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# Endotracheal Intubation in Children: Practice Recommendations, Insights, and Future Directions

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## Abstract

Management of airway is mandatory in a critically ill child with severe trauma or any other situation that threatens his or her life. It is important, that clinicians who attend critically ill pediatric patients requiring airway management know the rapid sequence intubation (RSI) procedure, identify a patient with difficult airway, know the devices and techniques for the management of difficult airway, and look for receiving a formal training in endotracheal intubation (ETI). Future strategies for teaching and/or training clinicians in pediatric and neonatal ETI should be evaluated through conducting controlled clinical trials to identify which type will be the most effective by considering the less number of attempts and complications.

**Keywords:** endotracheal intubation, children, review, training, procedure

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## 1. Introduction

Management and securing permeability of airway are mandatory in a critically ill child with severe trauma or any other situation that threatens his or her life. Airway's management can be defined as the performance of maneuvers and the use of devices that enable a correct and safe ventilation to patients that need this care.

Endotracheal intubation (ETI) is one of the procedures that every physician attending critically ill pediatric patients must not only know but also getting the skills and experience necessary to effectively perform.

In this chapter, we will summarize the most practical recommendations of ETI technique in children. In addition, we will discuss important anatomical particularities of the children's airway. We include a section of devices that could help permeate the airway of pediatric patients with a difficult airway; and recent results of studies conducted regarding the association between the level of previous training in pediatric ETI and success rates.

### 1.1. Indications of ETI in children

1. Patient with an unstable airway. In this category, integrity of airway is affected by different infectious, anatomical and neurological diseases. Some examples are: (a) upper airway infectious (CROUP, bacterial tracheitis, etc.), (b) traumatism, (c) congenital syndromes accompanied with macroglossia or micrognathia, (d) cystic hygroma, (e) branchial cleft cyst, (f) thyroglossal duct cyst, and (g) those patients with a large anterior mediastinal mass (non-Hodgkin lymphoma, acute leukemia, etc.). During childhood, the most common cause is infections [1].
2. Patient with neurological dysfunction secondary to trauma, seizures, metabolic disease, or toxic ingestion. Classically, we can find patients with a Glasgow Coma Scale (GCS) score of 8 or less, or a deterioration in the GCS score from 14 to 10.
3. Patient with impaired gas exchange:
  - a. Hypoxia. One of the most common indications of ETI. Clinically, the patient presents with respiratory distress, tachypnea, increased work of breathing, and an increase in alveolar-arterial gradient. Some causes of hypoxia are airway obstruction, hypoventilation, ventilation/perfusion mismatch, hemoglobinopathies, abnormal pulmonary diffusion, and intracardiac right to left shunt.
  - b. Hypercarbia. The pathophysiologic phenomenon consists of alteration in ventilation. There exists a reduced lung compliance and a V/Q mismatch increasing physiologic dead space. Alteration in ventilation can also be secondary to muscle weakness, altered mental status, exposure to toxins, or iatrogenic oversedation.
4. Patient with lower airway obstruction. Hypercarbia, tachypnea, increased work of breathing, wheezing, and a prolonged expiratory phase are characteristic. As lower obstruction progresses, dynamic hyperinflation and air trapping worsen, leading to a silent chest (inaudible breath sounds). This obstruction is common in asthma and bronchiolitis. We must remember that children can get intubated by this indication but it has been described an increase in mean airway pressure that may impede venous return. Therefore, under this indication children should only be intubated in EXTREME CIRCUMSTANCES [1].
5. Patient with a reduction of mechanical load, as seen in shock state and some patients with cardiovascular dysfunction.

## 2. Practice recommendations for pediatric endotracheal intubation

### 2.1. Rapid sequence intubation

By using rapid sequence intubation (RSI) method, a clinician can effectively achieve pediatric endotracheal intubation (ETI), however, we previously must identify if the patient has one or more of the following features related with a difficult airway [2]:

- To have congenital abnormalities related with a difficult airway such as Pierre Robins Syndrome and/or Treacher Collins Syndrome.
- A previous difficult ETI.
- A poor mouth opening, large tongue or tonsils, small chin, short mandible, decreased neck mobility, and/or an evidence of partial upper airway obstruction.

Note: later in this chapter, you can find information about the causes, techniques, and a variety of devices a clinician may use for the management of children with difficult airway.

