

Cuffed endotracheal tubes in paediatrics

Motiang MJ, MBChB, MMed

Department of Anaesthesia and Critical Care, University of Limpopo (Medunsa Campus)

Correspondence to: Mammie Motiang, e-mail: mammie@telkomsa.net

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Abstract

The basic function of a tracheal tube is to provide a reliable connection between the patient's airway and the anaesthetic circuit (bag or ventilator). Ideally, this connection should allow a leak at 15-20 cmH₂O to prevent pressure-related mucosal perfusion, which varies with age. The anatomy of the paediatric airway differs from that of the adult, until it matures between approximately eight and 14 years of age. For this reason, standard teaching has been to avoid placement of cuffed endotracheal tubes (CETTs) in children who are younger than eight years old. Most paediatric anaesthetists continue to safely use uncuffed endotracheal tubes (UETT) on a daily basis, with a belief that they make an adequate seal as they pass through the cricoid ring. The use of CETTs and UETTs has been reviewed and the advantages and safety of CETTs are outlined in this article.

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Introduction

Few objects in anaesthesia are as delicate and as vulnerable as the paediatric airway. In small patients, the airway must be protected to allow adequate ventilation, but must also be handled with utmost care to ensure that no injury occurs to the laryngotracheal structures. Although the introduction of the laryngeal mask airway has been a major breakthrough in paediatric and adult anaesthesia, the vast majority of major surgical procedures that are carried out in newborn babies and infants still require tracheal intubation to provide safety for the patient and to optimise conditions for both the anaesthetist and the surgeon.¹

For more than 50 years, uncuffed endotracheal tubes (UETTs) have been the gold standard for intubation in children under the age of eight years. This recommendation derived from descriptions of anatomical differences between the child and adult larynx and supported a view that the presence of a cuffed endotracheal tube (CETT) was not only unnecessary, but was also a potential source of airway morbidity. There were also concerns that ill-fitting or poorly designed CETTs could cause tissue damage to the larynx and airway mucosa, resulting in subglottic stenosis.²⁻⁵

A UETT was thought to seal adequately as it passed through the cricoid ring. This was fuelled by well-founded fears of tracheal injury from the high-pressure, low-volume cuffs that were in common use years ago and the fact that cuffed tubes in very small sizes were not available.³

The past decade has witnessed a growing body of evidence in support of high-volume, low-pressure CETTs in paediatric airway management.² Studies have confirmed that they are not associated with an increased risk of post-extubation stridor or the need for tracheostomy in general paediatric critical care units.³ Smaller-sized CETTs reduce the pressure that is exerted by the tube shaft on the susceptible, nondistensible cricoid and seal the airway within the less susceptible, more elastic trachea by means of a cuff with monitored cuff pressure. In contrast, larger diameter UETTs that are selected to seal the airway within the noncircular cricoid cause pressure damage on the internal mucosal layer.⁶

The paediatric airway

Knowledge of airway anatomy is important for successful endotracheal intubation. Attempting airway access

without prior anatomical knowledge can have serious consequences. The airways of children differ from those of adults and undergo significant changes from birth to school-going age. Children have a proportionately larger head, a prominent occiput, relative macroglossia, a shorter, smaller and narrower trachea, a cephalad, anterior larynx, a shorter epiglottis and a narrower cricoid compared to adults. These differences impact on the positioning for intubation and explain the different intubation techniques across the age groups.

Studies on the development and growth of the larynx have determined that the larynx is cylindrical from side to side, but conical in the transverse and anteroposterior dimensions, with the apex of the "cone" caudally positioned at the level of the nondistensible cricoid cartilage.^{7,8} These dimensions change during childhood, as the larynx assumes a cylindrical shape. The narrowest segment is at the level of the vocal cords.⁷⁻⁹

In anaesthetised, spontaneously breathing children, the transverse diameter of the larynx is shortest at and immediately below the level of the vocal cords, rather than at the cricoid cartilage. However, the rigid cricoid ring is still the smallest functional part of the infant airway, because the vocal cords and the subglottic tissues can be distended.^{8,10}

