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ORIGINAL INVESTIGATION

Recommendations from the Brazilian Society of Anesthesiology (SBA) for difficult airway management in pediatric care

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Abstract
Difficult airway management in pediatrics during anesthesia represents a major challenge, requiring a careful approach, advanced technical expertise, and accurate protocols. The task force of the Brazilian Society of Anesthesiology (SBA) presents a report containing updated recommendations for the management of difficult airways in children and neonates. These recommendations have been developed based on the consensus of a panel of experts, with the objective of offering strategies to overcome challenges during airway management in pediatric patients. Grounded in evidence published in international guidelines and expert opinions, the report highlights crucial steps for the appropriate management of difficult airways in pediatrics,

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encompassing assessment, preparation, positioning, pre-oxygenation, minimizing trauma, and, paramountly, the maintenance of arterial oxygenation. The report also delves into additional strategies involving the use of advanced tools, such as video laryngoscopy, flexible intubating bronchoscopy, and supraglottic devices. Emphasis is placed on the simplicity of implementing the outlined recommendations, with a focus on the significance of continuous education, training through realistic simulations, and familiarity with the latest available technologies. These practices are deemed essential to ensure procedural safety and contribute to the enhancement of anesthesia outcomes in pediatrics.

Difficult airway management in pediatrics presents unique clinical challenges, requiring a careful approach and precise protocols. Rapid assessment and interventions are crucial in this scenario, which can arise in a variety of clinical situations, from elective procedures to emergency cases. Continuous education, training in realistic simulations, and familiarity with the latest technologies are vital when dealing with a difficult airway in pediatrics. A multidisciplinary approach and collaboration among healthcare professionals, including anesthesiologists, surgeons, and nursing staff, play a crucial role in the successful management of the difficult airway in pediatric patients.

The present article primarily aims to provide a comprehensive framework of practical recommendations for the effective management of difficult airways in pediatric cases, covering everything from initial assessment to intervention strategies. The recommendations are based on a synthesis and analysis of the current literature and their goal is to assist the decision-making process in the context of pediatric anesthesiology.

Importantly, the recommendations developed by the Brazilian Society of Anesthesiology (SBA) do not seek to establish absolute standards, and their use cannot assure specific outcomes. The present recommendations may be implemented, adapted, or rejected according to the clinical scenario and the document can be revised as necessary to keep pace with evolving medical evidence.

Pediatric airway management

Airway management in children differs from that in adults, just as neonates and infants differ from older children when it comes to the management of difficult airways. An epidemiological study revealed that the incidence of difficult intubation was 0.28% in pediatric patients, being higher in neonates (1%) and children under 1 year of age (1.1%). In children aged 1 to 5 years, the incidence was 0.2%, while for children aged 6 to 12 it was 0.1%, and for those over 12 years of age, 0.1%.[1]

The strategy to ensure a safe airway must focus on the only true objective which is to ensure survival without causing harm but guaranteeing adequate oxygen supply to the brain and other organs and tissues. The current approach must incorporate oxygenation as the primary target, abandoning attempts to intubate at any cost in favor of oxygenating at any cost.[2]

The evidence for pediatric airway management is still scarce, and although recent studies have provided some guidelines, most of the studies lack methodology rigor.[3]

How to define difficult airway in children

Similarly to adults, a difficult airway in pediatrics is defined by a clinical situation, previously identified or not, in which a skilled anesthesiologist has to deal with one or more of the following difficulties: maintaining adequate ventilation; placing the laryngoscope in the correct position; visualizing the vocal cords; inserting the tracheal tube.[4,5]

Anatomical characteristics that make it difficult to approach the airway

The inherent anatomical features of the pediatric age group may, by themselves, cause difficult airway situations in neonates and children. As the child grows up to 10 years of age, the respiratory system undergoes size, shape, position, and constitution changes.[6] The smaller the child, the greater the airway differences compared to adults.[7]

Table 1 describes the most important pediatric anatomical features that make pediatric airway management more challenging.[8-10] Likewise, the anesthesiologist's expertise can be a factor for pediatric airway management failure.

Acquired clinical conditions

Airway patency and/or access are influenced by several clinical conditions that affect anatomical structures, leading to a variable degree of ventilation obstruction. Among them, we highlight congenital, inflammatory, metabolic, neoplastic, and traumatic conditions.[10] The children's larynx is a cartilaginous skeleton. Fracture of airway structures is uncommon, but as ligaments and membranes connecting cartilaginous structures are immature, laryngotracheal separation is more frequent after trauma.[10]

Penetrating trauma is associated with different injuries, due to the nature of the tissues that enclose the larynx. Edema and hematoma formation adjacent to the vocal cords are fairly common, in addition to lacerations, displacement of the arytenoids, cricoid separation, and vocal cord paralysis, all factors that combined make tracheal intubation more cumbersome[11] (Table 2).

Table 1 Airway anatomical features associated with challenging airway management in pediatric care.

Anatomical region	Feature	Risks
Head	Relatively large in relation to neck and chest. Greater prominence of the occipital region.	It favors flexion of the neck over the chest when in the supine position, making it challenging to align the airway axes and visualize structures. Facilitates upper airway obstruction.
Nose	Presents relatively more mucosa and lymphoid tissue. Smaller nostril diameters.	Increased risk of edema, obstruction, and bleeding during nasal intubation.
Nasopharynx	Adenoid is hypertrophied in early childhood, and it is located in the roof and posterior wall of the nasopharynx.	Greater risk of obstruction to nasal air flow. Risk of bleeding, edema, and tissue detachment during nasal intubation.
Anterior mandibular space (space to which the tongue is displaced during laryngoscopy)	Until approximately 2 years of age, the mandible is relatively hypoplastic, with consequent reduction in the anterior mandibular space.	Airway obstruction occurs and direct visualization of glottic structures is challenging due to the disproportion between tongue size and oral cavity size. Any other condition making the anterior mandibular space even smaller will make laryngoscopy and intubation difficult.
Genioglossus muscle	It is smaller and its insertion is more posterior.	Passive airway obstruction, particularly in the supine position.
Larynx — ligaments	Ligaments and membranes connecting the cartilaginous structures are immature.	Greater risk of separation of structures in trauma. Greater susceptibility to dynamic airway collapse in the presence of respiratory obstruction.
Larynx — location	More cephalad position (C3-C4), making the distances between tongue, hyoid bone, epiglottis, and rim of the mouth shorter.	Upper airway obstruction when tongue is pushed into the oral cavity.
Larynx — angle between the base of the tongue and the glottic cleft	The angle between the base of the tongue and the glottal cleft is more acute.	Makes direct visualization of structures problematic.
Larynx — mucosa and submucosa	Tissues are abundantly vascularized, and have abundant lymphatic tissue, conferring an appearance of engorgement to the region.	Edema and bleeding of the laryngeal fossa, epiglottis, and glottis during airway handling. Difficult visualization of the vocal cords when using straight blades.
Epiglottis — anatomy and location	In newborns, the epiglottis is narrow, longer, less tonic, omega shaped (Ω), and is located more angled to the axis of the trachea.	Elevating the epiglottis during laryngoscopy is problematic.
Vocal cords	They are more cartilaginous, inserted more anteriorly and have a more inferior closure.	Edema formation during tracheal cannula insertion or using a tracheal cannula of inadequate size can make it difficult to maintain adequate ventilation after tracheal extubation. More susceptible to trauma.
Trachea	Variable diameter (around 3 to 6 mm).	Greater risk of airway obstruction when edema is present, which can occur when an inadequate size tracheal cannula is chosen, facilitating extubation failure.
Cricoid cartilage	The cricoid cartilage forms a complete ring in the airway. The cricoid cartilage, that rests on a basement membrane, is almost devoid of elastic fiber, thus it is not an expandable or mobile structure. Until the age of 10 to 12, it is considered the greatest narrowing point of the larynx.	Prolonged tracheal intubation or using a cannula with an inadequate diameter increases the risk of cricoid compression injury, the likelihood of edema formation, reduction in tracheal lumen to a critical diameter and extubation failure. The injury may later progress to subglottic stenosis.

