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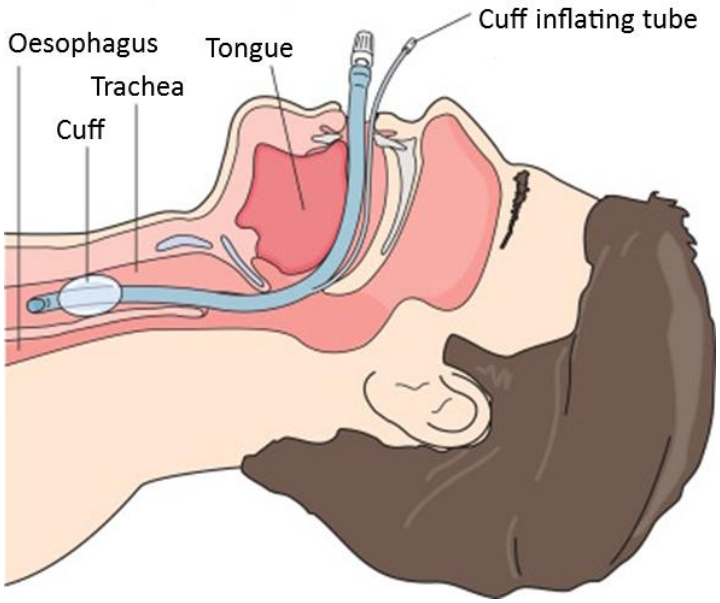
Endotracheal tubes



By the perioperativeCPD team

An endotracheal tube (ETT) is inserted into the trachea for the primary purpose of establishing and maintaining a definitive patent airway and to ensure the adequate exchange of oxygen and carbon dioxide. It is the gold standard for securing an airway, allowing positive-pressure ventilation while preventing contamination of the lungs from the contents of the pharynx and stomach.

This module covers the physical characteristics and safety features of endotracheal tubes rather than actual intubation.

History

The introduction of ether and chloroform, the first inhalational anaesthetics, in the 1840s allowed surgical procedures to become more common, longer and safer. The ether was administered by dripping it through a mask covering the patient's nose and mouth. The issue of gastric content aspiration was not generally appreciated, and postoperative pneumonia was a common problem.

An Ether mask

The first use of tracheal intubation as a dedicated airway in anaesthesia was by William Macewen (Glasgow) in 1878, on a patient with cancer of the base of the tongue. He was also the first to describe administering anaesthesia (chloroform) via an oral tracheal tube; he used a metal tube with a sponge collar placed into the pharynx to prevent aspiration.

Sir Ivan Magill then developed a rubber tracheal tube in response to the need to deliver anaesthetic gases to patients who incurred facial injuries in World War I. These first ETTs did not have cuffs; Magill used two green surgical swabs which were packed around the ETT and removed manually after extubation.

Guedel and Waters later introduced the inflatable cuff to Magill's rubber tube and are credited with starting a period of ETT design in the 1920's and 30's. Their first cuffs were made from the fingers of rubber gloves or rubber condoms. These cuffs, ranging from 3 to 4 inches long, sat half above and half below the vocal cords. Later, they designed cuffs that were shorter, and designed to sit below the vocal cords

For many years the 'classic' reusable red rubber Magill tubes were in standard use as they can be cleaned, sterilised, and reused multiple times. However, they are not transparent; they harden and become sticky with age, have poor resistance to kinking, become clogged by dried secretions more easily than plastic tubes, and do not soften appreciably at body temperature. Latex allergy was another problem.

