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REVIEW

Optimal depth of endotracheal intubation in pediatric patients

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Abstract

With the growing number of pediatric endotracheal intubations performed during general anesthesia, ensuring the correct placement of pediatric endotracheal tubes has become increasingly critical. Improving the accuracy of tracheal intubation and reducing complications of tracheal intubation are essential challenges faced by anesthesiologists. This review examines recent research on the optimal positioning of pediatric endotracheal tubes, focusing on the types and models of endotracheal tubes, the placement standards and positioning methods. Additionally, it explores the mechanism and impact of factors such as height, age and head and neck movement (flexion and extension) on tube positioning. This analysis aims to enhance the understanding of pediatric endotracheal intubation to improve clinical outcomes and patient safety.

Keywords

Tracheal tract; Tracheal length; Bronchial intubation; Head and neck flexion; Head and neck extension

1. Background

Tracheal intubation under general anesthesia is a common practice in surgical procedures, with at least 3.13 billion patients undergo surgical procedures annually. Endotracheal intubation has been considered the gold standard for airway management [1]. The proportion of pediatric patients requiring tracheal intubation is increasing year by year [2]. Ensuring the appropriate depth of endotracheal tube (ETT) insertion in pediatric patients has become a growing concern for anesthesiologists. The incidence of critical events during airway management is high, especially in newborns or infants [3–5]. Emergency scenarios often necessitate precise and safe airway management [6], as failure to establish a secure airway can lead to catastrophic outcomes [7]. Compared to adults, children have larger occipital bones, softer neck joints, smaller mouths, shorter tracheal lengths, and greater individual differences, making airway management distinct from that in adults. Inappropriate ETT depth can lead to significant complications: proximal intubation may cause vocal cord injuries or accidental extubation, while distal intubation can result in bronchial intubation and related complications [8]. 44% neonatus required two or more intubation attempts [9]. The length of the trachea in children increases with age, further complicating the precise placement of the ETT. Due to the different anatomical structures, physiology and pathophysiology of pediatric age spans, airway management in children presents unique challenges [10]. Maintaining a constant ETT depth during surgery is difficult, as intraoperative factors such as changes in patient positioning or the effects of muscle relaxants can alter the tube's placement. These challenges highlight the need for continued research and improved strategies to ensure safe and effective airway management in pediatric patients.

2. Types and models of pediatric endotracheal tubes

During pediatric anesthesia, anesthesiologists generally use tracheal intubation for positive pressure ventilation. Airway management is crucial, particularly when treating critically ill children, as it ensures proper ventilation and provides lifesaving support. Selecting an appropriately sized endotracheal tube (ETT) is crucial to provide better airway protection and effective invasive device ventilation support.

2.1 Selection of endotracheal tube types

Pediatric endotracheal tubes are divided into two types: cuffed endotracheal tubes (CETT) and uncuffed endotracheal tubes (UCETT). The use of CETT or UCETT in pediatric patients has distinct advantages and disadvantages.

Traditionally, UCETT has been used for children under the age of 8 for several years [11]. Prior to this age, the narrowest part of the airway in children is typically the cricoid cartilage, which is cone-shaped, ring-like and non-expandable [12, 13]. However, some studies suggest that the pediatric airway, with a greater anterior posterior diameter than the lateral diameter, and the narrowest point located below the glottic opening [14]. Isa *et al*. [15] confirm that the narrowest point of the infant larynx is the nondistensible cricoid cartilage and not the easily distended glottis. In clinical practice, the inflation of CETT airbags often interferes with the secure fixation of endotracheal intubation, which may pose a risk of twisting, blocking or damaging the cuff. This may result in the cuff being unable to inflate or deflate properly, potentially complicating airway management [16].