Table 2 Clinical conditions that can make pediatric airway management difficult according to etiology and anatomical structure.[10]

Etiology	Affected anatomical structure				
	Nasopharynx	Tongue	Mandible/ Maxilla	Pharynx/ Larynx	Trachea
Congenital				Laryngomalacia Stenosis Laryngocele Laryngeal membrane	Vascular ring Tracheomalacia Stenosis
Inflammatory	Adenoid hypertrophy Nasal congestion		Juvenile rheumatoid arthritis	Granuloma Epiglottitis Amygdalitis Abscess Diphtheria pseudomembrane Laryngeal polyps	Laryngotracheobronchitis Bacterial tracheitis
Metabolic		Mucopolysaccharidosis Hypothyroidism Glycogen disease		Laryngospasm associated to hypocalcemia	
Neoplastic	Teratoma	Teratoma Hygroma Hemangioma	Bone tumors	Tumors	Mediastinal tumor Neurofibroma Paratracheal nodules
Traumatic	Foreign body Burns Trauma	Lacerations Venous obstruction Lymphatic obstruction	Fractures Neck retracted scars	Fractures Separation of structures Inhalation injury Foreign body Post intubation stenosis Epidermolysis Bullosa	Post intubation stenosis

Congenital airway malformations

The most frequent syndromes and malformations that determine anatomical abnormalities that can result in a difficult airway are cleft palate and craniofacial dysostoses.[10,12] In some syndromes, the defects undergo changes during the child's growth or development, increasing the level of difficulty.[12] Maxillary hypoplasia often occurs associated with choanal atresia and/or some degree of nasal obstruction. These patients are mouth breathers and suffer from respiratory obstruction when the mouth is closed. Hypoplasia of the maxilla and mandible and tongue hyperplasia reduce the volume of the oral cavity, causing upper airway obstruction.[10] Micrognathism is an important and reliable risk factor for predicting difficult laryngoscopy, particularly in children under 6 months of age.[7]

Temporomandibular joint (TMJ) disorders prevent inferior and/or anterior displacement of the jaw, restricting mouth opening and making airway handling difficult. The fixed causes (congenital or traumatic conditions) of these defects do not change with anesthesia. Conversely, non-fixed causes (inflammatory processes or abscesses that cause trismus) are eased allowing patients to open their mouths completely under the effect of general anesthesia. Diseases reducing cervical spine mobility (vertebral and hemivertebrae fusions, arthropathies, etc.) make airway management and tracheal intubation challenging or even impossible.[9,10]

Clinical conditions presenting cervical spine instability have a greater risk of spinal cord injury, making it difficult to optimize the patient's position to access the airway.[9,10] The mass effect caused by soft tissue accumulation can also limit cervical mobility, mouth opening, and eventually airway management. The most commonly encountered mass effect is macroglossia, followed by tumors and arteriovenous malformations[9,13] (Table 3).

Assessment of the child's airway

Despite lacking validated criteria to identify difficult airway in a pediatric patient, airway assessment should comprise the following topics:

Table 3 Congenital airway malformations.[12]

Malformation	Characteristics	Associated risks
Cleft palate	Cleft palate is associated with other malformations, such as macroglossia, mandibular or maxillary hypoplasia.	Challenging both to adapt facial mask and insert oropharyngeal cannula (Guedel) When the clefts are bilateral, they generate angulation in the airway axes, and the insertion of the laryngoscope blade is problematic.
Craniofacial dysostoses/ premature closure of skull bones	Hypoplasia of facial bones, predisposing to a small jaw, high palate, and decreased development of paranasal sinuses. Modified tongue volume/oral cavity volume ratio.	Optimizing patient position for airway management is problematic. Restricted cervical mobility. Properly adapt mask to face is challenging. Increased risk of oral cavity occlusion.

Clinical history

It is important to identify the following information:[7,13,14] diseases or syndromes associated with difficult airway (Table 4); previous anesthesia with reports of struggle during airway management; acquired conditions with airway changes (examples: radiotherapy to the face and neck, inflammatory processes, burns or trauma); history suggesting respiratory obstruction (examples: choking, hoarseness, snoring, apnea, stridor, changes in sucking or swallowing); possible postural changes facilitating sleeping or improving respiratory condition.

Physical examination

It is necessary to evaluate:[5,7,14,15] abnormal movement, size, and aspect of the head (examples: low-set ears, facial asymmetries, limited range of movement of temporomandibular joint); mouth opening, palate shape, prominent upper incisors, and tongue size; changes in the maxilla, mandible, and submandibular region (for example: range of movement and presence of retrognathia); cervical changes and cervical range of movement; hyomental distance > 1.5 cm (neonates) and > 2.0 cm (infants) are associated with appropriate visualization of glottis structures; occurrence of scars, deviations, hematomas, tumors and subcutaneous emphysema; lung auscultation, chest expansion and use of accessory muscles.

The different methods used to detect a difficult airway in adults are not validated for the pediatric population.[7,16] The Mallampati classification can be useful in children over 5 years of age who can cooperate during the test.[17] In children between 0 and 2 years of age, an association is described between difficult laryngoscopy and body mass index (< 15.10 $kg.m^{-2}$), thyromental distance (< 3.55 cm, a more specific parameter), mandibular length (< 6.5 cm), tragus to mouth distance (< 7.75 cm) and age less than 1 year.[18] In children under 5 years of age, the combined assessment of the lower lip-to-chin distance (< 2.2 cm), the tragus-to-mouth distance (< 3.9 cm), and low body mass index (< 12.17 $kg.m^{-2}$) correlate with difficult glottis visualization during laryngoscopy, with high specificity and sensitivity.[15]

Retrognathism and micrognathism are associated with difficult laryngoscopy. Likewise, the inter-incisor distance, sternomental distance, and thyromental distance are predictive of difficulty in laryngoscopy. (7) In children under 2 years of age, the major predictors of difficult laryngoscopy viewing are age < 6 months, weight < 5 kg, and height < 61 cm.[19]

Mnemonic methods, such as ABCDE, aid airway assessment (Table 5). Complementary tests, such as x-Ray and CT scan help to elucidate data from medical history and physical examination suggestive of anatomical airway changes. Sublingual ultrasonography is accurate in predicting difficult tracheal intubation when the hyoid bone is not visualized, with sensitivity and specificity of 73% and 97%, respectively.[20]

Maintenance of adequate oxygenation during intubation

Apnea in the pediatric population causes oxygen saturation (SpO_2) to drop more quickly than in the adult population. This is due to a combination of physiological features of the child, such as high oxygen consumption (5 to 8 $mL.kg^{-1}.min^{-1}$), making children more dependent on normal ventilation to keep tissue oxygenation. Children's high minute volume (130 $mL.kg^{-1}.min^{-1}$) reveals this dependence. Early arterial desaturation onset is the lower functional residual capacity compared to minute volume, causing lower lung oxygen reserve at the end of expiration and during apnea.[8]

Thus, during a child's apnea, there is less available time for managing the airway, explaining the high incidence of hypoxemia during pediatric tracheal intubation, that is in up to 13% of tracheal intubations, and in up to half of difficult intubation cases.[8]

In newborns, hypoxemia events are even more frequent, reaching 75% of difficult tracheal intubation cases, and 42% of cases in which tracheal intubation was not deemed difficult.[21] Thus, it is critical to implement approaches to reduce the occurrence of hypoxemia, mainly: pre-oxygenation and oxygenation during intubation. Apneic oxygenation or

Table 4 Syndromes favoring the occurrence of a difficult airway situation.[10]

	Choanal defects	Micrognathia	Micro-stomia	Macro-glossia	Larynx defects	Palate defects	Cervical spine defects	Cardiac defects
Down's syndrome				X	X	X	X	X
CHARGE syndrome	X	X			X			X
Pierre-Robin syndrome	X	X		X		X		
Treacher-Collins syndrome	X	X	X		X			
Edwards syndrome	X	X	X		X		X	
Goldenhar syndrome		X			X		X	
Beckwith-Wideman syndrome				X				X
Klippel-Feil syndrome							X	
Freeman-Sheldon syndrome			X		X			
Apert syndrome	X	X						
Crouzon syndrome	X	X						
Pfeiffer syndrome	X	X						
Progressive fibrodysplasia ossificans		X					X	
Mucopolysaccharidosis				X	X			X

Table 5 ABCDE mnemonic method for airway assessment.

