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© Malaysian Journal of Anaesthesiology 2024; 2:137-156
Review article
https://doi.org/10.35119/myja.v3i2.81

Unveiling myths of the paediatric larynx: a comprehensive review of anatomical publications and modern insights on cuffed endotracheal tubes

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Abstract

This review critically analyses literature on the anatomy of the paediatric larynx published from 1897 to 2024, with an emphasis on key studies by Fayoux *et al.* and Isa *et al.* These pivotal investigations highlighted significant misconceptions and gaps in knowledge concerning the use of cuffed endotracheal tubes (ETTs) in infants and young children. Despite a comprehensive body of research spanning over a century, essential findings related to laryngeal dimensions and injury mechanisms during intubation were often overlooked or misrepresented in both historical and modern publications. Isa *et al.* conducted a detailed anatomical study using fresh paediatric larynges from autopsies, comparing their results to prior landmark research. Their methods included placing cuffless ETTs and Microcuff tubes (MCTs) in the laryngeal lumen and measuring the placement

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at the vocal cord level. The study demonstrated that the cricoid outlet (CO) is a rigid, circular structure—the narrowest part of the paediatric airway—and that it remains less distensible than the glottis or trachea. Fayoux *et al.*'s earlier work with 150 neonatal specimens confirmed this rigidity and emphasised the potential for significant airway damage when oversized ETTs are forced through the CO. This review highlights that radiological and endoscopic approaches often fail to accurately represent paediatric laryngeal anatomy, leading to clinical practices where inappropriate tube sizes are used. MCTs, despite their popularity, were shown to exceed CO dimensions in infants, risking mucosal damage and scarring. The failure to adopt these anatomical insights into clinical guidelines has led to practices that may compromise patient safety, such as using MCTs in premature infants where the deflated cuff's outer diameter (OD) exceeds CO diameters. Key measurements from Isa *et al.* reaffirm that cuffless ETTs based on ODs, rather than internal diameters, are more appropriate for the paediatric airway. This review urges the inclusion of accurate anatomical data, such as the findings of Fayoux *et al.* and Isa *et al.*, into clinical protocols to prevent airway trauma and improve paediatric intubation outcomes.

Keywords: anatomy, endotracheal tubes, Microcuff tubes, paediatric airway, paediatric larynx

Introduction

Microcuff® (Halyard, Alpharetta, GA, USA) endotracheal tubes (ETTs) are increasingly used in neonatal and paediatric airway management, but a review of paediatric airway anatomy is essential prior to widespread adoption. The cricoid outlet (CO), the narrowest part of the paediatric airway, is where the Microcuff tube's (MCT) cuff resides, raising concerns about mucosal injury, airway oedema, and complications such as subglottic stenosis. This article offers an overview of paediatric airway anatomy and the implications of using MCTs for clinicians.

The anatomy of the paediatric larynx has been studied extensively from 1897 to 2024, with significant contributions from Fayoux *et al.*[1] (Fig. 1) and Isa *et al.*[2] addressing misconceptions regarding cuffed ETTs for infants. A comprehensive understanding of this anatomy is crucial, as key studies on intubation-related injuries are often overlooked, revealing notable gaps in the literature.

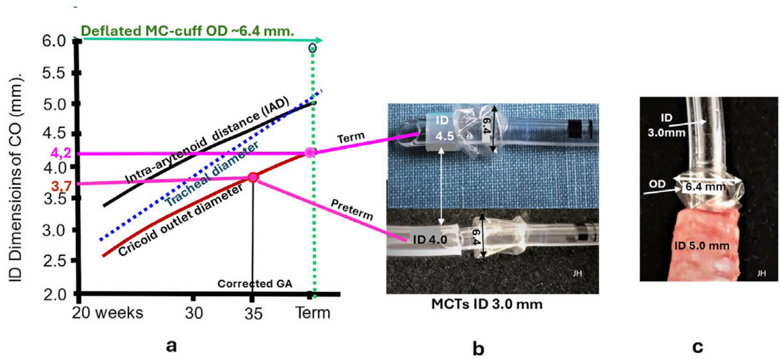

Fig. 1. Dimensions of the larynx and trachea of infants. Relation to MCTs with ID 3.0 mm. *(a)* Airway dimensions of 150 infants, from 35th week of gestation until term neonates.[1] CO diameter of infants (3.7 mm preterm, 4.2 mm term). Too small to permit free passage for deflated MCT cuffs (OD 6.3–6.6 mm) in the trachea (green line in graphic). The IAD is always larger than the CO diameter. Adapted from Fayoux *et al.*[1] *(b)* Deflated MCT cuffs, visibly too large to enter CO equivalents of ID 4.0 and 4.5 mm (premature and term infants, respectively) can be advanced only against marked resistance. *(c)* Deflated MCT cuff too large for animal trachea (ID 5.0 mm, size of 6-month-old infant CO).

