Endotracheal tubes in paediatric anaesthesia: the cuffed versus uncuffed debate

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Introduction

The paediatric airway demands respect, and appropriate and safe management of this delicate structure is of utmost importance.

With development of polyvinyl chloride (PVC) in the 1960s, uncuffed endotracheal tubes (ETTs) replaced tracheostomies for long-term intubation and ventilation in the intensive care unit (ICU). Since then, uncuffed ETTs have traditionally been used in infants and children under the age of eight (or even ten) years for both short- and long-term intubation in theatre and ICU. Cuffed ETTs were not considered appropriate in this age group, and until fairly recently many manufacturers of ETTs did not produce cuffed sizes smaller than a 5 mm internal diameter (ID). However, debate in the literature over the last decade questions this teaching, some saying that the routine use of uncuffed ETTs in infants and children is not based on scientific evidence.1,2 It is clear that the strongly emerging role of cuffed ETTs in the paediatric population has come to the fore.

The paediatric airway and endotracheal tubes

Ideally, an ETT should provide a leak proof connection between patient and ventilatory device. This allows for constant minute ventilation, respiratory monitoring and capnography, as well as the use of low fresh gas flows with minimal environmental pollution. An adequate seal should also minimise the risk of pulmonary aspiration without exerting undue pressure on laryngeal and tracheal structures.1,2

Apart from other important differences between adult and paediatric airways, the cricoid ring is functionally the narrowest part of the paediatric airway up to eight years of age.3 The cricoid has long been considered a circular structure. Evidence to the contrary reveals the cricoid to be ellipsoid in shape (transverse dimensions are narrower than anteroposterior dimensions) which has some important clinical implications.2,3 Thinking that the cricoid is circular in shape was, in part, what promoted the use of uncuffed ETTs in infants and children, the rationale being that a round tube placed in a round orifice would provide airway sealing at the level of the cricoid.2 It is believed that an air leak around the tube at about 20–25 cmH2O ensures the fit is not too tight, with no undue pressure on the cricoid walls. However, because the paediatric cricoid dimensions are ellipsoid, a round tube tends to lodge itself posteriorly. This may result in excessive pressure being placed on the posterolateral walls of the cricoid, and the air leak may be from the anterior part of the cricoid lumen. Thus, even with an adequate leak, one may still precipitate airway damage.

With cuffed ETTs, the seal is obtained at the level of the trachea by means of an appropriately positioned high volume low pressure cuff. In contrast to the cricoid ring, the tracheal rings are incomplete and thus slightly distensible, which has obvious pressure reducing effects at the level at which the airway is sealed. To facilitate passage of the cuff through the larynx, cuffed ETTs are selected a half to full size smaller for age compared with the uncuffed tubes. This results in minimal impingement on the walls of the cricoid once the tube is in situ.

Tables I and II briefly summarise the advantages and disadvantages associated with the use of cuffed and uncuffed ETTs.

Selection of an endotracheal tube

The following points highlight some of the controversy surrounding tracheal tube choice in the paediatric population.

Airway trauma

If not used appropriately, both cuffed and uncuffed tubes may precipitate airway trauma.
tissue contracts to form glottic or subglottic stenosis. Upon healing, fibrous scar ulceration, and/or to deep ulceration into the submucosal mucous gland hyperplasia, to superficial subglottic stenosis. Airway pathology may range from an important factor influencing the development of the cricoid, oversized uncuffed ETTs are the most pressure being placed on the posterolateral walls of for long-term intubation and ventilation. Later studies incidence of subglottic stenosis was reported but, this With early use of PVC tubes in the 1960s, a high rates can be extrapolated to all cuffed tubes. In 2009, Weiss et al published the largest study to date, in which more than 2,200 children from birth to 5 years were randomised to intubation with either a cuffed or uncuffed ETT. There was no significant difference in the incidence of postextubation stridor between the two groups. However, there were significantly fewer tube exchanges in the cuffed group. This is noteworthy, as the number of laryngoscopies and tube passages through the larynx are important factors influencing the likelihood of airway trauma. Of note is that only one type of cuffed ETT, the Microcuff® paediatric tracheal tube, was compared to numerous commercially available uncuffed tubes, so the results cannot be extrapolated to all cuffed tubes.