A. Congenital (syndromes) or acquired (tumors, burns, trauma, infections, trismus) anomalies;
B. Mouth (opening, tongue, tooth, hypoplasia);
C. Neck (cervical range of movement, deformities, TMJ);
D. Dysphagia, dysphonia;
E. Stridor and stenosis.

spontaneous breathing oxygenation are the recommended strategies during tracheal intubation of children.[22]

Evidence for pre-oxygenation in children

Previous studies suggest that administering tidal volume breathing for 3 minutes or 8 respiratory cycles at vital capacity, with the use of 100% oxygen, constitutes adequate strategies to extend safe apnea time.[23]

Apnea time with $SpO_2 > 95\%$ is shorter the younger the child, in line with the expected physiological development during childhood. In children of 2 months of age undergoing laryngoscopy for tracheal intubation, paralyzed and exposed to apnea, the time for oximetry to decrease from 100% to 95% is longer in those previously ventilated with 100% oxygen compared to those ventilated with a 40% oxygen mixture with nitrous oxide or air.[24]

Evidence for low- and high-flow apneic oxygenation in children

Apneic oxygenation during the management of the pediatric airway has become the standard technique both when the difficult airway is expected and when greater safety is required during the apnea period of elective tracheal intubation.[4]

Low-flow techniques

Low-flow techniques ($< 2\ L.kg^{-1}.min^{-1}$) include oxygenation through nasal or pharyngeal cannulas or a laryngoscope. Studies evaluating pharyngeal cannula with or without administration of supplemental oxygen during direct laryngoscopy revealed a decrease in desaturation incidence when oxygen is administered.[25] Experimental data have suggested that administering oxygen through an oropharyngeal cannula or a direct laryngoscopy blade has an advantage when compared to a nasal cannula.[26]

A randomized study comparing three techniques of administering supplemental oxygen to apneic children (nasal cannula supplying 100% O_2 at $0.2\ L.kg^{-1}.min^{-1}$; transnasal humidified rapid insufflation ventilatory exchange (THRIVE) supplying 100% O_2 at $2\ L.kg^{-1}.min^{-1}$ and THRIVE supplying 30% O_2 at $2\ L.kg^{-1}.min^{-1}$), showed that children receiving 100% O_2 perform better than those receiving 30% O_2.[27]

There have been reports describing gastric rupture associated with nasal or nasopharyngeal cannulas supplying gas at $3\ L.min^{-1}$ or more, although cannula location was checked, supporting the recommendation of using low gas flow rates. Using a cannula is safe when the following conditions are observed: administration for a short period, the child's mouth is kept open, the pharyngeal location of the cannula is confirmed, frequent gastric palpation is performed, and the cannula in the maxillary region is secured.[28]

Table 6 Flow rate values for high-flow systems according to weight.

Up to 3 kg	6 L.min^{-1}
3 to 5 kg	10 L.min^{-1}
5 to 10 kg	20 L.min^{-1}
10 to 20 kg	35 L.min^{-1}
20 to 40 kg	40 L.min^{-1}
40 to 60 kg	50 L.min^{-1}
Adults	70 L.min^{-1}

Apneic oxygenation with a nasal or pharyngeal cannula makes ventilation with a face mask difficult, due to the impossibility of maintaining the facial seal, requiring cannula removal for effective face mask ventilation.

High-flow techniques

During the past decade, we have observed increased use of apneic oxygenation with a high-flow nasal cannula (> 2 L.kg^{-1}.min^{-1}) aiming to reduce the incidence of hypoxemia during airway management.[21,29] High-flow systems consist of a gas mixer connected to the oxygen and compressed air high-pressure outlets, enabling titration of the fraction of inspired oxygen (FiO_2); heater; humidifier; circuit, and high-flow nasal cannula or mask. The high-flow technique allows administering up to 80 L.min^{-1} flow rate, generates airway positive pressure, reduces respiratory effort, and optimizes oxygenation.

In children, it is recommended to adjust the flow rate according to weight (Table 6), as excessive flow rates cause airway mucosa injury and are associated with gastric inflation and pneumothorax.[21]

To date, however, no robust evidence has been found showing the superiority of high-flow nasal cannula techniques for apneic oxygenation in pediatric intubation when compared to low-flow techniques.[21,29] The high-flow technique reduces alveolar CO_2 concentration, and decreases hypercapnia and respiratory acidosis in adults, findings that have not been reported in children.[27,30]

Children's physiological and anatomical features, such as high metabolic rate and small airway caliber increased flow resistance, are believed to prevent adequate elimination of CO_2. Moreover, the gas flow rates studied so far in children may be insufficient to overcome the high airway resistance and reduce CO_2.[21]

However, the advantage of the high-flow nasal cannula technique is that enables humidifying and warming the administered gas, lowering the risk of airway mucosal damage triggered by administering dry gases. Conversely, some disadvantages of high-flow systems must be pointed out, such as high cost, requirement of specific equipment not yet easily accessible in the operating room, and difficult face mask ventilation.[21]

Oxygenation with spontaneous breathing

For children with documented difficult airway, it is possible to choose an anesthetic technique that combines sedation and spontaneous breathing, especially when flexible bronchoscopy is planned. Also, when managing an apneic child, it is essential to maintain an O_2 supply as it optimizes oxygenation and minimizes adverse events. In these cases, oxygenation techniques with low and high O_2 flow can be used.[31] Comparing high-flow nasal cannulas with low-flow nasal cannulas in healthy, sedated and spontaneously breathing children has not revealed significant differences in hypoxemia, hypercapnia, and apnea rates.[31,32]

Summary of oxygenation recommendations in children

- Pre-oxygenation with 100% O_2 should be routinely used for airway management of every child, observing the patient's acceptance;
- When opting for intubation post-anesthetic induction (apneic child), apneic oxygenation is recommended, particularly when higher hypoxemia risk is identified;
- Whenever opting for apneic oxygenation, use the technique you feel more comfortable with, as no superiority between low- or high-flow techniques has been found;
- When opting for tracheal intubation under sedation and spontaneous breathing, the recommendation is to maintain oxygenation using the technique you feel more comfortable with (low or high-flow techniques);
- When using low-flow techniques, limit flow rate to 0.2 L.kg^{-1}.min^{-1}, optimize cannula position, and frequently palpate the abdominal region for early detection of gastric distension;
- When using a high-flow nasal cannula technique, adjust the flow rate according to weight and plan a prompt switch to a face mask and breathing circuit system, when required.

