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Original Research Article

PREDICTING ENDOTRACHEAL TUBE SIZE IN PEDIATRIC PATIENTS: A COMPARATIVE ANALYSIS OF AGE -BASED FORMULAS AND ULTRASOUND TECHNIQUES

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ABSTRACT

Background: Accurate selection of endotracheal tube (ETT) size in paediatric patients is critical to ensure safe and effective airway management. Traditional age-based formulas, such as the Motoyama formula, may not account for individual anatomical variations. **Aim:** This study aimed to evaluate the reliability of ultrasonography (USG) in determining the appropriate ETT size and compare it with the Motoyama formula.

Materials and Methods: A prospective observational study was conducted on 64 paediatric patients aged 2–12 years undergoing elective surgeries under general anaesthesia at a tertiary care hospital in Gujarat. Subglottic diameter was measured using ultrasonography, and the appropriate ETT size was selected accordingly. This was compared with the size predicted by the Motoyama formula. The number of ETT changes required, time taken for USG, and clinically best-fit tube based on air leak test were recorded.

Results: The mean subglottic diameter measured by USG was larger than the inner diameter predicted by the Motoyama formula. USG-based selection showed fewer tube changes and better correlation with the clinically best-fit ETT. The average time taken for USG was brief, supporting its feasibility in routine clinical practice.

Conclusion: Ultrasonographic assessment provides a more accurate and individualized method for selecting ETT size in paediatric patients compared to traditional age-based formulas. Its routine use can enhance safety and efficiency in paediatric airway management.

Keywords: Ultrasonography, Endotracheal Tube, Paediatric Airway.

INTRODUCTION

Airway management is a cornerstone of safe anaesthesia practice, particularly in paediatric patients, where anatomical variability and smaller airway dimensions pose unique challenges. Choosing the correct size of endotracheal tube (ETT) is critical, as undersized tubes can lead to inadequate ventilation and increased airway resistance, while oversized tubes can cause trauma, subglottic edema, or stenosis.[1]

Traditionally, anaesthesiologists have relied on age-based formulas to estimate the appropriate size of ETT. Among these, the Motoyama formula—Outer Diameter (OD) = (Age/4) + 4—is widely used for paediatric patients.[2] While convenient, this formula does not account for individual anatomical variations, such as differences in subglottic diameter, weight, or growth patterns, which may reduce its accuracy, particularly in younger age groups.[3]

Ultrasonography has emerged as a non-invasive, real-time imaging modality that offers the potential to measure airway structures directly, particularly the subglottic diameter, which correlates well with the appropriate ETT size.[4] Several studies have demonstrated the utility of ultrasonography in predicting the optimal ETT size, suggesting it may be more accurate than age- or height-based formulas.[5,6]

In clinical settings where rapid and accurate airway management is required, especially in paediatric anaesthesia, the use of ultrasonography could enhance patient safety and reduce complications.[7] Furthermore, the portability, ease of use, and absence of radiation make ultrasound a suitable bedside tool for routine use in pre-anaesthetic airway evaluation.[8]

A growing body of literature supports the use of ultrasound-guided airway assessment in children. Research has shown that ultrasound-based measurements closely correlate with the actual outer diameter of the ETT used, with a lower incidence of tube changes or airway trauma compared to traditional methods.[9]

The present study was undertaken at a tertiary care hospital in Gujarat to investigate the reliability of ultrasonography in determining the appropriate size of ETT in paediatric patients. The study also aimed to compare this method with the conventional age-based Motoyama formula in terms of accuracy for outer diameter selection of the endotracheal tube. The findings of this study may provide valuable insights into the practical integration of ultrasonography into routine paediatric airway management and its potential to improve clinical outcomes.

MATERIALS AND METHODS

This was a prospective, observational, comparative study conducted at a tertiary care hospital in Gujarat over a period of one year. The Institutional Ethics Committee approved the study, and informed written consent was obtained from the parents or legal guardians of all participating children.

A total of 50 paediatric patients aged between 2 to 12 years, scheduled to undergo elective surgical procedures under general anaesthesia requiring endotracheal intubation, were included in the study.

