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Correlation between correctly sized uncuffed endotracheal tube and ultrasonographically determined subglottic diameter in pediatric population

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ABSTRACT

Background: The size of the airway varies greatly in pediatric patients, making it difficult to predict an appropriate size Endotracheal tube (ETT) for securing the airway. Several formulae are used to predict approximate ETT size. With the wider availability of ultrasonography (USG), many clinicians have suggested it as a useful tool for airway management and have used USG to measure tracheal dimensions in adults and children. **Aims and Objectives:** The primary aim of this study was to evaluate the usefulness of USG for the selection of correct sized uncuffed ETT in pediatric patients and the secondary aim was to correlate the age-based formula with ultrasound measured subglottic diameter for predicting the size of ETT. **Materials and Methods:** A total of 64 patients of either gender in the age group of 2–6 years were enrolled in the study. Standard anesthetic induction was done and transverse subglottic diameter was measured using USG. The minimal transverse subglottic diameter was measured and noted and the patient was intubated with the tube size as determined by modified Cole's age-based formula. **Results:** Out of 64 patients, 33 were male and 31 female. Average age was 3.9 (±1.47) years, 42.2% belonged to the age group of (2–3) years, average weight of the patients was 20.3 (±10.45) kg. The mean ETT outer diameters (OD) based on age-based formula was 6.81 mm compared to 6.91 mm and 6.78 mm by USG based and actual ETT OD, respectively. Both the age based ETT OD and USG-based ETT OD showed good correlation with actual ETT OD used with r-value of 0.891 and 0.876, respectively. **Conclusion:** Although USG is a non-invasive, cost-effective, and reproducible technique its routine use for estimating ETT size in pediatric patients could not be justified over age-based formula as both of them have comparable results (statistically insignificant). The success rate of age-based formula and USG in precisely predicting ETT outer diameter is comparable with the size of actual ETT outer diameter (78% vs. 75%, P=0.86).

Key words: Airway ultrasonography; Endotracheal tube size estimation; Pediatric airway; Pediatric anesthesia

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INTRODUCTION

Endotracheal intubation is the gold standard for airway management during anesthesia. Intubation helps in the delivery of anesthetic gases and medications, the provision of positive pressure ventilation, and, most importantly, the isolation of the respiratory system from the gastrointestinal system, which lowers the risk of aspiration.[1] However, securing airway with an appropriate size endotracheal tube (ETT) can occasionally prove challenging in pediatric patients.

The size of the airway varies greatly with the age, height, and weight of pediatric patients, making it difficult to predict an appropriate size ETT for securing the airway.[2] Undersized

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ETT may cause air leak, hypoventilation and predispose to aspiration whereas oversized ETT can lead to increased sympathetic stimulation, mucosal edema, subsequent necrosis, and even tracheal stenosis.[3] Several formulae based on age, weight, height, and finger size have been developed over time to predict approximate ETT size and reduce the morbidity related to improper ETT size. However, these formulae are not always accurate and many times leading to multiple laryngoscopies and ETT changes. This may lead to increased risk of adverse airway outcomes.[4]

The appropriate size of the ETT is best judged at laryngoscopy and then checking for any peri-tubal air leak. However, with the wider availability of ultrasonography (USG) many clinicians have suggested it as a useful tool for airway management and have used USG to measure tracheal dimensions in adults and children.[5] Ultrasonographic assessments of the transverse tracheal diameter at the level of the cricoid cartilage has shown a substantial association with magnetic resonance imaging based measurements.[6] Besides, it is a simple and non-invasive real-time tool available at the point of care and can prove valuable in assessing airway anatomy. Since the narrowest diameter of the upper airway in pediatric patients is the subglottic region, ultrasound examination and measurement of the transverse diameter at the level of cricoid ring can be used for assessing the appropriate size of ETT.[7]

The primary aim of this study is to evaluate the usefulness of USG for the selection of correct sized uncuffed ETT in pediatric patients, and the secondary aim was to correlate the age-based formula with ultrasound measured subglottic diameter for predicting the size of ETT. Our hypothesis was that USG-based airway assessment for predicting ETT size will be superior to formula-based assessment of ETT and thus its routine use can reduce incidence of adverse airway events due to improper ETT size.

