ENDOTRACHEAL TUBES CUFFS

M ABDALLAH

Moderator: J Reddy
Commentator: C Rajah

Department of Anaesthetics
INTRODUCTION

Endotracheal tubes have advanced modestly in design since they were first introduced in the mid-20th century. Until that time, ETT's were packed on one side of the sub glottis by anaesthetic swabs to prevent gas leakage and Ribbon gauze was sewn by hand to aid extraction at extubation.

HISTORY

In 1871, Friedrich Trendelendurg described a tube which was inserted into the trachea through a tracheostomy tube. The tube had a small, thick-walled, low-volume inflatable rubber cuff.

In 1880, William McEwen, a Glasgow surgeon, described the use of ETT passed blindly into the trachea through the mouth to relieve airway obstruction and for anaesthesia as well.

In 1893, Eisenmenger in Vienna described the first tracheal tube with an inflatable high volume cuff. The intra-cuff pressure could be estimated by palpation of a large pilot tube.

In 1910, Dorrance described a tube with an inflatable cuff similar to those in use today.

Guedel and Waters, in 1928, described a cuffed tracheal tube designed for closed circuit intra-tracheal administration of anaesthesia using a carbon dioxide absorption technique. This tube was similar to the Dorrance tube. It had a thin rubber cuff cemented to the tube. When deflated the rubber cuff lay in folds close to the catheter wall. These tubes showed effectiveness in preventing aspiration and sealing the trachea.

In 1943, Macintosh described a tube with a self-inflating cuff designed by Mushin. This cuff facilitated controlled ventilation for thoracic anaesthesia. Holes were cut in the tube underneath the cuff, the cuff thus inflated only in inspiration. However, the holes sometimes became blocked by plugs of mucus.
Although, the first cuffed tracheal tube had been described in 1893, non-cuffed tubes were more commonly used until the 1950’s. In 1952 during the polio epidemic, cuffed tubes were used. After that experience, it became standard clinical practice to use cuffed tubes during anaesthesia. The use of non-cuffed tubes is now more common practice in paediatric anaesthesia.

Early tubes were made of red rubber with rigid thick-walled cuffs. High cuff and tracheal wall pressures were required to have an effective tracheal seal. These tubes were associated with major complications resulting from the high pressure exerted on the tracheal wall. Such complications include distal tracheal erosions. Increased understanding of the cuff related pathology has led to improved design of cuffs and techniques for limiting intra-cuff pressure. The introduction of disposable plastic tubes was an important development, which largely displaced rubber tubes.

The risk of cross infection and toxins that are released by the red rubber tube, supported the trend to use of the plastic tubes. Furthermore, the rubber tubes deteriorated on repeated autoclaving and were more liable to herniate, pushing the tube against the tracheal wall.

CUFF SYSTEM, DESIGN AND MATERIALS

The American society for Testing and materials (ASTM) specifies requirements for the proper design of both ETT’s and cuffs. The ASTM specifies a maximum distance from the tip of the tube to the end of the cuff, which varies with the tube size. The end of the cuff must not impinge on the opening of Murphy eye; it must not herniate over the tube tip under normal conditions; and the cuff must inflate symmetrically around the ETT.

All the cuffs are part of a cuff system consisting of the cuff itself plus a means of inflation, which typically includes a lumen in the wall of the tube, an external tube (portion that is visible outside the patient), a pilot balloon, and a valve.

The principle function of the ETT cuff is to prevent leakage around the trachea during ventilation by ensuring proper sealing between the ETT cuff and the patient’s trachea. The endotracheal cuff also centers the ETT in the trachea. This less obvious function makes the tip of the tube less likely to traumatize the
mucosal lining. The cuff pressure must be high enough to seal the trachea preventing any kind of aspiration and avoid leak of gases to the atmosphere. It must also be low enough that it allows perfusion of the tracheal mucusa.\textsuperscript{2} Insufficient sealing can result in micro or frank aspiration and resultant pulmonary infection.