How to manage an anticipated difficult airway

Anticipated pediatric difficult airway is performed under general anesthesia or sedation. It requires skills, detailed care, and an experienced professional.[4] Difficult airway management training emphasizes the importance of spontaneous breathing to maintain oxygen saturation and airway tone during the procedure. Moreover, it provides the patient with continuous oxygenation and fast recovery if tracheal intubation fails.[33] Thus, it is critical to maintain oxygen supply at all stages of airway handling.[4] Airway handling under an insufficient anesthesia depth is one of the major causes of laryngospasm and other adverse events during intubation.[34]

Sedatives, analgesics, and even neuromuscular blockers are indicated in most cases. They provide comfort, enable to optimize patient position, minimize sympathetic responses, facilitate glottis exposure, and make the procedure safe.[35]

How to choose drugs and techniques for sedation or general anesthesia

When compared to intramuscular and intranasal routes, intravenous sedation is safer, given its predictable effect and duration of action. Combining intravenous with inhalational agents may also be useful to reduce administered

doses and adverse events. Non-depolarizing neuromuscular blockers can be indicated for a patient with a suspected difficult airway, as they facilitate intubation by decreasing airway reactivity and vocal cord movement. Depolarizing neuromuscular blockers have the advantage of a fast onset of action and a relatively short duration of action.[33] Non-depolarizing neuromuscular blockers administered in high doses can create suitable intubation conditions at onset times similar to depolarizing agents, with longer duration of action. If a specific reversal is unavailable, its use is not recommended.[33] Clinicians must ensure that all required drugs, materials, and equipment are available, tested, functioning, and ready for use.

If succinylcholine is administered, the American Heart Association Pediatric Advanced Life Support guideline recommends using atropine (0.02 $mg.kg^{-1}$) for infants under 1 year of age, in children aged 1 to 5 years, and for adolescents receiving a second dose of succinylcholine.[36] However, atropine is not always effective in preventing bradycardia. Table 7 contains the most commonly used drugs during orotracheal intubation in pediatrics.

When to choose between a video laryngoscope and flexible bronchoscope for managing an anticipated difficult airway

First-attempt success rates with flexible bronchoscopy are similar to video laryngoscopy. Most of the literature related to tracheal intubation techniques for children with difficult airways is restricted to experimental simulation studies or studies with small samples or performed in a single center. During the initial approach to difficult airways in neonates, children, and adolescents, the number of intubation attempts should be limited. Oxygenation is critical during the instrumentation of an anticipated difficult airway. The apneic child has a short time to desaturate, less than 6.5 seconds in neonates and infants, and up to 13 seconds in adolescents.[37,38]

Flexible bronchoscopy is not indicated in emergencies, and some factors limit its use:[39,40] hypoxemia due to previous intubation attempts, with already inefficient ventilation or apnea; active bleeding or copious and/or thick secretion, rendering ineffective aspiration through the fiberscope working channel; ineptitude in handling the fiberscope. Table 8 describes the preparation for performing oral or nasal flexible bronchoscopy.

Spontaneous breathing can be attained with a facial mask designed for flexible bronchoscopy, or a regular facial mask attached to a swivel, through which the flexible bronchoscope can be inserted. Using a proper size flexible bronchoscope according to the patient's age enables inserting a tracheal tube with the correct size for the patient. During the entire procedure, assistance from another anesthesiologist is required, while one manages the airway, the other keeps the facial mask attached to the face, allowing spontaneous breathing and adequate oxygenation.

The working channel of the flexible bronchoscope enables the insertion of an 18- or 20-mm epidural catheter to instill local anesthetic, a technique called "spray-as-you-go". Monitoring the volume of local anesthetic used is critical for children, due to the risk of local anesthetic systemic toxicity. After visualization of the vocal cords and, with the airway secured by positioning the flexible bronchoscope, anesthesia can be deepened and the neuromuscular blocker can be administered, averting the reaction to the tracheal tube passage. It is important to be sure the tracheal tube has been inserted beyond the vocal cords.

Flexible bronchoscopy via a supraglottic device is an alternative approach to pediatric difficult airway, using a supraglottic device specifically designed. However, if a dedicated supraglottic device is unavailable, a regular supraglottic device can be used. A supraglottic device allows for continuous oxygenation and ventilation while providing a conduit for intubation. Compared with videolaryngoscopes the technique may be advantageous, as hypoxemia is the most common initial sign of adverse events related to intubation in children with difficult airways, especially in children under 1 year of age. Additionally, supraglottic devices also relieve upper airway obstruction and optimize the bronchoscope view of the larynx.[40]

Nasal flexible bronchoscopy can also be performed and maintenance of spontaneous breathing is also essential. The technique requires administering nasal vasoconstrictors, as nasal bleeding is associated with tracheal intubation failure.[41]

Exceptionally, when a proper-sized flexible bronchoscope is unavailable, the Seldinger technique can be used. Essentially, the airway management steps are the same, except, given its large size, the flexible bronchoscope is not inserted beyond the glottis. Thus, a malleable or J-shape tip hydrophilic guide wire is inserted through the flexible bronchoscope working channel. After visualizing the guide wire passing through the vocal cords, the flexible bronchoscope is removed, and an exchange tube is introduced, followed by the tracheal tube. It should be underscored that the technique is feasible only if it is possible to oxygenate the child using a proper face mask or supraglottic device.

Video laryngoscopy has become an important and frequently used tool in pediatric airway management. In children presenting a difficult airway, it enables superior glottic view and higher tracheal intubation success rates than conventional direct laryngoscopy. It is considered an alternative technique to flexible intubation bronchoscopy. The advantage of being a technique similar to conventional direct laryngoscopy makes the technique easier to learn. Nonetheless, it may be challenging in patients with small or limited mouth opening, situations in which flexible bronchoscopy is indicated. Hyperangulated video laryngoscope blades provide a better view of the rima glottidis and shorten the time to vocal cord visualization.[42-44] There is still no evidence in the pediatric population of the superiority of any device used for video laryngoscopy. Thus, the choice of device depends on the expertise of the clinician and the availability of the equipment.[45,46]

How to manage unanticipated difficult airway after anesthetic induction in children

"The ability to oxygenate and ventilate must be prioritized over tracheal intubation."[47]

The incidence of unpredicted difficult face mask ventilation in children can reach 6% and is not associated with

Table 7 Doses and characteristics of the drugs used during pediatric airway management.

Drug	Dose	Duration of action	Comments
Autonomic nervous system			
Atropine	IV: 0.01—0.02 mg.kg^{-1} (max.: 1 mg)	> 30 min	Inhibits the bradycardia response to hypoxia; can cause tachycardia May cause pupil dilation
Hypnotics sedatives and analgesics			
Diazepam	IV: 0.1—0.2 mg.kg^{-1} (max.: 4 mg)	30—90 min	May trigger respiratory depression or potentiate the depressant effects of narcotics and barbiturates
Midazolam	IV: 0.1—0.3 mg.kg^{-1} (max.: 4 mg)	1—2 h	Minimal cardiac depression Sporadic respiratory depression No analgesic properties
Fentanyl	IV, IM: 2—5 mg.kg^{-1}	IV: 30—60 min IM: 1—2 h	May cause respiratory depression, hypotension, chest wall rigidity with high dose infusions (> 5 mg.kg^{-1})
Anesthetic agents (when administered in the doses indicated)			
Etomidate	IV: 0.2—0.4 mg.kg^{-1}	5—15 min	May cause ventilatory depression Minimal cardiovascular effects Myoclonic activity; can decrease seizure threshold Cortisol suppression; contraindicated in patients dependent on the endogenous cortisol response No analgesic properties
Lidocaine	IV: 1—2 mg.kg^{-1}	~30 min	Myocardial and CNS depression with high doses May decrease ICP Occasionally associated with hypotension
Ketamine	IV: 1—2 mg.kg^{-1} IM: 3—5 mg.kg^{-1}	30—60 min	May increase arterial blood pressure, heart rate, cardiac output May cause increased secretions and laryngospasm Causes mild respiratory depression Bronchodilator May cause hallucinations and awakening hyperactivity
Propofol	IV: 2 mg.kg^{-1} (for small children up to 3 mg.kg^{-1})	3—5 min	May cause hypotension, especially in hypovolemic patients May cause injection pain Highly fat-soluble Causes less airway reactivity than barbiturates
Neuromuscular blocking agents			
Succinylcholine	Infant IV: 2 mg.kg^{-1} Children IV: 1—1.5 mg.kg^{-1} IM: Multiply the IV dose by two	3—5 min	Depolarizing muscle relaxant that causes muscle fasciculation May cause increased ICP, intraocular pressure and intragastric pressure May cause hyperkalemia May cause arterial hypertension Avoid in cases of renal failure, burns, crush injuries or hyperkalemia
Atracurium	IV: 0.5 mg.kg^{-1}	30—40 min	Metabolized by plasma hydrolysis May cause mild histamine release
Cisatracurium	IV: 0.1 mg.kg^{-1}, then 1—5 mg.kg^{-1}.min^{-1}	20—35 min	Metabolized by plasma hydrolysis May cause mild histamine release
Rocuronium	IV: 0.6—1.2 mg.kg^{-1}	30—60 min	Minimal cardiovascular effects
Vecuronium	IV: 0.1—0.2 mg.kg^{-1}	30—60 min	Minimal cardiovascular effects