In recent years, CETT has been increasingly used in tracheal intubation procedures for children under 8 years old. When using UCETT in newborns and children, a properly sized UCETT can cause air leakage around the cricoid cartilage and exert excessive pressure on the tracheal wall. In contrast, a smaller diameter CETT can provide sufficient sealing without exerting excessive pressure on the cricoid cartilage [17]. CETT use reduces gas leakage around ETT, the need for ETT replacement, the risk of accidental extubation, and the exposure of medical personnel to anesthetic gases during surgery [18]. The success rate of CETT intubation, with an average leakage rate of 10%–20%, is 30.9%, compared to 17.6% for UCETTs [19]. The use of micro-cushioned ETT is also increasing in newborns. Williams *et al*. [20] found that using CETT in newborns weighing less than 5 kg can reduce the number of laryngoscopes and improve safety. Zander *et al*.'s [21] study showed that body weight during endotracheal intubation and birth weight were the strongest predictors of the suitability of endotracheal intubation with or without a cuff. The threshold body weight during endotracheal intubation was 2700 g, and the probability of using endotracheal intubation with a cuff was >50%. The use of CETT has a lower incidence of postoperative wheezing in full-term newborns undergoing non-cardiac surgery [22]. Properly used cuffed tubes (correct size and correct cuff management) are currently recommended as the first option in emergency, anesthesiology and intensive care in all pediatric patients [23, 24].

In summary, CETT provides many advantages for the clinical use of endotracheal intubation in pediatric patients. As a result, CETT is increasingly recommended for use in this patient population.

2.2 Selection of endotracheal tube models

Choosing the appropriate model of ETT is crucial for airway protection in children. Pediatric Basic and Advanced Life Support (PALS) recommends choosing the ETT model according to the formula: ETT model = age/4 + 3.5 [25]. Additionally, ultrasound can be used preoperatively to measure the diameter of the subglottic upper airway or the cricoid cartilage, which has been shown to correlate strongly with the optimal ETT size for pediatric patients [26–29]. The consistency rate between the predicted ETT size based on ultrasound measurement and the final ETT size selected clinically is 98% (CETT) and 96% (UCETT), respectively [30]. Abdel Ghaffar *et al*. [31] identified ultrasound measurement of the distal radius transverse diameter and epiphyseal transverse diameter as reliable predictors for selecting the correct ETT size. In children under 12 years old, there is a linear relationship between CETT size and middle finger circumference, with CETT inner diameter (mm) = middle finger circumference (cm) − 0.2 [32]. If the model is too large, violent insertion during ETT through the pediatric glottis can easily cause postoperative sore throat and hoarseness [33]. If the model is too small, there may be complications such as reflux aspiration and increased airway pressure [34]. This poses certain difficulties in the selection of anesthesiologists and increases the risk of complications from endotracheal intubation. Adopting individualized planning helps address the variability in pediatric airway anatomy and reduces the risks associated with improper tube sizing.

3. Selection and positioning of depth for pediatric endotracheal tube insertion

3.1 Standards for depth of endotracheal tube placement

Determining the appropriate depth for endotracheal tube (ETT) insertion in children is essential for minimizing risks such as bronchial intubation, tracheal protuberance stimulation, and accidental extubation. To aid in the initial estimation of ETT depth, most clinical ETTs feature marked depth or length lines on the tube body, which serve as guidance during placement. The first depth marker line of ETT can be used as a reference point for positioning the laryngoscope through the vocal cords [35].

In recent years, many studies have conducted simple linear regression on the correlation between growth parameters of children and the optimal depth of ETT implantation and derived some formulas to calculate depth. For example, the traditional formula of ETT intubation depth = age/2 + 12 [25]; Thai neonates using a formula: Nasal-tragus length (NTL) + 6 cm (NTL $\leq$5.0 cm) and NTL + 5.6 cm (NTL >5.72 cm) [36]. Tube depth (cm) = 5.5 + 0.5 $\times$ weight (kg) (age <1 year), tube depth (cm) = 3.0 + 0.1 $\times$ height (cm) (age >1 year) [37], *etc.*; Propst *et al*. [38] proposed a formula after verifying the ETT positioning criteria: tube depth (cm) = 0.6 $\times$ height + 8.8 (cm); Zhuang *et al*. [39] proposed a formula suitable for Asian populations: tube depth (cm) = 4 + 0.1 $\times$ height (cm); The formula suitable for Indian children: tube depth (cm) = age/2 + 10 cm [40]; The formula based on middle finger length: tube depth (cm) = 3 $\times$ middle finger length (cm) [41]; In the Thai population, the study found that the ETT placement of 99/100 patients was appropriate with the formula: tube depth (cm) = 4 + (height (cm)/10) (cm) [42]; The formula for the depth of nasotracheal intubation: 9 + (height (cm)/10) (cm) is suitable for ETT placement in 93/100 patients [43]. Liu *et al*. [44] suggest that for newborns, weight-based recommendations for determining endotracheal tube (ETT) depth are more accurate than age-based recommendations when discrepancies arise between the two methods. Weight-based formulas provide a reliable approach to ensuring accurate pediatric intubation depth, which helps clinical doctors to make quick and appropriate decisions while reducing the risk of related complications.