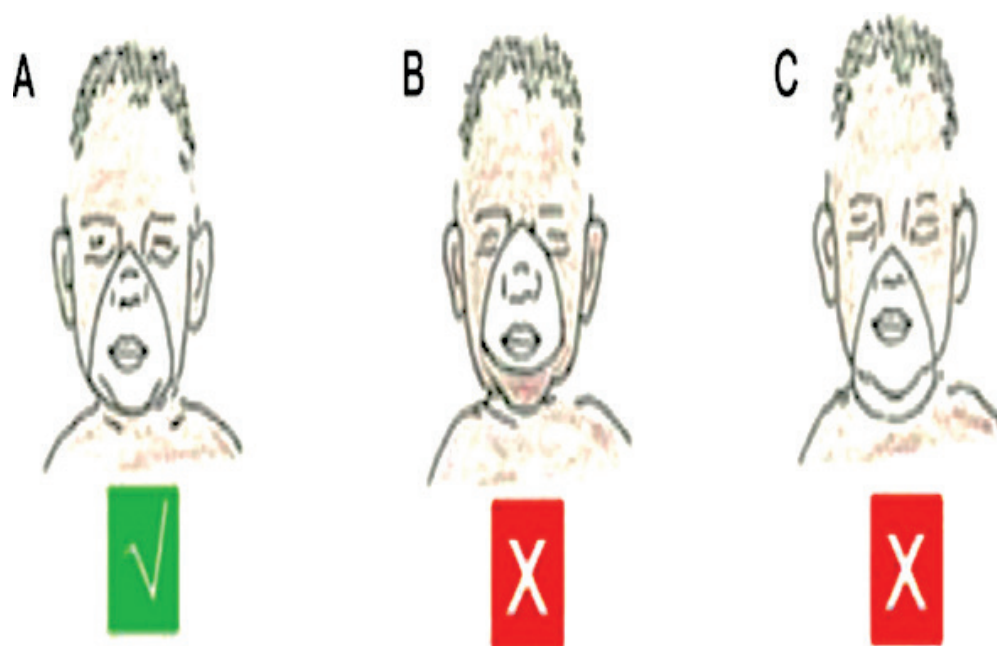
#### 2.1.1. Preparation

1. If it is not performed in an emergency setting (elective intubation), an informed consent must be obtained from the child's parents explaining the technique, complications, and benefits of performing the procedure [3].
2. All the materials to be used should be functional.
3. Team should consist of three persons (at least).
4. Patient's heart and respiratory rate, blood pressure, oxygen saturation, (capnography when available) must be monitored during the procedure.
5. Oxygen supply must be at least 10 l/min and suction equipment must be available and it must have pressures around 80–120 mm Hg.

#### Equipment

1. An appropriate mask and bag for ventilation. We must select the mask size that fits the nasal bridge and the chin of the patient without covering the eyes (**Figure 1**). Bag used for infants and young children is named pediatric bag (which provides a tidal volume of approximately 400–500 ml); for older children and adolescents, an adult bag should be used (providing a tidal volume of 1000 ml) [3–5].
2. Endotracheal tubes (ETs). Uncuffed ETs are mainly indicated for neonates, infants, and young children (<8 years). The correct size of these ETs can be calculated according to the equation  $(\text{child's age}/4) + 4$ . On the other hand, the formula  $(\text{child's age}/2) + 3.5$  might be used for cuffed ETs. Other methods to calculate ETs size include comparing the child's fifth finger with the internal diameter of the ET or by using resuscitation tape such as the Broselow Luten tape, and it is recommendable to have one size larger and smaller of the selected tube.
3. Stylet. Adult sized for 5.5 tubes and beyond, pediatric ones for lower endotracheal tubes.

4. Laryngoscope handle and blade. The first one can be an adult or pediatric one, and the second can be straight or curved depending on the experience of the laryngoscopist. The blades used in pediatrics ranged from 00 (extremely premature neonates) to 4. Blades 0–1 are used for preterm and full-term neonates, size 1 for infants. At age 2, size 2 blade; at this age, a curved blade can be used. For ages 10 and above, a number 3 blade is recommended.
5. Colorimetric end tidal carbon dioxide devices or capnography monitors.
6. Tape or a commercial holder to secure the endotracheal tube.
7. Syringe for cuff inflation.
8. Nasogastric and orogastric tubes.



**Figure 1.** (A) The correct size for the child because it covers the area between nasal bridge and chin. (B) The mask elected is not correct, it covers part of the eyes of the patient. (C) The mask elected is not correct it covers the area far from the chin.

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### Tips and tricks

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#### To remember all the preparatory equipment before starting intubation

You can use the **STOP MAID** mnemonic to remember all the preparatory equipment before starting ETI procedure:

Suction;

Tools for intubation;

Oxygen;

Positioning (sniffing position so that the external auditory canal is anterior to shoulder);

Monitors;

Assistant, Ambu bag with facemask, airway devices;

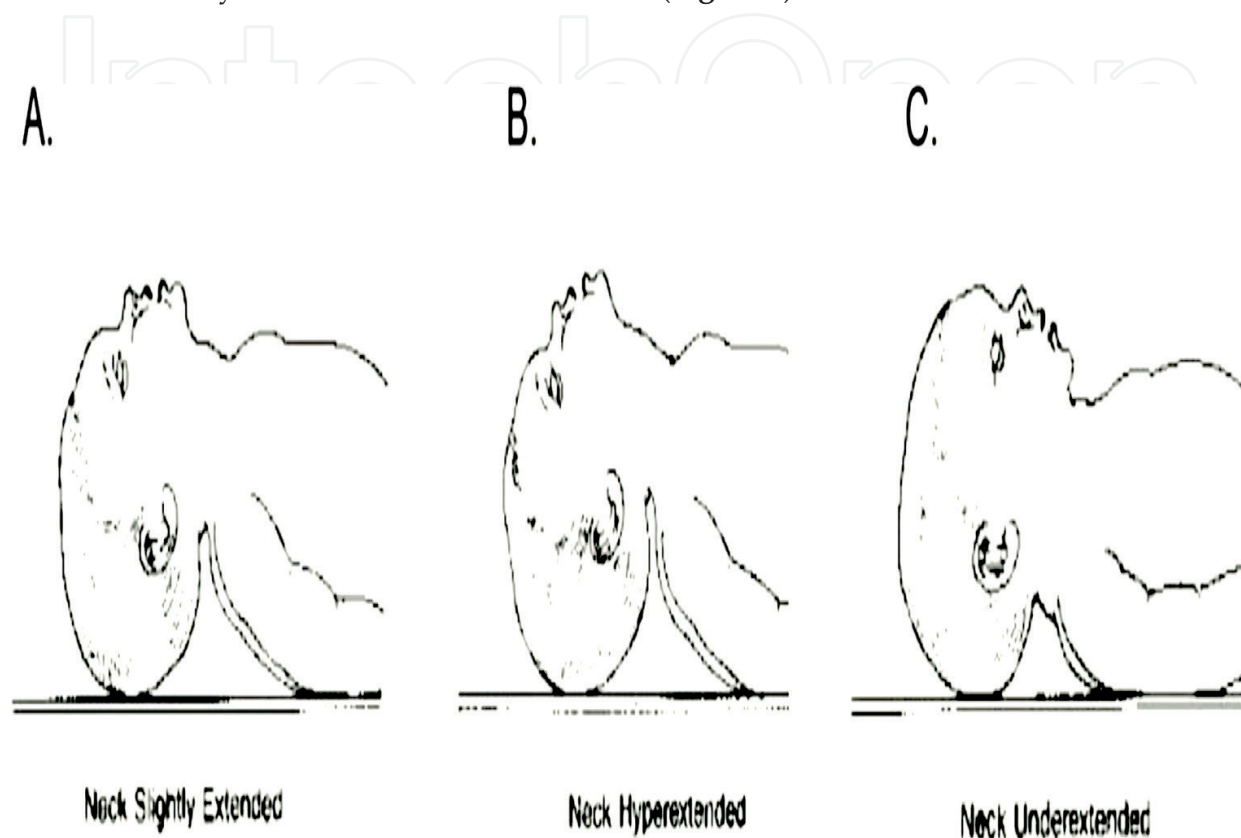
Intravenous access;