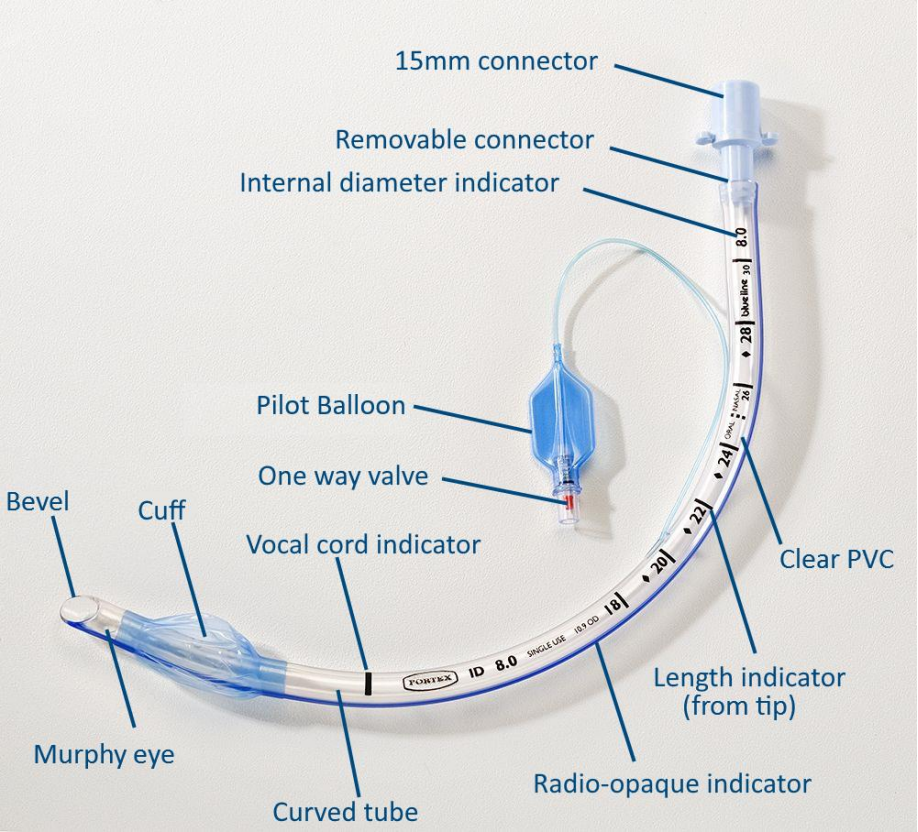
A Magill tube with integrated cuff

Design/material

ETTs today are single-use and are usually constructed from polyvinyl chloride (PVC) which is low-allergen and latex free. More expensive alternatives include polyurethane and silicone. Other characteristics of PVC include that it is transparent, nontoxic, cheap and conforms to the patient's anatomy at body temperature. It is semi-rigid material at room temperature, but becomes more pliable as it warms following placement in the trachea, which permits easy manipulation of the tube tip during intubation while reducing the risk of mucosal ischemia following placement.

The transparent plastic allows the visualisation of exhalational condensation (“breath fogging”), secretions, and other foreign materials within the tube. As the clear PVC does not show clearly on x-rays, a radio-opaque line runs the length of the tube to allow identification of the tube tip position on a chest x-ray.

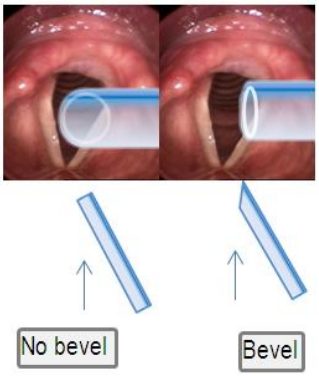
Adult ETTs have a have an inflatable cuff to seal the trachea and bronchi against air leakage and aspiration of gastric contents, blood, secretions, and other fluids. Uncuffed tubes are also available, though their use is mostly limited to paediatric patients.



ETT safety features

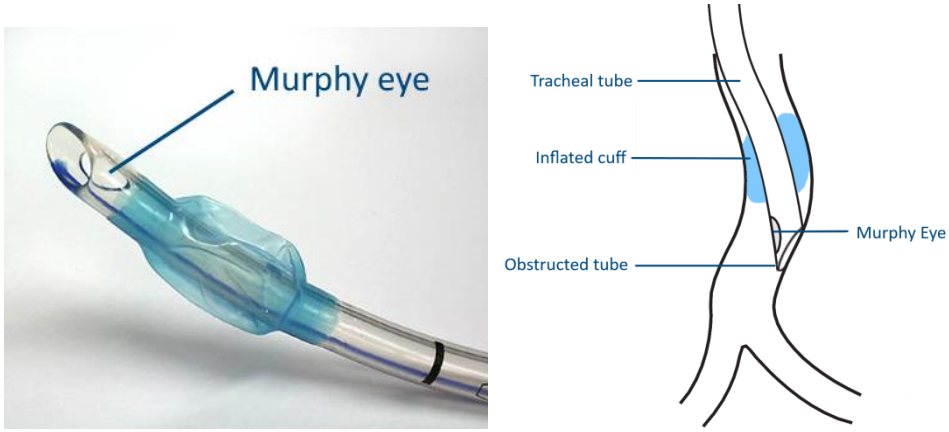
The tube has a gentle curve that approximates the curve of the oropharynx and improves manipulation during intubation. The development of this was largely by accident. The man responsible for the modern ETT was Sir Ivan Magill. He cut the first tubes used for research from a roll of rubber tubing; his tubing thus inherited the memory of the cylindrical roll in which it was stored. Magill realised that the natural curvature meant he didn’t have to use a stylet as often. To this day, the curvature of the ETT is called "the Magill Curve".