Due to the lack of depth markers for intubation, confusion of black lines on ETT, and the complexity of calculating the insertion depth of children's oral/nasal ETT based on age, other methods have emerged to determine the depth of ETT insertion.

One commonly used method involves determining the distance from the tip of the ETT to the tracheal protuberance as equal to the distance from the upper edge of the ETT sheath to the glottis [39]. Visual fiberoptic bronchoscopy can assist in these measurements. In clinical studies, the distance from the tip of the ETT to the tracheal protuberance and the distance from the upper edge of the ETT sheath to the glottis is often referred to as the optimal depth for intubation [38, 39, 45], with high accuracy. However, this method has limitations, as it relies on indirect measurement and lacks suitable equipment for directly assessing the distance from the ETT tip to the tracheal protuberance, which can result in measurement errors. Despite this, all enrolled patients in the study did not experience endotracheal intubation or accidental extubation, highlighting its effectiveness for determining the length of endotracheal intubation. It has been reported that placing the tip of the ETT approximately 2 cm above the tracheal protuberance results in 54% of intubations being located in the subglottic region, indicating that the ETT cuff may be positioned too high, too long or both [35]. Another approach is to position the ETT tip in the middle of the trachea [46]. The middle section of the trachea can also be determined by sternotomy palpation, allowing the accurate placement of the ETT. As long as the palpation is correct, the position of the ETT tip can be determined, saving time for establishing airway protection for patients in emergency intubation situations. The specific technique involves placing fingers above the suprasternal fossa to assess the position of the ETT cuff. If the cuff is palpated at the level of the sternum fossa, the tip of the catheter is too close to the tracheal prominence, which does not meet standard requirements. Conversely, if the cuff is positioned at the level of the cricoid cartilage, the insertion is too shallow, increasing the risk of dislodgement. The ideal position for the cuff should be between the suprasternal fossa and the cricoid cartilage [47–49].

3.2 Methods for determining the position of ETT

After determining the optimal insertion depth of the ETT, it is necessary to employ reliable methods and instruments to determine whether the ETT has reached the desired depth. In previous clinical work, the validation of the location of ETT was supported by clinical indicators, such as visualized ETT placement, equal movement of the bilateral thorax and auscultation of respiratory sounds, the presence of fog in the lumen of the ETT, or improvement in blood oxygen saturation. However, these traditional methods often lack the precision required for accurate validation. In patients with challenging airways, especially those wearing rigid neck braces due to suspected spinal injuries, visualizing the glottis may not be possible, and limited head and neck mobility can hinder proper assessment after visualization with a laryngoscope. According to the European Society of Anaesthesiology and Intensive Care (ESAIC)/British Journal of Anaesthesia (BJA) guidelines, electronic laryngoscopes with age-appropriate standard lenses are recommended as the first choice for endotracheal intubation [3]. Majeedi *et al*. [50] developed an artificial intelligence (AI) that improves the success rate of visualized laryngoscope intubation by automatically detecting the glottal opening of newborns, which may improve the intubation results of newborns in the future.

Once the ETT is inserted, end-tidal carbon dioxide ($ETCO_2$) detection is typically employed to confirm its placement in the airway $ETCO_2$ monitoring is considered the gold standard for initial or immediate confirmation [51]. $ETCO_2$ monitoring can be performed using waveform carbonation, numerical end-expiratory CO_2 monitoring, or qualitative colorimetric methods. The sensitivity and specificity of the colorimetric CO_2 determination method and CO_2 map are as high as 96.95% and 99.95%, respectively [52]. In the pediatric context, where physiological parameters can change swiftly, capnography emerges as a critical tool for respiratory assessment [53]. The biggest drawback of $ETCO_2$ detection is its inability to correctly distinguish between endotracheal intubation and bronchial intubation.

Chest X-ray remains the gold standard for secondary determination of ETT position [54]. In cases where visual confirmation or colorimetric end-tidal CO_2 detector (CECD) results are inconclusive, chest X-rays provide the most accurate means of evaluation [55]. However, chest X-rays come with drawbacks, including the need for professional training for image acquisition and interpretation, logistical challenges in obtaining timely imaging, and increased patient costs and radiation exposure. These limitations make chest X-rays impractical for routine clinical use, particularly in emergency settings where time is critical. Moreover, the method is rarely utilized to determine intubation depth in routine practice due to these constraints and the associated radiation risks.

