

DOI: <https://doi.org/10.5554/22562087.e945>

# Pediatric airway: What is new in approaches and treatments?

## Vía aérea pediátrica: ¿Hay novedades en su abordaje y tratamiento?

Daniel Rivera-Tocancipá<sup>a-c</sup> <sup>a</sup> Anesthesia Graduate Program, Universidad Surcolombiana. Neiva, Colombia.<sup>b</sup> Anesthesia Service, Hospital Universitario Hernando Moncaleano Perdomo. Neiva, Colombia.<sup>c</sup> Anesthesia Service, Clínica Emcosalud. Neiva, Colombia.**Correspondence:** Facultad de Salud, Universidad Surcolombiana. Calle 9 # 15-25. Neiva, Huila. **Email:** riverato@hotmail.com

### What do we know about the pediatric airway?

- Difficult management is the main cause of morbidity and mortality in pediatric anesthesia.
- Anesthesia-related morbidity and mortality are highest in patients in the extremes of life.
- General anesthetists are occasionally faced with the need to manage the pediatric airway, and complications may result in cardiac arrest, neurologic deficit or death.

### What is the contribution of this review?

- Nine not very well known or commonly used options to help with the successful management of the pediatric airway are described.
- Knowing and incorporating adequate devices and techniques into the practice of anesthesia can improve quality of care and reduce perioperative morbidity and mortality in children undergoing anesthesia.

### How to cite this article

Rivera-Tocancipá D. Pediatric airway: What is new in approaches and treatments?. Colombian Journal of Anesthesiology. 2021;49:e e945.

### Abstract

Perioperative morbidity and mortality are high among patients in the extremes of life undergoing anesthesia. Complications in children occur mainly as a result of airway management-related events such as difficult approach, laryngospasm, bronchospasm and severe hypoxemia, which may result in cardiac arrest, neurological deficit or death. Reports and new considerations that have changed clinical practice in pediatric airway management have emerged in recent years. This narrative literature review seeks to summarize and detail the findings on the primary cause of morbidity and mortality in pediatric anesthesia and to highlight those things that anesthetists need to be aware of, according to the scientific reports that have been changing practice in pediatric anesthesia.

This review focuses on the identification of “new” and specific practices that have emerged over the past 10 years and have helped reduce complications associated with pediatric airway management. At least 9 practices grouped into 4 groups are described: assessment, approach techniques, devices, and algorithms. The same devices used in adults are essentially all available for the management of the pediatric airway, and anesthesia-related morbidity and mortality can be reduced through improved quality of care in pediatrics.

### Key words

Airway management; pediatrics; algorithms; pediatric anesthesia; complications; devices.

### Resumen

Los pacientes en extremos de la vida sometidos a anestesia tienen la más alta morbimortalidad perioperatoria. Los niños se complican principalmente por eventos derivados del manejo de la vía aérea pediátrica (VAP), como dificultad en su abordaje, laringoespasma, broncoespasmo e hipoxemia severa, que pueden terminar en paro cardíaco, déficit neurológico o muerte. En los últimos años se han informado y retomado aspectos que cambian la práctica clínica sobre la VAP. Esta revisión narrativa de la literatura busca concretar y resumir estos hallazgos sobre la primera causa de morbimortalidad en anestesia pediátrica y enfatizar en lo que los anestesiólogos deben conocer, con base en los informes científicos que vienen cambiando la práctica anestésica pediátrica.

Esta revisión busca identificar las conductas “nuevas” y concretas que han surgido en los últimos 10 años, y que ayudan a disminuir las complicaciones derivadas del manejo de la VAP. Se señalan y describen al menos nueve conductas agrupadas en 4 bloques: Evaluación, técnicas de abordaje, dispositivos y algoritmos. Actualmente se cuenta con prácticamente todos los dispositivos de adultos para el manejo de la VAP y con consideraciones específicas se puede mejorar la calidad de la atención y reducir la morbimortalidad anestésica en pediatría.

### Palabras clave

Manejo de la vía aérea; pediatría; algoritmos; anestesia pediátrica; complicaciones; dispositivos.

Lea la versión en español de este artículo en [www.revcolanest.com.co](http://www.revcolanest.com.co)

Copyright © 2021 Sociedad Colombiana de Anestesiología y Reanimación (S.C.A.R.E.).

This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

### INTRODUCTION

Studies that assess morbidity and mortality in pediatric patients describe three main causes (1-3): respiratory complications derived from airway management - approach, laryngospasm, bronchospasm and acute hypoxia — which may result in cardiac arrest, neurologic deficit, or death; hemodynamic complications — hypotension and bradycardia; and medication errors. Some considerations that change clinical practice in pediatric airway management have been reported and reintroduced (Figure 1). This literature review aims to identify and summarize the findings related to the primary cause of morbidity and mortality in pediatric anesthesia, and emphasize things that anesthetists need to know based on the scientific reports that have been changing practice in pediatric anesthesia (Table 1).

TABLE 1. Pediatric airway: What is new?