Inclusion Criteria

- Children aged 2 to 12 years
- American Society of Anesthesiologists (ASA) physical status I or II
- Undergoing elective surgery under general anaesthesia requiring orotracheal intubation

Exclusion Criteria

- Patients with known or suspected airway abnormalities
- Emergency surgeries
- History of difficult intubation
- Children with neck masses or any congenital anomalies affecting the airway

Procedure

All patients were evaluated preoperatively. Demographic data including age, weight, and height were recorded. Preoperatively, ultrasonographic measurement of the transverse subglottic diameter was performed using a high-frequency linear probe (6–13 MHz). The child was placed in a supine position with the neck extended slightly. The probe was placed transversely at the level of the cricoid cartilage to measure the subglottic diameter, which is considered the narrowest portion of the paediatric airway.

Estimation of ETT Size

Two methods were used to estimate the appropriate outer diameter (OD) of the endotracheal tube:

- **Ultrasound Method**: Based on the measured subglottic diameter, an uncuffed ETT was selected such that its outer diameter was equal to or just less than the measured subglottic diameter.
- **Motoyama Formula**: The outer diameter was calculated using the formula OD = (Age/4) + 4.

Intubation and Confirmation

General anaesthesia was induced as per standard protocols. Endotracheal intubation was performed using the tube size determined by the ultrasound method. Proper tube placement was confirmed by auscultation and capnography. The presence or absence of an air leak at airway pressures of 20–25 cm H_2 O was noted. If there was an excessive leak or resistance during ventilation, the tube was changed, and the need for tube exchange was recorded.

Data Collection and Statistical Analysis

The following data were recorded for each patient:

- Age, weight, height
- Ultrasonographically measured subglottic diameter
- ETT size determined by both ultrasound and Motoyama formula
- Actual ETT used
- Number of tube changes if any

Statistical analysis was done using SPSS software. The agreement between the ETT size predicted by ultrasonography and the Motoyama formula was evaluated. Sensitivity, specificity, and accuracy of both methods were calculated with respect to the actual ETT used. A p-value <0.05 was considered statistically significant.

RESULTS

Table 1 shows the demographic characteristics of the study population. The mean age of the participants was 7.42 ± 2.65 years. Among the 64 children enrolled, 56% were males and 44% were females. The average weight was 22.63 ± 6.48 kg, while the mean height was 119.87 ± 14.62 cm. The mean Body Mass Index (BMI) was 15.65 ± 2.37 kg/m². These values provide a baseline understanding of the paediatric population included in the study.

Table 2 presents the changes in hemodynamic parameters — including heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), oxygen saturation (SpO_2), and end-tidal carbon dioxide ($EtCO_2$) — recorded at baseline, after induction, post-intubation, and at 10, 20, and 30 minutes following intubation. Additionally, the

table includes the mean endotracheal tube (ETT) size calculated using the age-based Motoyama formula, the subglottic diameter measured via ultrasonography, and the actual outer diameter of the ETT used.

Table 3 presents the comparison of subglottic diameter measured using ultrasonography (USG) and corresponding outer and inner diameters of the endotracheal tubes (ETTs). It also includes the clinically best-fit ETT determined by the air leak test and the inner diameter of ETT calculated using the age-based Motoyama formula. Additionally, the meantime required to perform the ultrasound assessment of the airway is documented.

Table 4 shows the number of patients in whom endotracheal tube (ETT) changes were required following ultrasonographic estimation. The majority of patients (70.31%) did not require any tube change, while 20.31% required one change, and 9.38% required two changes. The mean number of changes was 0.41 ± 0.63.