Aims and objectives

The primary aim of this study was to evaluate the usefulness of ultrasonography for the selection of correct sized uncuffed endotracheal tube in pediatric patients and the secondary aim was to see correlation between the age-based formula and ultrasound based size of endotracheal tube.

MATERIALS AND METHODS

This prospective, observational study was conducted in the Pediatric division of the Department of Anesthesiology at a tertiary care university (Deemed) hospital in north India. This study was conducted from November 2021 to November 2022 with prior approval from Institutional Ethics Committee (RP 196/2021). Written informed consent was obtained from the parents/guardians of each child for participation in this study.

A total of 64 patients of either gender in the age group of 2–6 years, with apparently normal airway, ASA class I and II, scheduled for elective surgeries requiring general anaesthesia with muscle relaxation and endotracheal intubation were selected for this study. Patients with known allergy to ultrasound gel, surgery on head and neck, pre-existing laryngeal disease ASA class III and IV anticipated difficult airway were excluded from the study.

On the day of surgery, patients were received in the operating room's holding area. Fasting status, any new clinical findings, and written informed consent were checked and confirmed before shifting the patient to the operation theatre. ETT size was calculated for each patient as per modified Cole's age-based formula.[8] ASA standard monitoring was started and patients were induced with Inhalational (sevoflurane) or intravenous (propofol 2 mg/kg) agents and neuromuscular blockade achieved with a non-depolarizing muscle relaxant (atracurium 0.5 mg/kg). At this stage, the transverse subglottic diameter was measured using a linear ultrasound probe of frequency 6–13 MHz (SonoSite Edge II FUJIFILM SonoSite, Inc) at the level of subglottis (cricoid cartilage), keeping the head in slight extension. The minimal transverse subglottic diameter was measured and noted. The patient was intubated with the tube size as determined by formula. After securing airway with ETT a leak test was performed by inflating the lungs to a pressure of 30 cm H_2O and then gradually decreasing the inflation pressure by opening the pop-off valve till no audible air leak was detected.

The presence of air leak was assessed by closing off the pop-off valve and allowing pressure to rise slowly until an audible leak was heard using a stethoscope. The ETT was changed to 0.5 mm smaller size if there is no leakage at 25 cm H_2O and to 0.5 mm larger size if there is a leak even below 15 cm H_2O. Airway pressure was not increased beyond 35 cm H_2O to avoid barotrauma. The optimal ETT size is the one which have no audible leakage below a pressure of 10 mm H_2O and with an audible leakage around the tube at an inspiratory airway pressure of 15–30 cm H_2O with the head and neck in a neutral position.

Age, gender, weight, type of surgery, anesthesia time, and surgery time were recorded in all patients.

In our study, we used RUSCH (Teleflex Medical Inc) uncuffed ETT s of sizes, 4, 4.5, 5, 5.5 and 6 corresponding to outer diameters (OD) of 5.3, 6, 6.7, 7.3, and 8 mm, respectively. The calculated size of ETT by age-based formula was compared to the size chosen by USG.

Statistical methods

The recorded data were compiled and entered in a spreadsheet (Microsoft Excel) and then exported to data editor of SPSS Version 20.0 (SPSS Inc., Chicago, Illinois, USA). Continuous variables were expressed as Mean (±SD) and categorical variables were summarized as frequencies and percentages. Graphically, the data were presented by bar and line diagrams. Student's independent t-test or Mann-Whitney U-test, whichever feasible, was employed for comparing continuous variables. Chi-square test was applied for comparing categorical variables. Karl Pearson's correlation coefficient was used to determine correlation of actual ETT size with various parameters. A P<0.05 was considered statistically significant.

RESULTS

A total of 64 patients, 33 males and 31 females, were included in the study. The average age of participants was 3.9 (±1.47) years, the majority of patients (42.2%) belonged to the age group of (2–3) years, followed by 15.6%, 21.9%, and 20.3% belonging to the age groups of >3–4, >4–5, and >5–6 years respectively. The average weight of the participants was 20.3 (±10.45) kg with the range of 8 to 45 kg (Table 1).

