# Functional Procedures in Upper Airway Disorders

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## Endotracheal Intubation

**Endotracheal intubation** is the introduction of a tube through the patient's mouth and into their airway. The usual reason this is done is to secure and facilitate airway flow and oxygenation for patients who will undergo general anesthesia and patient who suffer from severe pulmonary disorders that requires support from a ventilator. It is preferred for the patient to be unconscious in order to perform the rather uncomfortable procedure.

## Procedure

Assess intubation difficulty using the Mallampati and LEMON [1] scores. Prepare adequately. After loss of consciousness by the patient, adequate oxygenation is required to compensate for the lack of respiration during the respiration attempt. This is especially true for patients whose intubation may prove difficult and therefore take more time.

The head of the patient is placed in a position of extension [2], whenever it is possible, using the left hand of the physician. While the left hand of the physician keeps the head stable, the mouth is opened with the right hand. Then keeping the head stable and the mouth open with the right hand, the physician introduces the blade of the laryngoscope in the right side of the mouth and subsequently moves it toward the midline, moving the tongue along until the epiglottis is visible.

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A. M. Esquinas et al. (eds.), *Upper Airway Disorders and Noninvasive Mechanical Ventilation*, https://doi.org/10.1007/978-3-031-32487-1_36

The laryngoscope then is to be lifted in direction anterior and inferior to the patient. This way the larynx can be best visualized and the vocal cords exposed. Care must be taken to avoid rotation of the laryngoscope that may inadvertently cause damage to the patient's dental structures. An assistant can apply gentle pressure to the cricoid cartilage to assist with the visualization of the larynx [3].

Finally with the larynx and vocal cords exposed, the endotracheal tube is inserted into the trachea under direct vision. Optimal length from the tip of the endotracheal tube to the patient's dental structures varies depending on patient's height, but 23 cm for men and 21 cm for women can be used as a rule of thumb [2]. The blade of the laryngoscope is removed. The cuff of the tube is inflated and the oxygenation of the patient can resume. The physician performing the procedure must check that the tube is indeed placed correctly, usually by auscultating for bilateral breathing sounds and lack of gargling sounds in the stomach. Capnography can also be used, when available.

If for any reason difficulties are presented during the procedure, the performing physician needs to stop after due time, in order to oxygenate the patient, before resuming effort to prevent hypoxia. Adequate oxygenation is more important than intubation. Continuous monitoring of oxygen levels is mandatory when possible. In difficult cases an elastic bougie may be used as a guide for the tube. A video laryngoscope may also be used to provide vision in difficult intubations [2, 4].

## Emergency Cricothyrotomy

Cricothyrotomy is the procedure of gaining surgical access to the trachea with the purpose of securing the function of the airway. Whenever bag-mask or supraglottic ventilation is unfeasible and intubation of the patient is not possible [5] (CICO, an acronym, meaning cannot intubate, cannot oxygenate, may commonly be used to describe the situation), a cricothyrotomy can offer direct access to the upper trachea in order to achieve vital oxygenation, performed usually on the patient's bedside, during admission, or during transportation to the emergency unit. Cricothyrotomy should be avoided in children under the age of 12. The underdeveloped larynx of children is thinner and more prone the permanent damage due to the operation. Cricothyrotomy should also be avoided in individuals with laryngotracheal injuries, as it may worsen their condition. Tracheostomy should be considered as an alternative to cricothyrotomy in these cases.

### Procedure

The goal of cricothyrotomy is to gain access to the trachea through the cricothyroid membrane. After placing the patient's head in overextension whenever possible, the anatomical landmarks of the operation need to be identified. After the suprasternal notch, the thyroid cartilage, and the cricoid cartilage are located, the physician

performing the cricothyrotomy can palpate the cricothyroid membrane in the indentation between the thyroid and cricoid cartilages.

A 2 cm vertical incision is performed on the midline of the neck along the previously palpated cricothyroid membrane. The incision is further deepened with sharp dissection under guidance by palpation of the membrane using a finger. Due to the emergent nature of the procedure, slower blunt dissection and a more traditional slower surgical approach are discouraged [6].