The end of the tube has a left-facing bevel to improve the view at laryngoscopy as the tube goes through the vocal cords; this is because the tube is normally inserted from the right-hand side. It also increases the area of the opening, making it less likely to be blocked by secretions.



ETT with/out bevels

Many tubes incorporate a *Murphy eye,* invented coincidently by Francis J. Murphy, a side hole at the tip which allows continued ventilation if the end abuts the tracheal wall or is blocked with mucus. In theory, it also enables Right Upper Lobe (RUL) bronchus ventilation if the ETT is inserted too far.



ETT with a murphy eye.

Size

Endotracheal tubes have an inner and an outer diameter. The 'size' of an endotracheal tube refers to its internal diameter. Therefore a size 6.0 ETT is one with an internal diameter of 6.0 mm. Adult tubes come in half sizes from 6.0mm and 10.0mm.

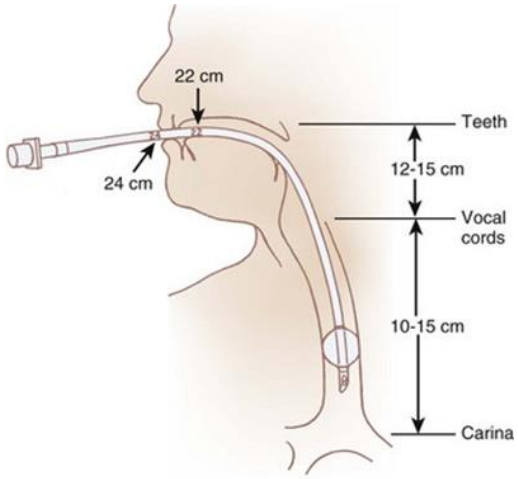
Although some anaesthetists use size 8.0 and 9.0mm ETTs (for females and males, respectively), there is good evidence that routine use of smaller tubes is less traumatic and size 7.0 and 8.0mm ETTs are becoming the norm.

Smaller ET tubes are also easier to place when laryngeal view is suboptimal, and the increased on work of breathing due to the smaller diameter has been overstated in the past. This is further helped with many modern ventilators having sophisticated pressure support modes to assist spontaneous breathing patients.

Larger tubes are less likely to become blocked by secretions and may be used where long-term ventilation is expected such as intensive care.
Note: paediatric tube sizes and lengths are discussed at the end of the module

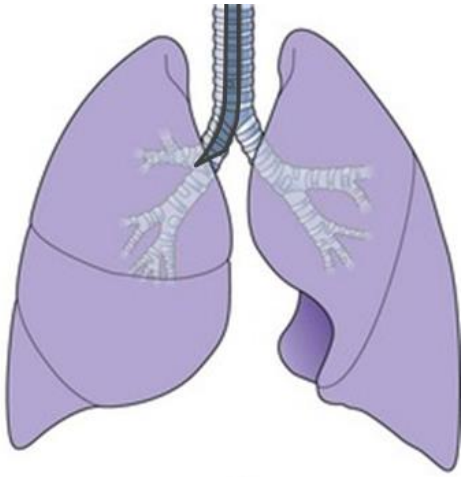
Length

The length (taken from the tip of the tube) is marked in centimetres on the outside of the tube. For adults a length of correctly positioned ETT is approximately 20-24mm at the central incisors, the lower end of the range for women, the upper end for men.



ETT typical depths

An endotracheal tube that is too long may be more prone to kinking and become obstructed. There is also more risk of bronchial intubation (usually the right bronchus due to the lefts sharper angle). A tube that is too short or not inserted far enough risks cuff herniation through the vocal cords.



ETT in the right bronchus

Tubes can be cut to a more appropriate length if necessary and whether to cut ET tubes is often decided at a local level. In certain circumstances it is unwise to cut tubes, this includes facial trauma and burns, as swelling may require the tube length to be regularly adjusted. Reinforced ET tubes and laser tubes cannot be cut.

