the risk associated with airway manipulation in children. Pediatric patients demonstrate higher basal metabolic rates and oxygen consumption compared with adults, while simultaneously having a lower functional residual capacity. This combination results in limited oxygen reserves and a rapid decline in oxygen saturation during periods of apnea. As a result, the margin for safe airway intervention is significantly reduced, and delays in securing the airway can quickly lead to hypoxemia, bradycardia, and cardiovascular instability.[2]

Recent advances in pediatric airway management have been largely informed by multicenter collaborative data and registry-based research. The Pediatric Difficult Intubation Registry has provided valuable insights into the incidence, management strategies, and complications associated with difficult pediatric airways. Findings from these large datasets have highlighted the risks associated with multiple intubation attempts, the importance of early use of advanced airway devices, and the need for structured airway management algorithms to improve safety and success rates. [3,4]

This review aims to provide a comprehensive and clinically relevant overview of current strategies in the management of the difficult pediatric airway, focusing on assessment, preparation, airway techniques, rescue options, and emerging innovations that contribute to improved patient outcomes.

Anatomy of the Pediatric Airway

A thorough understanding of pediatric airway anatomy is fundamental for safe airway management. The airway in children differs from that of adults not only in absolute size but also in structural proportions, spatial orientation, and functional behavior. These differences play a direct role in determining the ease of ventilation, visualization during laryngoscopy, and success of tracheal intubation, making pediatric airway management inherently more complex. One of the most notable anatomical characteristics is the relatively large occiput in infants and young children. When positioned supine, this leads to passive flexion of the neck, which may result in partial airway obstruction. Without appropriate positioning, this can compromise both spontaneous and assisted ventilation. Elevating the shoulders rather than the head helps achieve a more neutral alignment, improving airway patency and facilitating laryngoscopic view.[5]

The oral cavity also presents significant differences. The tongue occupies a larger proportion of the oral space, while the mandible is comparatively smaller and less developed. This reduces the available working space within the mouth and increases the likelihood of airway obstruction, particularly under anesthesia when muscle tone is reduced. In early infancy, the dependence on nasal breathing further increases vulnerability to airway compromise in the presence of even minor obstruction. At the level of the pharynx, relatively enlarged tonsillar and adenoidal tissues are commonly encountered in children. The larynx in pediatric patients is positioned higher and more anterior in the neck compared with adults. This alters the line of sight during direct laryngoscopy and makes visualization of the glottis more challenging. In addition, the pediatric larynx has a conical configuration rather than the cylindrical shape seen in adults, which influences the passage and positioning of the endotracheal tube. [3,4]

A key structural feature is the cricoid cartilage, which forms a complete and relatively rigid ring in children. Unlike adults, where the posterior portion is more compliant, the pediatric cricoid is non-distensible. It is often longer, narrower, and more curved, which may obscure the glottic opening during laryngoscopy. This explains the preference for straight laryngoscope blades in infants and small children, as they allow direct elevation of the epiglottis rather than relying on indirect lifting.[5]

Physiological Considerations of the Pediatric Airway

Beyond anatomical differences, pediatric airway management is strongly influenced by age-related physiological vulnerability. Infants and young children have a higher oxygen consumption per kilogram than adults, while their functional residual capacity is relatively small. This imbalance markedly reduces the available oxygen reserve during apnea. For this reason, modern pediatric airway practice emphasizes effective preoxygenation, maintenance of oxygen delivery during attempts, and early reoxygenation between airway maneuvers rather than prolonged attempts at tracheal intubation.[6]

The cardiovascular consequences of hypoxemia are also more pronounced in pediatric patients. In infants and small children, cardiac output is highly dependent on heart rate because stroke volume is relatively limited. Hypoxemia, vagal stimulation during laryngoscopy, airway suctioning, or repeated instrumentation may therefore precipitate bradycardia and hemodynamic instability more rapidly than in adults. This risk becomes more important in children with sepsis, congenital heart disease, anemia, dehydration, or reduced cardiopulmonary reserve. Airway manipulation should consequently be performed under adequate anesthetic depth, with continuous monitoring, readiness for immediate reoxygenation, and prompt treatment of clinically significant bradycardia.[7]