After the cricothyroid membrane is located, it is incised horizontally. The incision is further dilated with the use of the physician's finger or that of Kelly forceps. An endotracheal tube can now be placed to provide oxygenation and ventilation assisted by the use of an elastic bougie guide.

### Complications [7, 8]

During procedure:

- Bleeding
- Injury of the thyroid gland
- Laryngeal/vocal cord injury
- False passage through tissue
- Pneumothorax or subcutaneous emphysema
- Esophageal/mediastinal injury along perforation of the posterior tracheal wall
- Aspiration

After procedure:

- Dysphonia or voice changes
- Infection
- Hematoma
- Persistent stoma
- Scarring
- Laryngeal, glottic, or subglottic stenosis
- Tracheoesophageal fistula
- Tracheomalacia

## Tracheostomy

A tracheostomy is the surgical bypass of the majority of the superior airway via incision of the trachea. It is performed to allow the placement of an endotracheal tube in conditions of upper airway blockage, where traditional intubation is unfeasible, or to secure the airway in cases of prolonged ventilatory support, where tracheomalacia is likely to develop. Gas exchange into and out of the lung is facilitated

through this surgical opening and diverted away from the nasal and oral orifices, commonly performed in the operating theater, under total anesthesia.

A tracheostomy is usually performed under these circumstances [9]:

- Complete or partial obstruction of the upper airway (may warrant emergent approach).
- Allow access to the lower trachea, in order to facilitate a surgical procedure (e.g., removal of foreign body too big or too dangerous to pass safely though the larynx).
- Need of safe, secure, and easy airway access for oxygenation (e.g., oxygenation during facial surgery).

Upper airway disorders that may require intervention with tracheostomy are as follows:

- Severe facial, neck, or laryngeal trauma
- Exposure to fire or smoke that may lead to airway damage
- Foreign body aspiration
- Cancer of the upper airway
- Subglottic stenosis
- History of laryngectomy
- Congenital defects of the upper airway
- Extended periods of ventilatory support and tracheomalacia
- Vocal cord paralysis (bilateral)
- Infections, leading to increased secretions and/or swelling of the epiglottis or the larynx

## Procedure [10, 11]

The patient is placed under general anesthesia. Oxygenation of the patient is carried out by traditional endotracheal intubation when possible or different means, like nasal insufflation catheter when normal intubation is not feasible. The patient's neck is placed in a position of extension, using special pillows or sandbags, when possible. In cases of trauma where compromise of the cervical spine is suspected or evident, the patient's head must remain linear to avoid serious damage to the spinal cord and possible disability [12].

Using palpation, the performing physician identifies the landmarks of the sternal notch, the thyroid notch, and cricoid cartilage. The skin is incised 1–2 cm inferior to the cricoid cartilage. The incision may be vertical or horizontal, with a span of 3–4 cm.

The deep facia is to be vertically opened using electrocautery. Using blunt dissection, prepare and retract the strap muscles laterally. The thyroid isthmus may be divided or retraced inferiorly to provide sufficient area to operate. The later maneuver will expose the tracheal facia and the trachea beneath it.

The tracheal facia must be opened vertically, exposing the tracheal rings. After palpating the cricoid cartilage and counting the tracheal ring, the performing physician must choose the appropriate location to perform the tracheotomy. In adults the second and third rings are usually the site of the opening, and in prepubescent patients, the third and fourth rings are optimal. Congenital abnormalities and tumors may affect this choice.

After the location is identified, the performing physician can trace the shape of the tracheotomy before carefully incising it using a scalpel. The shape may be circular, square, or a vertical incision (preferably in prepubescent patients). Creating a flap to assist closure of the tracheal opening is optional.

Finally, after the trachea is opened, the endotracheal tube used to oxygenate the patient is retracted just enough to allow for the placement of a tube through the tracheal opening. After the ventilation of the patient is assumed using the tracheostomy, the distal ends of the incision are sutured and the tube stabilized on the patient's neck.