Table 8 Material required to perform flexible intubation bronchoscopy in pediatric anesthesia.

1. Material preparation
- Nasal cannula
- Mouthpiece
- Fiberoptic intubating airway (e.g.: Berman, Willians, or Ovapassian)
- Facial mask for fibro bronchoscopy and swivel mask
- Supraglottic devices (e.g.: intubating laryngeal mask, LMA Fastrach™, Air-Q™, iGel™, and Ambu-Aura-i™)
- Hydrophilic guide wire
- Suctioning device
- Flexible bronchoscope (with or without working channel) and external diameter of 2.8 to 6.3 mm
- Local anesthetic and atomizer
- Aintree intubation catheter and/or epidural catheter

2. Monitoring
- EKG
- Capnography
- Pulse oximetry
- Noninvasive arterial blood pressure

3. Anesthetic induction
- Inhaled or intravenous
- Keep patient breathing spontaneously

4. Antisialagogue
- Atropine

5. Topical administration of local anesthetic (lidocaine)
- Oral or nasal atomization
- Use an epidural catheter to atomize

difficult intubation.[3] However, previous data have revealed that 13% of difficult intubations in neonates and premature infants under 60 weeks of post-conceptual age also represent challenging face mask ventilation.[3] The Pediatric Difficult Intubation (PeDI) Registry shows that 8% of patients present both difficult tracheal intubation and face mask ventilation, and from these, approximately 7% are impossible to ventilate with a face mask.[22]

What to do during a "no oxygenation" scenario

In daily practice, it is essential to check the anesthesia equipment before connecting the patient. However, equipment failure is not uncommon and can make manual ventilation difficult. In this situation, the most correct approach is to separate the patient from the anesthesia machine and use an external source of oxygen with a self-inflating bag or mask bag.[3]

Airway obstruction is the major cause of anesthesia-related perioperative hypoxemia and requires prompt and appropriate detection and treatment. To manage the situation successfully, it is critical to distinguish anatomical (mechanical) from functional (physiological) causes to implement their distinct treatment strategies.[47]

Anatomical causes are physical and usually relieved with basic and advanced airway maneuvers, while severe functional causes are usually treated with drugs. For example, partial laryngospasm produces anatomical obstruction that can be readily reversed with airway maneuvers, while total laryngospasm often requires drug administration to be treated.

Some examples of mechanical obstruction include inadequate head positioning, adenotonsillar hypertrophy, obesity, foreign body and secretions, and gastric hyperinflation or distension. Functional obstruction occurs both in the upper and lower airway. The major causes are inadequate anesthetic depth, pharyngeal closure, laryngospasm or glottic closure, chest wall rigidity, and bronchial hyperreactivity.[47]

How to restore ventilation and oxygenation in anatomical obstructions

Optimized positioning

Optimal positioning for ventilation and intubation depends on age. In children over 6 years of age, proper positioning is similar to adults, slightly elevating the head, anteriorly displacing the cervical spine, and simultaneously, extending the head at the atlanto-occipital joint.[8]

In newborns and infants, head elevation is not required due to the disproportion of the occiput about the trunk, which maintains the anterior cervical displacement. It is useful to place a cushion below the shoulders or a roller to hold the occiput, preventing head rotation and aligning the oral and pharyngeal axes.[48]

Adjustment of the face mask

A proper face mask size must be selected. The mask is applied on the nose, keeping eyes free and the mask aligned to the nasolabial fold, resting the mask on the jaw and avoiding placing fingers in the region of the mentum. In neonates and infants, it is preferable to pull the jaw at the

temporomandibular joint, close to the tragus, keeping the mouth slightly open and resting the index and middle fingers on the mask and not on the jaw.[48] The combination of the sniffing position, mouth opening, and continuous positive pressure (CPAP) with a maximum inspiratory pressure of 10 cmH_2O set on an adjustable pressure-limiting (APL) valve improves the expiratory tidal volume and peak inspiratory pressure, optimizing face mask ventilation.[49] Another useful alternative for improving face mask ventilation is the bimanual technique.[3]

Devices to relieve airway obstruction

Several supraglottic device designs are available with some advantages over others. Second-generation devices are more effective as they enable lower-pressure ventilation and are easy to insert and secure. However, they are associated with a risk of displacement or poor positioning, incorrect sizing, and local trauma. Therefore, it is important to limit the number of insertion attempts to a maximum of three.[1] Alternatively, a correct size Guedel oropharyngeal cannula or nasopharyngeal cannula will relieve most anatomical upper airway obstructions.[47]

Nasopharyngeal cannulas are not a first-line strategy, but if the mouth opening is insufficient to allow for an oral cannula or a supraglottic device, it is the device of choice. The anesthesia breathing circuit can be connected to any type of nasopharyngeal cannula using the correct orotracheal tube adapter. The technique can facilitate intubation for patients with a difficult airway, allowing the administration of oxygen and anesthetics during airway management.[50]

Orogastric tubes are recommended in cases in which gastric distension results from forced bag-mask ventilation and prolonged ventilation with a face mask or supraglottic device. Gastric distension can obstruct ventilation and oxygenation due to changes in diaphragm mechanics requiring immediate decompression.[47]

How to treat changes in ventilation and oxygenation caused by functional obstruction

Anesthesia depth and neuromuscular blockers

Whenever mask ventilation is challenging and anatomical obstruction has been ruled out, the difficulty is possibly caused by functional obstruction. Therefore, it is recommended to deepen the anesthesia or use neuromuscular blockers.[3] For functional obstruction, prompt use of hypnotics and neuromuscular blockers is a better option than awakening the child, since tolerance to apnea in young children is low and the "no-oxygenation" situation is critical. Propofol is the first option to be used as it promotes airway relaxation. It is noteworthy that careful hemodynamic monitoring is essential, as severe hypotension may occur.[3] Neuromuscular blockers also improve tracheal intubation conditions.[47]

Specific situations of functional obstruction and their pharmacological treatment

Initial management for partial laryngospasm is the administration of 100% oxygen and continuous airway pressure (CPAP), followed by increasing anesthetic depth. In children without intravenous access, anesthesia can be deepened with inhalational agents and, if required, intramuscular succinylcholine at a dose of 4 to 5 $mg.kg^{-1}$ can be used.[3,8] In children with venous access, after initial management the approach is propofol (0.5 to 5 $mg.kg^{-1}$), titrated to the desired effect. If the situation deteriorates, succinylcholine (0.1 to 1 $mg.kg^{-1}$) or rocuronium (0.9 to 1.2 $mg.kg^{-1}$) can be used. Rocuronium has the advantage of neuromuscular blockade reversal if awakening the child is decided.