Endotracheal tube size
The fact that oversized tubes are important in precipitating airway trauma has been discussed previously in this paper. Undersized tubes are not without problems, either. A large air leak around a small tube may result in unreliable ventilation, oxygenation and capnography, and gas flow consumption is obviously higher. Studies have demonstrated higher concentrations of ambient nitrous oxide after intubation using uncuffed tubes with an “appropriate leak”, which highlights the issue of theatre and

Uncuffed endotracheal tubes and airway trauma:
If undersized for age, uncuffed ETTs may move up and down in the airway and damage delicate mucosal surfaces (movement trauma). Due to excessive pressure being placed on the posterolateral walls of the cricoid, oversized uncuffed ETTs are the most important factor influencing the development of subglottic stenosis. Airway pathology may range from submucosal mucous gland hyperplasia, to superficial ulceration, and/or to deep ulceration into the perichondrium or cartilage. Upon healing, fibrous scar tissue contracts to form glottic or subglottic stenosis.

With early use of PVC tubes in the 1960s, a high incidence of subglottic stenosis was reported but, this was mainly due to inappropriately large tubes being used for long-term intubation and ventilation. Later studies did not support these findings, reporting a low incidence of airway injury (around 1% incidence of post-extubation croup) following intubation with appropriately sized uncuffed tubes.

Cuffed endotracheal tubes and airway trauma:
Nasal mucosal injury from the sharp edges of a fully deflated cuff may cause significant bleeding. This is of little significance in routine cases but may be an important consideration in children with coagulopathies (e.g. hepatic transplant surgery) or where anticoagulation is necessary (e.g. heparinisation for cardiopulmonary bypass in surgery for congenital heart disease). Cuff overinflation is an obvious concern with the use of cuffed ETTs. Tracheal rupture with rapid and overzealous inflation is the most serious complication, but more commonly tracheal mucosal ischaemia may occur if cuff pressures are not maintained below 20 cmH2O. To avoid trauma to the larynx and subglottis, placement of the cuff distal to the vocal cords and glottis is crucial.

Is there a difference in airway trauma observed with cuffed and uncuffed endotracheal tubes?
A study by Khine et al in 1997, comparing cuffed versus uncuffed tubes in young children, showed similar rates of postextubation stridor in both groups. In 2009, Weiss et al published the largest study to date, in which more than 2,200 children from birth to 5 years were randomised to intubation with either a cuffed or uncuffed ETT. There was no significant difference in the incidence of postextubation stridor between the two groups. However, there were significantly fewer tube exchanges in the cuffed group. This is noteworthy, as the number of laryngoscopies and tube passages through the larynx are important factors influencing the likelihood of airway trauma. Of note is that only one type of cuffed ETT, the Microcuff® paediatric tracheal tube, was compared to numerous commercially available uncuffed tubes, so the results cannot be extrapolated to all cuffed tubes.

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### Table I: Advantages and disadvantages of uncuffed endotracheal tubes for paediatric use

| Advantages                      | Disadvantages                                      |
|---------------------------------|---------------------------------------------------|
| • Leak at 20–25 cmH2O may suggest minimal mucosal pressure | • High tube exchange rate:  |
| • No risk of tracheal rupture   | – Repeat laryngoscopies                           |
| • Larger internal diameter for age: | – Increased cost                                    |
| – Less resistance to air flow   | – Airway injury:                                    |
| – Ease of suctioning            | – Oversized tubes exert undue pressure on cricoid mucosa |
| – Less blockage by secretions   | – Undersized tubes precipitate movement trauma     |
|                                 | • Air leak:                                         |
|                                 | – Imprecise respiratory monitoring                 |
|                                 | – High gas flows                                   |
|                                 | – High gas consumption                             |
|                                 | – Environmental pollution                          |
|                                 | – Aspiration risk                                  |

### Table II: Advantages and disadvantages of cuffed endotracheal tubes for paediatric use

| Advantages                      | Disadvantages                                      |
|---------------------------------|---------------------------------------------------|
| • Smaller external diameter for age: | • Smaller internal diameter for age: |
| – Less pressure on cricoid mucosa| – Increased resistance to air flow                |
| • Reduced aspiration risk       | – Blockage by secretions                           |
| • Improved ventilation and respiratory monitoring, especially in low lung compliance | – Suctioning difficult |
| • Lower tube exchange rates:   | – Airway injury:                                    |
| – Cost effective               | – Nasal trauma                                      |
| – Fewer repeat laryngoscopies  | – Tracheal rupture/ mucosal ischaemia              |
|                                 | • Cuff pressure monitoring:                        |
|                                 | • Design flaws                                      |
|                                 | • Higher unit price                                 |
environmental pollution. Pulmonary aspiration of gastric contents is also of concern in those at risk.¹,²

Numerous formulae can guide tracheal tube size selection. However, tube exchange rates remain high with uncuffed ETTs. Design flaws found in many commercially available tubes complicate matters even further.