<b>1. Pediatric airway assessment</b>	1.1 Classification 1.2 New anatomy 1.3 Ultrasonography
<b>2. Approach techniques</b>	2.1 Apneic oxygenation 2.2 Extracorporeal oxygenation - ECMO 2.3 Fetal EXIT-to-intubation
<b>3. Devices</b>	3.1 Basic first line devices 3.2 Intubation · Laryngoscopes · Supraglottic devices · Fiberoptic bronchoscopes 3.3 Front-of-neck surgical access (FONA)
<b>4. Algorithms</b>	4.1 Differences with adults 4.2 Vortex protocol 4.3 Considerations during the Covid-19 pandemic

ECMO: Extracorporeal membrane oxygenation; EXIT: Ex uteri intrapartum treatment.  
SOURCE: Author.

### PEDIATRIC AIRWAY ASSESSMENT

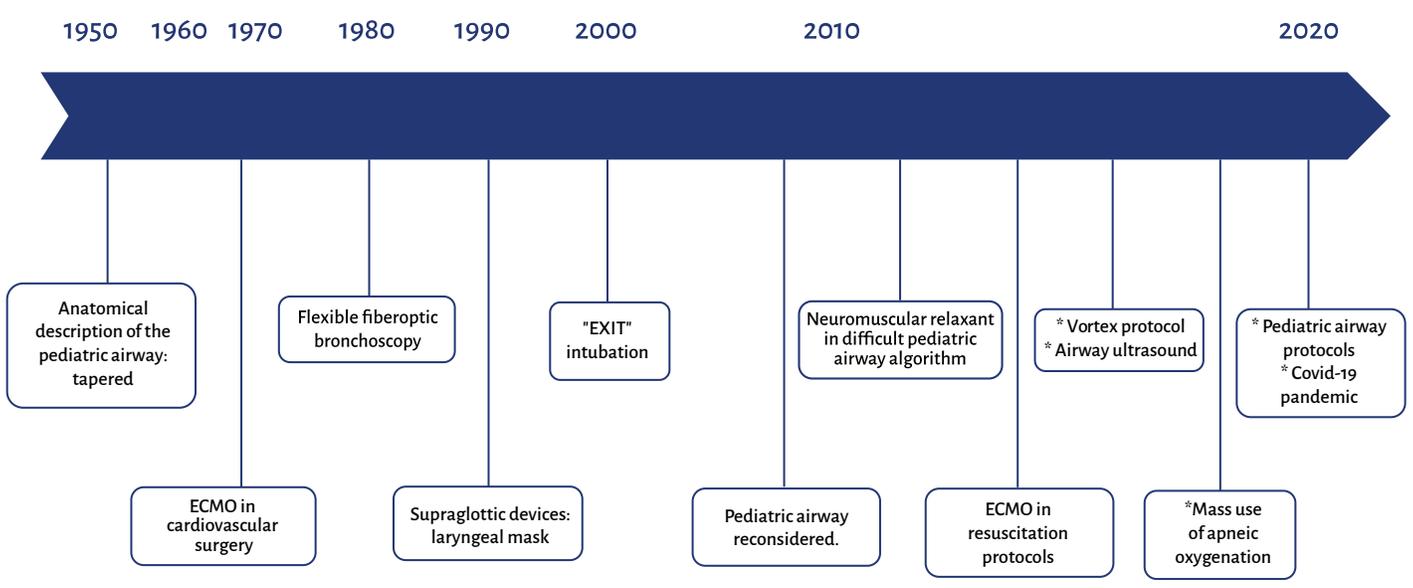
Three recently introduced elements are highlighted: pediatric airway classification, anatomical changes and ultrasound use.

#### Pediatric airway classification

Predictors in adults (Mallampati, thyromental distance, mouth opening, etc.) are not applicable in pediatrics because absolute measurements change in relation to growth. The Mallampati classification is valid in children over 5 years of age (4). In pediatrics, the use of a classification based on three elements has been proposed since 2010 (5-7):

• **Past history.** Previous experiences with the approach to the airway are considered. A history of a difficult management is highly sensitive and specific for the diagnosis of a difficult airway (DA); tracheostomy,

FIGURE 1. Timeline of developments in pediatric airway management.



From 1950 to 2020. ECMO: Extracorporeal membrane oxygenation; EXIT: Ex uteri intrapartum treatment; US: Ultrasound.

SOURCE:: Author.

prolonged intubation and post-extubation dysphonia are warning signs of potential difficulties during management.

· **Physiological changes.** Active flue or flu episode within the past three weeks; a history of epiglottitis, bronchospasm, rhinitis, obstructive sleep apnea syndrome, adenoid or tonsillar hypertrophy are associated with DA. Pediatric patients with an apparently normal airway may develop complications such as laryngospasm and bronchospasm, resulting in rapid arterial desaturation that requires immediate implementation of adequate management strategies.

· **Anatomical abnormalities.** Abnormalities of the lower third of the face, low-set ears, limited neck mobility and inability to open the mouth at least 3 of the child's finger breadths are associated with DA. In children who cooperate, the inability to project the mandible farther than the maxilla (inability to bite the upper lip with the lower teeth) is a finding associated with DA. A higher body mass index (obesity) is associated with greater perioperative complications (8).