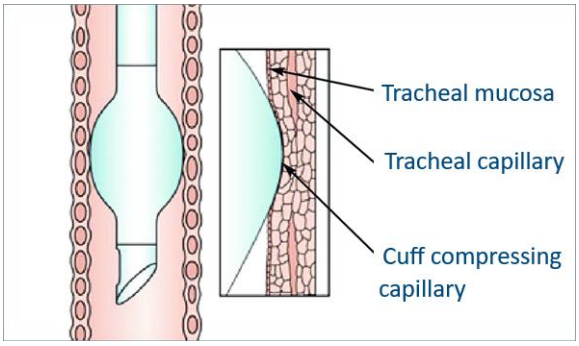
Black intubation depth markers (either single or double) located above the cuff can be seen in most designs. These assist the accurate placement of the tracheal tube through the vocal cords. These are only rough estimates based on the 'average' person and correct tracheal tube position/depth should always be confirmed by auscultation.

ET tube with double vocal cord indicators

The cuff

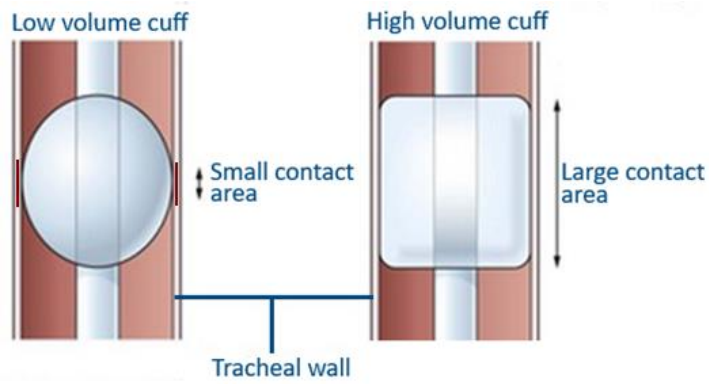
A cuff is an inflatable balloon at the end of the ETT. The cuff creates a seal in the trachea below the vocal cords to allow higher ventilation pressures and to prevent aspiration of foreign material into the lungs. It is connected to a pilot balloon which incorporates a spring loaded self-sealing valve for inflation.

Modern cuffs are usually low-pressure, high-volume designs which spread the pressure over a larger area of trachea. Older cuffs were high-pressure, low-volume and risked tracheal ischaemia and necrosis if used for long periods.



High-pressure, low-volume cuff pressure areas in trachea

The cuff should be inflated to the lowest pressure at which there is no longer an air leak, this should be below 30cm H_2O although the ideal range is 15-25cm H_2O. Above 40cm H_2O there is an increasing risk of mucosal necrosis. At 80cm H_2O mucosal necrosis can occur within 40 minutes.

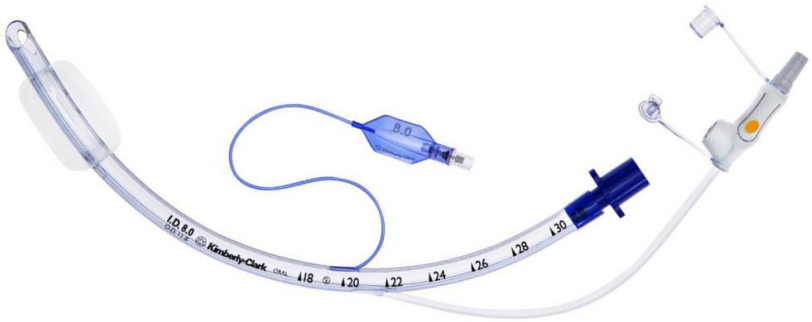


Low volume cuff vs high volume cuff

The width of the trachea in the 'normal' adult is normally less than 25mm and the cuff of a correctly sized tube should require less than 10ml of air.

Note: Nitrous oxide (N_2O) diffuses into tracheal tube cuffs filled with air and over time can increase the cuff pressure, so when using N_2O during anaesthesia cuff pressures must regularly be checked to prevent damage to the tracheal mucosa.

Some newer tube designs feature a suction lumen which ends just above the cuff to prevent pooling of secretions on the vocal cords. These are used mainly in intensive treatment units (ITUs) where patients are intubated for extended periods, with the aim of reducing ventilator acquired pneumonias for these patients.