## Alternative Procedure

In an alternative approach, the procedure can be performed using Seldinger's [13] principle. Patient position remains the same, and the performing physician gains access to the trachea in the same way. After the trachea is exposed, a needle is used to perforate the trachea between the second and third rings. The needle must be directed caudally with great care taken to avoid puncture of the posterior aspect of the trachea. Suction of air indicates correct positioning. For this approach to be possible, the anesthesiologist must maintain the endotracheal tube at the level of the vocal cords or lower larynx.

A guide wire with a j-tip can be presented through the needle, and the needle is subsequently removed. Dilation of the trachea is carried out using the guide wire and the appropriate dilator [14]. The tracheostomy tube is inserted and the guide wire removed.

Simultaneous bronchoscopy may be used to identify the optimal site for needle perforation (using the bronchoscope's light as a guide) and to assure correct placement of the tracheostomy tube as described by Marelli et al. [15]

**Complications** related to tracheostomy:

- Bleeding
- Tracheal damage or scaring
- Aspiration
- Infection or pneumonia
- Accidental removal of the tracheostomy tube
- Pneumothorax, pneumomediastinum or subcutaneous emphysema
- Esophageal damage or dysphagia
- Tracheoesophageal or tracheoarterial fistula
- Injury to the recurrent laryngeal nerve
- The tracheostomy tube can be obstructed by blood clots or excretions

## Tracheal or Laryngeal Dilation

In cases of tracheal or laryngeal stenosis, tracheal or laryngeal dilation is an effective treatment option. Under endoscopic guidance a dilation procedure can be undertaken using either a balloon catheter [16] or a series of progressively larger laryngeal dilators over the span of multiple dilation. Usually lower occurrences of stenosis are adequately treated with a balloon catheter, while upper tracheal and laryngeal stenoses are better treated with dilators.

## Vocal Cord Paralysis

Vocal fold paralysis can produce difficulty in breathing. Bilateral paralysis can be especially life-threatening as the vocal flaps may cover the entirety of the laryngeal outlet. The same effect can be observed in individuals with vocal cord fixation. To resolve this issue, a patient can undergo different procedures.

### Posterior Commissuroplasty

During this procedure the physician uses endoscopic guidance to create small incisions on the posterior aspect of both vocal cords, thus increasing airflow and improving breathing, without the need for a more severe tracheostomy, and preserving voice functionality better than a transverse cordotomy [17].

### Transverse Cordotomy

In a transverse cordotomy, after similar approach using endoscopic means [18], one of the two vocal cords is entirely dissected, to create passage and restore airway function. The incision is made anterior to the vocal process. An endoscope with 30-degree viewing capability can be used to ensure that the incision is performed at adequate length. This approach obviously hinders an individual's ability to vocalize and therefore must be weighed against voice-sparing interventions, like Commissuroplasty and tracheostomy.

### Arytenoidectomy

Arytenoidectomy may be partial or total. In the partial version of the procedure, only the most median part (2–3 mm, or more depending on the severity of the obstruction) of the arytenoid cartilage is removed. On the total version, the entirety of the cartilage is removed, following similar approach to the partial procedure. Total arytenoidectomy may also be performed in an open manner. Both arytenoidectomy and transverse cordotomy yield similar results [17].

## Foreign Body Removal

Aspiration of foreign bodies is a condition most commonly encountered in younger children, predominantly male, and constitutes a significant percentage of the cases that present to an emergency unit [19]. Foreign body aspiration can also present to the adult population, most often in the form of accidental hard food particle inhalation [20] (e.g., dry nuts or fish bones). The education of the population to the correct use of the Heimlich maneuver minimizes mortality in cases of acute airway obstruction but must be reserved in cases of partial obstruction, due to the risk of dislodging the foreign object deeper in the airways, causing complete obstruction.

### Presentation

The presence of a foreign body in the respiratory system can produce choking of the airways. The introduction of a foreign body in the components of the upper airways may present with coughing, wheezing, dyspnea that might be severe, or even loss of consciousness, as the complete blockade of the upper airway eliminates all airflow to the lungs. Objects of smaller dimensions may also be inhaled or pushed during unsuccessful retrieval attempts further down the airways, into the lower airway components causing bronchial blockage. Anatomically the right bronchus is the most likely site of such event in adults by a big margin, yet not so much in children, whose underdeveloped anatomy presents a more even spread, maintaining the right bronchus as the most common site of aspiration by a slimmer margin (<60%).