Bedside ultrasonography (BUS) offers several advantages, including simplicity, convenience, speed, non-invasiveness and objectivity. Use of BUS by clinicians at the point of care has expanded widely and rapidly [56, 57]. BUS is also one of the auxiliary measures for the correct placement of ETT [58–60]. BUS can identify esophageal intubation through the "double trachea sign", a specific ultrasound feature. Lin *et al*. [61] systematic review of several small-scale pediatric studies suggests that bedside neck and lung/diaphragm ultrasound may provide accurate and real-time information about ETT placement. This makes it a particularly useful tool for confirming ETT positioning in critically ill pediatric patients [62]. Ultrasound allows visualization of tracheal intubation through imaging and is effective in both emergency situations and routine surgeries. Importantly, it does not cause additional harm to patients and can assist in cases involving difficult airways. This is a simple and easy to learn technique, and an anesthesiologist trained in ultrasound can distinguish between endotracheal intubation and esophageal intubation in just 3 seconds [63, 64]. Ultrasound relies on the anatomy of the larynx and trachea. The trachea is located superficially and can be examined with an ultrasound probe at the highest resolution. The anterior wall of the trachea, thyroid gland, cricoid cartilage, tracheal ring, esophagus and the tissue before tracheal can all be well displayed, and the outer diameter of the trachea can also be measured through a cross-sectional view of the trachea. Alonso Quintela *et al*. [65] evaluated the confirmation of ETT by transtracheal ultrasound and diaphragmatic or pleural ultrasound. Patients under 1-year-old should use micro convex probes (8 MHz), while patients over 1-year-old should use linear probes (12 MHz). Images were obtained in both horizontal and vertical planes, utilizing the "comet tail sign" for visualizing the tracheal tube during esophageal intubation. They also believe that ultrasound is as effective and fast as chest X-rays in evaluating the depth of tracheal intubation insertion [61]. Ultrasound further confirms whether the intubation is in the trachea or too deep by observing the pleural sliding sign, curtain sign, and diaphragm displacement of both lungs. Datta *et al*. [66] used ultrasound to identify tracheal rings in children and accurately determined the appropriate depth of ETT. Ultrasound can also measure the distance between the ETT tip located at the sternal notch and the upper boundary of the aortic arch, with an optimal range of 5–10 millimeters [57].

Song *et al*. [67] proposed a new method: using an infrared sensor probe to place the ETT at a suitable position above the protrusion. This method places a probe at the tip of the ETT, which detects changes in reflected infrared radiation as the ETT advances. When the distance between the probe and the protuberance falls below a preset minimum range, an infrared indicator light activates, signaling proper placement. However, this method has only been tested on animals and is yet to be clinically validated, leaving its accuracy uncertain. Additionally, infrared continuous monitoring of ETT position has been explored [68].

Most of the above methods rely on indirect physiological parameters for judgment, and there is an urgent need in clinical practice for a method that can directly observe the position of ETT in the trachea after passing through the glottis. The clinical application of fiber optics can effectively solve such problems and can also be used to confirm correct catheterization. Fiberoptic bronchoscopy (FOB) is a commonly used method in operating rooms and emergency rooms for placing ETT, verifying the insertion depth of ETT, and examining the patient's airway for trauma or foreign objects. The direct visualization and flexible long lens of FOB is its biggest advantages. Combined with the monitoring of fog and $ETCO_2$ in ETT, the specificity and sensitivity for the correct placement of ETT are as high as 100% [69]. Due to the visualization of FOB, it is usually easy and clear to observe between the tracheal ring and the tracheal protuberance when the field of view is clear in the trachea. Smoke, blood and secretions may appear in the patient's trachea, blurring the FOB lens. Therefore, it is recommended to perform suctioning on patients before use. In addition, the instrument is relatively expensive and prone to damage, so cross infection should be avoided. After each use, the range should be sterilized according to the manufacturer's recommendations, making this method inconvenient for daily use [70].

No single method is entirely foolproof for confirming ETT placement. In clinical practice, various methods are used to determine ETT in order to reduce the incidence of ETT misalignment and ensure the safety of patients' lives.