Complications of an over excessive cuff pressure (>40cmH2O) include post-extubation pain, necrosis, bleeding, tracheal rupture and tracheoesophageal fistulæ.\textsuperscript{3-7} Lubrication of endotracheal tube cuff with Chamomile extract spray before intubation cannot prevent post-operative sore throat and hoarseness.\textsuperscript{34}

**Low-and high pressure cuffs**

During the 1960s, red rubber tubes were commonly used and classified as high-pressure low-volume (HPLV). Today, non-disposable silicone is used to make HPLV cuffs. High-volume low-pressure cuffs are made of tissue compatible polyvinyl chloride (PVC) or polyurethane.

**The difference between LVHP and HVLP ETT cuffs**

- **LVHP cuffs**

The cuff has a small diameter at rest and a low residual volume, which is the amount of air that remains in the cuff after it has been allowed to equilibrate with atmospheric pressure. The HPLV cuffs require a high pressure to overcome the low compliance of the cuff itself. The trachea deforms to a circular shape when the cuff is inflated and makes a small area of contact with the trachea.
When a high-pressure cuff contacts the tracheal wall, intra-cuff pressure does not change and the measurements of pressure inside the cuff and of the tracheal mucosa will not be consistent.

The possibility of ischaemic damage to the tracheal mucosa associated with the HPLV tube use is a concern, especially with the prolonged intubation. Another potential risk is that the cuff may inflate in a non-circular fashion and cause the ETT to injure the trachea, or cause the tube bevel to be blocked by the tracheal wall contrary to low-pressure cuffs, high pressure cuffs have an advantage of reusability and lower overall cost, and a lower incidence of sore throat. They also may provide better protection against aspiration. Furthermore, the cuff deflates very close to the ETT, making the tube and the cuff more easily visible during intubation.

When using a non-disposable HPLV ETT with a silicon cuff, such as that within the LMA Fastrach, it is prudent to pay careful attention to the intra-cuff pressure measurement. However, the lack of routine manometer use makes this difficult. Knowlson and Bassett demonstrated that proper inflation of the cuff can be achieved by inflating the cuff to the minimal volume that seals the trachea - minimal occlusion volume (MOV). MOV can be achieved by listening for a leak following intubation at peak inspiratory pressure (PIP) during PPV.
• HVLP cuffs

HVLP cuffs are made of a thin compliant wall that, when inflated, adapts and conforms easily to the irregularity of the tracheal wall. A significant advantage of HVLP cuffs over low-volume cuffs is that, provided the wall of the cuff is not stretched, the intra-cuff pressure will correlate closely with tracheal mucosal pressure (wilders 1996). Although HVLP cuffs are associated with fewer complications than HPLV cuffs, these devices may cause serious tracheal injury if the optimal intra-cuff pressure is exceeded (the ideal range is 20-30 cmH₂O).

**Volume, pressure and sealing characteristics**

The ETT cuff is aimed to provide a seal at a pressure enough to prevent aspiration but not to impede blood flow in the trachea. Seegobin and Van Hasselt has conducted an interesting study where various large volume cuffed endotracheal tubes were observed, including Portex Profile, Searle Sensiv, Mallinkrodt Hi-Lo, and Lanz. Tracheal mucosal blood flow in 40 patients undergoing surgery was assessed using an endoscopic photographic technique while varying the cuff inflation pressure. It was found that these cuffs when over pressurised impaired mucosal blood flow. It was also found that conventional HVLP cuffs require about 20 cmH₂O to seal the trachea. Microaspiration still occurred at pressures of up to 60 cmH₂O, so guidelines depend on clinical requirements. Pressure limits for routine cuff inflation are determined in part by the blood pressure of the capillaries supplying the trachea, which is approximately 48 cmH₂O. An intra-cuff pressure greater than 34 cmH₂O results in decreased perfusion to the trachea, whereas total obstruction of blood flow to the tracheal mucosa occurs at about 50 cmH₂O.

*Figure 2: Endoscopic photographic technique*
Figure 3: Effect of cuff pressure on arterioles in the posterior tracheal submucosa. 