Another relevant physiological feature is the high reactivity and collapsibility of the pediatric airway during anesthesia and sedation. Loss of pharyngeal muscle tone may lead to upper airway obstruction, while stimulation of the airway may provoke coughing, breath holding, laryngospasm, or bronchospasm. These events are more likely in children with recent upper respiratory tract infection, obstructive sleep apnea, reactive airway disease, gastroesophageal reflux, or airway inflammation. In addition, because the pediatric airway has a small diameter, even minor edema after traumatic or repeated attempts may substantially increase airway resistance and impair ventilation. Gentle handling, avoidance of repeated unsuccessful attempts, and early escalation to an alternative device or a more experienced operator are therefore essential safety principles.[8]

Airway Examination and Risk Assessment

Careful airway evaluation represents the first and most essential step in managing the difficult pediatric airway. Unlike adults, where airway assessment tools are relatively standardized and reliable, evaluation in children is often limited by poor cooperation and developmental factors. Despite these limitations, a structured and thorough assessment remains critical, as early identification of potential difficulty can significantly reduce airway-related complications. In addition, the presence of congenital syndromes, craniofacial abnormalities, or airway pathology should raise suspicion for a potentially difficult airway. Conditions such as Pierre Robin sequence, Crouzon syndrome, or mucopolysaccharidoses are well-recognized causes of airway difficulty in pediatric patients.[6]

Clinical examination, although sometimes challenging, should not be omitted. Inspection of facial symmetry, mandibular size, and oral cavity structure may reveal subtle abnormalities that impact airway management. Features such as micrognathia, limited mouth opening, or abnormal dentition may indicate difficulty with laryngoscopy or intubation. Assessment of neck mobility is equally important, as restricted extension may impair optimal positioning during airway manipulation. However, in children older than four years, some correlation with laryngoscopic view has been observed. Other bedside tests, such as thyromental distance, mouth opening, and jaw protrusion, may provide additional information but are limited by interobserver variability and inconsistent predictive value.[7]

The Cormack–Lehane grading system is commonly used to describe laryngoscopic view during intubation. While it provides useful intraoperative information, it cannot be applied as a preoperative predictive tool, as it requires direct laryngoscopy under anesthesia. Furthermore, its interpretation may vary depending on operator experience and patient positioning, limiting its reliability as a standalone predictor of difficulty. In addition to anatomical assessment, functional and clinical factors must be considered. Recent upper respiratory tract infections, obstructive sleep apnea, respiratory distress, or the presence of stridor may all increase the risk of airway complications. These conditions can lead to increased airway reactivity, higher likelihood of laryngospasm, and difficulty in maintaining adequate ventilation.[6]

Another important aspect is the distinction between anticipated and unanticipated difficult airway. While planned difficult airways allow time for preparation and strategy selection, unexpected difficulty remains a major contributor to airway-related morbidity. Data from the Pediatric Difficult Intubation Registry indicate that complication rates are higher in unanticipated cases, highlighting the importance of maintaining readiness and having a structured approach in all situations.[7]

Preparation and Planning

Preparation is the point where difficult pediatric airway management moves from simple assessment to active risk reduction. Once a difficult airway is suspected, the safest approach is not to depend on individual skill alone, but to create a clear airway plan that includes the first technique, backup options, rescue oxygenation, and a defined point for stopping repeated attempts. Poor preparation in pediatric airway management can rapidly convert a manageable problem into a hypoxic emergency because children have limited oxygen reserve and short tolerance to apnea.[8]

The site of airway management should be chosen carefully. An anticipated difficult pediatric airway is best managed in a fully equipped pediatric operating room or another controlled area where appropriately sized airway devices, monitoring, drugs, suction, oxygen delivery systems, and skilled assistance are immediately available. Managing such cases in remote locations increases risk because equipment may be incomplete, help may be delayed, and rescue options may be limited.[8]

