Section: Anaesthesiology

Original Research Article

PROSPECTIVE COMPARATIVE EVALUATION OF AGE-BASED MOTOYAMA FORMULA AND ULTRASONOGRAPHY IN PREDICTING ENDOTRACHEAL TUBE SIZE IN THE PAEDIATRIC AGE GROUP OF 5-12 YEARS UNDERGOING GENERAL ANAESTHESIA

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Abstract

Background: Ultrasonography (USG) is widely available and gives real-time dynamic images. Age-based Motoyama formula was used to choose the tube size and was compared with the USG method to assess which is the best predictor. This study was planned to compare the age-based Motoyama formula with the ultrasound method to determine the efficacy of ultrasound for predicting ETT size in paediatric populations. **Materials and Methods:** It was a cross-sectional, double-blinded prospective observational study performed on 60 paediatric patients. All patients were undertaken USG-guided subglottic diameter measurement in a routine pre-operative assessment clinic. Before surgery, patients underwent a thorough physical examination. High-resolution B-mode ultrasonography (USG) was used to measure the subglottic diameter. A comparison of the ETT size assessed by USG, the Motoyama formula based on age, and the final formula applied clinically was made. **Results:** No statistical significance at different intraoperative periods by conventional criteria in mean heart rate distribution, mean arterial pressure distribution and oxygen saturation distribution. There was statistical significance by conventional criteria in comparing the internal diameter of an improper endotracheal tube (ETT) by age-based formula with the USG method and clinically fit ETT tested by air leak test. Particularly in children between the ages of 5 and 10, the intraclass correlation coefficient (ICC) value for agreement demonstrates an excellent association between accurate ETT size and USG technique. **Conclusion:** For the right endotracheal tube selection in the paediatric population, USG-guided assessment of subglottic diameter is a better predictor than the age-based formula.

INTRODUCTION

One of the prime challenges of the medical sciences is safe anaesthesia, particularly for children. Since supplying oxygen is the most crucial aspect of airway management, it takes precedence over any other intraoperative intervention during anaesthesia. Because children are not miniature adults and have a different physiology from adult airways, paediatric anaesthesia differs from adult anaesthesia.[1] The paediatric larynx is higher level than the adult's.[2] In contrast to the cylindrical adult airway, the paediatric larynx is funnel-shaped.[3] The functional residual capacity of the paediatric population is lower than that of adults, making them more susceptible to hypoxemia. If an improper endotracheal tube (ETT) is inserted in a child's airways, there are known to be correspondingly higher complications.[4]

Age-based, height-based, and weight-based formulas have historically been employed to determine the suitable diameter size, although they are rarely applicable. The need for a better approach to calculating the size of ETT is highlighted by the conflicting evidence that has been provided for and against their usage in children. Theoretically, ultrasonography imaging of the airway could offer a more precise estimate of ETT size. Much research has been conducted recently to evaluate the difficult airway utilising ultrasonography. Using ultrasound as a screening technique for airway assessment is gradually gaining prominence. It can be used to confirm ETT installation, identify oesophageal intubation, anticipate the difficulty of laryngoscopy in obese patients, perform a percutaneous tracheostomy, and perform emergency cricothyrotomy, among other things.[5-8]

The ultrasound technique has also been tested on children aged one month to six years old. Evaluated the rate of agreement between USG and the appropriate size ETT. Gupta et al. observed similar agreement for optimum and ultrasonography-guided ETT in kids between 3 and 18. Children with airway issues may benefit from USG due to its accessibility, portability, ease of use, non-invasiveness, and quick examination. This is especially helpful in underdeveloped nations where inexpensive uncuffed tubes are utilised instead of pricey micro-cuffed ones.[7-9] This study was planned to compare the age-based Motoyama formula with the ultrasound method to determine the efficacy of ultrasound for predicting ETT size in paediatric populations.

MATERIALS AND METHODS

This cross-sectional and double-blinded prospective observational study was conducted on 60 Tirunelveli Medical College and Hospital paediatric patients between 2020-2022. All patients were undertaken USG-guided subglottic diameter measurement in a routine pre-operative assessment clinic. It was decided to record the ETT with the closest OD to the measured subglottic diameter.

Patients undergoing elective surgical procedures were evaluated following inclusion and exclusion criteria after receiving consent from the institutional ethical committee. After acquiring the informant's written consent to participate were included.

Inclusion Criteria

All elective surgeries were done under GA, aged 5-12 years, and American Society of Anesthesiologists (ASA) 1: a normal healthy patient and ASA 2: A patient with a mild systemic disease, were included.