In the presence of complete laryngospasm, with or without venous access, the management strategies are the same. If a neuromuscular blocker or repeated doses of propofol are administered, face mask ventilation is expected to be easier. If not, tracheal intubation is the next step to be considered.[3] Another example of functional obstruction is bronchospasm, which must be treated with bronchodilator drugs, such as inhaled salbutamol or sevoflurane. Low doses of intravenous epinephrine (1 $mcg.kg^{-1}$) are highly effective for treating severe bronchospasm.

Chest wall rigidity secondary to rapid administration or high doses of opioids is also a cause of functional obstruction, which can be treated using neuromuscular blockers. Attention should be paid to the use of neuromuscular blockers in patients with documented distal airway obstruction (tumors, mediastinal masses), as the drug can precipitate airway collapse, and worsen obstruction.[47]

It is important to underline that arterial oxygen saturation must be monitored in each additional intervention trying to rescue ventilation. Once arterial oxygen saturation has improved, the chosen maneuvers or devices can be resumed. If arterial oxygen saturation deteriorates, inserting a supraglottic device or a tracheal tube should be considered.[3]

What should be done in the "cannot intubate, cannot ventilate" scenario

First failed intubation attempt

When manual ventilation with a face mask is feasible, the clinician should call for help after the first failed attempt of tracheal intubation. This happens rather frequently and there are a limited number of recommended intubation attempts, so it is fundamental to have the best help available fast.[3] In this setting, alternative airway management techniques should be used straight away.[47]

Limit the number of intubation attempts

There is a strong relationship between severe cardiorespiratory events and the number of direct laryngoscopy attempts. Thus, a rapid shift to indirect laryngoscopy is recommended. When required, the initial airway management plan must be reassessed and changed. Intubation attempts should be limited to three to four.[1,22] When the first direct laryngoscopy is challenging, adjusting the head and neck extension is strongly recommended to optimize viewing.[3]

Strategies for optimizing laryngoscopy

The first tracheal intubation attempt must be performed using the best technique. In children up to 2 years of age, a straight blade allows proper tongue positioning in the submandibular space and the creation of a more acute angle between the lip rim and laryngoscope blade, providing a better glottis view.[48]

Larynx external displacement (BURP maneuver: backward, upward, and rightward pressure) is used when the laryngeal view is reduced. In young children, external maneuvers can distort the larynx or trachea anatomy due to excessive external pressure, making tracheal intubation impossible. In this case, prompt cessation or adjustment of cricoid pressure is recommended.[3]

Alternative techniques to assist tracheal intubation

The Gum Elastic Bougie (GEB) is a useful tracheal tube introducer when the epiglottis is visible, but the vocal cords are not, and there is no laryngeal or tracheal injury.[51] Blind insertion of a GEB in a child showing a laryngoscopy laryngeal view classified as Cormack-Lehane grade 4 is not recommended due to the likelihood of injuring the child's fragile airway structures.[3]

Video laryngoscopy is an alternative technique to direct laryngoscopy. It is crucial to provide training focused on the devices available at each facility. It must be underlined that video laryngoscope does not apply to all patients and its use does not assure successful tracheal intubation.[2] Failure in tracheal intubation using these methods should indicate the use of a supraglottic device or, even, canceling the procedure. If local experience and resources are available, tracheal intubation using a flexible bronchoscope (nasal, oral, or supraglottic device-aided) or combined techniques may be useful in the sequence of airway management.[47]

Supraglottic devices

Supraglottic devices are easy to insert confirming their value in pediatric difficult airway algorithms because they secure oxygenation and ventilation. The laryngeal mask airway is the first rescue device to be used in the event of intubation failure, provided that there is no complete obstruction of the upper airway or a condition that could be worsened by the injury resulting from multiple supraglottic device insertion attempts.

There are laryngeal masks dedicated to pediatric patients, particularly for babies and young children, with specific design features that enable better airway sealing and greater protection against lung aspiration and include a working channel for nasogastric tube insertion and stomach decompression. However, the laryngeal mask airway should be avoided in patients with airway obstruction or anatomical distortion.[51]

Once well positioned, supraglottic devices enable oxygenation and ventilation. If inadequate ventilation occurs, the device should be replaced by another with an increased size. For procedures that can safely proceed with a supraglottic device, this approach can become part of the anesthesia technique. Conversely, if the procedure requires tracheal intubation, flexible bronchoscopy aided by a laryngeal mask airway is the most indicated technique for tracheal intubation, providing it is performed by a trained practitioner. After successful insertion of the tracheal tube, the best approach is to maintain the laryngeal mask *in situ*.[3,52]

In case of tracheal intubation failures using the laryngeal mask airway, the first step is to evaluate oxygenation. If oxygenation is adequate, the device is maintained. Then, one should consider if the procedure should be resumed or if it is necessary to wake the patient. However, if after insertion of the supraglottic device inadequate oxygenation (SpO_2 < 90% with FiO_2 1.0) is observed, the device must be removed and ventilation with a face mask resumed.[3,52]

Although there is no consensus, studies suggest that the maximum number of supraglottic device insertion attempts be limited to three, direct laryngoscopy to four, and that only one attempt using a flexible bronchoscope through a well-positioned laryngeal mask airway is acceptable.[3] However, it is worth emphasizing that clinical judgment must be exercised when assessing the need to increase the number of attempts with any technique. Successful intubation allows the procedure to continue. However, if attempts at intubation and oxygenation by alternating devices fail, they result in the severe "cannot intubate, cannot ventilate" scenario.[3]

How to proceed in the "cannot intubate, cannot ventilate" scenario

This is a very rare scenario in children and for this reason, the literature lacks good-quality evidence, and its true incidence is unknown. Even though securing the airway surgically is indicated when it is impossible to intubate and oxygenate, there is no evidence determining the best technique to perform it.[53]

In the event of the condition, it is assumed that safe venous or intraosseous access and complete monitoring are present, that the child has received an adequate dose of neuromuscular blocker, and that all intubation attempts by the most experienced professional available have failed, with manual ventilation remaining inadequate.[3] Temporary oxygenation improvement while other interventions are implemented can save lives.[51]

There is no evidence to guide when to consider waking the child. It is recommended to awaken the patient, maintaining efforts to oxygenate, when oxygen saturation is higher than or equal to 80%, without hemodynamic impairment. In this case, if rocuronium was administered, sugammadex should be used to reverse the neuromuscular blockade. It is crucial to underline that, simultaneously with any attempt to awaken the patient, one must be prepared for surgical airway access, as clinical deterioration can happen at any time.[47]

If awakening the patient does not improve ventilation and oxygenation, airway rescue techniques should be initiated. Yet again, not enough evidence can be found to define exactly when to begin airway rescue techniques. Some researchers define either SpO_2 < 75% and decreasing associated with hemodynamic instability, or SpO_2 < 65% without hemodynamic instability, as thresholds for starting rescue techniques. In both cases, ventilation efforts with 100% FiO_2 should continue.[3] Other researchers argue that absolute values of SpO_2 are not as important as realizing that oxygen saturation is decreasing, despite all efforts.[3]

When and how to perform front-of-neck access in emergencies

The rare, but often discussed front-of-neck access (FONA) in children is considered the last resort during the airway management of cannot intubate, cannot ventilate in pediatric patients. The intervention probably will be ineffective in children in an emergency and, therefore, the priority is to avoid it. It is not possible to practice or gain enough experience to render FONA useful and reliable.[47] If the surgical

airway is deemed the final option after failed intubation attempts and, before airway trauma makes mask ventilation impossible, emergency FONA should be declared on the patient.[47] FONA can be performed with the percutaneous insertion of a cannula over a needle, with wire-guided cricothyroidotomy and transtracheal cannula, and with surgical access for tracheostomy and cricothyroidotomy with a scalpel and gum elastic bougie.[54]