**Endotracheal tube designs**

Figure 1 highlights design problems and inconsistencies found in commercially available uncuffed ETTs. Firstly, these tubes all have a consistent internal diameter of 3.5 mm, but the external diameter can vary by up to 0.5 mm. This is of great clinical importance when intubating neonates and small children. It is particularly relevant when changing an ETT for a different size, as, if it is changed for a different make, the external diameter may be no different from the one originally used. Secondly, there is significant variation in external tube markings in figure 1. Some have intubation depth markers and others do not, and there is no consistency between brands. Many intubation depth markers are incorrectly placed and, if used to guide tube placement at the cords, would result in frequent endobronchial intubation.³ This is reiterated by a review of commonly used tracheal tubes in paediatric practice published by a group from Singapore in 2003. They looked at the placement of intubation depth markers, and found discrepancies between brands and within brands.⁴ One of the most troublesome factors, other than those mentioned previously, is that few ETTs have centimetre markings along the entire length, from the tip of the tube to the connector. This marking is essential for meticulous placement at the vocal cords.

Figure 2 illustrates commercially available cuffed ETTs, all of size 4 mm internal diameter. Again, there is inconsistency in external diameters and external tube markings. Cuffed tubes can further be characterised by inadequacies in cuff design, such as the cuff being positioned too high up on the tube, being too long, or generating high cuff pressures when inflated to seal the trachea.

Figure 2: Cuffed endotracheal tubes available at Red Cross Children’s Hospital in November 2009 (internal diameter 4.0 mm)

External diameters (left to right): Well Lead® 5.5 mm, Rusch® 6.0 mm, Mallinkrodt Hi-Contour® 5.6 mm, Parker Flex-Tip® 5.6 mm.

Optimal cuff design is important to avoid intralaryngeal cuff inflation and endobronchial intubation, and to minimise pressure on the tracheal mucosa.⁵ The Microcuff® paediatric tracheal tube was developed
to address these problems. Design features include a shortened high volume-low pressure cuff with an ultra-thin cuff membrane made of polyurethane which allows airway sealing at low cuff pressures, no Murphy eye to allow for more distal cuff placement, and anatomically placed depth markers within the cuff free subglottic zone.\textsuperscript{11, 12}

**Cuff pressure monitoring**

Cuff hyperinflation is not only a paediatric problem. To avoid tracheal injury, inflation pressures should be kept below 20 cmH\textsubscript{2}O.\textsuperscript{1, 2, 6} Important to note is that cuff pressures need not be above peak inspiratory pressures during positive pressure ventilation. This is due to the cyclic redistribution of air within the cuff (self-sealing mechanism) which aids in tracheal sealing.

There are numerous devices available to monitor and moderate cuff pressures. Simple devices include cuff pressure pop-off valves and manual manometers, which are relatively cheap and easily available. More complex automated pressure regulators are expensive, and have been shown to worsen tracheal sealing as they interfere with the self-sealing mechanism of cuffed ETTs.\textsuperscript{5}

**Current trends and recommendations**

Both cuffed and uncuffed ETTs have advantages and disadvantages associated with their use. Apart from the development and refinement of the laryngeal mask airway which, in its own right, has decreased airway morbidity by reducing the need for direct laryngoscopy and tracheal intubation, there is nothing better than the cuffed and uncuffed tubes currently available. A trend towards the increased use of cuffed ETTs in the paediatric population is evident, especially in certain clinical situations such as high aspiration risk, low lung compliance, and where precise ventilation and carbon dioxide control is important. The use of cuffed ETTs is further endorsed by the American Heart Association (AHA) and the International Liaison Committee on Resuscitation (ILCOR), stating in their 2005 guidelines that cuffed ETTs are an accepted alternative to uncuffed ETTs in infants and children.\textsuperscript{13, 14}

**Conclusion**

For the safe use of cuffed ETTs in paediatric anaesthetic practice:

\begin{itemize}
  \item Monitor and control cuff pressure that it remains below 20 cmH\textsubscript{2}O, particularly if using nitrous oxide.
  \item To avoid vocal cord and/or subglottic injury, ensure that the cuff is placed sufficiently distal to laryngeal structures.
\end{itemize}

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