Isa *et al.* performed anatomical studies on fresh paediatric larynges to clarify the true configuration of the paediatric airway, comparing their findings with older literature.[2-5] Their research included assessing cuffless ETTs (Vygon Medizintechnik, Germany) and cuffed MCTs to determine their optimal placement in the paediatric larynx and proximal trachea.[2]

Prior beliefs shaped by radiological images lacked backing from endoscopic and anatomical data. Evidence of scarring mechanisms and the absence of stridor in severe airway injuries were neglected.[6-8] Additionally, risks associated with cuff positioning in the CO were noted, particularly in premature infants under 3 kg, despite existing warnings.[9-14]

Fayoux *et al.*'s[1] 2006 study of 150 cadaver larynges confirmed that the CO is rigid and minimally distensible in infants around 35–37 weeks of gestation, suggesting oversized ETTs may compress this outlet.[1] Despite its importance, this study has generally been overlooked in contemporary paediatric airway management discussions (Fig. 1).

Fundamental discrepancies between anatomical findings of the paediatric larynx and misconceptions about MCTs in the literature

Despite extensive anatomical and endoscopic research, misconceptions about the paediatric larynx and MCTs persist. Collaborations among paediatric ENT surgeons and forensic anatomists support the understanding that COs are circular and the narrowest part of the paediatric larynx, as opposed to the glottis, which measures wider in the anteroposterior (A-P) dimension (Table 1).[15-17]

Table 1. Measurements of antero-posterior glottis, cricoid outlet, and proximal trachea in 30 children

Values	Age group (years)		
	0–1	1–3	3–11
Number of children	19	6	5
Glottis A-P (mm)	7.2	10.1	13.7
Glottis IAD (mm)	7.7	9.0	9.5
VC-CO distance (mm)	10.9	13.3	15.2
CO, A-P/transverse (mm)	5.0/5.0	6.4 /6.3	8.3/8.8
Ratio of CO, A-P/transverse	0.99	1.01	0.94 wider than AP
Calibrations (mm)	4.9	6.3	7.9
Trachea, A-P/transverse (mm)	5.1/6.0	7.0 /7.3	8.8 /9.8

A-P: antero-posterior; IAD: inter arytenoid distance; CO: cricoid outlet; VC: vocal cord
Mean values are presented for the 3 different age groups.
Table reproduced from Isa *et al.*[2]

The influential 1951 publication by Eckenhoff led to a preference for cuffless ETTs among paediatric anaesthesiologists, particularly for infants and children up to 8 years of age.1[8] Many institutions maintain this preference, because they are convinced, that cuffless ETTs are less traumatic to the airway in children < 24 months of age. The reliance on cuffless ETTs is rooted in fears of fluid aspiration compared to cuffed tubes particularly with improper cuff placement within the CO that could result in airways trauma. Neglect of the CO's physiological properties has complicated clinical choices.[19]

Emerging literature contrasts essential anatomical insights with the practical considerations of choosing between cuffless ETTs and MCTs. Recent findings indicate that cuffed tubes, when correctly sized and placed, can minimise air leaks, enhance ventilation, and lower re-intubation rates.[17,18,20] This balance is especially significant given ongoing research into long-term outcomes linked to MCT use and the potential risks of subglottic stenosis.

In summary, integrating MCTs into paediatric airway management in children < 24 month of age is never beneficial according to Isa *et al.*'s fact-related findings,[2] yet an in-depth understanding of cricoid anatomy remains crucial.[21-23] The discourse around their application must harmonise historical practices with modern findings, ensuring safe, effective care for our youngest patients. Continued exploration of these discrepancies will be vital as we navigate the evolving landscape of paediatric airway management.

Cuffed intubation evidence and mucosal injury risks

Many institutions adhere to Eckenhoff's principle,[18] claiming that infrequent mucosal injuries occur when cuffless ETTs are carefully inserted. However, the injury patterns differ significantly between cuffless ETTs and cuffed MCTs. Injuries linked to cuffless ETTs predominantly affect the CO, while cuffed MCT injuries can extend from the distal larynx to the upper trachea, necessitating varying surgical interventions. Intubating infants with MCTs can present considerable resistance due to the prominent cuff folds, compounded by the size mismatch between MCTs and the infant cricoid (3.0-mm inner diameter [ID] compared with the infant CO diameter of 5.0 mm), thereby increasing the risk of mucosal injury (Fig. 2).