### Preoperative

The diagnosis of aspiration can present difficulty to the attending doctor since a definitive diagnosis may only be achieved through direct visualization of the object that may require the procedure of rigid bronchoscopy under total anesthesia [21]. Accurate patient anamnesis during the time of the incident, patient consciousness, the patients age, and the location of the inhaled object lead to variation of patient presentations. A patient may present with mild cough or cardiac arrest. Radiopaque bodies can be detected in the traditional chest X-ray but constitute only a minority of the offending objects aspirated. Unilateral airflow decrease auscultated by stethoscope or presented in radiographic findings along with emphysema is indicative of bronchial compromise [22, 23].

Securing adequate airway function is critical, and emergency cricothyroidotomy may need to be performed, prior to transporting the patient to the operating theater to remove the object. Otherwise tracheostomy may be required to facilitate proper anesthesia and oxygenation during the extraction of objects lodged in the larynx.

Complications of inhaled foreign bodies include chronic cough scarring of affected tissues, lung abscess, emphysema and/or edema secondary to obstruction, bronchial rupture or fistula, bronchial stricture, pneumothorax, and mediastinitis.

## Procedures

### Outpatient Office

Bodies located in the nasal cavity, the nasopharynx, and the oropharynx may be removed with the use of forceps under direct visualization, with the optional assistance of a tongue depressor, only when the patient is conscious and cooperative, to reduce the potentially catastrophic risk of pushing the object toward the hypopharynx and larynx. Before any intervention the patient should first be encouraged to cough aggressively, while assisted by percussive strokes on the back to provoke the forceful exhalation of the offending object.

### Laryngoscopy

Bodies lodged in the larynx require the patient to receive total anesthesia. Oxygenation is secured via nasally inserted insufflation catheter that doesn't travel below the hypopharynx. In cases of complete laryngeal blockage, use of a tracheostomy is critical. With a laryngoscope the larynx and the object are visualized, and the object is subsequently removed with the use of a fitting forceps. After a successful removal, careful reexamination of the larynx is undertaken, along with auxiliary rigid bronchoscopy to eliminate the possibility of secondary objects or the primary object fractured.

### Bronchoscopy

For removal of tracheobronchial objects, rigid bronchoscopy is required. In such cases the ventilation of the patient is carried out through the bronchoscope itself. Before any attempt is to be made, the patient first needs to be oxygenated with 100% $O_2$ to compensate for the decreased airflow that is to be expected during any retrieval attempt. The foreign object needs to be visualized and located. The rigid bronchoscope must be laid adjacent to the object that is to be extruded. Careful and gentle suction around the object may be required for better visualization. After the object is grasped, the rigid bronchoscope, the forceps used, and the foreign object are carefully pulled as one entity. After securing the foreign object, the rigid bronchoscope is immediately reinserted to provide oxygenation and examine the possibility of secondary foreign bodies [24].

Sharp object must have their perforating aspects rotated distally when possible to facilitate safety during extraction [25]. Exceptionally sharp objects, like safety pins, may require sheathing of their tip before extraction is attempted, least they became engaged and embedded in the mucosa. Unsuccessful attempts or the foreign object itself can cause inflammation of surrounding tissues that embeds the object into the mucosa. In such cases waiting 48–72 h for the inflammation to subside may be necessary (depending on degree of obstruction), as alternative to potential approach through thoracotomy.

## Conclusion

The function of the upper airway is crucial to the act of respiration. Therefore any reduction to the ability of this function may prove life-threatening in short amounts of time. Securing of the airway function to facilitate oxygenation is of paramount importance and a constant concern to the practicing physicians in emergency cases. The procedures of the upper airway are often performed in an emergent state, with patient oxygenation in an unsure state. Procedures that require general anesthesia may further be complicated by the presence of obstruction and the inability to intubate, in order to provide adequate ventilation. The application of these procedures by appropriately trained physicians provides high success rates and low occurrence of complications.

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