Team briefing is a central part of preparation. The airway plan should be discussed with all members involved before induction, including the anesthesiologist, assistant, surgeon, nursing staff, and any available airway expert. This discussion should define the expected difficulty, preferred primary device, backup device, maximum number of attempts, oxygenation strategy, and emergency pathway if ventilation or intubation fails. Clear communication reduces hesitation, role confusion, and fixation on a failing technique.[9]

Equipment preparation must be age-specific and not generic. Pediatric airway devices vary widely in size, and an incorrect size may lead to failed ventilation, poor seal, trauma, or inability to pass the tracheal tube. Face masks, oral and nasal airways, supraglottic airway devices, laryngoscope blades, video laryngoscopes, endotracheal tubes, stylets, bougies, flexible bronchoscopes, and rescue oxygenation tools should be checked before starting. It is also important to prepare one size smaller and one size larger than expected because airway dimensions may not match age-based formulas in children with syndromes, edema, or previous airway surgery.[8]

Drug preparation is equally important. Induction agents, anticholinergics, vasopressors, muscle relaxants, and emergency medications should be immediately available. In difficult pediatric airway cases, inadequate depth of anesthesia may worsen airway reactivity, leading to laryngospasm, coughing, breath holding, or complete obstruction. For this reason, the choice between sedation, general anesthesia, and neuromuscular blockade should be individualized according to the child's pathology, the expected airway problem, and the experience of the operator.[10]

Planning should also include oxygenation before, during, and between attempts. Preoxygenation may be difficult in anxious children, yet every effort should be made to increase oxygen reserve before airway manipulation. During intubation attempts, continuous oxygen delivery through nasal cannula, high-flow nasal oxygen, or another appropriate technique can prolong safe apnea time and reduce the severity of desaturation. This is especially important in infants and small children, where oxygen saturation may fall quickly after loss of ventilation.[11]

A major principle in modern pediatric difficult airway management is limitation of repeated attempts. Multiple attempts increase airway edema, bleeding, secretions, hypoxemia, and trauma, which then make subsequent attempts more difficult. Registry data have shown that complications rise when the same unsuccessful technique is repeated, especially in small children. Therefore, failure should trigger early change in device, technique, or operator rather than persistence with the same approach.[12]

Human factors strongly influence airway outcomes. Stress, time pressure, poor communication, unclear leadership, and fixation errors may delay escalation even when oxygenation is deteriorating. A predefined airway algorithm and shared mental model help the team recognize failure earlier and move to rescue steps without conflict or delay. Simulation-based training and regular review of airway carts and emergency pathways are valuable because they transform rare events into rehearsed actions.[9]

Stepwise Management of the Difficult Pediatric Airway

Management of the difficult pediatric airway should be approached as a structured sequence rather than a series of isolated attempts. The main priority is always oxygenation, not immediate intubation. In children, hypoxemia develops rapidly, and repeated traumatic attempts may transform a difficult but manageable airway into a swollen, bleeding, and obstructed airway. For this reason, every step should have a clear purpose, a limited number of attempts, and an early decision to change technique when progress is not achieved.[13]

The first practical step is optimization of positioning. Infants and small children should not be managed in the same position as adults. Because of the large occiput and short neck, lying flat may flex the neck and worsen obstruction. A shoulder roll or careful adjustment of head and neck position may improve airway alignment and facilitate both mask ventilation and laryngoscopy. In older children, a sniffing position may be useful, but positioning should always be individualized according to age, body habitus, and airway pathology.[14]

Mask ventilation remains the most important rescue skill in pediatric airway management. Before any intubation attempt, the clinician must confirm that ventilation can be maintained. A properly sized face mask, good seal, jaw thrust, chin lift, and use of oral or nasal airway adjuncts can improve patency. If ventilation is difficult, the depth of anesthesia should be reassessed, as inadequate depth may cause laryngospasm, breath holding, or airway closure. Early use of two-person mask ventilation is strongly advised when the seal or airway opening is poor.[15]

When mask ventilation remains inadequate despite simple maneuvers, escalation should be rapid. Corrective steps include repositioning, suctioning secretions, insertion of an airway adjunct, increasing anesthetic depth, applying continuous positive airway pressure, and considering neuromuscular blockade when appropriate. In many children, muscle relaxation may improve ventilation by reducing upper airway tone and laryngospasm. However, the decision should be individualized, especially in cases where spontaneous breathing is intentionally maintained due to airway mass, severe obstruction, or specific syndromic pathology.[16]