(a) = 30 cmH$_2$O  (b) = 40 cmH$_2$O  (c) = 80 cmH$_2$O  (d) = 100 cmH$_2$O

A review of the literature suggests 20 cmH$_2$O to be a reasonable lower limit of cuff pressure in adults when using HVLP PVC cuffs. The consensus regarding acceptable maximum cuff pressure ranges from 25 to 40 cmH$_2$O in adults.
THE RELATIONSHIP BETWEEN VOLUME AND PRESSURE

The relationship between the volume and pressure is not understood adequately by many clinicians.\textsuperscript{11-13} An exponential increase in pressure with rising volume is expected with high pressure ETT at lower volume of air but this can occur in HVLP cuffs if high volume of air is used. For HVLP cuffs, the relationship between volume and pressure is linear within the cuff over a range of sealing pressures. This phenomenon has been demonstrated by Hoffman et al in 2009.\textsuperscript{14} They calculated the correlation of volume and pressure of 0.97 or 97%, showing nearly perfect relationship.

However, the volume necessary to achieve a cuff pressure of 20 to 30 cmH2O varies considerably between patients, regardless of tube size and patient morphometric characteristics. Measuring cuff pressures therefore is still necessary. A persistent increase in the intra-cuff pressure can be a sign of a tracheomalacia.\textsuperscript{35}

CLINICAL PRACTICE

In the United Kingdom (and in South Africa), cuff pressures of ETT's are measured routinely in the intensive care unit but not in the operating room. Roman Cregg et al, assessed end-expiratory cuff pressures in 119 surgery patients at three London-area hospitals to validate the values variation from institution to institution.\textsuperscript{28} The researchers also looked at whether cuff pressures depended on other factors, such as the size and placement of the cuffs, how patients were positioned, the use of nitrous oxide and whether the procedure was
laparoscopic. Median pressures during surgery were higher than recommended at all three hospitals—ranging from 31 to 53 cm. The researchers reported that no other variables were associated with increased cuff pressures.

Many clinicians consider the most severe, and quite rare, complications of overinflated cuffs: tracheal rupture, stenosis and necrosis. The new findings suggest that much of what has been thought to be minor trauma caused by direct manipulation of the airway during intubation (the sore throats and dysphagia) may result from overinflation attributable to hyperinflated cuffs.

Andrade (2005) analyzed two groups. The first group was monitored three times a day, and the pressure was maintained at 20 mmHg. The second group was not monitored. Twenty four hours after extubation 30% of patients of the first group had moderate pain and 70% no pain at all, compared with 80% of moderate pain and 20% with no pain at all in the second group.36

Shai Efrati et al found that, in 72% of patients, primary ETT cuff pressures were significantly higher than the optimal cuff pressure determined by PCO₂ readings, with a mean change of 10.2 mmHg.30 Also there has been no difference in the ability of expert and non expert anesthesia provider to predict the ETT cuff pressure, using the palpation of the ETT pilot cuff.

![Figure 4: ETT cuff pressures relative to optimal as determined by PCO₂ leak monitoring](image)
ETT cuff pressure estimated by palpation with personal experience is often much higher than measured or what may be optimal. Proper control of ETT cuff pressure by a manometer helped reduce ETT-related postprocedural respiratory complications such as cough, sore throat, hoarseness, and blood-streaked expectoration even in procedures of short duration (1–3 hours).³³

Although intubation and cuff inflation were done by experienced anesthesiologists, they were unable to identify optimum intra-cuff pressure in 40% cases by their clinical judgment. It is supported by previous studies that this skill is not acquired over time with increased training or experience, justifying objective monitoring of intra-cuff pressure in routine practice.²⁹

**EFFECT OF N₂O**

When using nitrous oxide (N₂O) during general anesthesia, particular attention should be paid to changes in cuff pressures.² The increase in cuff pressure varies directly with the partial pressure of N₂O and time, and inversely with cuff thickness. The gas will expand the resting inflated cuff over time during the administration of general anesthesia, with the greatest change occurring after the first hour of anesthesia. Using a mixture of 50% O₂ and N₂O to inflate the ETT cuff, creates less increase in the intracuff pressure after one hour of delivering anaesthesia in comparison with using only air.²⁵ However, the perceived benefit of adding N₂O to the cuff when first delivering anesthesia is questionable because the gas will
diffuse out of the cuff as easily as into it when the concentration of inspired N₂O is decreased, resulting in unwanted loss of cuff pressure and sealing.