4. Factors affecting the position of pediatric endotracheal tubes

4.1 Growth factors

Due to the different growth and development of children, the length of the trachea varies, and the placement of ETT naturally differs. Studies conducted in Germany indicate that the tracheal length in pediatric heart disease patients ranges from 6% to 10% of their height, while in Japan, it varies from 7% to 11%. These regional differences highlight the impact of population-specific growth patterns on tracheal dimensions. The minimum tracheal length for European children is approximately 6% of their height, compared to 7% for Asian children [71]. Multiple studies have confirmed that the length of the trachea in children increases with age and height, and there is no difference between genders [72]. According to reports, the tracheal lengths of children aged 4 to 6 are 5.6, 6.4 and 7.2 cm, respectively [73]. In the previous text, we also mentioned the correlation between the appropriate depth of ETT placement and the age and height of children and proposed a series of feasible formulas. It is difficult to measure the length of the trachea in infants *in vivo*. Lee *et al*. [74] found that in infants under 3 months old, the tracheal length from the vocal cords to the tracheal protuberance correlates most strongly with weight, followed by height and age.

4.2 Head and neck flexion, extension and rotation

Due to the relatively short trachea in children, the safe range of ETT positioning is narrow. Once the optimal insertion depth of the ETT is determined, any external factors, such as head and neck movement, can affect the ETT's position, increasing the risk of bronchial intubation and accidental extubation due to shallow insertion. During general anesthesia for pediatric surgeries, the head may be repositioned to improve surgical visibility. For example, in otolaryngology, pediatric tonsillectomy and adenoidectomy, the head is tilted back and extended, in dentistry, the head needs to rotate to the opposite side of the affected tooth during extraction of obstructed teeth, and in neurosurgery, the head also needs to be rotated during pediatric craniotomy surgery. These changes in head and neck position can impact ETT placement.

Regarding the impact of changes in head and neck position on the position of the ETT, in most cases, the tip of the ETT retracts when the neck is extended and moves towards the tracheal protuberance when the neck is flexed. This has been confirmed by many subsequent studies [75–77]. However, this viewpoint is also controversial. Tailleur *et al*. [46] argue that after head flexion, the movement of the ETT does not have a fixed direction, as their study showed that 24% exhibited displacement of the ETT tip towards the vocal cords. Zhuang *et al*. [78] also had similar results, with 6.3% showing withdrawal of the ETT tip towards the vocal cords after head flexion.

They mainly studied the changes in ETT tip and original position after head flexion, extension, and left-right rotation. When the head is bent 45 degrees, the ETT tip moves 0.5 ± 0.4 cm towards the tracheal protuberance ($p < 0.001$). After stretching 45°, the tip of the ETT moved 0.9 ± 0.4 cm towards the vocal cords ($p < 0.001$). Rotate the ETT tip 60° to the right and move it 0.6 ± 0.4 cm towards the vocal cords ($p < 0.001$). In addition, there was no displacement when the head turned 60 degrees left ($p = 0.126$) [78]. Yan *et al*. [76] found that when the head position changes from neutral to olfactory, the average distance of ETT tip displacement is 1 cm. Similarly, Kim *et al*. [8] also explored this issue in the data of 22 children aged 1–9 who underwent catheterization, where the ETT shifted in the direction of withdrawal; When the child's head rotates left and right, the tip also shifts, with an average of 0.6 cm and 1.1 cm, respectively. If the axis of rotation of the head is the trachea, the movement of the ETT tip will not be affected by the direction of head rotation. However, the rotation axis of the head is generally based on the cervical spine, and the trachea is located in front of the cervical spine. Therefore, when the ETT is initially inserted and fixed at the corner of one mouth, rotating the head towards the side where the ETT is fixed will cause displacement towards the vocal cords.

This displacement can cause complications such as accidental dislodgement of bronchial tubes or ETTs. According to reports, in 83.9% of cases, the ETT tip moved towards the tracheal protuberance when the head was flexed 45 degrees, with an average movement distance of 0.5 cm, and 2 children experienced bronchial intubation [78]. Another study showed that after maximum head extension, 4% of endotracheal tubes were found to become right bronchial tubes [79]. It can be seen that head and neck movements can cause ETT ectopia, and children are at high risk of endobronchial intubation or accidental extubation. Hence, relying on a single positioning after intubation does not guarantee that the ETT will remain correctly positioned throughout the procedure.