Exclusion Criteria

Patients having predicted difficult airway, any anatomical deformity of the upper airway, the presence of a scar, ulcer, or lump in the neck, prior neck surgery, upper respiratory tract infection, the patient's parents refused to give informed consent, ASA 3: A patient with a serious but not life-threatening systemic illness, ASA 4: A patient whose life is constantly in danger due to a severe systemic illness, and patient undergoing emergency surgery were excluded.

Before surgery, patients underwent a thorough physical examination, including a clinical examination and history evaluation. High-resolution B-mode ultrasonography (USG) was used to measure the subglottic diameter with a linear array transducer placed in the midline of the neck at a depth of 6 cm on an MTurbo Sono site ultrasound machine. At the same time, the patient's head was extended, and the neck was flexed (the sniffing posture). It was determined that the transverse air column diameter is less at the cephalic than the caudal portion of the cricoid cartilage. It was decided to record the ETT with the closest OD to the measured subglottic diameter.

All patients were placed on a 6-hour fast. Before beginning the procedure, the anaesthesia machine and paediatrics circuit were verified, ensured the availability of a functioning paediatric laryngoscope, various-sized oral airways, and endotracheal tubes. Confirmed the availability of emergency medications and that 22G venflon was used to secure intravenous access. Regular monitoring devices such as an ECG, NIBP, and pulse oximeter were attached to the operating room, and baseline vital signs were recorded. Each patient received preoperative injections of glycopyrrolate (10mcg/kg) and midazolam (0.05mg/kg) intramuscularly 45 minutes before surgery. Baseline oxygen saturation, $EtCO_2$, blood pressure, and other cardio-respiratory measurements were taken before induction. Three minutes of preoxygenation with 100% oxygen. The induction was carried out using Inj. Propofol 2mg/kg intravenous and Inj. Fentanyl 2mcg/kg intravenous.

The patient was paralysed with an atracurium injection of 0.5 mg/kg. The patient was intubated utilising direct laryngoscopy and the ETT with the nearest OD to the measured subglottic diameter. The air leak test was carried out after the ETT's proper placement had been verified. After closing the APL valve and increasing the airway pressure, a stethoscope auscultation over the trachea detected the leak. ETT was replaced with a tube of a bigger capacity if there was a leak at pressures of 10 cmH_2O or less. The tube size was acceptable if the leak was between 10 and 20 cmH_2O. If there was no air leak, even at 20 cm of water, the ETT was changed to smaller. It was specified what internal diameter of ETT was ultimately employed.

Cardio-respiratory measurements, including heart rate, blood pressure, oxygen saturation, and $EtCO_2$, were taken during surgery. Neostigmine 50 g/kg and glycopyrolate 10 g/kg were administered intravenously to the patient after the procedure. The patient was moved to the post-operative ward for monitoring. Based on the previously noted recorded findings, a comparison of the ETT size assessed by USG, the Motoyama formula based on age, and the final clinically applied formula was made.

Statistical Analysis

All data were subjected to descriptive statistics presented as mean values and percentages. Appropriate statistical comparison tests were conducted. The unpaired t-test and the single-component ANOVA test were used to evaluate continuous variables. The Fisher Exact Test and the Chi-Square Test will be used to assess categorical variables. The threshold for statistical significance is

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a p-value less than 0.05. The analysis of the data will be done with SPSS version 20.

RESULTS

Among the study population of 60 patients, 54 (90%) were between 5 and 10 years old, and 6 (10%) were above 10. Among the study population of 60 patients, 31 (52%) were boys, and 29 (48%) were girls. Between the ages of 5 to 10 years old, 28 patients were male children, and 26 were female children. Three male and three female children are over ten years old. Among the study population, six patients (10%) were weighing less than 30kg, 18 patients (30%) were weighing between 31 to 40kg, 31 patients (52%) were weighing between 41 to 50kg, five patients (8%) were weighing above 50kg. Among the study population of 60 patients, 40 kids (67%) were assessed under ASA 1, and 20 kids (33%) were evaluated under ASA 2. Age vs sex distribution indicated that 28 and 3 females belonged to the 5-10 age group, whereas 26 and 3 males belonged to the >10 age group [Table 1].

Table 1: Age distribution

		No of patients	Percentage
Age in years	5-10 years	54	90%
	> 10 years	6	10%
Sex	Male	31	52%
	Female	29	48%
		Female	**Male**
Age	5-10 years	28	26
	> 10 years	3	3
Weight in kg	< 30	6	10%
	31-40	18	30%
	41-50	31	52%
	> 50	5	8%
ASA PS	I	40	67%
	II	20	33%

The mean heart rate, mean arterial pressure, and oxygen saturation among the study population at different intraoperative periods shows no statistical significance.
The mean subglottic diameter was 7.97 (SD-0.77), the Mean ID of ETT corresponding to USG measured subglottic diameter-ETT USG was 5.8 (SD 0.46), the Mean ID of ETT calculated by an age-based formula was 5.45 (SD-0.43), Mean ID of ETT clinically fit was 5.74 (SD-0.51).