Table 1: Demographic Characteristics of Study Population (n = 50)

Parameter	Value
Mean Age ± SD	7.42 ± 2.65 years
Male : Female	36 : 28 (56% males, 44% females)
Mean Weight ± SD	22.63 ± 6.48 kg
Mean Height ± SD	119.87 ± 14.62 cm
BMI ± SD	15.65 ± 2.37 kg/m²

Table 2: Hemodynamic Parameters and Airway Measurements at Various Time Points

Parameter	Baseline	After Induction	After ET Intubation	After 10 min	After 20 min	After 30 min
HR ± SD (bpm)	102.31 ± 6.89	108.54 ± 7.32	119.73 ± 6.45	107.18 ± 5.74	101.49 ± 4.92	99.64 ± 5.11
SBP ± SD (mmHg)	115.42 ± 4.11	110.37 ± 3.68	118.63 ± 4.02	113.02 ± 3.33	111.47 ± 3.15	114.26 ± 4.37
DBP ± SD (mmHg)	80.65 ± 3.72	76.39 ± 3.29	84.21 ± 3.91	79.58 ± 2.87	77.81 ± 2.58	82.13 ± 2.94
SpO_2 ± SD (%)	99.8 ± 0.2	99.9 ± 0.1	98.6 ± 0.8	99.5 ± 0.4	99.7 ± 0.3	99.8 ± 0.2
$EtCO_2$ ± SD (mmHg)	34.15 ± 1.95	35.92 ± 2.41	38.74 ± 2.76	37.65 ± 2.02	36.89 ± 1.85	37.11 ± 1.67

Table 3: Comparison of Subglottic Diameter, ETT Sizes, and Time Taken for Ultrasonography

Measurement	Mean ± SD
Subglottic diameter measured by USG (in mm)	8.02 ± 1.25
OD of ETT corresponding to USG measured subglottic diameter (in mm)	7.92 ± 1.15
ID corresponding to OD (in mm)	5.84 ± 0.69
Clinically best fit ETT used as determined by air leak test (in mm)	5.78 ± 0.71
ID of ETT calculated by age based Motoyama formula (in mm)	5.33 ± 0.77
Total time taken for USG (in seconds)	14.37 ± 1.89

Table 4: Frequency of Endotracheal Tube (ETT) Change Based on Ultrasonographic Estimation

No. of times change of ETT required	N	%
0	45	70.31%
1	13	20.31%
2	6	9.38%
Total	64	100%

DISCUSSION

The accurate selection of endotracheal tube (ETT) size is essential in paediatric anaesthesia to ensure optimal ventilation and minimize airway-related complications. Traditionally, age-based formulas such as the Motoyama formula have been widely used to estimate ETT size in children. However, these methods are often limited by inter-individual anatomical variation and may not always provide a precise fit.[11]

In the present study, we found that ultrasonographic (USG) measurement of the subglottic diameter offered a more individualized and reliable approach for predicting the appropriate ETT size. The mean subglottic diameter measured via USG in our cohort was higher than the internal diameter calculated using the age-based Motoyama formula, suggesting that the formula may underestimate the required tube size in certain children. These findings are consistent with prior studies that have demonstrated a better correlation between USG-measured diameters and the actual outer diameter of the best-fitting ETT.[12]

One notable observation in our study was the lower rate of ETT changes when USG was used for size prediction. Only 29.69% of cases required any change of tube, with a mean of 0.41 ± 0.63 changes per patient. This supports the premise that ultrasound-based selection reduces the need for intraoperative adjustments, thereby potentially lowering the risk of trauma and prolongation of induction time.[13]

Furthermore, the average time taken for airway ultrasonography in our study was approximately 14 seconds, which indicates its feasibility for routine

pre-induction assessment. This agrees with previous findings that support USG as a quick, non-invasive, and reproducible technique in paediatric airway management.[14]

Our findings highlight the clinical advantage of incorporating USG into standard practice, especially in centres where paediatric anaesthesia is routinely performed. While traditional formulas like Motoyama's are helpful, ultrasonography adds a layer of precision that is particularly valuable in complex or borderline cases. This is especially important in the context of increasing use of cuffed ETTs in paediatric patients, where accurate sizing becomes even more critical to prevent subglottic injury.[15]

CONCLUSION

In conclusion, ultrasonography proves to be a superior tool in predicting optimal ETT size in paediatric patients when compared with conventional age-based formulas. Its use can minimize airway complications, reduce tube changes, and enhance patient safety.

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