The mean (±SD) ETT OD calculated by age-based formula was 6.81 (±0.571) mm compared to 6.91(±0.631) mm and 6.78 (±0.612) mm by USG-based and actual ETT OD, respectively. The ETT OD size was comparable between age-based ETT OD method and the actual ETT OD used with P=0.811. When ETT OD size was calculated by USG, it was found comparable with actual ETT OD used with P=0.239. Similarly, the difference between age based ETT OD method and USG based method was statistically insignificant with P=0.327 (Table 2).

Both the age-based ETT OD and USG-based ETT OD showed good correlation with actual ETT OD used with r-value of 0.891 and 0.876, respectively. Association of age and weight with actual ETT OD used was significant, with P<0.001 (Table 3).

When the accuracy of age-based formula and USG-measured subglottic diameter in predicting ETT size was assessed, it was found that the age-based formula correctly predicted ETT size in 78.1% of the cases, however; age-based formula overestimated the ETT size in 12.5% and underestimated in 9.4% of the cases. USG measured subglottic diameter correctly predicted ETT size in 75% of the cases but overestimated and underestimated in 15.6% and 9.4% of the cases, respectively. Evidently, both techniques are statistically comparable with P=0.876 (Table 4).

Table 1: Age and weight distribution

Parameter	Range	Mean	SD
Age (years)	2–6	3.9	±1.47
Weight (kg)	8–45	20.3	±10.45

Table 2: ETT OD size by age-based formula versus ETT OD size by USG versus Actual size used

ETT (in mm)	n	Mean (in mm)	SD	95% CI
Age based ETT OD	64	6.81	0.571	6.65–6.94
USG ETT OD	64	6.91	0.631	6.74–7.06
Actual ETT OD	64	6.78	0.612	6.62–6.93

ETT OD: Endotracheal tube/outer diameters, USG: Ultrasonography

Table 3: Correlation of age based and USG based subglottic diameter with actual ETT OD

Parameter	Pearson correlation (r-value)	P-value
Age based ETT OD	0.891	<0.001*
USG measured subglottic diameter	0.876	<0.001*
Age (years)	0.614	<0.001*
Weight (kg)	0.725	<0.001*

ETT OD: Endotracheal tube/outer diameters, USG: Ultrasonography, *Statistically significant

DISCUSSION

Providing safe anesthesia and airway management in pediatric patients is a challenging task. Predicting an appropriate size ETT in pediatric patients is difficult due to wide variation in airway dimensions with age, weight, ethnicity etc., In the present study, carried out in northernmost part of Indian subcontinent, we explored the usefulness of USG in the determination of ETT size in pediatric patients and its comparison with modified Cole's age-based formula in terms of outer diameter determination of ETT. Subglottic diameter was preferred for USG assessment, as this is the narrowest part of the trachea.

We observed that there was no statistically significant difference in the mean size of ETT OD between the age-based formula and actual ETT OD used, the mean outer diameter was 6.81 (±0.571) mm and 6.78 (±0.612) mm, respectively, with a P=0.811. Similarly, the mean size of ETT OD by USG was 6.91 (±0.631) mm, which is also comparable with the actual size of ETT OD with a p-value of 0.239. The mean ETT OD determined by age-based formula and the one determined by USG were also comparable with a P=0.327.

Similar results were reported by Bharathi et al.,[9] in their study, the mean size of ETT OD according to age-based formula was 6.00 (±1.190) mm and the mean size

Table 4: Accuracy of age-based formula and USG based subglottic diameter in predicting ETT size

Method	Correctly predicted ETT size		Overestimated ETT size		Underestimated ETT size	
	n	%	n	%	n	%
Age base formula	50	78.1	8	12.5	6	9.4
USG measured subglottic diameter	48	75.0	10	15.6	6	9.4

Chi-square=0.263; P=0.876. USG: Ultrasonography, ETT: Endotracheal tube

with actual ETT OD was 5.909 (±0.8257) mm with no significant difference between the two.