Rigid bronchoscopy is indicated in specific cases if equipment is available, and the team is experienced. It is worth underscoring that not enough evidence and clinical experience support the superiority of any specific device or technique over another.[47]

Performing FONA in infants and young children is challenging. Cricothyroid membrane identification by palpation is difficult when compared to identification by ultrasound, although in emergencies it is not always possible to use ultrasonography.[54] The anatomic relationship between the mandible and trachea makes cricothyroid puncture significantly problematic, even with maximal extension of the neck. The percutaneous technique can lead to compression and perforation of the posterior wall of the trachea, while surgical cricothyroidotomy has a risk of fracturing the laryngeal cartilage. Moreover, the cricothyroid membrane of neonates is very small, about 2.6 to 3 mm, and their larynx is quite cephalad in the neck, making it hard to have enough space to position the needle.[53] The outer diameter of the smallest available tracheal tube exceeds the longitudinal dimensions of the cricothyroid membrane of neonates.[54] The trachea is very mobile and compressible, increasing the likelihood of inadvertent subcutaneous or esophageal puncture and cannulation, especially in techniques requiring blind puncture and force application, such as catheter-on-needle techniques, guided by wire and cannula. Some authors support the technique of using a scalpel in children under 8 years of age or direct exposure of the cricothyroid membrane with a scalpel followed by cannulation under direct vision.[53]

Thus, for children up to 8 years of age, guidelines are unclear. In this population, surgical tracheostomy is preferred and recommended if a trained practitioner is available. However, most airway emergencies leading to "cannot intubate, cannot ventilate" occur in children under one year of age, restricting the usefulness of the technique.[49,51] In children over eight years of age, the size of the cricothyroid membrane allows percutaneous cricothyroidotomy.[54]

It is essential to prevent the need for emergency FONA by identifying high-risk patients and limiting the number of attempts of laryngeal mask airway insertion and tracheal intubation.[44] But if all other measures fail, some form of surgical airway should be attempted.[53] In the presence of specialists (pediatric surgeon, otolaryngologist, general surgeon, or head and neck surgeon), a surgical tracheostomy is recommended.[3,54]

Oxygen jet ventilators are unidirectional flow devices that incorporate a thumb control valve that allows the interruption of gas flow between jets. Transtracheal jet ventilation can be safely performed provided that upper airway patency is maintained. Thus, it is vital to use an oropharyngeal or supraglottic device to facilitate jet ventilation. A time ratio of 1:4 seconds between active jet insufflation and passive exhalation is also recommended, or clinical observation of complete exhalation. The wall-mounted oxygen flow meter connected via oxygen tubing to the cricothyroid cannula and tracheostomy system is a unidirectional system. However, the incorporation of a Y-connector allows for bidirectional flow and pressure release during passive exhalation. An initial gas flow rate of 1 $L.min^{-1}$/year of age is suggested, with increments of 1 L until adequate chest expansion is observed. Using three-way connections to replace the Y-connector is not recommended, given the open side port does not allow sufficient exhaustion of the insufflated gas, resulting in high airway pressures.[3]

The Ventrain™ (Ventinova Medical, Eindhoven, Netherlands) is a new device that allows effective ventilation through a small-caliber cannula, evacuating gas through suction and reducing barotrauma risk.[52]

When to indicate extracorporeal membrane oxygenation (ECMO) for "cannot intubate, cannot ventilate"

The 2022 American Society of Anesthesiologists (ASA) guidelines for the management of difficult airway, suggested using ECMO, when available, as an alternative to invasive airway techniques in the "cannot intubate, cannot ventilate" condition.[4] However, using ECMO in this scenario merits some consideration.

The first relates to the availability of ECMO in Brazil where only a few centers are accredited to perform ECMO (https://elso.org). Moreover, the success of ECMO depends on a setting controlled by precise protocols and qualified staff. For ECMO to be used in emergency scenarios, material and personnel must be readily available for device installation.[55] Due to the time required to assemble and fill the ECMO circuit, many centers keep a standby device ready, pre-primed with crystalloid solution, with the replacement fluid added at the time of ECMO initiation. It is considered safe to keep pre-primed circuits for up to 30 days, and perhaps beyond if the circuit is assembled and primed using standard sterile techniques and the priming is an electrolyte solution. So far, there have been no reports of a cannot intubate, cannot ventilate scenario managed by ECMO in pediatric patients.[56]

How to confirm tracheal intubation

Tracheal intubation confirmation is indicated in all situations, and detection of expired CO_2 or capnography is the gold standard method.[4] Other methods are direct visualization of the tube passing between vocal cords, lung auscultation, flexible bronchoscopy, chest ultrasound, or x-ray. When confirming tracheal intubation is not feasible, tracheal tube removal and face mask or supraglottic device ventilation are recommended.[4]

Undetected esophageal intubation is critical during pediatric difficult airway management. Even when promptly identified, it can be associated with severe hypoxemia, lung aspiration of gastric contents, cardiac arrest due to hypoxemia, and esophageal or gastric rupture. The key points for preventing unrecognized esophageal intubation are:[57] monitoring end-tidal CO_2 and pulse oximetry for all patients; routine use of video laryngoscopy, when available; verbalizing visualization during laryngoscopy in all attempts; always suspecting esophageal intubation at exhaled CO_2 detection failure; when it is impossible to detect exhaled CO_2, the tube

must be removed and face mask or supraglottic device ventilation must be initiated; if the tube was not promptly removed, other methods should be used, such as ultrasound, flexible fiberoptic bronchoscopy, or another laryngoscopy attempt (direct or indirect); physical examination should not be used alone to rule out esophageal intubation.

How to extubate a child with a difficult airway

Children with difficult airways are at high risk of extubation failure; thus, the anesthesiologist must be ready to respond and optimize oxygenation or ventilation.[58] Children presenting a difficult airway should be extubated awake. Observation of at least three of the following signs suggests awake extubation will be safe: contraction of facial muscles (grimacing), spontaneous movement (not to be confused with reflex cough), spontaneous eye opening, spontaneous breathing showing tidal volume > 5 mL.kg^{-1} and conjugate gaze.[59]

Tracheal extubation failure must be anticipated and planning to correct it must be established. The equipment required for extubation and the strategy for reintubation must be prepared, including anesthesia equipment or a bag-valve-mask device, oropharyngeal and nasopharyngeal cannulas, material for epinephrine nebulization for post-extubation stridor treatment and oxygenation equipment for post-extubation support, such as noninvasive ventilation devices or high-flow catheters.[58]

There is little evidence for the use of a tube exchanger for tracheal extubation of children presenting a difficult airway. A series of cases in which the tube exchanger was used led to reintubation success, and the new tracheal tube insertion was easy. Using a tube exchanger enables the detection of exhaled CO_2 and provides oxygen while preparing for reintubation.[60] The size of the tube exchanger is chosen according to the internal diameter of the tracheal tube as depicted in Table 9.[61]

Tracheal reintubation after extubation failure can be even more challenging than initial intubation, especially if anatomical or functional airway changes have happened. A suggestion for safe extubation is to request help from an experienced practitioner and provide all the material used in the difficult airway management that led to the initial tracheal intubation. All tube exchangers come with a 15 mm connector.[61]

Human factors in crisis management

The literature reveals a gradual and constant reflection on how anesthesiologists perform, analyzing the skills required for better performance in a high-risk environment such as the operating room. Some features and limitations of human perception and cognition, in addition to human factors, contribute to adverse events and challenges during crisis management. Cognitive psychology reveals that under stress even well-trained professionals can make common cognitive errors and experience memory retrieval problems. An important component of diagnostic and therapeutic decision errors is cognitive error, which is a thought process failure that happens despite adequate knowledge and skills. Some examples are fixation error (when attention is focused on a particular parameter or condition to the detriment of understanding the situation as a whole) or premature closure (when the first plausible diagnosis is accepted before ruling out others).[62] Cognitive errors cannot be overcome purely by just being aware of them. Cognitive aids such as flowcharts, algorithms, and checklists can help practitioners interrupt a cycle of errors.[52]

In addition to cognitive factors, human factors play an important role in the management of a difficult airway. Understanding human factors and their impact is vital to effectively manage crises. During the management of a difficult airway, human factors cause adverse outcomes in up to 40% of cases.[37] Non-technical skill training (communication, teamwork, and leadership) is believed to result in superior outcomes for patients during crisis management. The concept was included in the 2022 ASA difficult airway management guidelines.[4] Despite the evidence of the importance of human factors in the effectiveness of the anesthesiologist's performance, their inclusion in a guideline does not necessarily translate into changes in clinical practice. Thus, guidelines must be supported by educational planning to ensure that these vital areas are not neglected.