Subglottic secretion drainage endotracheal tube

Connectors

All ET tubes connect to the anaesthetic circuit with an international standard 15mm connector. The standard sizes for anaesthetic connectors are 15mm and 22 mm (30mm for scavenging). The reason for this standard is self-evident: all airway equipment should be connectable to all other airway equipment, so that there should never be a nightmarish situation where a patient is without ventilation, while the anaesthetic assistant is scrambling desperately to find the right adaptor.

Either the breathing system or the catheter mount has a matching female 15mm connector. This two-part design permits a rapid disconnection and reconnection. Connections should be made secure with a 'push and twist' movement.

Advantages of the ETT

- The gold standard 'definitive' airway.
- Helps prevent aspiration.
- Allows some leeway in sizing of the tube due to the cuff.
- Allows higher ventilation pressures.

Disadvantages

- Requires advanced airway skills to insert when compared with supraglottic airway devices.
- Risk of pressure necrosis at the level of the cuff, if used for long periods.
- Risk of micro-aspiration through cuff wrinkles, which may lead to ventilator-associated pneumonia.
- Risk of bronchial intubation (the tube is in too far).
- Risk of cuff herniation through the vocal cords (if the tube is not in far enough).
- Risk of damage to teeth, vocal cords, trachea.

Part: Specialised endotracheal tubes

RAE tube - South facing

The south facing oral RAE tube is named after its designers (Ring, Adair and Elwyn) and is an anatomically shaped tube designed to position the tube, filter and breathing circuit out of the surgical field. It is mainly used for ENT/Max-fax surgery.

The pre-forming during manufacturing reduces the risk of kinking and obstruction which could occur if a 'standard' ET tube was bent into the same shape as a RAE tube. A black marker bar is imprinted on the tube at the point of maximum angle of the bend (see picture below) and gives a rough guide to were the tube should end. They are available cuffed or uncuffed.

South facing RAE tube

One disadvantage of the oral RAE tube is that depth of tube insertion is very much pre-determined by the tube's pre-formed shape, i.e. the bend of the RAE tube will always want to sit just at the lower lip, not allowing much flexibility as to how deeply you can place the tube into the trachea. In some patients, especially very tall or short ones, it might be difficult to achieve a good tube 'fit'.

North RAE

The north facing RAE can be used for either oral or nasal intubation, mainly during maxillofacial or dental surgery where the circuit is required to go over the head out of the surgeon's field. Bronchial intubation is more common than with standard ETTs.

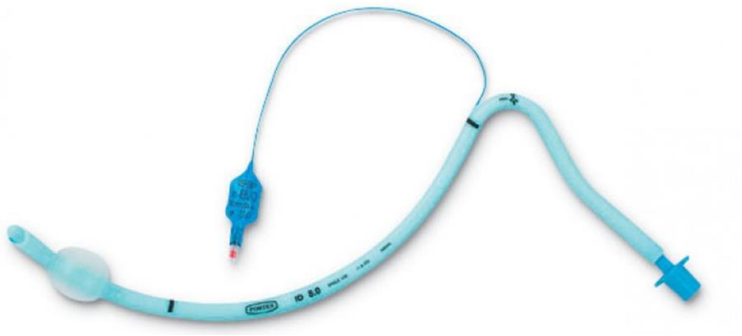
It suffers from the same issue as the south-facing RAE tube, where the tube wants to sit at the curve, no matter where the end of the tube is situated. For nasal intubation, tubes with softer materials such as the Portex Ivory are often preferred as they are more flexible and less traumatic.

North facing RAE tube

Portex Ivory tubes

Portex (Smiths Medical), have a range of nasal tubes in a softer more pliable PVC material with a similar design to the north facing RAE that takes the end of the tube along the nose and over the forehead.

The softer material of the Ivory range is relatively atraumatic in the nose, which in combination with the springiness of these tubes makes them popular for nasal intubation and especially fibreoptic nasal intubation. The ivory range is also available other tube styles.