Based on these three elements, the pediatric airway is classified as follows:

**A. Anticipated difficult airway.** Patients with abnormal anatomy or a clear history of DA. Examples: dysmorphic syndromes such as Pierre Robin. These children must be referred to specialized centers with expert staff and special resources for pediatric anesthesia.

**B. Altered or suspect airway.** Patients with no anatomical abnormalities but with physiological respiratory disorders or a history of prolonged airway manipulation, e.g., intubation in the ICU, history of tracheostomy or a flu episode. These children can be managed by general anesthetists provided the support from experts in pediatric anesthesia is available at the service.

**C. Normal airway.** Patients with no past history or anatomical of physiological disorders who can be managed by general

anesthetists. An extremely low percentage of these patients may present with unanticipated DA.

### Pediatric airway anatomy

Anatomical differences between pediatric and adult airways are clear. In the past, the shape of the pediatric larynx was described as tapered while the adult airway was described as cylindrical. This “dogma” in pediatric anesthesia emerged more than half a century ago from the studies by Eckenhoff (9), based on prior studies by Bayeux (10) and experiments with mummified pediatric anatomical models. In vivo studies (11,12) with computed tomography, magnetic resonance and fiber-optic bronchoscopy with spontaneous breathing suggest that the pediatric larynx has the same cylindrical shape of the adult larynx - even somewhat elliptical - with the anteroposterior diameter being longer than the lateral diameter and having two sites of maximum narrowness at the level of the cricoid ring, as described in old studies, and at the level of the vocal cords as a new finding (13,14). The controversy is still open with some experts challenging these findings (15) partly on the grounds that these measurements — comparisons not only between cadaver models and live children but also between spontaneous and controlled breathing, or even between inspiratory and expiratory phases — make consensus difficult (16,17). A useful recommendation in pediatric anesthesia is the use of tubes with pneumoplug, taking care not to exceed a balloon pressure of 20 mmHg (18), which has shown to be associated with a lower incidence of reintubations from tube exchanges, and a lower need for inhaled anesthetics (19).

### Ultrasonography for the study of the pediatric airway

Ultrasound (US) was initially used to assess the adult airway (20), but publications on

the assessment of the pediatric airway have been emerging over the past five years (21). US is used to make measurements that help predict a difficult approach to the airway, including the amplitude of the retrolingual space and the ability to measure the distance between the arytenoid cartilages in order to select the right endotracheal tube diameter (22). A superficial neck scan allows to identify the location of the cricothyroid membrane and tracheal rings for guidance should the need for emergency percutaneous access arise. Correct endotracheal intubation as well as selective ventilation due to endobronchial intubation can be detected by US through comparison of bilateral “pleural movement”. Although these are simple, real-time bedside measurements, they are operator-dependent and require training to ensure correct image interpretation.

### APPROACHES

Three techniques that have been reintroduced over the past decade are described.

#### Apneic oxygenation

An old technique consisting of the use of high flow nasal cannula (up to 15 liters per minute in adolescents) besides the conventional facial mask during anesthetic induction in order to achieve longer safe apnea time (23) and reduce the possibility of arterial desaturation which is faster and more severe in pediatric patients because of their lower functional residual capacity (oxygen reserve) and higher tissue oxygen consumption. The effectiveness of this simple practice has been proven, especially in the presence of DA, in patients with prior lung compromise, in critically ill patients (24), or whenever there is a risk of aspiration, where positive pressure ventilation during induction would be contraindicated (25). Isolated cases of pneumothorax have been described with the use of high flow devices in children (26).

## Extracorporeal oxygenation

Derived from cardiovascular surgery, this form of oxygenation is maintained by means of an external oxygenation membrane and a pump to drive circulation while the heart remains in asystole. This device can provide two hours of cardiopulmonary support; after that time, it triggers inflammatory processes and serious cellular alterations. Extracorporeal membrane oxygenation (ECMO) came later and allows for longer periods of pulmonary and/or cardiac support, even over several days, without the acute problems associated with the extracorporeal circulation pump used in cardiovascular surgery. The use of ECMO, described in pediatrics since the 1970s (27), has been expanded and has been incorporated in cardiopulmonary resuscitation algorithms, for example (28). It also offers a management option in cases in which the pediatric airway is lost completely, for example in mediastinal mass resection or tracheal surgery (29,30). ECMO is effective at providing adequate oxygenation of the blood and removing CO<sub>2</sub>, allowing work on the airway for as long as it is needed. A specialized center with the necessary resources and staff training is required for its implementation. It is not widely used in our setting as of yet.

## Fetal EXIT (Ex Uteri intrapartum treatment)

This procedure consists of maintaining the fetus attached to the placenta during cesarean delivery while the fetal airway is approached with the most appropriate technique for each individual case, ranging from traditional laryngoscopy to flexible fiberoptic bronchoscopy assistance or tracheostomy (31). It was first described in 1997 (32) and its use has been growing due, on the one hand, to prenatal visits that allow early identification of fetal abnormalities that compromise the airway and, on the other hand, to ease of implementation (33). Once the airway is secured, the umbilical

cord is ligated and the delivery can proceed. There is always the possibility of placental detachment or interruption of blood flow to the umbilical cord, requiring either faster maneuvers on the fetal airway or delivery and traditional neonatal airway management in an adjacent room.