Drugs (sedation, neuromuscular blocking medications).

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### 2.1.2. Preoxygenation phase

With all the necessary tools already prepared, next, we must position the patient for the denominated preoxygenation phase. This position consists in a sniffing situation avoiding hyperextension and/or hyperflexion of the neck. The correct sniffing position is the one with exterior auditory canal anterior to the shoulders (Figure 2).

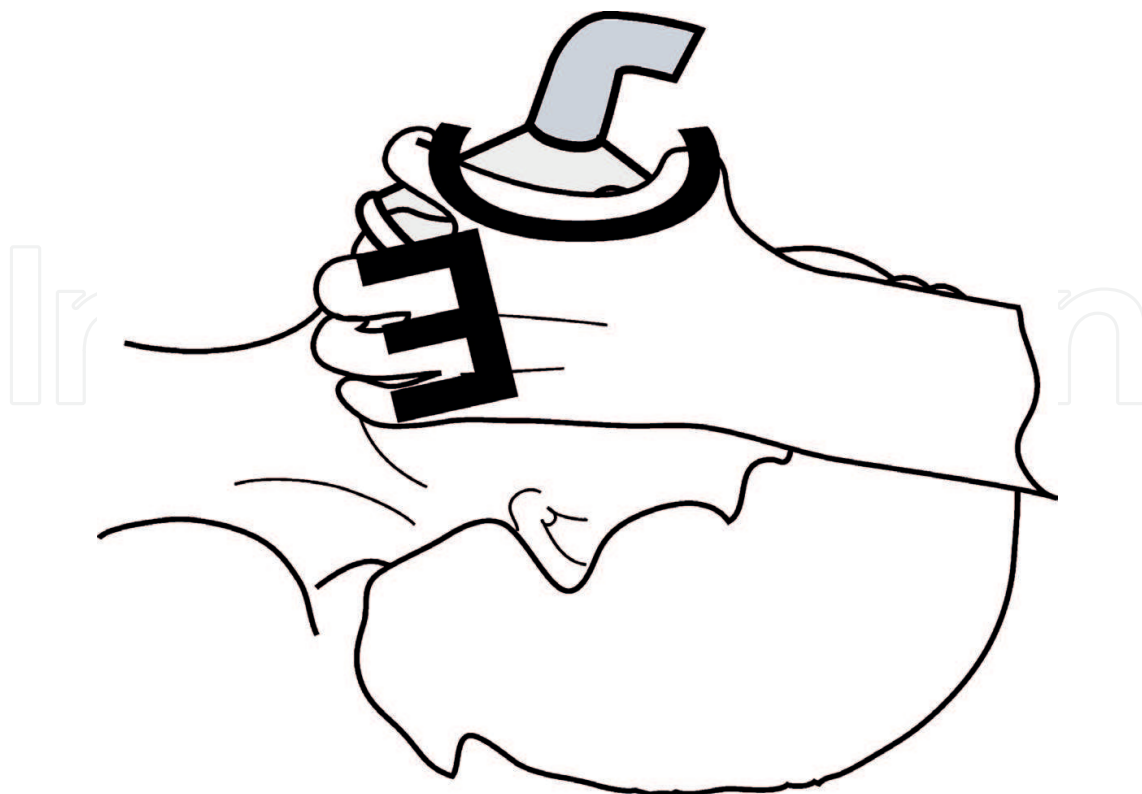


**Figure 2.** (A) Correct sniffing position is shown the external auditory canal is anterior to the shoulders of the patient. (B) Incorrect position because neck is hyperextended. (C) Incorrect position because patient's neck has hyperflexion.

Selection of ventilation technique relies on the number of persons available at preoxygenation phase:

- One-person ventilation technique. The head must be positioned backwards, using the C-E technique and the chin must be elevated pressing and sealing the mask to the face. Sealing is very important. We may corroborate that ventilation technique is correct when elevation of the chest is observed (Figure 3).
- Two-person ventilation technique. One member of the health care professional team will use the C-E technique but now with two hands while the other person will be pressing the bag (Figure 4).