Newer cuff designs claim to allow less N₂O to diffuse into them over time by virtue of their design and/or material. The Profile Soft-Seal (Smiths Medical) is theoretically impervious to diffusion of N₂O because it contains a plasticizer with a high gas barrier and high compliance. One study comparing this cuff with traditional PVC devices revealed that although the design clearly inhibits an increase in cuff pressure when N₂O is used, the underlying mechanism is not from the reduction of diffusibility into the cuff but rather the higher compliance of the thinner cuff of the Profile Soft Seal.¹⁸

**INTRA-CUFF PRESSURE DURING CARDIOPULMONARY BYPASS (CPB)**

Indada et al, studied the effect of CPB on the intra-cuff pressure, where, intra-cuff pressure changed significantly during CPB, decreasing to 8.0 (1.0) mmHg before rewarming (P < 0.01 vs immediately before CPB) and increasing to 17.0 (0.6) mmHg after the start of rewarming (P < 0.01 vs before rewarming).³¹ After CPB, intra-cuff pressure did not differ significantly from that immediately before CPB (20mmHg). It has been concluded that the decrease in intra-cuff pressure during the hypothermic phase of CPB, may protect the tracheal mucosa against hypotensive, ischaemic injury.

**INTRA-CUFF PRESSURE AT HIGH ALTITUDE**

A linear expansion in cuff dimensions as a function of altitude increase was identified in an unpressurized cabin. For ETT's, a formula for removal of air from the cuff with increasing altitude was calculated and is recommended for use in aeromedical transfers.³²

\[
\frac{1}{17} \times 1.1 = 0.06 \text{ ml/1000 foot ascent/ml initial cuff inflation}
\]
DYNAMIC CUFF PRESSURE CHANGES

The effect of ventilation on low and high pressure cuffs has been investigated both in *vitro* and in *vivo*. The effect of ventilation on cuff pressure is less important in high than low pressure cuffs. Small changes in pressure seen in a high volume may be due to cardiac displacement; the intra-tracheal inflation pressure is transmitted to the cuff during inspiration.

These dynamic changes show that it is not necessary for the cuff pressure to be above the inflation pressure to maintain a seal. In a spontaneously breathing patient, the cuff pressure changed in a negative direction on inspiration and in a positive direction on expiration. Transient large increases in cuff pressure were measured during coughing. The open tube prevents a large increase in intrathoracic pressure, thus precluding this as the causative mechanism.

It was suggested that during a cough, the trachea changes in shape and constricts the cuff of the tube. Cuff pressure with low pressure cuffs increased from 24 to 110 mmHg during coughing, with high pressure cuffs from 61 to 129 mmHg. There was no relationship between the cough force and peak cuff pressure. Such high pressures could theoretically, at least, cause collapse of the tube or cuff herniation. The pressure on the tracheal wall exerted by the cuff has also been shown to rise temporarily during vibration and 'bagging' physiotherapy.

It also rises when a patient 'fights' the ventilator. Therefore, if this is prolonged, potential damage to the mucosa could result.

UNIQUE CUFFS

**Foam Cuff Tubes**
A foam-filled cuff (Bionva Adult Fome-Cuf, Smiths Medical) is an HVLP device that expands following intubation, becoming completely devoid of air. Once expanded, it passively conforms to the contour of the trachea. Although the cuff will not cause tracheal injury, the risk for aspiration with these tubes is a concern.

**Laser-Flex Tracheal Tube Cuff**
These tubes and cuffs are designed for use with carbon dioxide and potassium-titanyl-phosphate lasers. Two PVC cuffs at the distal end are inflated using
separate tubes. The distal cuff can be inflated if the proximal one is damaged. These cuffs are designed to be filled with saline.

