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Cuffed Endotracheal Tubes in Children: Size Does Matter!

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The use of a cuffed endotracheal tube (ETT) has become standard of care in pediatric anesthesia. This applies even to neonates and infants and increasingly to pediatric intensive care medicine.[1] The main advantage of using cuffed ETTs in children is the markedly reduced tube exchange rate to find an appropriately sized ETT with a smooth fit and a good seal of the pediatric airway when compared with uncuffed ETTs.[2]

Fundamental advances in the understanding of the pediatric upper airway anatomy and the availability of newer cuffed pediatric ETTs have changed the old historical practice to seal the pediatric airway using an uncuffed ETT just fitting into and/or slightly deforming the elliptical shaped cricoid (cricoidal sealing).[3,4] This is in contrast to the use of a slightly smaller-sized cuffed ETT with a thin high-volume low-pressure (HVLP) cuff that allows the smooth passage through the vulnerable larynx and to gently seal the pediatric airway within the less susceptible trachea (tracheal sealing). Sealing the pediatric airway by means of a cuff within the trachea allows the anesthesiologist to compensate for the problem of age-related and individual variations of subglottic size within a certain age group of children. Both can result in high ETT exchange rates, insufficient sealing of the airway, and pressure-related lesions within the larynx when using uncuffed ETTs.[2–5]

With the use of modern pediatric cuffed ETTs, exchange rates range from 0% to 2.1% with a median cuff inflation pressure of about 10 cm H_2O.[2,6–8] This sufficiently seals the trachea without increasing the incidence of postextubation stridor. Postextubation stridor as a scientifically valid outcome measure for assessing the pediatric airway injury after endotracheal intubation has been vehemently criticized.[9] Endoscopic data in children aged from birth to 6 years, however, did not reveal increased airway injury in children after short-term endotracheal intubation with a cuffed ETT when compared with children without earlier airway instrumentation.[10] Many of the airway alterations so far attributed to endotracheal intubation were found in children who had never undergone intubation before. Endoscopic results of prolonged endotracheal intubation with uncuffed and cuffed ETTs in pediatric intensive care patients are expected for 2017 (ClinicalTrials.gov NCT02350933).

It must be emphasized that the above-mentioned benefits and safety of cuffed ETTs in children are only achieved if careful endotracheal intubation, confirmation of an air leak with the cuff not inflated, cuff pressure limitation to a maximum of 20 cm H_2O, strictly evidence-based selection of ETT size, and the use of an ETT designed to fit the pediatric anatomy are guaranteed.[11]

The case report by Imai et al[12] in this issue of *Anesthesia and Analgesia* documents the considerable dimensional differences between similarly sized cuffed pediatric ETTs from different manufacturers, and the lack of knowledge and information regarding appropriate selection of cuffed ETT size, both resulting in difficulties and even failure to insert a cuffed pediatric ETT.

Historically, the selection of uncuffed ETTs in pediatrics was based on their outer diameter (OD).[13] In the past, very experienced pediatric anesthesiologists used their knowledge of OD differences between ETTs from different manufacturers when exchanging an inappropriately sized ETT to adjust for the individual pediatric airway anatomy. Today, however, the size of ETTs is internationally defined by its internal diameter (ID), and the ID is used in the age-adjusted selection of an ETT in pediatric patients.[14] Although the ID of a specific ETT has to be within a certain manufacturing tolerance, there are considerable differences in the OD of pediatric ETTs because of differences in the wall thickness of pediatric tracheal tube ETTs, not only between ETTs from different manufacturers, but also between ETTs from the same manufacturer.[15]

However, for the selection of an appropriately sized ETT, the OD is more important than the ID in predicting uncomplicated passage of the ETT through the larynx. Although listing of the OD on the ETT package insert and the ETT surface is required by medical equipment regulations, even the experienced anesthesiologist caring for a child is rarely aware of these subtle differences. Hospitals may change ETT brands for logistic or financial reasons. The accompanying changes in ETT dimensions are not routinely communicated to the medical staff. Moreover, anesthesiologists rarely know age-adjusted laryngeal dimensions of pediatric patients. At present, ultrasound assessment of airway dimensions is more of a research tool than routine practice before endotracheal intubation. It may be helpful in patients with suspected or known subglottic narrowing (eg, in patients with Down syndrome).