After patient is positioned, then, ventilation must start with 100% inspired oxygen creating an oxygen reservoir. It is important to avoid hyperventilation. Therefore, a slow ventilation lasting around a second each must be applied being overall preoxygenation phase duration 3–5 min.



**Figure 3.** One-person C-E ventilation technique is illustrated.



**Figure 4.** Two-person C-E ventilation technique. First person is doing a double hand C-E maneuver while a second person (not shown in the image) is pressing the bag.

### 2.1.3. Sedation and neuromuscular blockade

Premedication increases success rate of pediatric ETI independently from degree of previous training [6]. By using the rapid sequence intubation in children, success rate of 52% and a complication rate of 61% can be achieved [7], however, sedation can be omitted in obtunded or comatose patients and neuromuscular blockade must be avoided in patients with difficult airway. **Table 1** summarizes the drugs, indications, and doses used for sedation and neuromuscular blockade during pediatric ETI procedure.

Medications		Indications	Doses (IV)
Sedation	Etomidate	Hemodynamic instability, neuroprotective	0.3 mg/kg
	Ketamine	Hemodynamic instability, patients with bronchospasm and septic shock	1–2 mg/kg
	Midazolam	It can cause hemodynamic instability	0.2–0.3 mg/kg
	Propofol	In hemodynamically stable patients	1–1.5 mg/kg
	Thiopental	Neuroprotection	3–5 mg/kg
NM blockers	Rocuronium	For children in which succinylcholine is contraindicated	0.6–1.2 mg/kg
	Succinylcholine	Do not use in extensive crush injury, chronic myopathy	2 mg/kg

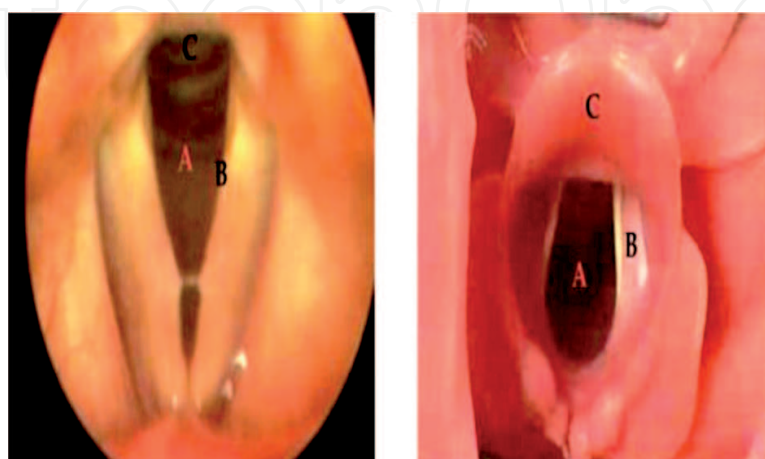
**Table 1.** Drugs, indications, doses for achieving sedation and neuromuscular (NM) blockade during pediatric ETI.

#### 2.1.4. Procedure

Clinician may most easily perform direct laryngoscopy by standing behind to the patient’s head and with height of the bed adjusted to the level of the laryngoscopist xiphoid appendix (**Figure 5**). After sedation and neuromuscular blocking, the clinician must perform a scissor maneuver to open mouth before laryngoscopy. Then, laryngoscope must be held in the left hand (regardless of dominance), inserting the blade in the right side of the patient’s mouth along the base of the tongue following the contour of the pharynx, and sweeping the tongue to the left.

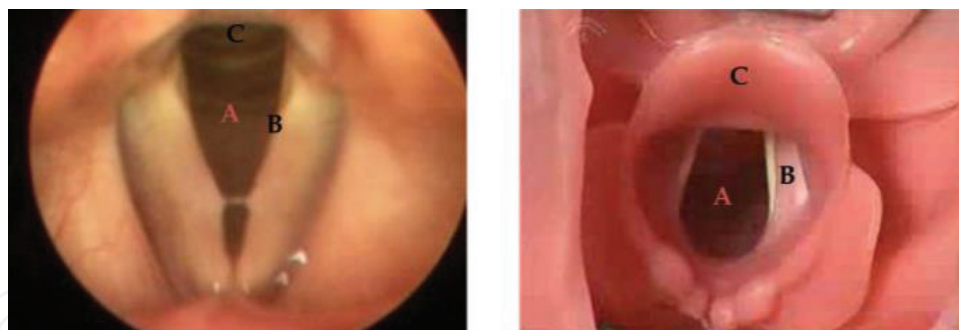
Once the tongue and soft tissues are retracted, clinician must recognize the following anatomic structures: epiglottis, arytenoid cartilage, and esophagus (**Figure 6**). After identifying epiglottis, this must be elevated exposing the vocal cords by handling laryngoscope at a 45° angle. Next step, endotracheal tube (ET) must be inserted into the trachea by holding it (with right hand) like a pencil (**Figure 7**).

ET insertion in airway must be confirmed by the observation chest wall rise and down with ventilations, auscultation of breath sounds in both axillae and not heard over stomach, and, to observe an adequate oxygen saturation (>90%). Radiographically, a correct position of the



**Figure 5.** Proper position of laryngoscopist and correct introduction of laryngoscope after opening patient’s mouth through a scissor maneuver (not shown).





**Figure 6.** A comparison between a real larynx and a model. Structures of the larynx must be identified before trying to insert ET. (A) Glottis, (B) Vocal cords. (C) Epiglottis.