(a) ![Laser-Flex tracheal tube with double cuff](imagea.png)  
(b) ![Foam Cuff Tubes](imageb.png)

**Figure 6:** (a) Laser-Flex tracheal tube with double cuff (Covidien)  
(b) Foam Cuff Tubes

### CHANGES IN CUFF DESIGN TO IMPROVE TRACHEAL SEALING

**Contour**

Newer cuff designs may improve tracheal sealing to reduce micro-aspiration and possibly ventilator-associated pneumonia (VAP). During positive pressure ventilation, ETT cuffs tend to auto seal, some better than others. Increased pressure in the trachea produces retrograde compression in the distal part of the cuff and moves air within the cuff toward the upper end of the device, creating a seal. The result is fewer subglottic secretions leaking past the cuff. Some cuff designs seal the trachea better than others, and there is some suggestion that changes to the contour of the cuff itself leads to better self-sealing during positive pressure ventilation.

The Taper-Guard ETT (Covidien) features a specially contoured PVC cuff that adheres better to the trachea during positive pressure ventilation and reduces subglottic secretions escaping past the cuff. One study found a 90% reduction in micro-aspiration with the Taper-Guard as compared with the Hi-Lo cuffed tube.19-20
The mechanism of improved sealing of the Taper-Guard tube cuff is presumably because it is taper-shaped. This allows the cuff diameter to match the diameter of the trachea at some point along the cuff and thus markedly reduces the micro-channels at the sealing zone. In another improvement, the Taper-Guard Evac ETT consists of the tapered cuff design and allows for the drainage of secretions through an integrated suction lumen. The Taper-Guard Evac ETT is associated with a significant reduction in the risk for VAP compared with non-subglottic suctioning tubes.¹⁹

Figure 7: Taper-Guard (Covidien)

Polyurethane

The architecture of the trachea is non-uniform, non-cylindrical, irregular, and D-shaped. When a cuff with redundant PVC material is inflated, tiny channels are created that encourage pooling or collection of secretions within the folds (The HVLP cuff is 1.5-2 times the diameter of the trachea when fully inflated). VAP can occur as a result of these secretions. In order to prevent micro-aspiration and VAP, intra-cuff pressures as high as 50 cmH₂O have been used to seal PVC cuffs. Cuff material made of ultrathin (10 micron) polyurethane, instead of the traditional polyvinylchloride (50-80 micron) allows sealing of cuff in the lumen of the trachea at pressures of 15 cmH₂O or lower.

This effect may result from the polyurethane material draping over the irregular tracheal mucosal contours, perhaps similar (Covidien) tube incorporates the same tapered cuff design as the TaperGuard but is made from polyurethane rather than PVC.
Similarly, the Micro-cuff (Kimberly-Clark) creates an effective seal at intra-cuff pressures of 15 cmH\textsubscript{2}O, and has been shown to reduce VAP by 43% when compared with traditional PVC cuffs.\textsuperscript{21} The use of polyurethane cuffs have been shown to reduce the incidence of early VAP in cardiac patients compared to use of traditional cuffs.\textsuperscript{22}

Alberto Zanella et al, have studied fluid leakage across tracheal tube cuffs, looking at the effect of different cuff materials, shape, and positive expiratory pressure (see table below). Fluid leakage was compared across a cylindrical double-layer guayule latex prototype cuff, three cylindrical PVC cuffs (Mallinckrodt Hi-Lo, Mallinckrodt High-Contour, Portex Ivory), one conical PVC cuff (Mallinckrodt Taper-Guard), and two polyurethane cuffs (Mallinckrodt Seal-Guard conical; Micro-cuff, cylindrical). Ten centimeters of dyed water was poured above the cuffs inflated (pressure 30 cmH\textsubscript{2}O) in a vertical cylinder (diameter 20 mm).

A respiratory circuit connected the bottom of the cylinder to a breathing bag inflated at four pressures (PEEP = 0, 5, 10, 15 cmH\textsubscript{2}O). Pictures were taken every 60 seconds for 24 hours to measure leakage as a reduction in the water column above the cuff. Five new ETT’s of each type were tested. The guayule latex cuffs showed no leakage at all the PEEP levels. Both the cylindrical and conical polyurethane cuffs showed limited leakage (2.1 ± 1.8 cm of water) only for PEEP zero. The PVC cuffs showed reduced leakage with increasing PEEP: 8.4 ± 1.5, 7.8 ± 2.2, 2.2 ± 1.0, and 0 cm of water at 0, 5, 10, and 15 cmH\textsubscript{2}O respectively. Among all the PVC cuffs, the conical shape ensured higher sealing properties.