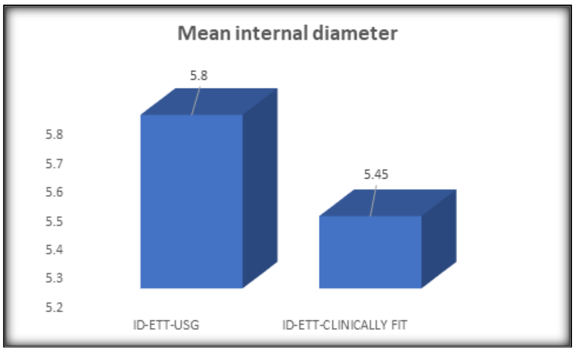

Figure 1: Comparison of an internal diameter of ETT BY age method VS USG method

Figure 1 shows that, by conventional criteria, the comparison of the internal diameter of ETT by age-based formula and USG method among the study population was statistically significant (p-value: 0.001).

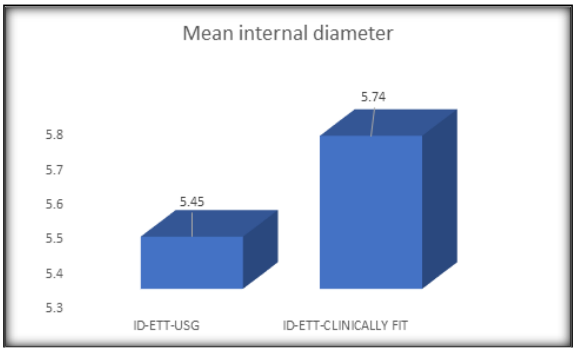

Figure 2: Comparison of an internal diameter of ETT BY age method VS clinically fit

Figure 2 shows that the comparison of the internal diameter of ETT by age-based formula and clinically fit ETT tested by air leak test among the study population was statistically significant (p-value: 0.003).
According to a method of tube selection, the final clinically fit ETT distribution among the 60 study participants was as follows: Age-based tube selection was accurate in 8 (13%), USG-based tube selection was accurate in 35 (59%) patients, and both methods were accurate in 17 (28%) patients.

Table 2: Reliability of age-based method and USG method to correct tube size- intraclass correlation coefficient

Agreement	ICC
USG & correct method	0.968
Age & correct method	0.928

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With the proper size tube, the ultrasound-based method's ICC of 0.968 was regarded as excellent and was backed up by a strong 95% confidence limit. But the ICC for the age-based formula approach with the right ETT was also 0.928, which was good. These results indicated that for youngsters, a USG-based technique is preferable to an age-based formula (Table 2).

The comparison of ETTa (clinically fit) and sex among the study population shows no statistical significance (p-value: 0.216). The comparison of ETT USG and sex among the study population shows no statistical significance (P-value - 0.153). The comparison of ETTm (age-based formula) and sex among the study population shows no statistical significance (p-value: 0.082).

The ICC of the USG and Correct technique was 0.958 for male children and 0.844 for female children. The ICC of the Age-Based Method and the Correct Method was 0.913 for male children and 0.835 for female children. In both males and females, there was a higher degree of agreement between USG-based tube size and the right tube size than the age-based tube size.

The mean Internal diameter of Clinically fit ETT for ages between 5 to 10 yrs was 5.67 (SD 0.49), and for ages above ten years was 6.33 (SD 0.25) (p-value: 0.002). The mean Internal diameter of ETT chosen by the USG method for ages between 5 to 10 yrs was 5.75 (SD 0.44), and for ages above ten years, it was 6.33 (SD 0.25) (p-value-0.007). The mean Internal diameter of ETT chosen by the Motoyama formula for ages between 5 to 10 yrs was 5.38 (SD 0.41), and for ages above ten years, it was 6.00 (SD 0) (p-value: 0.003) (Figure 3).

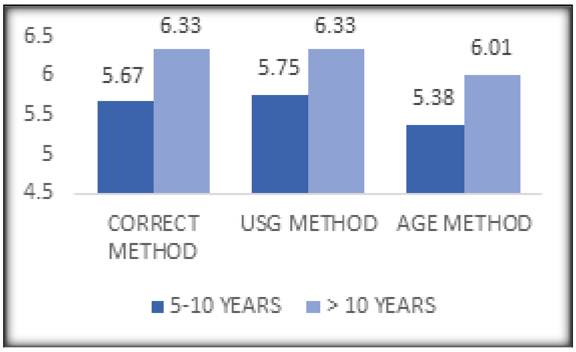

Figure 3: Relation of age on internal diameters

Table 4: Intra class correlation coefficient of age

	Intra-class correlation coefficient	
Age	USG & correct method	Age & correct method
5-10 years	0.962	0.921
> 10 years	0.986	0.986

Particularly in children between the ages of 5 and 10, the ICC value for agreement demonstrates an excellent association between accurate ETT size and USG technique. Between 5 and 10 years, the age-based method did not match the accurate ETT and the USG-based method. When choosing the proper ETT size for children older than ten, there was no difference between the USG technique and an age-based formula (Table 4).

