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CORRELATION BETWEEN ULTRASOUND-GUIDED SUBGLOTTIC DIAMETER AND MID GLOTTIC TRANSVERSE DIAMETER WITH THE OUTER DIAMETER OF THE ENDOTRACHEAL TUBE IN PAEDIATRIC POPULATION

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ABSTRACT

Background: Pediatric airway management presents unique anatomical challenges. Traditionally, age-based formulae have been used to determine endotracheal tube (ETT) size, but their effectiveness has been debated. Ultrasound offers a non-invasive and potentially more accurate means of predicting appropriate ETT size. This study explores the correlation between ultrasound-guided measurements (subglottic and mid-glottic transverse diameters) and the outer diameter of ETT calculated using age-based formulas in children. **Materials and Methods:** In this prospective observational study, 30 children aged 4-8 years scheduled for elective surgery under general anesthesia were evaluated. Subglottic diameter and mid-glottic transverse diameter were measured using ultrasound prior to intubation. The ETT size was determined via Penlington's age-based formula, and the outer diameter was compared against ultrasound measurements. Statistical analyses included Pearson's correlation and linear regression. **Result:** The sample included 21 males (70%) and 9 females (30%). Urological procedures constituted 63.3% of cases, with the rest comprising orthopaedic, gastrointestinal, and ENT surgeries. Strong positive correlations were observed: subglottic and mid-glottic diameters ($r=0.9827$), mid-glottic diameter and ETT size ($r=0.9848$), and subglottic diameter and ETT size ($r=0.9727$). Regression analysis yielded predictive formulas: Outer ETT diameter = 0.9720 × Subglottic diameter – 0.5521. Outer ETT diameter = 0.9606 × Mid-glottic transverse diameter – 0.003296. Both relationships were statistically significant ($p<0.0001$). **Conclusion:** Ultrasound measurements of both subglottic and mid-glottic transverse diameters show a strong correlation with age-based ETT outer diameter, supporting the use of ultrasound as an alternative or adjunct in ETT size selection. This method may improve precision and safety in pediatric airway management.

INTRODUCTION

Effective and safe airway management in pediatric anesthesia is critical, given the distinct anatomical and physiological differences between children and adults. The pediatric airway is funnel-shaped, with a relatively narrow subglottic region that is especially susceptible to trauma and complications from inappropriate tube sizing. Traditional practice relies on age-based formulae (e.g., Penlington's, Cole's, Khine's); however, recent advancements suggest that ultrasound imaging provides a more personalized approach, allowing direct measurement of airway diameters relevant for ETT sizing.

MATERIALS AND METHODS

Study Design & Population: Prospective observational study performed at the Institute of Child Health and Hospital, Madras Medical College, Chennai, with institutional ethical committee approval (Ref. No. 18092023).

Subjects: Children aged 4–8 years (n=30) scheduled for elective surgery under general anesthesia, ASA grade I/II. Exclusion criteria: difficult airway, ASA III/IV, parental refusal.

Procedure: Standard anesthesia induction was followed. A linear ultrasound probe was placed on the anterior neck to measure:

- Subglottic diameter: transverse air column at the cricoid cartilage
- Mid-glottic transverse diameter: measured at the level of the true vocal folds

Endotracheal tube size was calculated using Penlington's formula, and corresponding outer diameters were recorded. Three readings were averaged for final values.

Data Collection: Demographics, diagnosis, procedure, ASA status, ETT size (calculated and used), ultrasound diameters, and perioperative details were recorded in a master chart.

Statistical Analysis: Descriptive statistics for patient variables. Pearson's correlation coefficients assessed relationships between ultrasound measurements and ETT size. Linear regression provided predictive models for outer ETT diameter.

RESULTS

Demographics & Clinical Characteristics:

- Age distribution: evenly spread (Mean ± SD: 6 ± 1.6 years)
- Gender: 70% male, 30% female
- Weight: Mean ± SD varied with age, showing expected growth trends
- ASA status: 46.67% ASA I, 53.33% ASA II
- Surgical specialties: 63.33% urological, 16.67% orthopaedic, 10% gastrointestinal, 10% ENT