Conclusions: The guayule latex cuffs always prevented fluid leakage; the polyurethane and PVC cuffs required incremental levels of PEEP to prevent fluid leakage ever-present at zero PEEP.

<table>
<thead>
<tr>
<th>Endotracheal tube</th>
<th>Material</th>
<th>Shape</th>
<th>Length (cm)</th>
<th>Diameter (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double-layer prototype</td>
<td>Guayule latex</td>
<td>Cylindrical</td>
<td>3.6</td>
<td>3.4</td>
</tr>
<tr>
<td>Micro-cuff</td>
<td>Polyurethane</td>
<td>Cylindrical</td>
<td>4.7</td>
<td>2.3</td>
</tr>
<tr>
<td>Mallinckrodt Seal-Guard</td>
<td>Polyurethane</td>
<td>Conical</td>
<td>4.7</td>
<td>1.6-2.4</td>
</tr>
<tr>
<td>Mallinckrodt Taper-Guard</td>
<td>Polyvinyl chloride</td>
<td>Conical</td>
<td>3.8</td>
<td>1.4-2.5</td>
</tr>
<tr>
<td>Mallinckrodt Hi-Lo</td>
<td>Polyvinyl chloride</td>
<td>Cylindrical</td>
<td>3.6</td>
<td>3.4</td>
</tr>
<tr>
<td>Mallinckrodt High-Contour</td>
<td>Polyvinyl chloride</td>
<td>Cylindrical</td>
<td>3.2</td>
<td>3.2</td>
</tr>
</tbody>
</table>

*Table 2: Major characteristics of tested cuffs (bench-top study by Alberto Zanella et al)*
MONITORING CUFF PRESSURE

The aneroid manometer is the most commonly used device for monitoring cuff pressures. Manometers are precise and accurate but troublesome to use, expensive, require calibration, and carry an infection risk to patients if not properly cleaned. Pressure-limiting valves are attached to the proximal end of the inflation tube, where they act as a reservoir for excess pressure within the cuff and keep intra-cuff pressures within a preset range, usually around 25 cmH₂O.

The drawback of these valves is their inability to change pressure limitations, a problem when higher sealing pressures are needed. The latest technologies for controlling pressure include electronic regulators designed specifically for ETT’s. These devices seem to solve the problem of cuff management, but they have some drawbacks. One in vitro study, for example, found that the regulators may interfere with the self-sealing mechanism of HVLP cuffs when set pressures are lower than peak inspiratory pressures. In addition, if the distal end of the tubing, which has a standard lower connection, is connected inadvertently to a blood line, a fatal air embolus could be delivered.

Figure 8: Schematic representation of study settings
<table>
<thead>
<tr>
<th>Device Description</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aneroid manometer</td>
<td>- Precise and accurate;</td>
</tr>
<tr>
<td></td>
<td>- Must be calibrated;</td>
</tr>
<tr>
<td></td>
<td>- May transfer infectious agents unless cleaned;</td>
</tr>
<tr>
<td></td>
<td>- Some need complex set up using tubing and stopcocks.</td>
</tr>
<tr>
<td></td>
<td>- Intra-cuff pressures can be lost during set up if not careful.</td>
</tr>
<tr>
<td>Lanz pressure-regulating valve</td>
<td>- Limits intra-cuff pressure to approximately 30 cm H₂O.</td>
</tr>
<tr>
<td></td>
<td>- May not be useful in children because cuff sealing pressures should be lower than adults.</td>
</tr>
<tr>
<td></td>
<td>- May not form a seal when high ventilatory pressures are present.</td>
</tr>
<tr>
<td>Brandt tube system</td>
<td>- Useful during long periods of anesthesia</td>
</tr>
<tr>
<td></td>
<td>- Using N₂O as intra-cuff pressure is stabilized via a large pilot cuff reservoir and an internal pressure regulating valve</td>
</tr>
<tr>
<td>Smiths Pressure Easy Cuff Controller</td>
<td>- Electronic devices that automatically keep pressure within set limit.</td>
</tr>
<tr>
<td></td>
<td>- Need to be set according to PIP.</td>
</tr>
<tr>
<td></td>
<td>- Costly.</td>
</tr>
</tbody>
</table>