## DEVICES

Devices for the management of the pediatric airway may be grouped under three categories, as described below.

### Basic or first-line (for ventilation)

The use of the facial mask, with or without the support of an oral or nasal cannula (34), to secure appropriate ventilation and oxygenation in the vast majority of children is the cornerstone for the management of the pediatric airway. Endotracheal intubation is secondary, except in specific conditions such as the risk of aspiration which requires securing the airway as soon as possible. There are no new considerations to discuss in this regard.

### Intubation devices

- **Laryngoscopes.** Essentially everything that is available today for adults is also available for pediatric patients, from the traditional laryngoscope with different blade sizes and styles - the straight blade offering some advantages in children - all the way to modern videolaryngoscopes (35). The latter, however, have not been shown to have the same results as in adults because they require longer intubation times when compared to the conventional laryngoscopes and are associated with lower first-attempt success. This may be attributed to the curvature angle of the blades which should be greater in pediatrics and also to the fact that they do not necessarily offer better alignment of the oral, pharyngeal and tracheal

axis for intubation even though vision is better (36,37). Greater success with videolaryngoscopy has been reported in intensive care settings (38,39). Vendors offer blade sizes ranging from 00 to adult sizes and even devices that can be connected to a cell phone screen. Some of the most common videolaryngoscopes are the Storz®, GlideScope®, Truview®, Pentax AWS®, Airtraq®, McGrath®, and KingVision®, among others. The choice depends on the preference of each work team, budget availability and experience.

- **Supraglottic devices.** There is a wide range of supraglottic devices for pediatric use, essentially the same as in adults (40). The first version of the laryngeal mask was described by Archie Brain in 1980 and its use in pediatrics became widespread since 1990. Studies show that second generation laryngeal masks offer greater advantages in terms of placement, less dislodgement, ease of ventilation and oxygenation; they also allow suction of gastric contents, some incorporate bite protector, and they also allow passage of traditional tubes for endotracheal intubation (41). Each work team must make a rational selection of the devices that best suit their practice.

- **Fiberoptic bronchoscope.** Flexible fiberoptic bronchoscopy is the gold standard approach to the anticipated DA, while rigid fiberoptic bronchoscopy is the choice for removal of foreign bodies lodged in the airway. In "cannot ventilate, cannot oxygenate" scenarios, it can be used before front-of-neck access (FONA) (42). Since the description of flexible fiberoptic bronchoscopy in pediatrics in 1978, fiberoptic bronchoscopes of different sizes, even in diameters as small as 1.8 mm that allow the passage of a 2.5 mm internal diameter endotracheal tube have been developed. The smaller the fiberoptic bronchoscope, the finer the optic fiber and the greater the probability of damage. The 2.8 mm fiberoptic bronchoscope is the most commonly used in pediatrics and passes through 3.5 mm internal

diameter tubes and larger. In the absence of experience with fiberoptic bronchoscopy in children, support from the pediatric pulmonologist must be requested. An option that has gained increasing popularity is the combination of devices, for example, flexible bronchoscopy-guided endotracheal intubation through a supraglottic device, described as successful in large series (43).

### Front-of-neck surgical access (FONA)

There is an ongoing debate in pediatrics on whether this access is useful, especially in very young children, because of the very high incidence of complications and failed procedures, with an increase in in-hospital mortality (44) due to issues such as location of the cricothyroid membrane and incorrect approach (45). This approach requires a very clear rationale. In a “cannot ventilate, cannot intubate” scenario in which none of the available options have worked when applied correctly and the child is going into acute hypoxemia, bradycardia, cardiac arrest and death, the only option is to resort to this procedure. The approach through the cricothyroid membrane is not recommended in children under 8 years of age due to the difficulty in identifying the space correctly and passing a tube of adequate size; therefore, it must be done through the tracheal rings (46). This procedure may be performed through puncture - percutaneous or open cricothyroidotomy - or through an incision - percutaneous or open tracheostomy. If no surgeon is available, the percutaneous access must be established by the anesthetist.

## WHAT IS NEW IN ALGORITHMS

### Different considerations

The different algorithms give priority to facial mask ventilation over endotracheal intubation because it is usually easier to

ventilate children with the adequate facial seal technique which allows, with positive pressure, to create an air column that acts like a “splint” to maintain an open patent airway. In this scenario, intubation, usually more difficult in children, would take second place (47). On the other hand, in case of difficult ventilation or intubation and the absence of anatomical predictors of a difficult airway, neuromuscular relaxation can be used, as it makes it easier to provide facial mask ventilation and endotracheal intubation (48,49). The basic algorithm of facial mask ventilation followed by attempted intubation and/or placement of a supraglottic device continues to prevail, and if a “cannot ventilate, cannot oxygenate” emergency occurs, access through the neck would be considered. In pediatrics, combining strategies is valid, especially the combination of fiberoptic bronchoscopy + supraglottic device. The possibility of arousing the child to allow spontaneous breathing must be considered depending on each particular case (50). Intubation without muscle relaxation is feasible in neonates, using “gentle” ventilation (high frequency and low volume) in anticipation to rapid desaturation.