Tracheal intubation should be planned with the highest probability of first-pass success. Direct laryngoscopy may still be useful in selected cases, but registry data have shown poor success when it is repeatedly used in known difficult pediatric airways. Videolaryngoscopy has become an important early option because it improves glottic visualization and allows shared viewing by the team. In small infants, the type of blade is important, as standard-shaped video blades may provide better tube delivery than highly angulated blades in some cases.[17]

A failed intubation attempt should not be repeated without changing something meaningful. Repeating the same device, same operator, and same technique increases trauma and complications. After an unsuccessful attempt, the airway should be reoxygenated, the problem should be identified, and the next attempt should involve a clear modification, such as improved positioning, different blade, external laryngeal manipulation, use of a stylet, change to videolaryngoscopy, or involvement of a more experienced airway operator.[18]

Flexible bronchoscopy remains a valuable technique, particularly in anticipated difficult airways, limited mouth opening, craniofacial anomalies, or situations where neck movement should be minimized. It requires preparation, suction, adequate topicalization or anesthesia, and an operator familiar with pediatric airway dimensions. Its limitation is that secretions, blood, or airway collapse can obscure the view, especially after previous traumatic attempts.[19]

Hybrid techniques have gained increasing importance in difficult pediatric intubation. Combining videolaryngoscopy with flexible bronchoscopy allows one device to improve airway opening and visualization while the bronchoscope guides the tube into the trachea. This approach may be especially useful when the glottic view is visible but tube advancement is difficult, or when bronchoscopy alone is limited by secretions or poor orientation. It usually requires two trained clinicians and good coordination.[20]

Supraglottic airway devices are essential rescue tools, not only for ventilation but also as conduits for intubation. When mask ventilation is inadequate or intubation fails, early insertion of an appropriately sized supraglottic airway can restore oxygenation and provide time for decision-making. In selected cases, flexible bronchoscope-guided intubation through a supraglottic airway can secure the trachea while maintaining ventilation. This approach is particularly useful when oxygenation must not be interrupted for repeated laryngoscopy.[21]

Front-of-neck access in small children is rare but may be lifesaving. It is technically difficult because the cricothyroid membrane is small, the laryngeal structures are less palpable, and the distance from skin to airway is short. Ultrasound marking of the cricothyroid membrane before induction may be helpful in selected high-risk cases. Each institution should have a clear pediatric emergency airway plan that identifies who performs surgical airway access and what equipment is available.[22-24]

Advanced Airway Techniques and Rescue Approaches

Recent advances in pediatric airway management have shifted clinical practice toward earlier use of advanced airway devices and structured rescue strategies. Conventional direct laryngoscopy may still be effective in selected patients, but difficult pediatric airways increasingly require techniques that improve visualization, maintain oxygenation, and reduce repeated airway trauma. The modern approach therefore focuses on selecting the most appropriate technique according to the underlying pathology, anticipated difficulty, and response to previous attempts.[25]

Videolaryngoscopy has become an important development in difficult pediatric airway management. By improving visualization of the glottic structures, it may increase intubation success and reduce the need for excessive airway manipulation. In addition, the shared screen view allows better supervision and coordination between clinicians during airway management. Nevertheless, successful tube placement still depends on proper blade selection, tube shaping, and familiarity with pediatric airway anatomy, as visualization alone does not guarantee easy intubation.[26]

Flexible bronchoscopy remains one of the most valuable techniques in anticipated difficult airways, particularly in children with craniofacial anomalies, restricted mouth opening, cervical spine instability, or distorted airway anatomy. It allows controlled advancement through the airway under direct vision while minimizing neck movement and tissue trauma. However, its effectiveness may decrease in the presence of blood, edema, or excessive secretions, especially after multiple failed attempts.[27]

Combining airway devices has emerged as another useful strategy in complex pediatric airways. Hybrid techniques integrating videolaryngoscopy with flexible bronchoscopy may improve tube guidance and facilitate tracheal intubation when either technique alone is insufficient. Such approaches are particularly useful when visualization is adequate but advancement of the endotracheal tube remains difficult. [28,29]