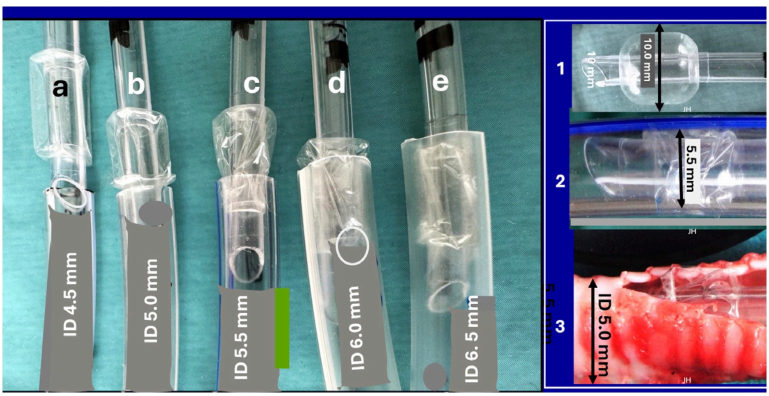

Fig. 2. MCTs too large to enter paediatric airways < 2 years of age. MCTs with ID 3.0 mm, deflated cuffs with ODs ~ 6.4 mm, unable to enter mock COs, diameter of 4.5–5.5 mm, 6.0 mm only with force. *(a, b)* MCTs with ID 3.0 mm, designed for infants. Only the tips of the tubes can enter the artificial infant COs, never the cuffs. *(c)* Only the distal part of MCT cuff with ID 3.0 mm can enter the 5.5-mm diameter CO (child = 18 months of age), but cannot reach the mid-trachea, where it should be. *(d, e)* MCT can enter a 6.0-mm CO (size of 2-year-old child CO) against resistance, but freely first in 6.5-mm CO. *(1)* Inflated MCT with ID 3.0 mm and OD 10 mm. Can never drape freely against the tracheal wall. *(2)* Deflated MCT with ID 3.0 mm, in mock infant trachea. Cuff folds impinge constantly on the mucosa. *(3)* MCT with ID 3.0 mm, deflated cuff in infant-size animal trachea. Opening the anterior wall, the folds of the cuff pop out of the trachea due to the pressure; the cuff folds exert on the tracheal wall.

A pivotal 1997 study by Khine *et al.* popularised cuffed intubation, positing it as a means to reduce intubation attempts in paediatric patients.[24] However, scientific validation was lacking, as the study lacked airway endoscopy. Notably, it did not report intubation rates in neonates, despite advocating for cuffed intubation in this population—a recommendation based on "very low-quality evidence", stated by the Cochrane review.[17] Although cuffed intubation may lessen the number of attempts for clinicians, it simultaneously poses potential risks for paediatric patients due to oversized MCT cuffs.

Fundamental discrepancies in cuffed intubation findings

Khine *et al.* highlighted the growing trend for cuffed intubation, based on the presumption that it would reduce intubation attempts among children.[24] This assumption lacked scientific backing, primarily due to an absence of airway endoscopy data in their study. Although no neonatal intubation rates were documented, cuffed ETTs were nonetheless recommended. Subsequent evaluations by De Orange *et al.* reviewing cuffed versus uncuffed intubation showed similarly low-quality evidence regarding laryngeal mucosa evaluation.[17] Although fewer ETT exchanges occurred in the cuffed group, the absence of endoscopy data meant that documented severe injuries from single MCT insertions remained unaccounted for.

These findings illustrate that the general clinical application of MCTs in young children largely relies on very low-quality evidence. It is crucial that tube selection charts incorporate cuffless ETT options for infants and children, featuring slight variations in outer diameters (ODs) while maintaining similar IDs for enhanced sizing flexibility.

Moreover, depending on stridor as an indicator of airway injury is problematic. While transient subglottic oedema can lead to immediate stridor, more severe, invasive mucosal injuries often manifest no stridor at all, resulting in scarring and stenosis over time. Additionally, Litman's[25] imaging was conducted too high above the CO, as noted by Tucker *et al.*,[26] who provided histological evidence demonstrating that the cricoid is circular at the appropriate level. Tucker's[26] findings dispute Litman's assertion of an oval cricoid,[25] highlighting the necessity of accurate anatomical data in paediatric anaesthesia.

Furthermore, neither Litman *et al.*[25] nor Dalal *et al.*[27] validated the existence of an oval lumen in the paediatric cricoid. Dalal *et al.* performed an endoscopy-based *in vivo* study using a Hopkins lens on 13 children under 2 years, suggesting an oval shape based on illumination observed at the cricoid ring's superior aspect.[27] However, Isa *et al.*[2] rebuffed these findings by applying the same methodology to an A-P section from a fresh infant autopsy specimen (Fig. 3), clarifying that Dalal *et*