The classical description of the child's larynx is based on cadaver studies. Two recent *in vivo* studies, one using magnetic resonance imaging in sedated children, and the other videobronchoscopy in paralysed children, have revealed that the cricoid area is ellipsoid with a smaller transverse diameter, and is not circular in shape, as previously thought.^{2,11,12} This means that a tight-fitting UETT or even an optimally fitted tube in young children with acceptable pressure leak, i.e. 20 cmH₂O, would exert more compression, if not ischaemia, on the transverse mucosa of the cricoid ring. This finding supports the recent trend of favouring the use of CETTs over UETTs in infants and children for their safety.¹³ It also confirms that the glottis, rather than the cricoid, is the narrowest part of the paediatric airway. The glottis is also more cylindrical than funnel shaped.¹²

These anatomical variations, coupled with the fact that the airway is smaller and narrower, make intubation in a child more challenging than in an adult. More expertise and precise selection of ETT size is required.⁸

The disadvantages of uncuffed tubes

UETTs are popular in paediatric anaesthesia and critical care, because of the flow dynamics of gas through these airways and the lower incidence of airway complications following their use.

The Broselow tape is a well-known tool that was designed to estimate body weight and ETT size based on body length in emergency paediatric patients. This formula predicts the appropriate ETT size within ± 0.5 mm in 98.5% candidates. Although the predictability of this formula is quite satisfactory, some tube replacements are still needed, especially if a UETT is used.¹⁴

When a UETT has been used, rather than a CETT, children are significantly more likely to demonstrate clinically significant loss of tidal volume, with unreliable ventilation and oxygenation and high gas flow consumption, and will require immediate reintubation to change tube size.¹³ They have an increased risk of aspiration also, especially when an undersized UETT is used.¹⁵ Despite these potential problems, UETTs remains popular and with experience, paediatric anaesthetists have learnt to overcome these shortcomings effectively.¹⁶

An oversized UETT exerts undue pressure on the laryngeal structures and causes laryngeal injury. Even if an UETT reasonably seals the trachea and has a leak, the pressure that is exerted on some parts of the cricoid mucosa may still be excessive.¹¹

Airway injury that is attributed to a UETT can result from repeated tube exchanges, tracheal mucosal trauma caused by the tube tip and up-and-down movement of the tube within the larynx during ventilation. A UETT tends to lie against the lateroposterior cricoid wall, potentially impairing mucosal blood flow, even in the presence of a positive leak test.² While UETTs have a fixed outer diameter and must be sized precisely to form a secure fit within the cricoid ring, the outer diameter of modern high-volume, low-pressure CETTs may be adjusted by gentle cuff inflation to seal such leaks, while placing minimal pressure on the tracheal mucosa. UETTs that leak are more likely to result in physiological complications, e.g. hypoventilation and hypercarbia, that in most cases cannot be rectified without repeat laryngoscopy and reintubation.⁴

During the 2003 severe acute respiratory syndrome (SARS) outbreak in Hong Kong, it was thought that there was a higher risk of dispersion of infectious droplets when ventilating a child with a highly communicable respiratory ailment with a UETT.¹⁷

The benefits of cuffed tubes

Normally, CETT sizes in children are selected in accordance with the modified Cole's formula. This relates UETT size to age, i.e. internal diameter (ID) (mm) = (age/4 + 4). The tube size is reduced by 0.5 mm [(Holzman¹⁸ ID (mm) = age/4 + 3.5)] or by 1 mm [(Khine et al¹⁹ ID (mm) = age/4 + 3)] to allow

for the presence of the cuff.

CETTs are selected with an ID of 0.5-1.0 mm smaller than that of UETTs for patients of the same age, in order to compensate for the cuff bulk at the distal tube shaft within the trachea, and to reduce the need for tube exchange because of variation in subglottic size.^{6,20} However, the smaller ID can cause higher resistance to gas flow, increasing the work of breathing and causing difficulty in tracheal suctioning.¹⁴

An appropriately designed CETT should not increase postoperative morbidity, as well as the risk of post-extubation stridor in newborn babies, infants and small children.

The benefits of CETTs in adult practice are well established and include a reliable, sealed airway, reduced pollution from anaesthetic volatile agents, the ability to use lower fresh gas flows, improved protection against aspiration, more effective control of ventilation, and improved capnography trace.^{2,4,5,21-23}

CETTs obviate the need to have a close fit in the subglottic region to ensure effective ventilation. For this reason, it may be preferable in children with a known tendency to subglottic stenosis, e.g. Down syndrome, to use a tube of smaller diameter together with a cuff to seal the airway.¹⁵ Good sealing is also important in an emergency situation and in patients with severe lung disease. It would also be of benefit to use CETTs in cases of possible difficult intubation (to avoid any chance of tube exchange) and in patients who are admitted to critical care.

