Comparison of Ultrasonographic Estimation of Endotracheal Tube Size with Age-Based Formula in Pediatric Patients a cross sectional randomized study.

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Abstract
Background and Aim of study: Endotracheal intubation in pediatric patients might be challenging due to anatomical variances. One problem is selecting the appropriate size of endotracheal tube for intubation (1). Choosing the right Endotracheal tube size is crucial, especially for young patients. Using an incorrectly sized ETT can have serious consequences, including death. Various methods are used to estimate correct ETT size based on patient demographics, such as age, weight, and height. Some anesthesiologists use the diameter of the little finger for crude estimation. However, these methods have poor agreement with the actual ETT size appropriate for the patient. This study evaluated the efficacy of ultrasonographic assessment of ETT size to the usual age-based calculation.
Material and Method: This cross sectional randomised study was done on 72 patients undergoing elective procedures at the Department of Anaesthesiology, Integral Institute of Medical Sciences, Lucknow, between September 2022 and March 2024, after institutional ethics committee permission.Patients were separated into two groups of 36 each. Group A's ETT size was approximated using Pennington's method. Group B where ETT size was assessed by ultrasonography. The results were evaluated using descriptive statistics and compared between groups. Categorical data were summarized as proportions and percentages (%), whereas discrete data were reported as mean ± SD.
Results: Insertion of ETT estimated by ultrasound had greater rate of successful insertion in first attempt, easy insertion and less postoperative complications when compared to ETT size estimated by Penlington's formula.
Keywords: Ultrasonography, Age-based formula, Endotracheal tube, Airway management, Complication, Pediatric patients.

Introduction:
Maintaining a patent airway is crucial for successful resuscitation and life support efforts. The anaesthesiologist is primarily responsible for managing the airway during anesthesia induction. Endotracheal intubation in pediatric patients might be challenging due to anatomical variances. One problem is selecting the appropriate size of endotracheal tube for intubation (1).

There are several distinctions between the adult and pediatric populations, including:

- The elevated location of the larynx in pediatric patients affects airway management by making the glottic aperture easier to visualize with a straight laryngoscope. (2)
- Children's tongues are larger in proportion to the mouth cavity than adults.(3)
- During general anesthesia, small nasal passages may become clogged with blood or secretions.(3)
- Adenoidal and tonsillar tissue are small at birth but quickly increase during ages 4-7. Hypertrophied tonsils and adenoid tissue may represent the most common cause of upper airway blockage after administration of general anesthesia in children.
- Their epiglottis is omega-shaped, and their vocal cords are arched, making it easier for a blindly passed tracheal tube to lodge in their anterior commissure instead of the trachea.(4)

Aside from the aforementioned variations, the cricoid cartilage is the narrowest section of the upper airway in small children with pharmacologically induced neuromuscular blockade because it cannot stretch as much as the voice cords can. (3) A tracheal tube that could pressure the mucosa on the surface at the level of the cricoid cartilage, which may result in oedema, inflammation, and eventually scarring and stenosis. In a pediatric airway, the effect of 1 millimetre of oedema in the sectional area at the point of the cricoid ring may shrink airway opening by up to 75% (%), but in an adult airway, the reduction is only 19%. (5,6) Since adult patients' airways are broader, it is usually easier to push commonly used tracheal tubes past the glottic aperture. A tracheal tube that readily passes the vocal cords in a newborn or early child may be constricted in the subglottic area due to a considerably larger corresponding narrowing at the midpoint of the cricoid cartilage.

The cricoid cartilage, the narrowest part of the upper airway in children, is crucial in determining the optimum size of an ETT. (7)

Choosing the right size ETT is very critical, since using the wrong size ETT might result in serious mortality and morbidity. A too-large tube may put excessive pressure on the tracheal mucosa, leading in upper airway injury such as ulceration, sore throat, ischaemia, scar formation, post-extubation stridor, In the short term, this can cause mucosal oedema and stridor after extubation, while in the long run, it may contribute to the development of subglottic stenosis.(2,6) A too small ETT, on the other hand, can cause a substantial air leak, higher airway resistance, an increased risk of aspiration, inadequate tidal volume monitoring, anesthetic gas pollution in the operating theatre, reduced minute ventilation, increased struggle of breathing, and reintubation.