### Vortex protocol

Described by an anesthetist and emergency physician in Australia (51), it consists of a funnel visual schematic that begins, at the top, with airway management using three of the four “life lines” - facial mask, endotracheal intubation and supraglottic devices - which are applied and alternated depending on the individual case in order to always maintain the patient in the green safety zone, with adequate oxygenation and ventilation. The fourth “life line”, i.e., neck access in any of its modalities already described, is activated when the previous have failed. The protocol highlights non-technical skills and teamwork and includes other important considerations besides the mere implementation of a sequence of

steps contained in the algorithms. It can be accessed for free at <http://vortexapproach.org> where a more thorough description of the components and uses is available.

### Considerations during the COVID-19 pandemic

The incidence of asymptomatic carriers among children is high, requiring great care during their management. Crying should be avoided whenever possible, because of abundant droplet production; therefore, excellent premedication and peaceful arousal are required. Positive pressure ventilation is allowed in neonates considering that low volumes result in minimal droplet scatter - less than 10 cm radius. Whenever possible, tubes with adequately inflated pneumoplugs should be used over supraglottic devices. This topic not being within the scope of this review, only the most important recommendations are summarized in Table 2, based on the recommendation of the Colombian Neonatology Association (ASCON) (52) and the consensus guidelines of the Pediatric Difficult Intubation Collaborative and the Canadian Pediatric Anesthesia Society (53).

## CONCLUSIONS

Recent studies have led to paradigm changes in pediatric airway management. The anatomy of the pediatric airway is reassessed in vivo and the use of endotracheal tube with pneumoplug is proposed. Although intubation in children is more challenging, when a good technique is used, facial mask ventilation and oxygenation are easier. Tools are available for the objective assessment of the pediatric airway, enabling classification and determination of the level of care. The classification of altered or suspect airway is highlighted as a warning sign to anticipate

**TABLE 2.** Recommendations for pediatric airway management during the COVID-19 pandemic.

<p><b>Preoperative period</b></p>	<ul style="list-style-type: none"> <li>· Cross-check personal protection elements before bringing the child in</li> <li>· Prepare and implement check-lists</li> <li>· Prepare and have all things ready before bringing the child in</li> <li>· Prepare closed suction system</li> <li>· Provide sufficient premedication: control crying and coughing</li> <li>· Avoid nasal premedication</li> <li>· Do not allow family members in the operating room area</li> <li>· Use a negative pressure operating room</li> </ul>
<p><b>During intubation</b></p>	<ul style="list-style-type: none"> <li>· Prefer intravenous rapid sequence induction over inhaled induction</li> <li>· Do not use rapid sequence induction in neonates.</li> <li>· Use muscle relaxant</li> <li>· Use clear plastic to cover the airway during the procedure.</li> <li>· The airway must be approached by the person with most expertise</li> <li>· Use the facial mask quickly (to limit droplets)</li> <li>· Avoid high flow nasal cannula</li> <li>· Prefer endotracheal tube with pneumoplug</li> <li>· Prefer videolaryngoscopy</li> <li>· Avoid laryngeal masks, but if needed, use second generation masks (better seal)</li> </ul>
<p><b>Extubation and recovery</b></p>	<ul style="list-style-type: none"> <li>· Apply suction before extubation</li> <li>· Place facial mask promptly after extubation (limits droplets)</li> <li>· Maintain adequate distance between patients in the recovery room</li> <li>· Avoid nebulizations</li> </ul>

**SOURCE:** Author.

potential complications. A large number of devices for approaching the airway are available in the market, essentially the same as are available for adults, including laryngeal masks for neonatal intubation. In a “cannot ventilate, cannot intubate” scenario, neuromuscular relaxation is an accepted option before front-of-neck access, or arousing the child if circumstances allow it. Techniques such as apneic oxygenation, ECMO and fetal EXIT may

save lives in many cases. Finally, everything that has been described regarding pediatric airway management will be truly effective if anesthetists are trained in the use of the most accessible and adequate devices for every circumstance and if protocols and care guidelines are designed, shared and implemented, without losing sight of the fact that the cornerstone of pediatric airway management continues to be facial mask ventilation and oxygenation.

**ACKNOWLEDGEMENTS**

**Authors’ contributions**

DRT: Only author of the entire the entire article.

**Assistance for the study**

None declared.

**Financial support and sponsorship**

Author’s own resources. No funding that could have influenced the result of this worker was received.

**Conflict of interest**

The author declares that there are no known conflicts of interest associated with this publication and no significant financial support has been received that could have influenced the results of this article.

**Presentations**

The review is based on the lecture “Myths and realities of the pediatric airway: what is new” of my own authorship presented during the XXXIII Colombian Anesthesiology and Resuscitation Congress in Bucaramanga, Colombia, in August 2019.