A study that examined the incidence of upper airway symptoms, such as croup, regarded as evidence of a laryngotracheal injury, found no more croup in the CETT group than in the UETT group during the postoperative period, even after long-term intubation, provided the CETT size was carefully selected and the cuff pressure was monitored and adapted.¹⁶

Oversized outer tube diameters, inadequately designed cuffs, wrongly positioned or missing depth marks and cuff overinflation have been identified as causes of airway damage in children managed with a cuffed tube. The choice of an optimally sized CETT requires that the inner diameter, as well as the outer diameter, is taken into account. Diameters may greatly differ from one manufacturer to the next.¹⁶

Most anaesthetists are probably not aware of differences in outer tube diameters because tracheal tubes are chosen according to ID. This leads to possible use of oversized, ill-fitting tubes. The tube may need to be changed or there could be risk of subglottic damage.⁵

The stability that is provided by a cuff minimises tube movement, may tend to lift the tube tip away from the tracheal wall and allows the tube to attain a more central position within the cricoid area, thereby potentially reducing the risk of airway trauma.²

During 50% nitrous oxide (N₂O) anaesthesia in children, Felten et al observed that cuff pressure increases occurred mainly during the first 105 minutes of mechanical ventilation. Therefore, they came to the conclusion that cuff pressure is unpredictable after free air inflation and that numerous gas removals are required to maintain the pressure less than 25 cmH₂O during N₂O anaesthesia in children.²²

Care needs to be taken when actively deflating the cuff of the tube, as it results in sharp folds and edges in the cuff membrane, which lead to mucosal damage within the airway by "cutting" the mucosa with every tube movement during the respiratory cycle. Active deflation should only be carried out prior to tracheal extubation and must not be used to achieve an air leak in an overly large tube.²⁴

When deep extubation is being carried out in selected patients, it is probable that removal of a CETT will require a deeper level of anaesthesia than that of a UETT. The evidence in the literature does not resolve whether or not the incidence of post-extubation laryngospasm is any different.¹³ Furthermore, there is no reported increased risk of subglottic tracheal injury when using CETTs rather than UETTs.⁴

The mucosal perfusion pressures in children are lower than those in adults, and coupled with the risk of inadvertent cuff overinflation, has led to the suggestion that measurement of intra-cuff pressure should be considered to be mandatory.²

Conclusion

The literature provides strong evidence that supports the safe use of CETTs in paediatrics. CETTs are not associated with higher airway morbidity in children, typified by Weiss et al as post-extubation stridor.²³

The tube size should be carefully selected and the cuff pressure meticulously monitored to remain at "just seal" or "minimal occlusion pressure" in order to avoid hyperinflation and subsequent tracheal mucosal damage, which is greatly feared. CETTs also have a much greater chance of fitting at first attempt than UETTs. Second-generation microcuff tracheal tubes with an ID of 3.5 mm should be used in infants

from eight or nine months onwards to reduce the tracheal tube exchange rates.⁶ They should be the first choice when a tube with an ID of 3.5 mm or more is selected.²⁰

A leak should be present at 20 cmH₂O before inflating the cuff, which must be placed below the cricoid area. If this does not occur, the tube should be changed to a smaller size. Therefore, it is recommended that cuff pressures of 3.3 kPa should not be exceeded.^{12,25}

Post-extubation endoscopic examination studies are necessary to assess their safety.^{12,24}