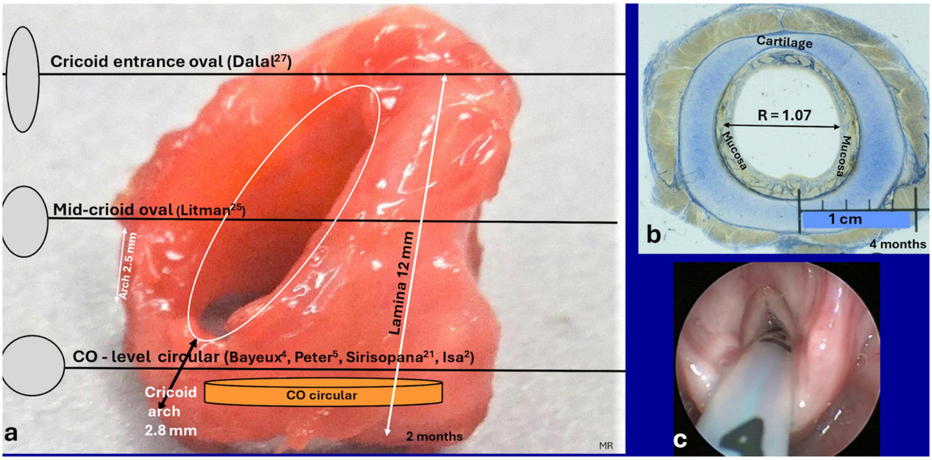

Fig. 3. Cricoid cartilage and CO in infants and small children (fresh and fixed autopsy specimen). *(a)* Oval transection at entrance of cricoid cartilage (Dalal *et al.*[27]) pasted on autopsy specimen (Isa *et al.*[2]). The entrance appears necessarily as an oval, as well as in Litman's MRI findings25). *(b)* Near circular CO (R = 1.07), with well-preserved mucosa by Eckel *et al.* Image courtesy HE Eckel.[23]

al.'s measurements were taken at the entrance of the cricoid cartilage rather than at the circular cricoid, which is located approximately 8 mm lower. This highlights the limitations of indirect imaging techniques in accurately documenting CO levels.

Additionally, Fayoux *et al.*,[1] who studied 300 infant autopsy specimens, was not referenced in Dalal *et al.*'s research,[27] which weakens the validity of their results. Fayoux *et al.* provided critical insights into internal airway diameter at the posterior glottis,[1] illustrating a funnel-shaped narrowing from the glottis to the cricoid outlet—an important detail overlooked by Dalal *et al.*'s claim that a lack of airway sequelae from cuffed tubes has contributed to the reliance on MCTs remains unsupported,[27] especially considering their small sample size and reliance on stridor as an outcome measure instead of post-extubation airway endoscopy.

While MCTs are thought to prevent fluid aspiration into the lungs, studies indicate that MCT cuffs do not effectively block fluid passage into the trachea under various cuff pressures (Fig. 4a-c). Experimental conditions reveal substantial differences in cuff performance between inflated and deflated MCTs, which starkly contrast with industry claims of MCTs providing protection against microaspiration. (Fig. 4d).[28]

Tobias' assertion of a free space behind cuffless ETTs in the "elliptical larynx at or just below the vocal cords" lacks support from any *in vitro* or *in vivo* evidence

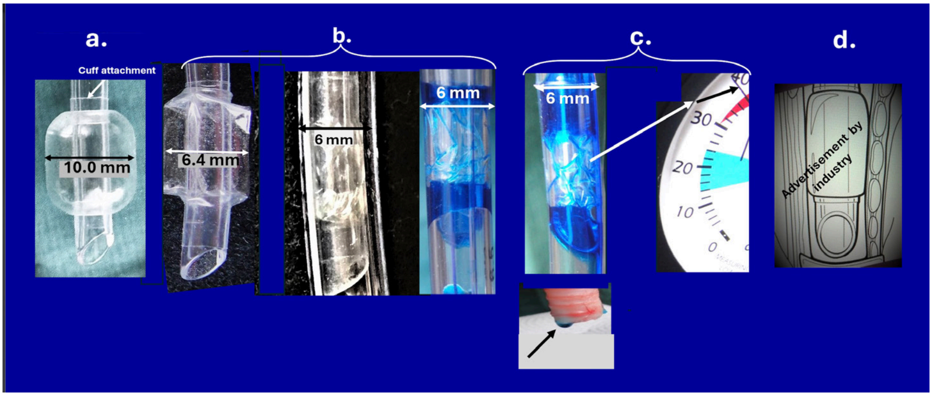

Fig. 4. All ETTs in this image are MCTs with ID 3.0 mm, which are too large for the infant larynx and upper trachea. Cuff wrinkles permit leaking of fluids into the trachea. *(a)* Inflated MCT cuff, OD 10 mm, too large to be placed in infant airway. *(b)* Deflated MCT cuff with OD ~ 6.4 mm. This cuff compressed in a 6.0-mm ID artificial trachea (~ 18-month-old child) shows pronounced impingement of cuff folds on tracheal mucosa. Tinted fluids above the cuff leak constantly into the trachea via capillary spaces between the compressed folds. *(c)* Same situation as *(b)*. Intra-cuff pressure 40 cm H2O. Despite this high intra-cuff pressure, fluids still leak into the trachea. The same occurs in infant-sized animal tracheas (below leaking cuff). *(d)* Drawing of inflated MCT with inflated cuff, supposedly draping the tracheal wall freely and supposedly preventing fluid aspiration (as advertised by industry). This allegation is incorrect!