**REFERENCES**

1. Apricot group of the european Society of Annaesthesiology Clinical Trial network. Incidence of severe critical events in paediatric anaesthesia (APRICOT): a prospective multicentre observational study in 261 hospitaes in Europe. *Lancet Respir Med.* 2017;5(5):412-25. doi: [http://doi.org/10.1016/S2213-2600\(17\)30116-9](http://doi.org/10.1016/S2213-2600(17)30116-9).
2. Cheon E, Longhini A, Lee J, Hansen J, Jagannathan N, De Oliveira G, Suresh S. Predictive

- factors for adverse outcomes in pediatric patients undergoing low-risk skin and soft tissue surgery: A database analysis of 6730 patients. *Pediatric Anesthesia*. 2019(29):44-50. doi: <http://doi.org/10.1111/pan.13550>.
3. Uffman J, Tumin D, Beltran R and Tobias J. Severe outcomes of pediatric perioperative adverse events occurring in operating rooms compared to off-site anesthetizing locations in the Wake Up Safe Database. *Pediatric Anesthesia*. 2019;(29):38-43. doi: <http://doi.org/10.1111/pan.13549>.
  4. Jagannathan N, Sohn L, Fiadjo J. Paediatric difficult airway management: what every anaesthetist should know! *Br J Anaesthesia*. 2016;117(S1):i3-5. doi: <http://doi.org/10.1093/bja/aew054>.
  5. Weiss M, Engelhardt T. A child with a difficult airway: Wat do i do next? *Curr Opin Anaesthesiol*. 2012(25):326-32.
  6. Hagberg C. Current concepts in the management of the difficult airway. *Anesthesiology Newz. Supplement special edition*. 2018;15(2):105-36.
  7. Engelhard T, Fiadjo JE, Weiss M, Baker P, Bew S, Echeverry Marín P, et al. A framework for the management of the pediatric airway. This article has been accepted for publication and undergone full peer review. doi: <http://doi.org/10.1111/pan.13716>.
  8. Raghavan K, Ying Moo DX, Tan Z. Severe obesity in children as an independent risk factor for perioperative respiratory adverse events during anaesthesia for minor non-airway surgery, a retrospective observational study. *Proceeding Singapore Healthcare*. 2019;28(2):83-9. doi: <http://doi.org/10.1177/2010105818802994>.
  9. Eckenhoff JE. Some anatomic considerations of the infant larynx influencing endotracheal anesthesia. *Anesthesiol*. 1951;12(1951):401-10.
  10. Bayeux. Tubage de larynx dans le Croup. *Presse Med*. 1987;20:1.
  11. Litman RS, Weissend EE, Shibata D, Westesson PL. Developmental changes of laryngeal dimensions in unparalyzed, sedated children. *Anesthesiology*. 2003;98(1):41-5.
  12. Dalal PG, Murray D, Messner AH, Feng A, McAllister J, Molter D. Pediatric laryngeal dimensions: an age-based analysis. *Anesth Analg*. 2009;108(5):1475-9.
  13. Wania T, Bissonnette B, Engelhardt T, Buchhe B, Arnouss H, AlGhamdi F, Tobias J. The pediatric airway: Historical concepts, new findings, and what matters. *Int J Pediatric Otorhinolaryngol*. 2019(121):29-33. doi: <http://doi.org/10.1016/j.ijporl.2019.02.041>.
  14. Wani T, Rafiq M, Akhter N, Saeed F, AlGhamdi, Tobias J. Upper airway in infants—a computed tomography-based analysis. *Pediatric Anaesthesia*. 2017;27(5):501-5. doi: <http://doi.org/10.1111/pan.13126>.
  15. Holzk J, Brown K, Carroll R, Cot Ch. The anatomy of the pediatric airway: ¿Has our knowledge changed in 120 years? A review of historic and recent investigations of the anatomy of the pediatric larynx. *Pediatric Anesthesia*. 2018;(28):13-22. doi: <http://doi.org/10.1111/pan.13281>.