Pearson correlation test was used to evaluate the extent of correlation between ETT inserted and ETT estimated by age-based formula and USG. The correlation coefficient between age-based ETT OD measurements and actual ETT OD was ($r=0.891$, $P<0.001$). Moreover, the correlation coefficient between USG-based ETT OD measurements and actual ETT OD was ($r=0.876$, $P<0.001$) showing a significant correlation of actual ETT OD size with both the estimated size using age-based formula and USG-based size. Agrawal et al.,[10] in their study, screened 13179 pediatric patients and evaluated the usefulness of USG in predicting appropriate size ETT among Indian pediatric patients. They also reported that both age based ETT OD and USG based ETT OD were significantly associated with the actual used ETT ($r=0.965$ and $r=0.917$, $P<0.001$). Sutagatti et al.,[11] reported in their study that ETT size estimated by USG strongly correlated with actual ETT inserted. The results of their study were comparable to present study. However, unlike our study, they did not compare age-based ETT size with actual ETT size, and they used both cuffed and uncuffed ETT.

In another study involving children aged between 3 and 18 years, Gupta et al.,[12] reported that ETT size predetermined by USG highly correlated with actual used ETT compared to one predicted by age-based formula. However, 50% of their patients were above 10 years of age.

In the present study, both the age and weight of patients were significantly associated with actual ETT OD. Schramm et al.,[13] reported a strong correlation between the size of the ETT actually used and the minimal transverse diameter of the subglottic airway. The bias determined using Bland Altman analysis was 0.02 mm, with a range of 1.12–1.08 mm. Their findings demonstrated that choosing an adequate ETT for pediatric patients was made easier by ultrasound-guided measurement of minimal transverse diameter of the subglottic area, which was similar to the results in our study.

In this study, the accuracy of the age-based formula and USG-measured subglottic diameter in predicting ETT size were assessed and was found that out of 64 patients, the age-based formula correctly predicted ETT size in 78.1% of the cases compared to 75% by USG measured subglottic diameter. However, the age-based formula overestimated ETT in 12.5% of the cases and underestimated it in 9.4% of the cases compared to 15.6% and 9.4%, respectively, by USG. Makireddy et al.,[7] in their study reported that USG based ETT OD correctly predicted the ETT diameter in 70.7% of cases, while it underestimated and overestimated actual ETT size in 9.7% and 19.5% of cases, respectively, which is comparable with the present study. On the other hand, they reported that age-based determination (Cole's formula) of ETT was correct in only 65.8% compared to 78.1% observed in our study. In their study, age based ETT OD size was underestimated and overestimated in 31.7% and 2.4%, respectively. The success rate of Cole's ETT OD formula for predicting the actual ETT size was high in present study (78.1%) compared to results of Shibasaki et al.,[14] (60%). The success rate of Cole's age-based formula has been reported to range from 47% to 77%. The variation in success rate of Cole's formula may be attributed to the varying study design adopted in different studies.

According to a study by Bae et al.,[8] Cole's formula miscalculated the size of the uncuffed ETT in a population of a comparable size, with just 31% of the patients undergoing an intubation with the proper-sized tube. However, compared to 75% agreement between USG and actual ETT OD size as observed in the present study, they reported only 60% agreement between the actual tube diameter and US-measured ETT outer diameter. Shibasaki et al.,[14] compared both cuffed and uncuffed tubes and stated that the rate of agreement between the expected ETT size based on the ultrasonic measurement and the clinically selected final ETT size was 98% for cuffed ETTs and 96% for uncuffed ETTs compared to 75% success rate observed in our study. The variable success rate of USG in determining the actual ETT OD may be attributed to multiple factors that includes; heterogenic pediatric age group between the studies, interracial difference of growth rate between Asian and Caucasian races, varying study designs adopted in different studies and failure to standardize the time of the respiratory cycle at which US measurement was done.

Limitations of the study

The present study has a limitation of containing a relatively less number of patients, so we recommend a larger study for establishing general guidelines on use of USG for predicting ETT size.

CONCLUSION

This study concluded that the success rate of the age-based formula and USG in precisely predicting ETT outer diameter is comparable with the size of actual ETT outer diameter (78% vs. 75%, P=0.86). Although USG is a non-invasive, cost-effective, compact, and reproducible technique but the routine use of ultrasound in pediatric ETT size estimation could not be justified over age-based formula as both of them have comparable results. However, the present study has a limitation of containing a relatively low number of patients, so we recommend a comprehensive multi-center studies for more reliable results that can be generalized in a better way.

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