(Fig. 3c).[15] ETTs can be advanced into the trachea only without a free space behind the ETT, contradicting Tobias' statement. Minimal air leaks anterior of cuffless ETTs do not permit fluid aspiration.[28] Small air leaks anterior to cuffless ETTs do not permit fluid aspiration when a standard positive end-expiratory pressure (PEEP) of approximately 2–4 cm H_2O is applied. These findings challenge Tobias' assertion that MCT cuffs "drape freely" against the paediatric trachea.[15] In reality, MCT cuffs cannot freely conform to the tracheal wall when compressed within the narrower paediatric airway.[28]

Moreover, Tobias misquoted Bayeux's 1897 article, failing to substantiate his claims.[15] The phrase "leak around the tube" is misleading; leaks only occur anteriorly in ETTs (Fig. 3c). A proper spatial representation of the paediatric larynx, which narrows from the glottic level to the cricoid cartilage, is best observed using a Hopkins lens, highlighting the clear distinction between the wide glottis and the circular CO.

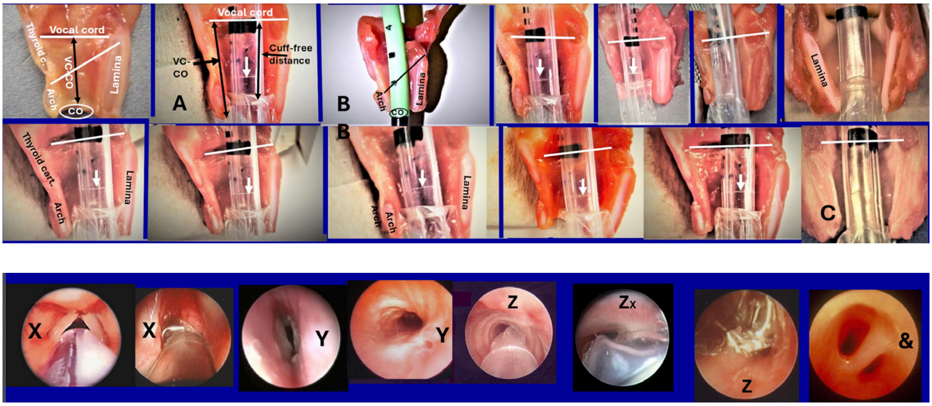

Fig. 5. Position of proximal MCT cuffs within CO, despite depth marks at vocal cord levels.
(a) MCTs placed on A-P transections of autopsy specimens of the paediatric larynx. Most important are the findings that all MCT cuffs lie with the proximal part within the CO instead in the mid-trachea, where they should be *(A)*. The cause is the longer VC-CO distance compared to the cuff-free distance on the MCT-shaft, which is too short, never directly measured before the Isa investigation2. This is an intrinsic deficit of all MCTs. Cuffless ETTs of adequate size impinge only minimally on the airway mucosa *(B)* even when moving. Particularly dangerous is the position of the sharp attachment of the cuff close to the CO *(C)*.
(b) Endoscopic evidence of injuries by MCT intubation (admissions to paediatric ENT Centre, Children's Hospital Cologne, Germany). Endoscopic findings controlling position of MCTs before and after extubation, and during mechanical ventilation. MCTs are regularly misplaced into the larynx *(X)*, a dangerous position relating to airway injury. Significant tracheal injuries after short- and long-term intubation *(Y)*. Evidence of tracheal injury during mechanical ventilation, difficult to get, but extremely important. There was no overinflation of cuffs *(Z)*. Years-old scar after cuffed intubation *(&)*. Accidental finding.

Isa *et al.*[2] first illustrated this anatomy, correcting the misconception that the vocal cords are the narrowest part of the paediatric larynx; they are, in fact, distensible. During autopsies, the cords often appear nearly closed (cadaveric position), yet they remain distensible in both *in vitro* and *in vivo* settings.[26] In vivo, vocal cords can close tightly during laryngospasm but also distend widely during deep breaths, refuting claims that the paediatric glottis is the narrowest portion of the airway.

Publications suggesting an oval shape for paediatric cricoid cartilage are based on radiologic imaging conducted under neuromuscular blockade or deep sedation, which misrepresents natural anatomy. While vocal cords may appear narrow under these conditions, they are typically distensible. Appropriately sized cuffless ETTs can be effectively used during intubation, as shown in various anatomical investigations.[24-26]

Isa *et al.* first identified the flawed relationship between MCT cuffs and paediatric larynx anatomy in a study involving 30 autopsy specimens.[2] They found that MCT cuffs are often positioned too deep within the distal larynx, heightening the risk of mucosal damage from cuff folds. In 23 of the specimens examined, MCT cuffs were found lodged deep within the CO, failing to reach the mid-trachea as intended (Fig. 5a).