Various equations based on age, weight, height, and finger diameter have historically been used in determining adequately sized ETT in pediatric patients, such as,

Age-based formulas are the most popular. Modified Cole's: Age/4 + 4 mmID. Motoyama: Age/4 +3.5 mm ID. Khine's formula Age/4 +3.0 Penlington's: Age/3 + 3.5 mm ID Weight-based formula: kg/10 + 3.5 mm ID. Height-based formula: Height in cm/30 +2 mmID. However, such methods are not always appropriate since the size of the airway varies greatly across individuals, and the minimum diameter cannot be accurately predicted using height or weight.(8)

Pre-anesthesia tracheal diameter measurement is crucial for avoiding unnecessary airway instrumentation and reducing trauma risks. Recently, USG has emerged as a non-invasive, portable, and real-time imaging option for airway control. (9) USG can visualize anatomical features in the supraglottic, glottic, and subglottic areas, allowing for accurate estimation of ETT size. (10)

Using ultrasound to visualize the pediatric airway diameter can help anaesthesiologists forecast ETT size and avoid unnecessary tube change and airway trauma. Cricoid cartilage is a reliable marker for measuring the narrowest diameter. Sagittal sonography reveals uncalcified cricoid cartilage in a pediatric patient as a round or oval structure with varying echogenicity, positioned postero-medial to the thyroid gland.(11) There is limited research on using USG to estimate ETT size in pediatric patients. This study compares the accuracy of USG-guided tracheal diameter measurement in predicting ETT size in pediatric patients to an age-based estimation.

Aim and objectives: The study aimed to compare Ultrasonographic Estimation of Endotracheal Tube Size with an Age-Based Formula in Paediatric Patients. The primary goal was to estimate and analyse the accuracy of endotracheal tube size using ultrasound guidance, taking into account ease of insertion, number of attempts, and the necessity for tube size change. To compare data obtained from both groups. And assess any post-operative problems.

Material and Method: This study was done on 72 patients undergoing elective procedures at the Department of Anaesthesiology, Integral Institute of Medical Sciences, Lucknow, between September 2022 and March 2024, after institutional ethics committee permission. A cross-sectional randomised research was done on all paediatric patients receiving general anaesthesia. Patients were separated into two groups of 36 each. Group A's ETT size was approximated using Pennington's method. Group B where ETT size was assessed by ultrasonography. ● Patient of either gender. ● Age between 1 and 6 years and ASA status of I,II,and III Were included in the study while those with a history of difficult airway or intubation, congenital airway anomalies, ASA Grade IV and Weight < 3 kg or > 25 kgwere excluded from the research.

Guardians of individuals aged 1–6 years with ASA status I, II, or III provided written informed consent for procedure under general anesthesia. Patients were then anesthetized according to our institutional protocol. All patients had a regular pre-anesthetic checkup. We conducted a thorough medical history, general examination, and routine patient examinations. Children were given either oral midazolam (0.5 mg/kg) or nasal midazolam spray (0.3 mg/kg) as a premedication. In Group A, Pennington's formula was used to estimate the ETT size. ETT size depends on age (1-6 years) (Penlington's formula) ID in mm = age (years) / 3 + 3.5. In Group B, we employed ultrasonography to estimate the right size ETT. To measure subglottic diameter, a USG machine with a high-resolution linear probe (40 mm length, frequencies 6-13 MHz) was positioned on the midline of the anterior neck while the head was stretched and the neck was flexed (sniffing posture). We examined the cricoid cartilage and voice chords. We examined the transverse air column diameter at the bottom edge of cricoid cartilage, also known as subglottic tracheal diameter, to estimate the outer diameter of the endotracheal tube. The results were evaluated using descriptive statistics and compared between groups. Categorical data were summarized as proportions and percentages (%), whereas discrete data were reported as mean ± SD.

Observation and results: The current data does not show significant t-test results, hence the null hypothesis is kept hence It is believed that both samples come from the same population.Patients in Group A had a mean age of 4.22 ± 1.63 years, while those in Group B had a mean age of 4.29 ± 1.58 years, ranging from 1 to 6 years old.Group A recruited 26 males (72.22%) and 10 females (27.78%), whereas Group B had 19 males (52.78%) and 17 females (47.22%). The total male/female ratio was 1.66:1.Patients in Group A had a mean weight of 13.19 ± 3.91 Kg, with a maximum weight of 20 Kg and a minimum weight of 6 Kg. In Group B, the mean weight was 13.89 ± 3.54 Kg, with a maximum weight of 20 Kg and a minimum of 7 Kg.In Group A, the average height was 99.47 ± 13.07 cm, with a maximum of 117 cm and a minimum of 67 cm. In Group B, the average height was 100.31 ± 12.73 cm, with a maximum of 120 cm and a minimum of 12.73 cm.

In Group A, 83.3% of patients were intubated in the very first attempt, 13.8% in the second attempt, and 2.7% required three attempts to be effectively intubated.In contrast, in Group B, 94.4% of patients were successfully intubated in the first attempt, with just 5.5% requiring another go and no patients requiring a third attempt.In Group A, 80.5% of patients were smoothly intubated, whereas 19.4% had difficulties successfully intubating. In group B, however, the majority (94.4%) of patients were easily intubated, with only 5.5% experiencing difficulties.Group A had post-operative problems such as post-extubation bronchospasm in 1.3%, sore throat in 4%, and mucosal edema in 1.3% of the study group. In Group B, just 2.7% of patients experienced sore throats, with no additional problems reported.