**Table 3: Devices That Measure, Limit, or Control ETT Cuff Pressure**
ENDOTRACHEAL CUFF USE IN CHILDREN

Children under the age of 8 years were a demographic previously considered ineligible to receive cuffed ETT’s. The clinical consensus seems to be shifting, however. The practice of using cuffed tubes in children under age 8 now is considered safe, as long as pressure is strictly monitored.\textsuperscript{24} Advantages of cuffed tubes in children are similar to those of adults: improved monitoring of end-tidal gas, reduced risk for aspiration, ability to use high inflation pressures and low fresh gas flows, decreased pollution in the operating room, and avoidance of repeat laryngoscopy. However, placing cuffed tubes in children also requires the use of an ETT with a small internal diameter, which limits suctioning capability. Wheeler et al provide a set of recommendations for proper use of cuffed ETT’s in children.\textsuperscript{24} The recently introduced Micro-cuff ETT for children has a short, ultra-thin polyurethane cuff located away from the subglottic region, a cuff-free subglottic zone.

This is an important feature for children because it is the narrowest portion of the glottis and thus vulnerable to cuff-induced damage. The cuff also effectively seals the tracheal wall at pressures as low as 10 cmH\textsubscript{2}O by virtue of the thin polyurethane, in both children and adults. Some major recent improvements in ETT cuff design have offered clinicians real choice between these devices depending on the clinical setting. A recent trend among ETT makers is to pay particular attention to cuff contour, material, and the prevention of cuff-related injury, micro-aspiration, and VAP. With the increasing use of cuffs in children under age 8, newer cuff design has played an important role in assuring safety and reducing the number of re-intubations associated with uncuffed tubes.

\textbf{Figure 9: Micro-cuff (Kimberly-Clark)}
Weiss et al compared cuffed and uncuffed ETTs in small children.\textsuperscript{26} One outcome of interest was the number of ETT exchanges needed to find an appropriate sized tube. The exchange rate was 2.1% in the cuffed group and 30.8% in the uncuffed group, and the cuffed ETTs did not increase the risk for post-extubation stridor compared with uncuffed ETTs. The authors concluded that cuffed ETT’s were reliable for small children and reduced the need for tube exchanges. Parravicini et al performed a pilot study comparing ultrathin-walled two-stage twin endotracheal tubes with conventional endotracheal tubes in very premature infants.\textsuperscript{3} No significant differences were found for insertion complications, traumatic injury of the upper airway, accidental extubations, number of reintubations after attempted extubation, or prevalence of air-leak syndrome.

CONCLUSION

The improvement of the knowledge of the endotracheal tubes cuffs related pathology has led to improvement in the design, material and function of the ETT cuff. There has been a shift from red rubber tubes with major disadvantages to tissue compatible disposable plastic tubes such as PVC and polyurethane tubes. This has resulted in the reduction of serious complications of intubation, especially prolonged intubation in ICU. However, the literature reveals that clinicians are unable to identify optimum intra-cuff pressures in >40% of cases by their clinical judgment. This skill is not acquired over time with increased training or experience, justifying objective monitoring of ICP in routine practice.\textsuperscript{29}
REFERENCES


21. Data on file. Roswell, GA, KCCW. (Study performed at the University of Michigan, Ann Arbor, MI)


25. Dr. Jesni Joseph Manissery1 Dr. Vijaya Shenoy2 Dr. Ambareesha M: Endotracheal Tube Cuff Pressures During General Anaesthesia While Using Air Versus a 50% Mixture Of Nitrous Oxide And Oxygen As Inflating Agents; Indian J. Anaesth. 2007; 51(1): 24- 27


33. Jianhui Liu, MD, Xiaoqing Zhang, MD, Wei Gong, MD, Shitong Li, PhD, Fen Wang, MD, Shukun Fu, MD, Mazhong Zhang, PhD and Yannan Hang, MD: Correlations Between Controlled Endotracheal Tube Cuff Pressure and Postprocedural Complications: A Multicenter Study: A & A November 2010 vol. 111 no. 5 1133-1137