Supraglottic airway devices have an expanding role beyond temporary rescue ventilation. In Maintenance of oxygenation throughout airway manipulation remains a cornerstone of pediatric airway management. Continuous oxygen delivery during airway attempts, including apneic oxygenation techniques, may prolong safe apnea time and decrease the severity of desaturation. This is particularly important in infants and small children because of their limited oxygen reserve and rapid oxygen consumption.[30]

In situations where both ventilation and intubation become unsuccessful, rapid transition to emergency rescue pathways is mandatory. Delayed escalation after repeated failed attempts increases airway edema, bleeding, and hypoxemia, significantly worsening patient outcomes. Although emergency front-of-neck access is rarely required in children, every airway team should be familiar with institutional rescue protocols and prepared for immediate intervention when conventional airway management fails.[31]

Use of Ultrasound in Pediatric Airway Management

Ultrasound has emerged as an important adjunct in pediatric airway management because it allows direct bedside visualization of airway structures in a rapid, noninvasive, and radiation-free manner. In pediatric patients, where airway anatomy is smaller, more dynamic, and frequently variable, ultrasound provides additional anatomical information that may not be obtained through routine clinical examination alone. The growing interest in airway ultrasonography is related to its potential role in airway assessment, prediction of difficulty, procedural guidance, and confirmation of airway device placement.[32]

Ultrasound has also been increasingly investigated as a predictor of difficult laryngoscopy and difficult intubation. Several sonographic parameters have been studied, including tongue thickness, anterior neck soft tissue thickness, hyomental distance, and measurements of the subglottic airway. Increased soft tissue thickness in the anterior neck and reduced hyomental distance may correlate with more difficult glottic visualization during laryngoscopy. Although pediatric evidence is still evolving, ultrasound offers the advantage of objective anatomical measurement compared with bedside clinical tests that may be unreliable in younger children because of poor cooperation.[33]

Another important use of airway ultrasound is endotracheal tube sizing. Traditionally, tube selection in children has relied on age-based formulas, which may be inaccurate in patients with abnormal growth patterns, congenital syndromes, or airway pathology. Ultrasonographic measurement of the subglottic airway diameter allows individualized tube selection based on actual airway dimensions rather than estimated age. This may reduce complications associated with oversized tubes such as mucosal trauma, edema, and postextubation stridor, while also decreasing the need for repeated tube exchanges caused by undersized tubes.[33]

Ultrasound also has an expanding role in confirmation of airway device placement. Real-time sonographic visualization of tracheal tube passage can help distinguish tracheal from esophageal intubation rapidly, particularly in emergency situations where capnography may be delayed or unreliable. Bilateral lung sliding and diaphragmatic

movement can additionally be assessed to confirm effective ventilation and detect endobronchial intubation. In critically ill pediatric patients, this bedside assessment may reduce delays in recognition of misplaced airway devices.[34]
Another emerging application is the use of ultrasound in emergency airway rescue planning. Identification of anterior neck anatomy and localization of the cricothyroid membrane may be particularly difficult in infants and small children because laryngeal landmarks are small and poorly palpable. Preprocedural ultrasound marking may improve anatomical orientation in anticipated difficult airway cases where emergency front-of-neck access could become necessary. Although surgical airway access remains rare in pediatric practice, ultrasound may provide an additional safety measure in selected high-risk situations.[34]

Conclusion

Management of the difficult pediatric airway requires a structured and well-prepared approach that prioritizes oxygenation, minimizes repeated airway trauma, and promotes early use of advanced airway techniques when difficulty is encountered. Understanding the unique anatomical and physiological characteristics of the pediatric airway remains essential for safe clinical practice. Modern strategies including videolaryngoscopy, flexible bronchoscopy, supraglottic airway devices, and ultrasound-guided airway assessment have significantly improved airway management and patient safety. Successful outcomes depend not only on technical skill, but also on thorough assessment, careful planning, appropriate device selection, and timely escalation to rescue strategies when conventional techniques fail.

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