Discussion: Recent research have explored the use of Ultrasonography to accurately estimate the size of ETTs. Predicting the exterior diameter of an ETT is a more reliable guide for selecting the appropriate size compared to estimating the interior diameter using various methods. This is because the outer diameter of an ETT from different companies might differ. Ultrasonography for airway assessment has the advantage of not requiring strict immobility, unlike MRI. However, operator expertise and training are required. This research compared the efficiency of Ultrasonography for determining endotracheal tube size to the usual age-based determination (Penlington formula) for paediatric patients aged 1 to 6 years undergoing general anaesthesia.

Our study included 72 patients separated at random into two groups using computerised randomisation. Both groups had comparable age, weight, and height. No patients were excluded from the study. The average age of patients in this study was 4.25± 1.60 years, with a male predominance (62% male and 38% female). This is comparable to a study conducted by Neha Bhardwaj et al. (6), which found 32% female and 68% male patients aged 2-6 years. Makireddy et al. (12) studied 43 individuals with an average age of 3.1 years and a range of 2 to 6 years, with a female predominance. Gunjan et al. (13) studied 100 individuals with an average age of 3.47 years, ranging from 1 to 5 years. Gehlaut et al.(14) studied 64 paediatric patients with an average age of 5.9 years and a range of 2 to 12 years. Altun et al.(10) studied 50 children, with an average age of 5.3 years and a range of 2 to 8 years. In this study, the average weight and height were 13.1 kg and 100 cm, respectively, which were similar to those reported by Bae et al. (8), who had a mean weight of 16.2 kg and a mean height of 98 cm. Another study by Gunjan et al.(13) reported mean height of 94.1 cm. Study by Subramani et al.(15) reported mean weight of 12.89 kg and mean height of 94.14 cm.

In our study Penlington formula predicted correct size ETT in 80% patients and required change of tube size in 19% cases. In most cases tube size was overestimated by the formula used. Whereas Ultrasonographic estimation of ETT resulted in correct prediction in 94.4% instances and only 5.6% needed adjustment of tube size. The outcomes of our study was similar with Nandini K et al.(9) where Age based formula predicted accurate ETT size in 75.6% patients while ultrasonography predicted proper ETT size in 94% patients. Study by Neha Bharadwaj et al. (6) found that ultrasonography had a 90% agreement rate in estimating ETT, whereas an age-based formula had a 56% agreement rate. Jagdish G Sutagatti et al. (7) found 89.3% accuracy in ultrasound-estimated ETT size and 75.3% accuracy in age-based size estimation. In contrast, Makireddy et al. (12) found that an age-based formula accurately predicted ETT size in 73% of patients, whereas ultrasonography only did so in 70%. ETT size calculated by Pennington formula resulted in successful intubation in first attempt in 83.3%, 13.8% patients were intubated in second attempt and 2.7% required 3 attempts for successful intubation whereas 94.4% patients successfully intubated in first attempt and only 5.5% required second attempt for successful intubation, no patient required third attempt in ETT size estimated by USG. These findings were consistent with Nandini K et al.(9) where 94% patients were intubated in first attempt and 6% required second attempt in ETT size calculated by ultrasound. On contrary another study by Gehlaut et al.(14)

reported successful intubation in 80%, 14% and 6% at first, second and third attempt respectively. A total of 7 patients reported post operative complications in both group ETT estimated by penlington formula resulted in sore throat in 4%, Mucosal edema in 1.3% and post extubation bronchospasm in 1.3% due to use of over-estimated tube estimated by Penlington's formula. Whereas only sore throat in 2.7% patients encountered in ETT size estimated by ultrasonography. Occurrence of sore throat is attributable to use of endotracheal tube irrespective of size of ETT used for intubation, Hence association of sore throat with either of modality used for ETT size estimation can not be established. Findings of our study were consistent with Koka et al.(16) where croup was reported as post operative complications in 1% patients which was due to tight fitting ETT and more than 1 attempt at intubation. Another study by Subramani et al.(15) reported incidence of post extubation laryngospasm in 1.33% of patients as post operative complication. Study by Lee at al. reported 7.6% incidence of croup as post operative complication.

Conclusion: In pediatric anesthesia, selecting the appropriate size ETT is critical for airway management. Various approaches have been employed in the past to determine the right size ETT, including physical indices such as age, weight, and height. Recently, ultrasonography has entered the scene, leading to substantial advances in airway examination. Ultrasonography is a simple, non-invasive real-time method that has been shown to be extremely beneficial for airway evaluation in the paediatric population. There is a high association between ultrasound and MRI assessments of subglottic diameter. Our study suggests that using ultrasonography to estimate endotracheal tube size is more accurate than using an age-based algorithm. Ultrasound assessment of subglottic diameter can prevent needless tube changes caused by inaccurate tracheal tube size. Ultrasonography improves prediction of optimum ETT size and reduces difficulties caused by incorrect tube size or frequent adjustments.The limitation in this study includes limited age group of enrolled patients, variability in tube size due to equipment quality and operators experience and disproportionate variation in age and weight of children.

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