References

1. Lonnqvist PA. Cuffed or uncuffed tracheal tubes during anaesthesia in infants and small children: time to put the eternal discussion to rest. *Br J Anaesth*. 2009;103(6):783-785.
2. Flynn PE, Black AE, Mitchell V. The use of cuffed tracheal tubes for paediatric tracheal intubation, a survey of specialist practice in the United Kingdom. *Eur J Anaesthesiol*. 2008;25(8):685-688.
3. Sheridan RL. Uncuffed endotracheal tubes should not be used in seriously burned children. *Paed Crit Care Med*. 2006;7(3):258-259.
4. Dorsey DP, Bowman SM, Klein MB, et al. Perioperative use of cuffed endotracheal tubes is advantageous in young pediatric burn patients. *Burns*. 2010;36(6):856-860.
5. Weiss M, Dullenkopf A, Gysin C, et al. Shortcomings of cuffed paediatric tracheal tubes. *Br J Anaesth*. 2004;92(1):78-88.
6. Salgo B, Schmitz A, Henz G, et al. Evaluation of a new recommendation for improved cuffed tracheal tube size selection in infants and small children. *Acta Anaesthesiol Scand*. 2009;50(5):557-561.
7. Litman RS, Weissend EE, Shibata D, et al. Developmental changes of laryngeal dimensions in unparalyzed, sedated children. *Anesthesiology*. 2003;98(1):41-45.
8. De Caen A, Duff J, Coovadia AH, et al. Airway management. In: Nichols D, Ackerman A, Argent A, et al, editors. *Rogers' textbook of pediatric intensive care*. 4th ed. Philadelphia: Lippincott Williams & Wilkins, 2008; p. 303-323.
9. Taylor C, Subaiya L, Corsino D. Pediatric cuffed endotracheal tubes: an evolution of care. *Ochsner J*. 2011;11(1):52-56.
10. Matsumoto T, de Carvalho WB. Tracheal intubation. *J Pediatr (Rio J)*. 2007;83(2 Suppl):S83-S90.
11. Weiss M, Gerber AC. Cuffed tracheal tubes in children: things have changed. *Pediatr Anaesth*. 2006;16(10):1005-1007.
12. Veyckemans F. Recent advances in airway management in children. *F1000 Med Rep*. 2009;1:p1172.
13. Motoyama KE, Finner JD. Respiratory physiology in infants and children. In: Davis PJ, Cladis FP, Motoyama EK, editors. *Smith's anesthesia for infants and children*. 8th ed. Philadelphia: Mosby inc., 2011, p2279.
14. Shih MH, Chung CY, Su BC, et al. Accuracy of a new body length-based formula for predicting tracheal tube size in Chinese children. *Chang Gung Med J*. 2008;31(3):276-279.
15. Lerman J, Cote CJ, Steward DJ. *Manual of pediatric anesthesia*. 6th ed. Philadelphia: Churchill Livingstone; 2010.
16. Weber T, Salvi N. Cuffed vs non-cuffed endotracheal tubes for paediatric anaesthesia. *Pediatr Anaesth*. 2009;19(Suppl 1):46-54.
17. Ho MH, Karmakar MJ. Cuffed versus uncuffed pediatric endotracheal tubes. *Can J Anesth*. 2006;53(1):106-111.
18. Holzman RS. Airway management. *Smith's anesthesia for infants and children*. In: Davis PJ, Cladis FP, Motoyama EK, editors. 8th ed. Philadelphia: Mosby, 2011; p. 344-364.
19. Khine HH, Corddry DH, Kettrick RG. Comparison of cuffed and uncuffed endotracheal tubes in young children during general anaesthesia. *Anaesthesiology*. 1997;86(3):627-631.
20. Cox RG. Should cuffed endotracheal tubes be used routinely in children? *Can J Anesth*. 2005;52(7):669-674.
21. Ashtekar CS, Wardhaugh A. Do cuffed endotracheal tubes increase the risk of airway mucosal injury and post-extubation stridor in children? *Arch Dis Child*. 2005;90(11):1198-1199.
22. Felten ML, Schmautz E, Delaporte-Cerceau S, et al. Endotracheal tube cuff pressure is unpredictable in children. *Anesth Analg*. 2003;97(6):1612-1616.
23. Weiss M, Dullenkopf A, Fischer JE. Prospective randomised controlled multi-centre trial of cuffed or uncuffed endotracheal tubes in small children. *Br J Anaesth*. 2009;103(6):867-873.
24. Dillier CM, Trachsel D, Bualig W, et al. Laryngeal damage due to an unexpectedly large and inappropriately designed cuffed pediatric tracheal tube in a 13-month-old child. *Can J Anesth*. 2004;51(1):72-75.
25. Hofstetter C, Scheller B. Cuff overinflation and endotracheal tube obstruction: case report and experimental study. *Scand J Trauma*. 2010;18:18.