**Figure 7.** ET is introduced like a pencil into the airway.

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### Tips and tricks

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#### To identify epiglottis and/or glottic structures

If epiglottis and/or glottic structures are not visible, blade must be pulled back slowly until they are visible. Other useful technique for helping to identify epiglottis and/or glottic structures is the named “Sellick maneuver” or so known as “cricoid pressure” (**Figure 8**). To perform it, another member of the resuscitation team slightly push the region of cricoid cartilage while laryngoscopist observes the structures and introduce ET.

#### To calculate ETT length insertion

ET length insertion can be determined by any of the following two formulas [5, 8, 9]:

#1- (Patient’s age (in years)/2) + 12

#2- ET internal diameter \* 3

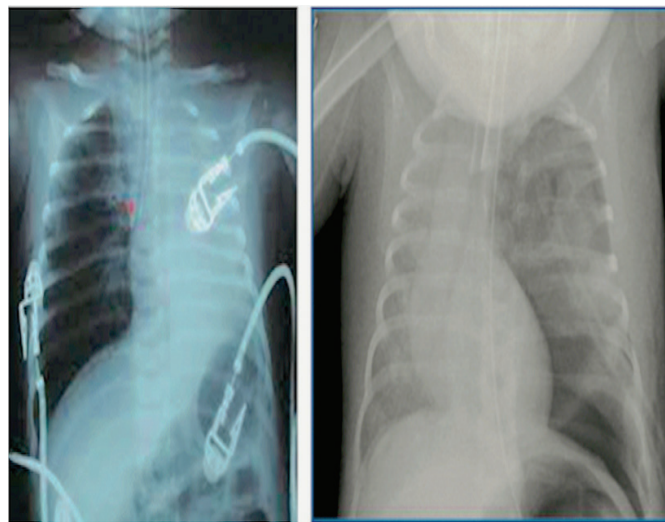
Note: we recommend first equation because it has been reported as more accurate.

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tube is below the thoracic inlet and 3 cm above the carina (**Figure 9**). In case of ETT is located at esophagus or right bronchus, immediate measures must be taken to remove it and secure an adequate ventilation of patient (**Figures 9 and 10**).



**Figure 8.** Sellick's Maneuver (also known as cricoid pressure).



**Figure 9.** X-ray on the left shows a misplaced endotracheal tube which is in the right bronchus. Right X-ray shows a correct placement of the endotracheal tube, where the tip is located above the carina.



**Figure 10.** ET located in esophagus.

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Tips and tricks [5, 10]

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#### **In case of acute respiratory deterioration after intubation**

**Remember the mnemonic DONE** which can help you to identify the probable causes:

**Deviation** of ETT to the main bronchus or misplacement during suction. Signs that can suggest this are asymmetric elevation of the thorax or asymmetric auscultation, specially the right hemithorax.

**Obstruction** due to secretions obstructing tube's lumen.

**Pneumothorax** if are present signs as breath sounds diminished on the affected side, conduction of vocal vibrations to the surface of the chest may be increased, and hyperresonant at percussion.

**Equipment**, if problem is in the ventilator hardware or software.

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### **3. Neonatal intubation**

#### **3.1. Indications**

ETI in neonates can be most commonly performed as an emergency procedure or as part of an elective or semi-elective treatment:

1. **Emergency.** When mask ventilation or non-invasive mechanical ventilation fails, in case of structural or congenital airway abnormalities, diaphragmatic hernia, prolonged cardiopulmonary resuscitation, if thoracic compressions are needed, surfactant administration and for direct tracheal aspirations if thick secretions exist [11].
2. **Elective/semi elective.** Prematurity, positive pressure ventilation lasting more than 1-min, in case of ET must be changed, and in patients with an unstable airway [11].

#### **3.2. Important anatomical considerations in neonates**

In comparison to older children, adolescents and adults, anatomy of neonatal upper airway structures is different, being neonates a subpopulation where the ETI becomes a challenge. Some of these differences are the following: (a) a tongue proportionately larger, in consequence, trying to sweep it during ETI might be difficult and its backward movement might result in an airway obstruction; (b) epiglottis is longer, narrower, less flexible, and sometimes omega-shaped; (c) a cranial position of larynx can be an obstacle for observing the glottis during laryngoscopy, being this issue the reason why is preferable to use straight blades rather than curved ones in neonates; and (d) trachea is proportionally shorter and narrower [12, 13].

It is important to highlight, that neonates <1000 g, >4000 g, or those with congenital craniofacial abnormalities have less chance to be intubated at first attempt, representing a subgroup of neonates with a difficult airway which require special attention [14].

On the other hand, each attempt of intubation in neonates provokes injury of the mucosa which subsequently leads to an inflammation decreasing the caliber of the field of observation, and therefore, making the intubation less effective. Currently, it has been recommended a limit of 20 s for each intubation attempt in neonates, and if it fails, the ET must be removed and patient must be ventilated with a mask-bag reservoir until recovery [11, 15, 16].

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**Tips and tricks**

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**Premedication phase in neonates is different from older children**

In neonates, premedication phase must be only used as part of an elective ETI and not for emergency situations.

The American Academy of Pediatrics (AAP) and the Canadian Pediatric Society (CPS) recommend a combination of vagolytic agents and neuromuscular blockers for premedication phase in neonates. Also, the AAP recommends that muscular blockers and sedatives must not be used alone without analgesia [3].

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**Tips and tricks**

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**ET size election for neonates**

Election of ET size based on neonate's weight and gestational age:

Weight (g)	Gestational age (weeks)	ET size (internal diameter in mm)
<1000	<28	2.5
1000–2000	28–34	3.0
>2000	>34	3.4

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**3.3. Estimating length insertion of ET in neonates**

Two methods may be used, and the objective is to place the tip of ET in the middle portion of trachea.