Portex Ivory nasal tube

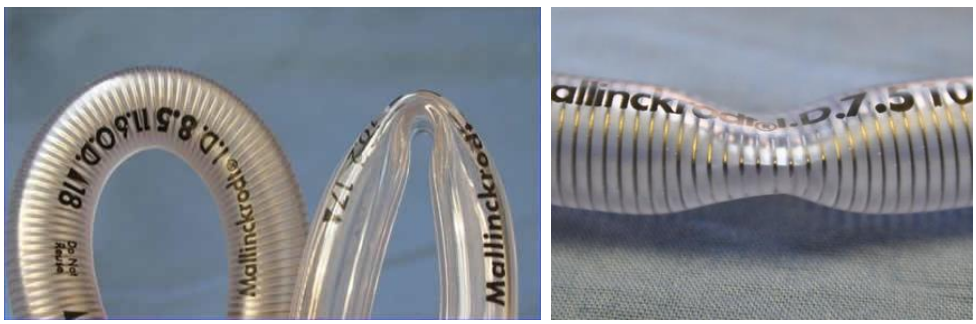
Reinforced or armoured tubes

Reinforced tubes are made of PVC, with a spiral metal reinforcement which allows the tube to bend without kinking. These are often used for prone patients, thyroid, neurosurgery and shoulder surgery.
In contrast to 'standard' ET tubes, the 15mm tube connector of armoured tubes is firmly fixed to the tube shaft and not detachable. They cannot be cut to length.

They can be used for fibreoptic intubation but the many prefer the reinforced tube provided with the fastrach LMA as it It has a removable 15mm connector and a softer tip.

A further difference is that armoured tubes are bendier and do not keep their shape as well preformed as standard tubes, because of this they are more likely to require a stylet for successful intubation.

Like reinforced supraglottic airways, the coil reinforcement may remain deformed if bitten hard by a wakening patient, therefore causing an airway obstruction and requiring immediate removal.



Reinforced tubes

Laser tubes

Laser tubes are specifically designed for laser airway surgery on the trachea and larynx. Standard PVC tubes readily ignite, particularly at high FiO_2 and in the presence of N_2O, but resist ignition when wrapped with copper or aluminium foil.

Laser tubes are designed to also disperse any laser energy that strikes the tube preventing it bouncing back onto the patient's trachea, preventing fire or tissue damage. Although it is defocused, the reflected laser beam may still cause some damage.

Most laser tubes have a double cuff which is normally filled with saline or water instead of air. The liquid in the cuff serves two functions:

1. It acts as an indicator in case the cuff bursts. Puncture of the top cuff from the laser beam causes the water to spill under the cuff pressure. If the top cuff is compromised, the lower cuff will continue to secure the airway. This is why the lower cuff is inflated first.
2. It acts as fire prevention/fire extinguisher. An air-filled cuff, hit by the laser beam, may ignite.

Some designs laser tubes have cuffs that contain a blue dye that helps indicate if there is a puncture.
Many surgeons prefer that no dye be added. Surgeons know if they perforate the proximal cuff with the laser beam because they will see the saline well up in the trachea. If the saline contains dye, the dye stains tissue, making continued surgery difficult.

A double cuff laser tube

Microlaryngeal tube (MLT®)

These are 5.0–6.0 mm ETTs with a longer length than normal for a tube of the same diameter, so that they can be used in adult ENT surgery on the trachea and larynx. The smaller diameter of these tubes allows the surgeon an easier view and access to the vocal chords and adjacent structures.

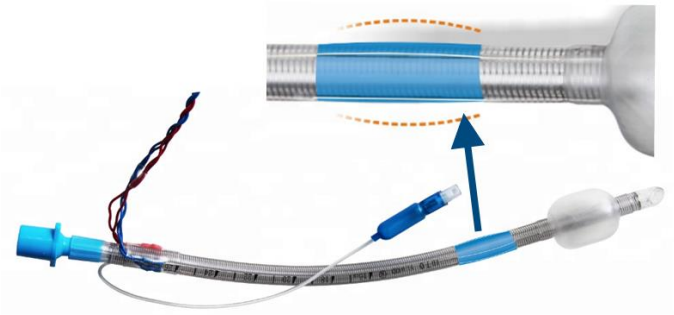
One thing to keep in mind when using ETTs of such small size in adults is the relatively high resistance to gas flow through these tubes, meaning that higher airway pressures are required to deliver the desired tidal volumes.

Nerve integrity monitoring tubes

These tubes are used in a number of surgical procedures where there is risk of damage to the recurrent laryngeal nerve, e.g. ENT & thyroid surgery. The proximity of the nerve to the vocal cords lets sensors attached above the cuff of the tube continuously monitor the nerve throughout surgery.