Despite these important findings, there have been no improvements in MCT design. One potential way forward involves comparing cuffless tubes with MCTs of the same internal diameter (3.0 mm) to assess performance during transected autopsy larynges. Differences in ODs could be further evaluated by manipulating the tubes within the larynx during autopsy and *in vivo* trials. Cuffless ETTs allow for minimal mucosal impingement during movement or turning.[29,30]

Cuffless ETTs minimise mucosal impingement during head movement, whereas mispositioned MCTs continuously exert pressure on the CO mucosa. A noted paediatric ENT surgeon remarked that the narrow CO effectively acts as a “cuff” for cuffless tubes, leading to reduced contact and decreased granuloma formation. In contrast, MCT cuffs compress against the distal larynx, increasing the risk of mucosal injury, particularly when infants move (Fig. 5a).

Greany *et al.* conducted endoscopies 6 months post-intubation in nearly 300 infants who were intubated with 3.0-mm internal diameter MCTs, which had deflated ODs of approximately 6.3 mm.[31] This is concerning, considering that Isa *et al.* found CO diameters in neonates and infants up to 10 months to be approximately 5 mm, with tracheal diameters ranging from 5.1 mm to 5.4 mm.[2] An MCT cuff of ~ 6.3 mm is too large for the paediatric airway, risking mucosal compression, especially with prolonged cuff presence. Parents of children with airway injuries are often hesitant to return to the same medical facility where an injury occurred. (Fig 5b).

Endoscopies performed months later can miss prior airborne injuries, as vocal function damage can be undetectable at this stage. Acute injuries such as ulcers may heal well and can be absent during later examinations. Early airway endoscopy following exposure to oversized cuffs is vital for prompt injury treatment and preservation of vocal function.

Greany *et al.*’s findings lack scientific validation for MCT use in children[31] and clash with anatomical evidence by Isa *et al.*[2] and Fayoux *et al.*[1] The chronic misplacement of MCT cuffs in the distal larynx, due to insufficient cuff-free distance on the tube shaft, heightens the risk of significant mucosal injury.[31,32] Improved MCT design is critical for enhancing airway safety for paediatric patients.

Despite existing evidence, 3.0-mm ID MCTs with approximately 6.3-mm cuff ODs are still recommended for infants up to 8 months.[14] Conversely, a 3.5-mm ID MCT intended for children aged 8 to 24 months, which has a cuff OD of nearly 7.8 mm and a typical CO diameter of 5.5 mm, has proven excessively large in experimental studies.[1,2] Findings show that MCT cuffs often do not sit in the mid-trachea but remain in the CO. Literature advises that "a cuffed paediatric tracheal tube should have adequate depth markings and not be inflated in the subglottic region." In practice, however, depth markings generally denote placement at the vocal cord level, yet MCT cuffs frequently end up improperly positioned in the CO (Fig. 5b).[33,34] This misplacement has not been reliably assessed through airway endoscopy.

To assess the effects of MCT cuff folds on the tracheal mucosa, a 2.0-mm OD Hopkins lens was placed alongside an MCT shaft to observe the deflated cuff during mechanical ventilation. The cuff folds scraped the mucosa, resulting in visible damage, which can only be thoroughly evaluated through endoscopy. Unfortunately, late endoscopies may miss critical injury assessments necessary for effective treatment.

The ongoing improper positioning of MCT cuffs too close to the CO necessitates design improvements for better airway safety in paediatric patients.[33,34] The impact of 3.0-mm ID MCT cuffs on infant laryngeal mucosa can be clearly documented using high-quality infant manikins during intubation. The effects of the cuff folds on the glottis are observable during both intubation and extubation.

Both *in vitro* and *in vivo* evidence—such as intubation of manikins and real infants—highlights the mucosal effects of cuff folds. Given that all MCT cuffs remain positioned within the CO in children studied by Isa *et al.*,[2] these findings should urge physicians to reevaluate their use of MCTs for tracheal intubation in premature and infant patients, and manufacturers should reconsider their guidelines for recommending 3.0-mm ID MCTs for this population.

Several authors have proposed modifications to MCTs to improve their fit in the airways of infants and small children. Jordi-Ritz *et al.*[34] found that MCT cuffs can move approximately 7 mm up and 5 mm down the airway during movement or repositioning, potentially causing injuries to the CO.[34] Isa *et al.*,[2] along with Kemper *et al.*[35] and Moehrlen *et al.*,[36] recognised the issue of oversized MCT cuffs, suggesting that repositioning depth markings further up the MCT shafts and shortening the cuff's length and width could ensure proper placement in the mid-trachea while preventing right mainstem bronchus intubation. Despite the reasonableness of these design changes, they have not been implemented. Misleading advertisements still claim that "MCTs are specifically designed with correct anatomical depth markings," which is inaccurate, as demonstrated in desktop experiments (Fig. 4).