**a. DNT method**

We must add 1 cm to the distance (cm) between the newborn's nasal septum and ear tragus (**Figure 11**) [17].

**b. Gestational age method (Table 2)**

**c. "7-8-9 rule" method:** in 1979, Tochen described a simple equation for the ET insertion length based on patient's weight at birth.

Formula:  $1.17 * \text{weight at birth (kg)} + 5.58$ .

This equation has been supported by the AAP and the American Heart Association (AHA), establishing ET insertion length can be calculated by adding 6 cm to the newborn weight (e.g., for a newborn weighing 1 kg = 1 + 6 = 7 cm), from the patient's lip [14].

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### Tips and tricks

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#### ET length insertion when nasotracheal intubation is used

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When nasotracheal intubation is performed, the ET length must increase in 20% (e.g., for a newborn weighing 2 kg;  $(2 \text{ kg} + 6) \times 1.2 = 9.6 \text{ cm}$ ). We must also take in consideration that the 7-8-9 rule can overestimate the insertion length in newborns with a birth weight less than 1000 g. In consequence, it is preferred to use the gestational age method (Table 2) [18].

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Figure 11. DNT method.

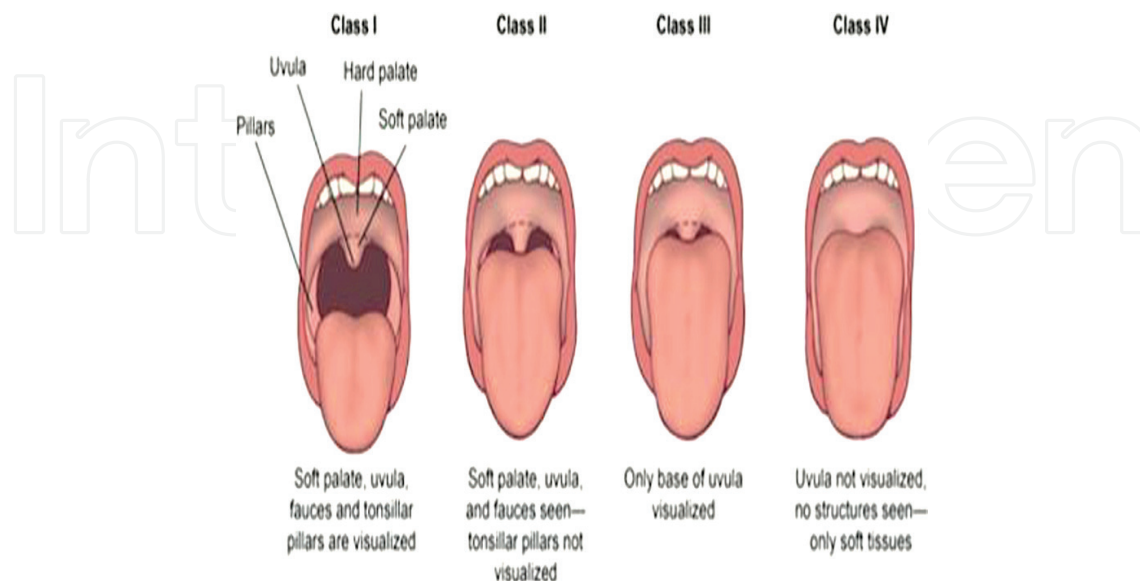
Gestational age (weeks)	ET length insertion (cm) from the patient's lips	Weight (g)
23–24	5.5	500–600
25–26	6.0	700–800
27–29	6.5	900–1000
30–32	7.0	1100–1400
33–34	7.5	1500–1800
35–37	8.0	1900–2400
38–40	8.5	2500–3100
41–43	9.0	3200–4200

Table 2. Gestational age method to calculate ET length insertion [18].

## 4. Management of the child with difficult airway (DA)

Difficult airway can be defined as the clinical situation in which a conventionally trained physician has trouble for achieving an effective upper airway ventilation with a face mask, for tracheal intubation or both and where interact patient's factors, setting conditions and operator skills [19]. First, we must evaluate child's airway to identify those clinical, and/or laboratory factors that

could make difficult to achieve ETI. Among the anatomical factors related with DA are the form and size of mouth, nose, mandible, neck, existence of masses or congenital malformations, and other childhood diseases that eventually could difficult ETI (**Figure 12, Tables 3 and 4**) [20–24].



**Figure 12.** Difficult airway for ETI based on modified Mallampati classification [25, 26].

- 
- Cranium’s bone displacement. Apert syndrome, Crouzon syndrome, hydrocephalus
  - Mandible hypoplasia. Pierre Robin syndrome, Treacher Collins syndrome, Goldenhar syndrome, Apert syndrome
  - Abnormal neck mobility. Klippel-Fleil syndrome, Down syndrome, mucopolisacridosis
  - Limited oral aperture: Sheldon Freedman syndrome, Hallerman-Strieff syndrome, bullous epidermolysis
  - Small oral cavity: Pierre Robin syndrome, Treacher-Collins syndrome
  - Macroglossia: hypothyroidism, Beckwith Wiedemann syndrome, Down syndrome, mucopolisacridosis
  - Airway or neck masses: cystic hygroma, teratomas, hemangiomas
  - Laryngeal or subglottic anomalies
- 

**Table 3.** Pediatric syndromes associated with DA.

#### 4.1. Devices and techniques for the management of the child with DA

DA devices can be classified according to the anatomical structure from where they will act and/or on their optical properties [27]:

#### 4.2. Supraglottic airway devices

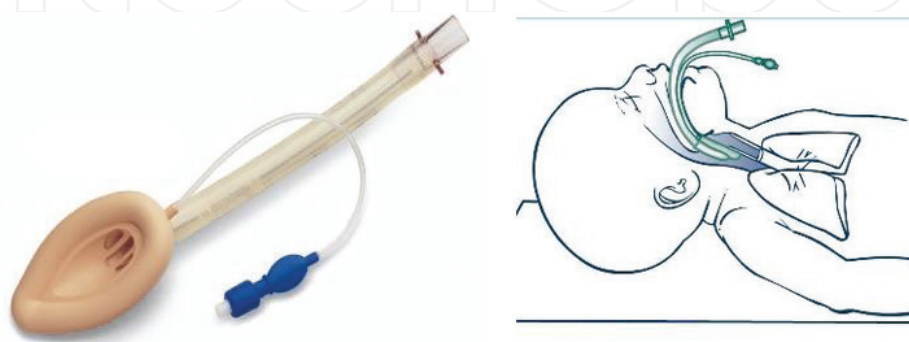
##### 4.2.1. Classic laryngeal mask

It was developed in 1980 by Dr Archie Brain and forms part of the rescue devices in the ASA algorithm for the difficult airway management. It was designed to be situated in the

Infectious	Traumatic	Neoplastic	Inflammatory	Neurologic	Other
<ul style="list-style-type: none"> <li>• Epiglottitis</li> <li>• Abscess (sub-mandibular, retropharyngeal, Ludwig's angina)</li> <li>• Croup</li> <li>• Papillomatosis</li> </ul>	<ul style="list-style-type: none"> <li>• Foreign body</li> <li>• Cervical column lesion</li> <li>• Skull base fracture</li> <li>• Maxillary or mandible lesion</li> <li>• Laryngeal fracture</li> <li>• Postintubation laryngeal edema</li> <li>• Facial trauma</li> <li>• Burns</li> </ul>	<ul style="list-style-type: none"> <li>• Upper airway tumors (pharynx, larynx)</li> <li>• Inferior airway tumors (trachea, bronchi, mediastinal)</li> <li>• Post-radiation area</li> </ul>	<ul style="list-style-type: none"> <li>• Angioedema</li> <li>• Anaphylactic shock (laryngeal edema)</li> <li>• Ankylosis</li> <li>• Juvenile Rheumatoid arthritis</li> </ul>	<ul style="list-style-type: none"> <li>• Spastic cerebral paralysis</li> <li>• Tetanus</li> </ul>	<ul style="list-style-type: none"> <li>• Lung hemorrhage</li> <li>• Obesity</li> <li>• Cranium-facial malformations</li> <li>• Micrognathia</li> <li>• Superior incisive protrusion</li> <li>• Short and wide neck</li> <li>• Big tongue</li> <li>• Previous intubation difficulty</li> <li>• Oral aperture limitation</li> <li>• Clift lip and palate</li> <li>• Mallampati classes 3 or 4 (Figure 12)</li> </ul>

**Table 4.** Childhood diseases associated with DA.

hypopharynx, with an anterior aperture situated at the glottis entrance, the mask's border is made of a silicone inflatable cuff, sealing the hypopharynx permitting positive pressure ventilation (less than 20 cm H<sub>2</sub>O). The mask is introduced using the index finger of the dominant hand as a guide towards the hypopharynx, following the palate's curvature, until a resistance is felt, then the cuff must be inflated with a determined volume (the specific volume comes in a legend on the mask itself and depends of the number of the mask). Choosing the size mask depends on the weight of the patient. As complications of the procedure we can find aspiration of gastric contents, uvula, and pharyngeal pillars lesions (Figure 13).



**Figure 13.** Laryngeal mask.

#### 4.2.2. ProSeal laryngeal mask airway

In 2000 Brain published the description of a new laryngeal mask that tried to improve the airway's protection against gastric aspiration. This was accomplished by including a second tube lateral to the airway's tube and which in its distal end is located on the tip of the mask. This tube has the function of separating the digestive tract from the respiratory, and also Permits accessing the stomach with an orogastric probe (**Figure 14**) [28].

#### 4.2.3. Fastrach or intubation laryngeal mask (ILMA)

This type of laryngeal mask is designed with the objective of achieving intubation through the mask itself, it consists of an anatomically curved rigid tube, wide enough to accept in it endotracheal tubes this end is united to rigid metal loop that makes the insertion much easier, removal, and adjustment of the position with one hand only. Once installed, and ventilation achieved an ET is inserted, the mask is then removed maintaining the tube in place, with a specially designed stylet, so that after the mask is removed the ET remains in place (**Figure 15**).



**Figure 14.** ProSeal laryngeal mask airway.



**Figure 15.** FASTRACH or intubation laryngeal mask (ILMA).





**Figure 16.** New type of Fastrach laryngeal mask.

Other type of *Fastrach laryngeal mask (2005) with an incorporated camera*, permits once it has been introduced into the hypopharynx, setting a monitor on the outer part of the mask so that it can be possible introducing an ET under direct vision (**Figure 16**).