Lack of knowledge about variations in OD of ETTs at comparable ID has caused serious airway damage in children.[16] The use of oversized cuffed ETTs (by selection or choice of manufacturer) is considered the likely cause of most cases of postextubation stridor and severe laryngeal damage observed in children after intubation with a cuffed ETT.[1,17]

The introduction of HVLP cuff ETTs has increased the effective OD of a cuffed ETT, making insertion more difficult, at times even impossible, particularly in pediatric patients. This was systematically investigated many years ago. Considerable differences between low-volume high-pressure and HVLP cuff ETTs were shown.[18] The large cuff bulk of conventional HVLP pediatric ETTs resulted in the recommendation to decrease the calculated ID by 1.0 mm

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when using a cuffed pediatric ETT.[18] In the past, 2 formulas for the selection of cuffed ETTs in children have been published.[14,19] One is the formula by Motoyama (ID = [age/4] + 3.5);[14] the other by Khine (ID = [age/4] + 3).[19] The Motoyama formula is associated with a high incidence of adequate tracheal seal, but, at the same time, with a higher chance of selecting a too large ETT, particularly with a HVLP cuff. By contrast, the Khine formula[19] is associated with a lower incidence of selecting an inappropriately large ETT, but at the expense of more frequent inadequate tracheal seal, particularly with low-volume high-pressure cuffs. In addition, the use of the Khine formula results in considerable reduction of the ID compared with an uncuffed ETT. This marked reduction of ID may cause difficulties with ventilation, suction catheter passage, and ETT obstruction by secretions. Furthermore, in case of a smaller sized preformed (RAE) ETT, the cuff becomes seated higher in the pediatric airway, that is, within the larynx or even above the vocal cords. This is because tube insertion length is related to their preformed shape, which is related to the tube size.[20]

Shortcomings in ETT dimensions and lack of evidence-based recommendations for the appropriate selection of cuffed ETT size in children were highlighted more than 10 years ago.[15] Most cuffed pediatric ETTs were downscaled from adult cuffed ETTs without any consideration for pediatric airway dimensions. This does not only concern the OD but also residual cuff diameter, length and location of the cuff, and presence and location of the insertion depth mark.[20] At present, the principal manufacturers of cuffed pediatric ETTs have not adapted their pediatric products. The development of the Microcuff pediatric ETT that was designed on the basis of anatomical dimensions, combined with an evidence-based recommendation for tube size selection, presented a major step forward.[6,7] However, this ETT still does not fulfill all criteria to be considered as the perfect pediatric cuffed ETT.[11]

Pediatric anesthesiologists and nonpediatric anesthesiologists caring for children have to be aware that cuffed pediatric ETTs can vary considerably in design, OD, and cuff dimensions. Published recommendations for the selection of cuffed ETT size in children do not apply to all cuffed ETT brands commercially available. Poor ETT design and inappropriate ETT size, apart from inadequate handling, can lead to serious difficulties and complications when cuffed ETTs are used in children.

Manufacturers are urged to improve the design of their cuffed pediatric ETTs in accordance with the pediatric airway anatomy, and to provide clinically tested recommendations for the age-adjusted selection of specific ETTs that allow smooth laryngeal passage, optimal tracheal sealing, and cuff placement.

The increased use of extraglottic airways in pediatric airway management will inevitably lead to reduced experience with endotracheal intubation in children. This renders reliable airway equipment even more important in pre-hospital and in-hospital pediatric airway management. In this context, cuffed ETTs have definite advantages over uncuffed ETTs in children regarding correct fit in almost all cases and sufficient seal at the first attempt. However, as unmistakably demonstrated by the case report from Imai et al,[12] this only applies when appropriately designed and correctly sized ETTs are selected, because size also matters in cuffed pediatric endotracheal tubes.

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