A major disadvantage of MCTs is the inadequacy of the cuff-free distance on their shafts. Although Isa *et al.*'s findings2 received limited attention, one editorial[35] correctly stated that the circular CO is the narrowest rigid point of the paediatric airway but overlooked the issue of improper cuff positioning. It failed to address the significant concern raised by Isa *et al.* regarding MCT cuffs being inadequately positioned in the distal larynx.

Do Isa *et al.*'s findings impact on daily paediatric intubation with MCTs?

Yes, they document the harmful effects of improperly positioned cuffs on the mucosa of the paediatric larynx and trachea. Scientific articles that fail to consider CO dimensions, including glottic length and the OD of deflated MCT cuffs, should be viewed sceptically, as they neglect the well-being of children.[37]

Airway endoscopy is vital for detecting trauma, even after what seems like uneventful intubations. An insightful editorial[38] highlighted this, noting that many anaesthesiologists are surprised by post-intubation findings, indicating that even minor injuries may occur. This underscores the ineffectiveness of late airway endoscopies, such as those conducted in Greany *et al.*, in evaluating airway injury 6 months after intubation with MCT cuffs.[31]

Case-control studies with large participant numbers can help answer unresolved questions.[39] A study was conducted to assess the safety of MCTs for long-term airway outcomes in children under 2 years, involving 2,200 participants from 24 institutions.[39] The results showed similar outcomes between groups in terms of post-extubation stridor, intubation attempts, and effective sealing against aspiration.

However, the study had notable limitations. It provided no new insights compared to prior research. Physicians were allowed to use cuffless ETTs at their discretion without specifying tube ODs, which vary greatly, leaving the impact on airway mucosa unaddressed. Additionally, the ODs of deflated MCT cuffs—a key factor in airway injury—were not discussed. The assertion that MCT cuffs conform freely to tracheal walls is technically inaccurate, as demonstrated by Isa *et al.* The study's industry funding raised concerns about bias and contributed to an unnecessarily large sample size. The Cochrane review[17] noted this issue and highlighted the absence of post-anaesthesia airway endoscopy, a consistent limitation in previous studies.

Importantly, the study did not address potential airway injuries from MCT cuffs, providing no compelling argument for their advantage. Despite the large sample, it added limited scientific value and was rated as very low-quality evidence.[17]

The assertion by Weiss *et al.*[32] that depth markings on MCT shafts assist in positioning endotracheal tubes in children is contradicted by Isa *et al.*'s research.[2] Stridor, a symptom of airway injury, is not an effective indicator of airway obstruction post-intubation, as it usually occurs only when over 50% of the airway lumen is blocked; severe mucosal ulcers may not cause stridor after extubation. Damaged tissue can heal, forming scar tissue that might only become apparent later (Fig. 5b), emphasizing the importance of airway endoscopy for the timely detection of post-anaesthesia airway injuries.

Dariya *et al.* investigated cuffed versus uncuffed ETTs in neonates, including 69 subjects.[40] Their results showed very low evidence of differences between the 2 groups, and potential bias was evident. The absence of endoscopy results limited the evaluation of airway injuries, thus making their review unhelpful in determining the preference for cuffed or uncuffed tubes in neonates.

Bernet *et al.* found that 3.0-mm ID MCTs used in premature infants under 3 kg led to significant injuries requiring invasive treatment, cautioning against the use of MCTs in these patients.[41] Additionally, they noted that post-extubation stridor could be due to oversized cuff wrinkles, aligning with Isa *et al.*'s anatomical descriptions.[2] Bernet *et al.* recommended relying on formulas for cuffless tube insertion to ensure safe ETT placement in infants, rather than using cuffed tubes.[41]

A retrospective study raised further safety concerns regarding MCTs for premature infants, analysing 29 neonates intubated with MCTs and 21 with uncuffed ETTs for up to 20 days.[42] It found that the post-extubation stridor rate was significantly higher in the MCT group (17.2%) versus the uncuffed group (7.5%), reaching 19.2% in infants under 3 kg. Although no endoscopy was performed, the symptoms were deemed reliable indicators. These findings underscore the necessity for larger studies with post-extubation airway endoscopies following extended intubation.

There is no scientific basis for using MCTs in premature infants and children under 2 years of age, despite fewer ETT exchanges. A redesign of cuffed ETTs for this demographic group is critical, as Isa *et al.*'s findings raise alarm about the care of premature infants up to 24 months using 3.0-mm ID MCTs, which necessitate compression to fit their airways.[2] One alternative proposed by C. Coté from Harvard University is to revert to cuffless intubation for infants, a practice already adopted by many institutions, including those in Europe and the Children's Hospital in Cologne, complemented by airway endoscopy and the use of tube selection charts. These charts account for both IDs and ODs (measured in French sizes), significantly affecting the risk of airway injury. Since 1955, tube selection charts have guided the careful intubation of cuffless ETTs in paediatric patients, offering slightly smaller and larger tube options with the same ID. This method minimises the occurrence of “multiple attempts at intubation,” a practice that should be avoided whenever possible. These charts, however, need to be adjusted for different population sizes.