When the head and neck are extended, not only is there displacement of the ETT, but the pediatric trachea itself also shows significant elongation. When the neck is fully extended, the length of the trachea increases by 0.95 cm, accounting for 12.1% of the trachea length. Therefore, this issue cannot be ignored. In older children, neck extension still causes the ETT tip to shift to the vocal cords [80]. The younger the child, the shorter the length of the trachea. So the complications of such events, such as bronchial intubation or accidental extubation, are more likely to occur if the trachea is shorter. At the same time, the pressure of the ETT cuff will also increase after stretching the head and neck [81, 82].

The direction and amplitude of ETT movement depend on the movement of the head and neck, and correct ETT positioning is the key to tracheal intubation. Therefore, if there is movement in the head and neck during the process of intubation, a quick and accurate secondary evaluation of the ETT position should be performed after stabilizing the position.

5. Complications after ETT removal in children

Intubation may cause laryngeal injury through the action of the intubation process itself or the pressure exerted by the endotracheal tube. The incidence of wheezing after extubation ranges from 1.0% to 30.3%, with throat injuries found between 34.9% and 97.0%. Factors such as sedation levels and gastroesophageal reflux are factors associated with post-extubation throat injuries [83]. Although most injuries heal on their own after extubation, some children may experience severe laryngeal stenosis accompanied by typical signs of severe upper airway obstruction [84]. There is no consensus on the relationship between age, weight, gender, duration of intubation, multiple intubations, traumatic intubation, tube size, air leakage and infection [85, 86]. There was no difference in the incidence of wheezing after extubation between UCETT and CETT in infants weighing 2 to 6 kg [87]. Vahabzade *et al*. [88] installed strain-sensitive graphene nanosheet sensors and commercially available force-sensing resistors behind the larynx and observed that the force exerted by various ETTs on the larynx increased with ETT size. They proposed a "novel ETT clip" to reduce the force exerted by ETTs on the larynx [88]. Burton *et al*. [89] also proposed that measuring the pre-extubation laryngeal air column width difference (LACWD) before extubation may diagnose post-extubation wheezing (PEW)). Additionally, measuring the appropriate cuff pressure may reduce complications after extubation. Güneş *et al*. [90] proposed the formula to predict the most suitable tracheal cuff volume: tracheal cuff volume (mL) = 1027 × height (m) + 0104 × subglottic transverse diameter (mm) − 00191.

6. Conclusions

There were several limitations to this review. First, the exclusion of non-English literature might have omitted relevant perspectives from non-Anglophone regions. Second, the included studies predominantly focused on children, potentially limiting the applicability of findings to non-children contexts. Additionally, due to the lack of clinical evidence, this study was unable to establish unified standards for catheter type selection, size determination and optimal insertion depth.

Pediatric airway management is an essential skill that every anesthesiologist must master, yet it also presents significant challenges. Currently, there is no unified standard in clinical practice for the selection of ETT types and sizes or for determining the optimal depth and position of the tube. In most cases, the safety of using CETT is higher than that of UCETT for all pediatric patients. Due to the considerable individual variability among children, anesthesiologists typically prepare one size larger and one size smaller ETT in addition to the calculated size. After tracheal intubation in clinical practice, multiple methods are often used simultaneously to determine the depth of the ETT. In recent years, the advantages of ultrasound in airway assessment have become increasingly prominent, showing great potential for precise depth localization in pediatric tracheal intubation. During changes in positioning, it is important to keep the child's head in a neutral position as much as possible to minimize displacement of the ETT. Additionally, during anesthesia, adjusting the position of the child's head and neck or reassessing the ETT placement can facilitate rapid repositioning of the ETT. This provides valuable guidance for clinical management of ETT displacement in anesthesia practice.

The tracheal length of children is shorter than in adults, and their unique anatomical characteristics require more precise ETT placement to reduce the risk of accidental dislodgement and bronchial intubation. When performing pediatric endotracheal intubation, anesthesiologists must consider various factors, propose individualized approaches, and prepare multiple emergency plans to enhance patient safety.

AVAILABILITY OF DATA AND MATERIALS

Data and materials are not publicly available but are available to corresponding or first authors upon reasonable request.

AUTHOR CONTRIBUTIONS

YZ—helped in drafting of the article or revising it critically for important intellectual content. JRW—helped in the references of the article. WJG—helped with all aspects of the work, ensuring that questions were related to the accuracy.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The review was approved by the Ethics Committee of Yijishan Hospital of Wannan Medical College (2023-140).

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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