#### 4.2.4. Combitube

This device can only be used to ventilate in emergency situations. It was designed in Austria in the year 1980. Insertion is easy for any person and insertion is blindfold. It consists of a double lumen latex tube that combines the functions of an esophageal obturator and a conventional ET. Combitube has two balloons which inflate from the exterior. First one corresponds to an oropharyngeal balloon (85–100 ml of capacity) situated in a proximal position to the pharyngeal perforations with a function of serves as a sealing of the oral and nasal cavity; second one, is called traqueo-esophagic balloon, and needs a volume of 12–15 ml to seal the trachea or esophagus. Combitube can be placed either in the esophagus or in trachea, and in case of tube passes to the esophagus, the patient can still be ventilated because the perforations existing in combitube esophageal lumen, and the stomach can be aspirated from the tracheal lumen. In case of combitube is set in the trachea, the patient can also be ventilated from the trachea lumen (**Figure 17**) [29, 30].



**Figure 17.** Combitube.

### 4.3. Transglottic airway devices

#### 4.3.1. Gum Elastic Bougie

*Eschman Guide* or *Gum Elastic Bougie (GEB)* is a semi-flexible guide of polyester covered in resin (to avoid laryngeal trauma). GEB has a 15-Fr diameter and can be introduced in 6 mm internal diameter tubes. Insertion technique consists of sliding the angulated tip underneath the epiglottis, then, dragging at the tracheal cartilages must be perceived (**Figure 18**) [31].



**Figure 18.** Gum Elastic Bougie (GEB).

#### 4.3.2. Lightwand device (Trachlight)

In some countries, a lighted stylet is used for ETI, this is the called *Trachlight*. It is based on transillumination of the soft tissue of the neck with a high effectivity for achieving intubation in an approximate time of 25 s (**Figure 19**) [32].



**Figure 19.** Lightwand device (Trachlight).

### 4.4. Optical devices

#### 4.4.1. Video laryngoscopes

They are laryngoscopes that carry in its distal blade's end a high-resolution video camera to visualize the glottis and to introduce an ET without the need of observing the glottis directly

but through a high-resolution screen which can be located in the same device or at the patient's side. Among the main complications reported are the soft palate lesions (**Figure 20**).



**Figure 20.** Video laryngoscope.

## 5. Insights and future directions

### 5.1. Direct laryngoscopy vs. video laryngoscopy

Learning curve (LC) in the case of the direct laryngoscopy requires of approximately of 45–50 previous intubations [33], while LC for video laryngoscopy is around 5 attempts. ETI using a video laryngoscopy is possible with little training, due to transmitted image from the blade's distal tip makes easier the visualization of the larynx entrance. When intubation attempts using Miller or Macintosh laryngoscopes or video laryngoscopy fail other methods to secure pediatric airway are recommended to be used (i.e. supraglottic devices). Recent studies have reported that ETI with video laryngoscopy even performed by less experienced medical personnel, increases significantly the success rate in the first attempt in comparison with direct laryngoscopy [34]; moreover, it has been reported that video laryngoscopy decreases the intubation time with less desaturation and less failure rate when it is compared with conventional laryngoscopy [35, 36]. Nevertheless, other video laryngoscope methods (GlideScope) implying other type of learning (mainly based on exploration), have resulted to be inferior to direct laryngoscopy regarding the time required for ETI [37].

### 5.2. Importance of formal training in pediatric ETI

Until date there is no standard definition for the term proficiency in pediatric/neonatal airway ETI. In a recent study, defined a formal training in pediatric airway management as having received at least 2 weeks of training by pediatric anesthesiology teachers. In that study was reported that after formal training, intubation success rate increased from 65.1 to 75.7% ( $p = 0.01$ ), and it was observed a significant decreasing in the number of intubation attempts ( $p = 0.01$ ). However, they did not find statistically significant differences in the time for achieving Intubation nor for the frequency of complications [38].

In a study conducted by Kerrey et al., where rapid sequence intubation technique was used, pediatricians in emergency departments and anesthesiologist had higher success rates (88–91%) in comparison to physicians in formation (45%) [7]. These results were similar to the reported by Goto et al. where intubation success was higher at the first attempt in pediatricians (OR 2.36; CI 95% 1.11–4.97) and in emergency room physicians (OR 3.2; CI 95% 1.78–5.83) in comparison to pediatric residents of the first and second year [39].

It has also been evaluated the skills for neonatal ETI between residents. Interestingly, skills significantly improved with a success rate from 27% during the first year of formation to 79% for the second year. Number of attempts also improved decreasing from 3.6 to 1.2 from the first to the second year, respectively [38]. This and other study results highlight the relevance of implementing training strategies from early stages of education in medicine to effectively achieve ETI in children with the less number of attempts and complications [6, 40, 41].

#### *5.2.1. ETI training models, live models, and simulation training sessions for increasing success in pediatric and neonatal intubation*

Recently, it has been mentioned that there are no differences in the learning curve or the skills for performing neonatal intubation by comparing live models versus ETI training models. Retention curves with a follow-up of 6, 18 and 52 weeks remain constant after 6 weeks and get lost after 18 and 52 weeks; although, retention is higher when skill levels are higher too [42, 43]. Additionally, it has been reported that educational interventions such as training sessions using didactic and simulation components have not been related with an improvement in intubation success rate; even, performance points decrease after 8 weeks of the intervention [44]. Importantly, other studies have not found differences in pediatric ETI success rate at first attempt by comparing groups with and without training [45].

## 6. Conclusions

It is important to highlight, that clinicians who attend critically ill pediatric patients requiring airway management know the rapid sequence intubation procedure, identify a patient with difficult airway, know the devices and techniques for the management of difficult airway, and look for receiving a formal training. Future strategies for teaching and/or training clinicians in pediatric and neonatal ETI should be evaluated through conducting controlled clinical trials to identify which type is the most effective by considering the less number of attempts and complications.

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