  16. Schmidt A, Weiss M, Engelhardt T. The paediatric airway: Basic principles and current developments. Review Article. *Eur J Anaesthesiol*. 2014(31):293-9. doi: <http://doi.org/10.1097/EJA.000000000000023>.
  17. Dave M, Kemper M, Schmidt A, Both C, Weiss M. Pediatric airway dimensions—A summary and presentation of existing data. *Pediatric Anesthesia*. 2019; 00:1-8. doi: <http://doi.org/10.1111/pan.13665>.
  18. Sathyamoorthy M, Ierman J, Okhomiya VI and penman AD. Use of cuffed tracheal tubes in neonates, infants and children: A practice survey of members of the Society of Pediatric Anesthesia. *J Clin Anesth*. 2016;33:266-72.
  19. De Orange FA, Andrade RGAC, Lemos A, Borges PSGN, Figueiroa JN, Kovatsis PG. Cuffed versus uncuffed endotracheal tubes for general anaesthesia in children aged eight years and under. *Cochrane Data base of Systematic Reviews*. 2017;11:CD011954. doi: <http://doi.org/10.1002/14651858.CD011954.pub2>.
  20. Kristensen MS. Ultrasonography in the management of the airway. *Acta Anaesthesiol Scand*. 2011;55(19):1155-73.
  21. Engelhardt T, Teoh W, Stafrace S, Kristensen M. Review Article: Essential ultrasound techniques of the pediatric airway. *Pediatric Anesthesia*. 2016;(26):122-31. doi: <http://doi.org/10.1111/pan.12787>.
  22. Orhan-Sungur M, Altun D, Ozkan-Seyhan T, Aygun E, Koltka K, Camci E. Learning curve of ultrasound measurement of subglottic diameter for endotracheal tube selection in pediatric patients. *Pediatric Anesthesia*. 2019;00:1-7. doi: <http://doi.org/10.1111/pan.13751>.
  23. Lyons C, Callaghan M. Uses and mechanisms of apnoeic oxygenation: a narrative review. *Anaesthesia*. 2019;74:497-507. doi: <http://doi.org/10.1111/anae.14565>.
  24. Napolitano N, Laverriere EK, Craig N, et al. National Emergency Airway Registry for Children (NEAR4KIDS) and Pediatric Acute Lung Injury and Sepsis Investigators (PALISI). Apnoeic oxygenation as a quality improvement intervention in an academic PICU. *Pediatr Crit Care Med*. 2019;20(2):e531-7. doi: <http://doi.org/10.1097/PCC.0000000000002123>.
  25. Holyoak R, Melhuish T, Vlok R, Binks M, White L. Intubation using apnoeic oxygenation to prevent desaturation: A systematic review and meta-analysis. *J Crit Care*. 2017(41):42-8. doi: <https://doi.org/10.1016/j.jcrc.2017.04.043>.
  26. Hegde S, Prodhan P. Serious air leak syndrome complicating high-flow nasal cannula therapy: a report of 3 cases. *Pediatrics*. 2013;131(3):e939-44.
  27. Díaz R, Fajardo Ch, Rufs J. Historia del ECMO. *Med Clin Condes*. 2017;28(5):796-802. doi: <https://doi.org/10.1016/j.rmclc.2017.10.004>.
  28. Zapata R, Naranjo C, Méndez M, Montoya C, Jaramillo J, Cruz G, Posada L. Reconstrucción traqueal bajo oxigenación con membrana para circulación extracorpórea para el manejo de una lesión traumática: reporte de caso y revisión bibliográfica. *romb Cir*. 2018;(33):211-9. doi: <https://doi.org/10.30944/20117582.64>.
  29. Malpas G, Hung O, Gilchrist A, Wong C, Kent B, Hirsch G, Hart R. The use of extracorporeal membrane oxygenation in the anticipated difficult airway: a case report and systematic review. *Can J Anesth*. 2018;(65):685-97. doi: <https://doi.org/10.1007/s12630-018-1099-x>.
  30. Chen R. Concern regarding the use of extracorporeal membrane oxygenation in the anticipated difficult airway. *Can J Anesth*. 2019;66:1115-6. doi: <https://doi.org/10.1007/s12630-019-01416-6>.
  31. Sancho-Hernández R, Solorio-Rodríguez L, Durán-Colín A, Cuevas-Schacht F. Procedimiento EXIT (ex utero intrapartum) en las