Airway Diameters

Age in years		Sub-glottic diameter	Mid-glottic Transverse diameter Median [IQR]	Outer ETT diameter (mm) Median [IQR]	ETT size (mm ID) Median [IQR]
4 (n=8)	Median [IQR]	7 [6.875, 7.05]	6.5 [6.4, 6.6]	6.2 [6.2, 6.2]	4.5 [4.5, 4.5]
	Mean + SD	6.988 ± 0.155	6.513 ± 0.113	6.2 ± 0	4.5 ± 0
5 (n=4)	Median [IQR]	7.4 [7.35, 7.45]	6.95 [6.825,7.05]	6.8 [6.8, 6.8]	5 [5, 5]
	Mean + SD	7.4 ± 0.163	6.925 ± 0.25	6.8 ± 0	5 ± 0
6 (n=6)	Median [IQR]	8.4 [8.325, 8.475]	7.95 [7.825, 8]	7.4 [7.4, 7.4]	5.5 [5.5, 5.5]
	Mean + SD	8.5 ± 0.358	7.833 ± 0.273	7.4 ± 0	5.5 ± 0
7 (n=4)	Median [IQR]	8.9 [8.8, 9]	8.6 [8.55, 8.6]	8.2 [8.2, 8.2]	6 [6,6]
	Mean + SD	8.9 ± 0.115	8.55 ± 0.1	8.2 ± 0	6 ± 0
8 (n=8)	Median [IQR]	9.5 [9.4, 9.6]	9.05 [9, 9.02]	8.8 [8.8, 8.8]	6.5 [6.5, 6.5]
	Mean + SD	9.475 ± 0.149	9.088 ± 0.099	8.8 ± 0	6.5 ± 0

The above table represents measurements related to age and various anatomical diameters, primarily focused on sub-glottic and mid-glottic transverse diameters, as well as outer and inner endotracheal tube (ETT) diameters.

- **Subglottic diameter:** Mean values increased with age
- **Mid-glottic diameter:** similar trend as subglottic diameter
- **Outer ETT diameter (by Penlington's formula):** median 6.2mm across age groups

Comparison of correlation between diameters

Correlation pair	Pearson's r	Interpretation
Suglottic and midglottic diameters	0.9827	Very strong correlation
Midglottic and endotracheal tube size	0.9848	Very strong correlation
Subglottic and endotracheal tube size	0.9727	Very strong correlation

Linear Regression Formulae:

- **Subglottic:** Outer ETT diameter (Y) = 0.9720×Subglottic diameter (X) – 0.5521
- **Mid-glottic:** Outer ETT diameter (Y) = 0.9606×Mid-glottic diameter (X) – 0.003296

All regression models were statistically significant ($p<0.0001$). The study found that subglottic and mid-glottic diameters measured by ultrasound closely predicted the required outer diameter of ETT, suggesting interchangeable utility of these measurements for tube size selection.

DISCUSSION

Numerous studies have been conducted focusing on the application of ultrasound in airway management, both in adult and pediatric populations. These studies explore various aspects of ultrasound-guided techniques, including but not limited to:

1. **Identification of Airway Structures:** Ultrasound allows for real-time visualization of key airway structures, facilitating accurate identification of anatomical landmarks such as the epiglottis, vocal cords, trachea, and surrounding tissues.
2. **Assessment of Pathologies:** Ultrasound imaging aids in the diagnosis and assessment of airway pathologies such as masses, cysts, stenosis, and edema, providing valuable insights for treatment planning and management.
3. **Confirmation of Procedures:** Ultrasound can be used to confirm the proper placement of endotracheal tubes, tracheostomy tubes, and other airway devices, reducing the risk of complications such as oesophageal intubation or malpositioning.
4. **Guidance for Interventions:** Ultrasound-guided techniques can assist in performing various airway interventions, including nerve blocks, tracheostomy, percutaneous dilatational tracheostomy, and cricothyrotomy, with improved precision and safety. 5. Monitoring During Procedures: Ultrasound allows for continuous monitoring of airway structures and dynamics during procedures such as intubation, extubation, and airway manipulation, enabling prompt detection and management of complications.

This study supports previous evidence that ultrasound-guided measurement of airway diameters provides a reliable and individualized method for ETT size selection in pediatric patients. Given the anatomical variability in children—even within the same age group—relying solely on age-based formulas may risk under- or over-sizing, potentially leading to airway trauma or inadequate ventilation.

Ultrasound is non-invasive, provides real-time imaging, and is adaptable at the bedside. Although measuring the glottic diameter may require more expertise due to small airway dimensions, both subglottic and mid-glottic diameters proved highly predictive of appropriate ETT sizing.

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Clinical Implications:

- Ultrasound can complement or replace age-based formulas for ETT size selection, especially in children aged 4–8 years.
- Both subglottic and mid-glottic diameters are useful; choice can be based on operator experience and measurement accessibility.
- Standardizing ultrasonography techniques and further research to validate formulas in larger, diverse populations is warranted.

Limitations:

- Limited sample size (n=30)
- Study included only healthy children without airway abnormalities
- Results may not fully generalize to older children or those with abnormal airways.

CONCLUSION

Ultrasound-guided measurement of both the subglottic and mid-glottic transverse diameters correlates strongly and significantly with the outer diameter of endotracheal tubes calculated by age-based formulas. This finding endorses the clinical utility of airway ultrasonography in personalized pediatric airway management, potentially minimizing complications and improving intubation safety.

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