The electrodes are connected to a nerve stimulator and this provides visual and audible warnings if the surgeon gets too close to the nerve. If muscle relaxation is used during intubation it must be short acting as it prevents the nerve stimulator working.

The sensors are also available separately, so they can be attached to any ETT tube.



Evoked potential tracheal tube

Parker Flex-Tip® tube

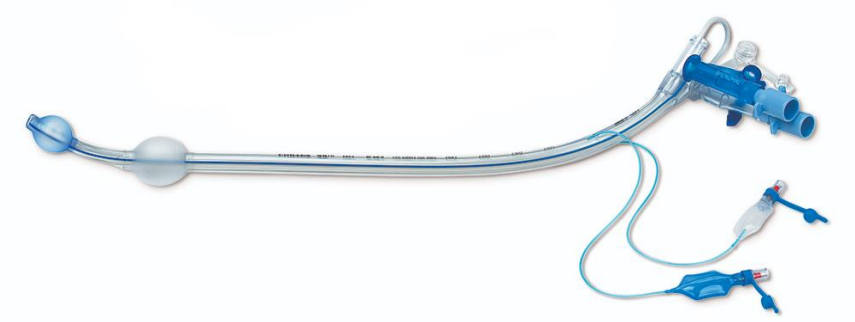
This type of endotracheal tube has a flexible, curved and tapered tip which is meant to facilitate atraumatic intubation. The tip is designed to slide past protruding features of the airway, such as the vocal cords and nasal turbinates, without getting hung up on them, causing trauma. The curved tip also helps when intubating over an introducer or a fibreoptic scope.

The device is available in a large number of variations, cuffed vs. uncuffed, oral vs. nasal preformed versions, and in a range of sizes suitable for adult and paediatric patients. A reinforced version is also offered.

Parker Flex-Tip® tube

Double lumen endobronchial tubes

Double lumen tubes (DLTs) are specialised tubes which allows the isolation of a lung and single lung ventilation. DLTs are most commonly used in thoracic surgery as it allows one lung to be collapsed for safe surgery without movement. DLTs have a tracheal lumen and a bronchial lumen, each with an inflatable cuff. They also have two cuffs and 2 exit portals and they come with a connector to join the two exit portals into one and to enable connection to a circuit. The tube has two curves, a bronchial curve at the tip and an oropharyngeal curve more proximally.

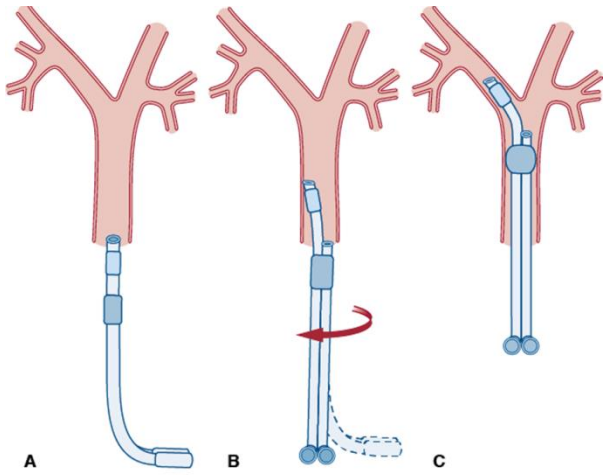


Double lumen endobronchial tube

Left and right-sided tubes are available, but left-sided tubes are often preferred even for right-side surgery because the right main bronchus is shorter (2.5 cm) than the left which makes right-sided tubes more difficult to position. They are sized differently from standard tubes, using the French gauge. Available in 26, 28, 32, 35, 37, 39 and 41 Fr sizes.