- malformaciones congénitas broncopulmonares de alto riesgo. Descripción de la técnica y revisión de la literatura. *Neumol Cir Torax*. 2016;75(4):281-90.
32. Mychaliska GB, Bealer JF, Graf JL, Rosen MA, et al. Operating on placental support: the ex utero intrapartum treatment procedure. *J Pediatr Surg*. 1997;32:227-30; discussion 230-21.
33. Kumar K, Miron C, Singh SI. Maternal anesthesia for EXIT procedure: A systematic review of literatura. *J Anaesthesiol Clin Pharmacol*. 2019;35(1):19-24. doi: [https://doi.org/10.4103/joacp.JOACP\\_302\\_17](https://doi.org/10.4103/joacp.JOACP_302_17).
34. Rivera-Tocancipa D, Díaz-Sánchez E. Vía aérea pediátrica. ¿Tan difícil como dicen? *Colombian Journal of Anesthesiology*. 2018;46(Sup):56-62. doi: <https://doi.org/10.1097/CJ9.000000000000046>.
35. Fiadjoe JE, Kovatsis P. Videolaryngoscopes in pediatric anesthesia: what's new? *Minerva Anesthesiol*. 2014;80(1):76-82.
36. Abdelgadir IS, Phillips RS, Singh D, Moncreiff MP, Lumsden JL. Videolaryngoscopy versus direct laryngoscopy for tracheal intubation in children (excluding neonates). *Cochrane Database of Systematic Reviews* 2017,5: CD011413. doi: <https://doi.org/10.1002/14651858.CD011413.pub2>.
37. Lingappan K, Arnold JL, Shaw TL, Fernandes CJ, Pammi M. Videolaryngoscopy versus direct laryngoscopy for tracheal intubation in neonates. *Cochrane Database Syst Rev*. 2018;2018(6):CD009975. doi: <https://doi.org/10.1002/14651858.CD009975.pub3>.
38. Grunwell JR, Kamat PP, Miksa M, et al; National Emergency Airway Registry for Children (NEAR4KIDS) and the Pediatric Acute Lung Injury and Sepsis (PALISI) Network. Trend and Outcomes of Video Laryngoscopy Use Across PICUs. *Pediatr Crit Care Med*. 2017;18(8):741-9. doi: <https://doi.org/10.1097/PCC.0000000000001175>.
39. Poupirt NR, Nassar R, Napolitano N, et al. Association Between Video Laryngoscopy and Adverse Tracheal Intubation-Associated Events in the Neonatal Intensive Care Unit. *J Pediatr*. 2018;201:281-4. doi: <https://doi.org/10.1016/j.jpeds.2018.05.046>.
40. Stendall C, Glaisyer H, Liversedge T. Actualización en dispositivos supraglóticos para la vía aérea pediátrica. *Colombian Journal of Anesthesiology*. 2017;45(S2):39-50. doi: <https://doi.org/10.1016/j.rca.2017.07.013>.
41. Koele-Schmidt L, Vásquez M. NewB for newbies: a randomized control trial training housestaff to perform neonatal intubation with direct and videolaryngoscopy. *Pediatric Anesthesia*. 2016;(26):392-8. doi: <https://doi.org/10.1111/pan.12832>.
42. Black AE, Flynn PE, Smith HL, et al. Development of a guidelines for the management of the unanticipated difficult airway in pediatric practice. *Pediatr Anesth*. 2015;25:346-63.
43. Burjek NE, Nishisaki A, Fiadjoe JE, et al. Videolaryngoscopy versus fiber-optic intubation through a supraglottic airway in children with a difficult airway: an analysis from the multicenter pediatric difficult intubation registry. *Anesthesiology*. 2017;127(3):432-40.
44. Lee JH, Smith PB, Huey Quek MB, et al. Risk factors and in-hospital outcomes following tracheostomy in infants. *J Pediatr*. 2016;173:39-44. doi: <https://doi.org/10.1016/j.jpeds.2016.01.072>.
45. Fennessy P, Walsh B, Laffey J, McCarthy Kand McCaul C. Accuracy of pediatric cricothyroid membrane identification by digital palpation and implications for emergency front of neck Access. *Pediatric Anesthesia*. 2020;30:69-77. doi: <https://doi.org/10.1111/pan.13773>.
46. Pawar DK, Doctor JR, Raveendra US, et al. All India difficult airway association 2016 guidelines for the management of unanticipated difficult tracheal intubation in paediatrics. *Indian J Anaesth*. 2016;60(12):906-14. doi: <https://doi.org/10.4103/0019-5049.195483>.
47. Echeverry P, Engelhard T. Algoritmo para el manejo de la vía aérea difícil en pediatría. *Colombian Journal of Anesthesiology*. 2014;42(4):325-34. doi: [10.1016/j.rca.2014.05.008](https://doi.org/10.1016/j.rca.2014.05.008).
48. Weiss M, Engelhardt T. Cannot ventilate—paralyze! *Paediatr Anaesth*. 2012;22(12):1147-9. doi: <https://doi.org/10.1111/pan.12054>.
49. Ozawa Y, Ades A, Foglia EE, et al; National Emergency Airway Registry for Neonates (NEAR4NEOS) Investigators. Premedication with neuromuscular blockade and sedation during neonatal intubation is associated with fewer adverse events. *J Perinatol*. 2019;39(6):848-56. doi: <https://doi.org/10.1038/s41372-019-0367-0>.
50. Streiff A, Chimhundu-Sithole T, Evans F. Manejo de la vía aérea pediátrica Difícil en centros con altos y bajos recursos: Una comparación de algoritmos y carros de vía aérea difícil. *Paediatric Anaesthesia Tutorial* 399 [internet]. 5 de marzo de 2019. Disponible en: [www.wf-sahq.org](http://www.wf-sahq.org)
51. Chrisme N. The Vortex: a universal “high-acuity implementation tool” for emergency airway management. *Br J Anaesthesia*. 2016;117(S1):i20-i27. doi: <https://doi.org/10.1093/bja/aew175>.
52. Baquero H, Celis LA, Martínez I, Restrepo N, et al. Consenso de manejo en vía aérea y soporte ventilatorio en neonatos con sospecha o riesgo de Covid19. 1ra. ed. Bogotá: Asociación Colombiana de Neonatología (ASCON); 2020.
53. Matava C, Fiadoe JE, Kovatsis P, et al. Pediatric airway management in Covid-19 patients: consensus guidelines from the Society for Pediatric Anesthesia's Pediatric Difficult Intubation Collaborative and the Canadian pediatric Anesthesia Society. *Anesth Analg*. 2020;131:61-73. doi: <https://doi.org/10.1213/ANE.0000000000004872>.