Practice training (including high- and low-fidelity simulation) is critical to ensure that technical skills can be effectively delivered during crises. Discussing technical skills (i.e., skills not imposing additional cognitive load on the operator) in different difficult airway scenarios improves situational awareness and the performance of non-technical skills. The emphasis should also be on training the multidisciplinary team.[63]

New guidelines from the European Society of Anaesthesiology and Intensive Care (ESAIC) and the British Journal of Anaesthesia (BJA)

Recently, the European Society of Anaesthesiology and Intensive Care (ESAIC) and the British Journal of Anaesthesia (BJA) jointly published a new guideline on airway management in neonates and infants.[64] The ESAIC and BJA guideline

Table 9 Characteristics of the tube exchanger.

Tube exchanger size	Tube exchanger internal diameter	Length	Tracheal tube internal diameter
8	1.6	45	3.5 – 4.5
11	2.3	83	5.0 – 6.0
14	3.0	83	6.5 – 7.0

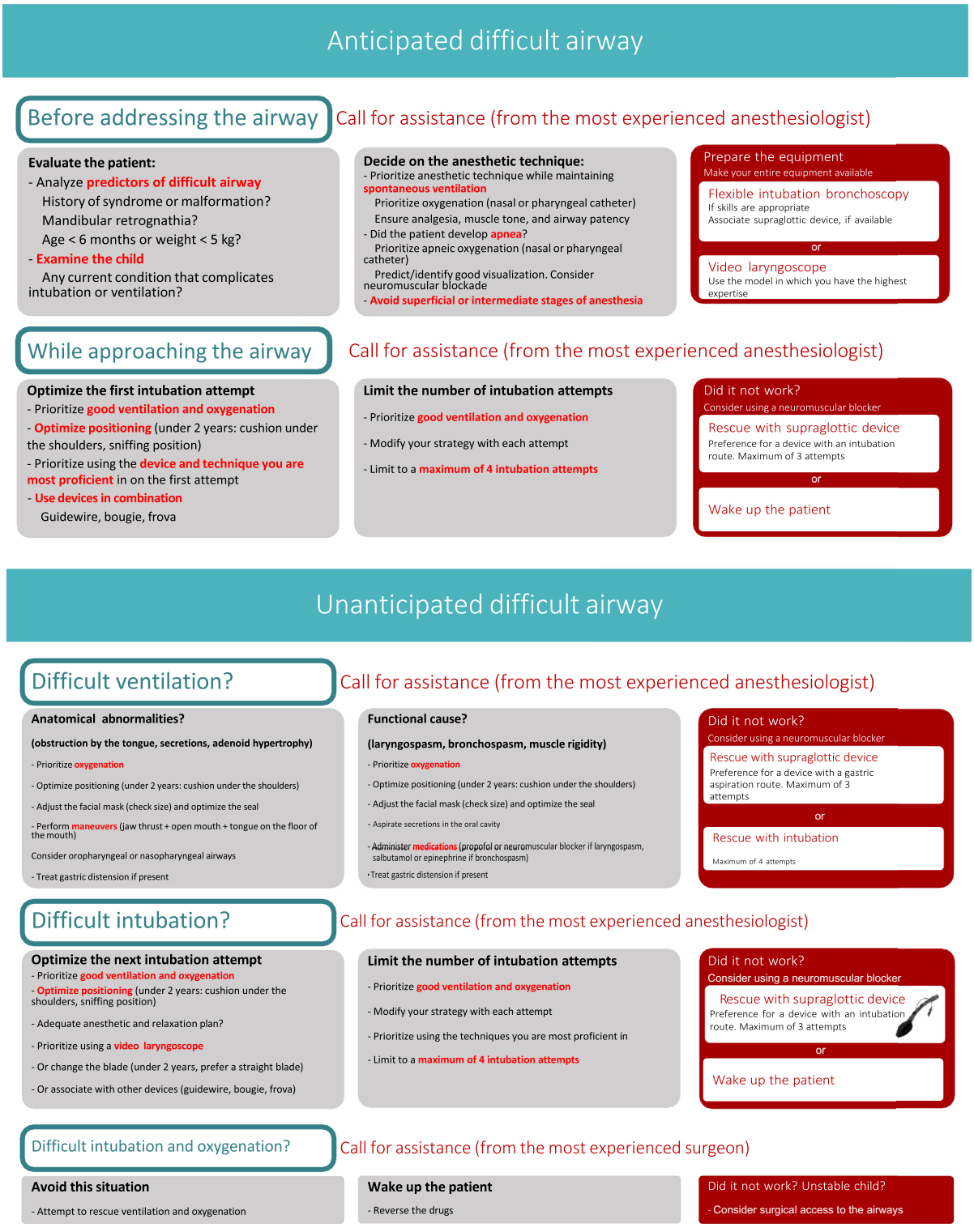

Figure 1 The management of anticipated and unanticipated difficult pediatric airways, as recommended by the task force of the Brazilian Society of Anesthesiology (SBA).

identifies seven key areas of focus for airway management in neonates and infants: preoperative assessment and preparation, medications, techniques and algorithms, identification and treatment of difficult airways, confirmation of tracheal intubation, tracheal extubation, and human factors. The recommendations were formulated using the GRADE (Grading of Recommendations, Assessment, Development, and Evaluation) methodology, assigning strong '1' or weak '2' recommendations with high 'A', medium 'B', or low 'C' quality of evidence.

In summary, the guidelines recommend the following: utilize medical history and physical examination to predict difficult airway management (1C); ensure an adequate level of sedation or general anesthesia during airway management (1B); administer neuromuscular blockers before tracheal intubation when spontaneous breathing is not necessary (1C); use a video laryngoscope with an age-adapted standard blade as the first choice for tracheal intubation (1B); apply apneic oxygenation during tracheal intubation in neonates (1B); consider a supraglottic airway for rescue oxygenation and ventilation if tracheal intubation fails (1B); limit the number of tracheal intubation attempts (1C); use a stylet to reinforce and pre-shape tracheal tubes when hyperangulated videolaryngoscope blades are used and when the larynx is anatomically anterior (1C); verify successful intubation with clinical assessment and end-tidal CO_2 waveform (1C); and apply high-flow nasal oxygenation, continuous positive airway pressure, or nasal intermittent positive pressure ventilation for post-extubation respiratory support when appropriate (1B).

Finally, considering all the pertinent evidence elucidated in the present document, the task force of the SBA advocates that, in the management of challenging pediatric airways, whether anticipated or unanticipated, practitioners should meticulously adhere to the procedural sequence outlined in Figure 1.

Conflicts of interest

The authors declare no conflicts of interest.

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