Insertion of endobronchial tubes

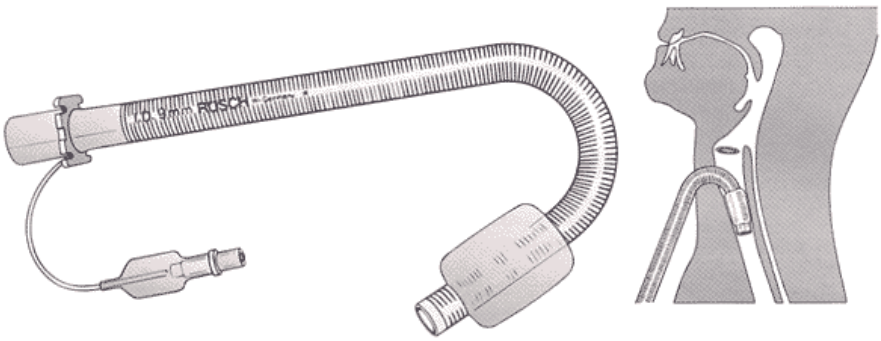
Insertion of these tubes is an advanced skill. The tube is held with the bronchial curve to the front (as with normal endotracheal tubes). As the tip is passed through the larynx, the tube is rotated 90 degrees to direct the endobronchial part to the intended side. Fibreoptic guidance and confirmation of the position is recommended. The tube is then connected to the breathing circuit via a double catheter mount.



Insertion of endobronchial tubes

Laryngectomy Tube

Laryngectomy tubes are short anatomically shaped (j shape) reinforced tube designed to be inserted into a formed tracheotomy. It allows the tube to be directed away from the surgical field.

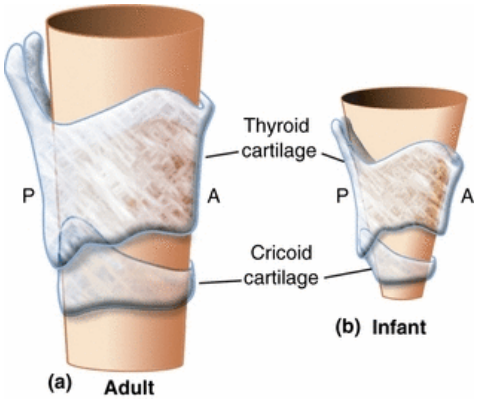


Laryngectomy tube

Paediatric tubes - Uncuffed

Before the introduction of microcuff tubes, uncuffed tubes were used in paediatrics because of concerns of necrosis caused by cuff pressure at the level of the cricoid cartilage, the narrowest point of the paediatric airway.

Another issue with uncuffed ETTs was if the tube selected was too small there would be a considerable leak and ventilation pressures could not be achievable due to the leak. There were two solutions to this, exchange for a larger tube or pack around the tube with a throat pack.



Adult trachea(a) vs paediatric trachea(b)

Since the introduction of microcuff ETTs there has been a reduction in the use of uncuffed ETTs but some anaesthetists still prefer them. Recent Cochrane review showed two trials comparing cuffed versus uncuffed ETTs, which found no difference between the groups for post-extubation stridor. However, trials demonstrated a lower rate of ETT exchange in the cuffed group.

Uncuffed paediatric tube

Paediatric tubes - Microcuff

Since 2004 microcuff tubes with an anatomically designed high volume–low pressure cuffs are increasing being used for paediatric anaesthesia, although there is still debate to whether these also cause damage to the still developing paediatric airway.

The cuff is made of thinner (10 µm) material compared to standard 70 µm ETT cuff and therefore inflates and seals at lower pressures (average 11 cmH_2O), reducing the risk of mucosal ischaemia.

Microcuff tube

The microcuff ETT also has no Murphy eye and a modified short tip. The elimination of the Murphy eye allowed the position of the balloon to be moved down the endotracheal tube shaft which reduces the risk of endobronchial intubation.

Paediatric microcuff ETTs should not have the cuff inflated over 20 cmH_2O.

Kimberly-Clark microcuff tube showing sizing guide

Paediatric tube sizes & lengths

Note: There are various methods or formulae used to determine the size and length of paediatric tracheal tubes. Paediatric micro-cuffed tubes are generally sized a half size smaller and many have the size printed on the packaging (see above)

Formula:

Uncuffed ET tube size: **Child 1 -12 years** **Age/4 + 4**

Depth of ETT insertion oral: **Age/2+ 12**

Age	Typical Weight	(Inner) diameter (mm)	Length oral (cm)
Prem	2 kg	2.5	8
Newborn	3 kg	3.0	9
2 months	4.5 kg	3.5	10
6 months	7 kg	3.5	11
1 year	10 kg	4.0	12
2 years	13 kg	4.5-5.0	14
4 years	17 kg	5.0-5.5	15
6 years	21 kg	5.5-6.0	16
8 years	25 kg	6.0-6.5	17
10 years	31 kg	6.5-7.0	18
12 years	40kg	7.0-7.5	20
All figures from RHSC, Edinburgh Guide to Paediatric Sizes...			

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