Using cuffless ETTs until the end of the second year is rational and effective. This technique, along with precautionary measures such as small amounts of PEEP to limit fluid aspiration, has been successfully practiced for many years. There is an increasing preference for intubating infants with precisely selected cuffless ETTs rather than MCTs with oversized cuffs (Figs. 4, 5).

A visual comparison in Figure 5a demonstrates the notable difference between the OD of a smooth cuffless ETT and the bulging cuff of an MCT, both with the same ID. The oversized OD of the MCT cuff and the compressed folds entering the glottis illustrate that the MCT cuff does not drape freely in the upper paediatric airway. Instead, the compressed folds consistently press against the airway mucosa, exerting unknown pressures that may lead to potential injuries.

This evidence underscores the urgent need for a redesign of MCTs. The cost discrepancy is significant, with a single cuffless ETT costing approximately €1.90 in Germany compared to nearly €15.00 for an MCT.

Recent airway management guidelines have emerged, though many of their recommendations are based on limited or low-quality evidence.[43,44] These guidelines reflect historical data and may not adequately address future requirements. While they correctly state that insufficient data supports the routine use of cuffed ETTs in children under 3 kg due to restrictive ODs, they erroneously claim that cuffed ETTs are safe for infants over 3 kg.[45] This contradicts findings from Fayoux *et al.*[1] and Isa *et al.*,[2] which reveal that the ODs of deflated MCT cuffs (~ 6.4 mm) are too large for the average infant cricoid (mean 5.0 mm).

The recommendation to adhere strictly to manufacturer instructions appears biased, with important discussions about the role of post-anaesthesia airway endoscopy in detecting airway injuries after intubation missing from the guidelines. Ponde *et al.*[45] emphasised these inaccuracies, asserting that only randomised studies independent of industry funding, which also encompass endoscopic evaluations, can yield dependable data for managing the airways of premature infants and small children.[45]

At the 18th Asian Society of Paediatric Anaesthesiologists (ASPA) meeting in 2022, several lectures and workshops emphasised significant findings from Isa *et al.*[2] Experienced paediatric anaesthesiologists recognised that the cricoid is the narrowest, circular, and rigid part of the paediatric larynx prior to school age.

Isa *et al.*'s discovery that proximal MCT cuffs were either within or very close to the CO in all studied autopsy specimens[2] stimulated substantial discussions regarding the implications for intubation practices, significantly influencing this article's creation.

A review of references for paediatric endotracheal intubation reveals that most studies lack airway endoscopy, insights from ENT surgeons, and consultations with paediatric anatomists. This absence impedes real-time documentation of mucosal injuries and delays timely treatment for airway trauma.

Critiques of this study are guided by the Cochrane Handbook for Systematic Reviews,[43] emphasizing that valid, historical publications should not be overlooked. References must originate from primary sources to avoid secondary citations. Additionally, studies with disproportionately large participant pools that yield no new data possess limited scientific value, and industry-funded studies frequently demonstrate bias.

This article uses visual aids and simple experiments to substantiate its claims, making replication straightforward for readers.

Declarations

Ethics approval and consent to participate

This is a review article and as such does not require ethical approval nor informed consent.

Competing interests

None to declare

Funding

None to declare

Acknowledgements

Dr. Hans Hoeve, former head of the Department of Paediatric ENT Surgery at Erasmus University, Rotterdam, Netherlands, significantly contributed to this article by reviewing the entire study twice for content adequacy and verifying the accuracy of the endoscopic images based on his extensive paediatric ENT surgical experience.

Dr. Masao Yamashita, former head of the Department of Paediatric Anaesthesia at Ibaraki Children's Hospital, Mito, Japan, provided invaluable support by thoroughly reviewing the global literature on the paediatric airway over several years and offering editorial advice. Dr. Zehra Serpil Ustalar Özgen of Acibadem University, Istanbul, Turkey, and president of the Asian Society of Paediatric Anaesthesiologists (ASPA), engaged in comprehensive review sessions, meticulously examining all images alongside the author, enhancing the understanding of the visuals, and providing additional editorial feedback. Dr. Vrushali Ponde, President-Elect of ASPA and Founding Director of the Children's Anaesthesia Services in Mumbai, India, offered continuous critical feedback throughout the article's development, refining numerous paragraphs and providing consistent editorial guidance. She interpreted the new guidelines,[43,44] resulting in a published letter to the editors[45] cited in the reference list. Professor Charles G. Coté of Harvard University, Boston, MA, USA, provided continuous advice on key focal points for this study on the paediatric airway, as he had in previous publications[2,3] on which this article is based. His extensive knowledge of paediatric anaesthesia and editorial expertise greatly supported the development of this article. Part of this article was presented at the 18th ASPA meeting held in Istanbul, Turkey, in October 2022.

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