DISCUSSION

Securing a paediatric airway is an extremely difficult task. Selecting the proper tube size is crucial because a smaller tube may increase airflow resistance and add to the effort required to breathe. Greater tube size may harm the laryngeal mucosa and result in mucosal edema, which may limit the airway after extubation. Age-based calculations, height-based formulas, and weight-based formulas have historically been tried to determine the correct diameter size, although they are rarely helpful. The need for a better approach to calculating the size of ETT is highlighted by the conflicting evidence that has been provided for and against their usage in children.[5-9]

Ultrasonography (USG) is frequently used and provides live, dynamic images. For the greatest benefit in airway management, USG must be used dynamically in close coordination with airway procedures. Theoretically, ultrasonography imaging of the airway could offer a more precise estimate of ETT size. Much research has been conducted recently to evaluate the difficult airway utilising ultrasonography. Using ultrasound as a screening technique for airway assessment is gradually gaining prominence. It can be used to confirm ETT installation, identify oesophageal intubation, anticipate the difficulty of laryngoscopy in obese patients, perform a percutaneous tracheostomy, and perform emergency cricothyrotomy, among other things. The ultrasound technique has been tested on kids as well.[7,8]

Compared to age-based formulas, recent research showed that ultrasonography was a more accurate predictor of the subglottic diameter of the airway in children and the optimal endotracheal tube size for intubation.[8,9] The current study aimed to determine the value of using ultrasonography to identify endotracheal tubes in paediatric patients. Comparing the age-based algorithm and the ultrasound-guided approach for determining the proper endotracheal tube in children.

In a study by Gehlaut et al., the ICC between the two measurements (Clinically Best Fit ETT and ID corresponding to OD measured by USG) was significantly positive and very high (r=0.981, p-value 0.001), indicating a close concordance between the two measurements.[10]

In the study by Gehlaut et al., the ICC (r = 0.927, p-value 0.001) between the two measurements (clinically best fit ETT and age-based Motoyama formula) was significantly positive, demonstrating good concordance between the two measurements. Although it is much higher than the mean ID corresponding to the age-based Motoyama formula,

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which was 4.86 ± 0.82 mm, the mean ID corresponding to the clinically best-matched ETT was 5.15 ± 0.68 mm (p-value 0.001). This demonstrates that Motoyama's formula gravely undervalues the ID by 0.32 ± 0.3 mm.[10]

In our study, the difference between the internal diameter of the ETT measured using the USG method and the study population was statistically significant. Still, not the difference between the internal diameter of the ETT measured using the age-based formula and the clinically fit ETT assessed using the air leak test. Among 60 study participants, the distribution of the final clinically fit ETT used corresponds to a tube selection method as follows: patients with USG-based tube selection were correct in 35 (59%) patients, patients with age-based tube selection were correct in 8 (13%), and patients with both methods were correct in 17 (28%) patients.

With the proper size tube, the ultrasound-based method's ICC of 0.968 was regarded as excellent and was backed up by a strong 95% confidence limit. But the ICC for the age-based formula approach with the right ETT was also 0.928, which is good. These results imply that a USG-based approach is preferable to an age-based formula for children. With the approach of tube selection in our investigation, hemodynamic metrics, including HR, SpO2, and mean arterial pressure, do not demonstrate any statistical significance among the study population.[11-14]

This study has some limitations, including the clinical nature of the leak test assessment and the possibility of inter- or intra-observer variability. The leak test is the only practical test that can accurately measure the size of an ETT. Acoustic shadow prevents USG from seeing the posterior tracheal wall. Antero-posterior diameter cannot be disclosed by it. In addition, a randomised controlled study would have been preferable to an observational one for level 1 evidence. It was also necessary to mention using cuffed or micro-cuffed tubes, which will reduce the number of times the age-based formula is reintubated.

CONCLUSION

In this study, we concluded that for the right Endotracheal tube selection in the paediatric population, USG-guided assessment of subglottic diameter is a better predictor than the age-based formula. In children under the age of 10, USG has a clear benefit over age-based formulas; however, for patients older than 10, both age-based formulas and the USG approach are equally successful in determining the proper ETT.

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