Comparison of Accuracy of Ultrasound Measurement of Subglottic Diameter Versus Conventional Age Based Formula for Estimating Endotracheal Tube Size for Pediatric Surgical Patients- A Prospective Randomized Controlled Study

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Introduction: The main aim of this study is to determine if ultrasonography (USG) based measurement of subglottic diameter is the best size predictor for endotracheal tube (ETT) in pediatric surgical cases over age-based formula with micro cuff tube. Also, to test reintubation percentage and post-operative complications in children.

Methodology: This research is double-blind randomized control study with 68 children undergoing elective surgery requiring general anaesthesia with micro cuff tube. They were divided into 2 groups i.e. ETT size by USG (group U) and ETT size by age-based formula group A) (with 34 children in each. Both groups ETT measurement was calculated by independent Samples t-test, and correlation of both groups with actual ET Tube was measured by Pearson's correlation coefficient. Reintubations or post-op complications was measured by Chi-squared test.

Results: Mean age of group A and U are 5.65 ± 2.77 and 5.97 ± 2.77 respectively. Mean weights were from 13.5±2.06 kgs to 27±4.63kgs. Statistical significance with a P-value (P=0.0460) is observed in group U whereas no significance was seen in group A. A strong positive correlation (R=0.960) between USG-estimated ETT size and actual ETT size is observed. The difference in reintubations and post-op complications in group U were statistically significant with P < 0.002.

Conclusion: The present study concludes that the sub glottis diameter measured by USG is a good predictor for correct size of micro cuff endo tracheal tube in children.

Keywords: Ultrasonography, Subglottic diameter, Pediatric, Microcuff Endotracheal tube, Reintubation.

Introduction

Pediatric intubations are difficult for most of the anesthesiologists because of their anatomical differences in the airway compared to adult. Pediatric airway is different from adults due to the developmental and anatomic variations. In the neonatal period trachea is funnel shaped with upper end wider than the lower and as the age advances it becomes cylindrical. As the child grows, laryngeal dimensions differ and the knowledge of the changing airway dimensions is very important for the pediatric anesthesiologists.[1] Selection of the appropriate size of the endotracheal tube (ETT) along with difficult airway cart is the essential step in pediatric anesthesia. If the tube selected is inappropriately larger it may cause damage to the airway and lead to post operative complications like post extubation stridor and subglottic stenosis.

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If the tube selected is too small it results in inadequate ventilation, risk of aspiration, unreliable gas monitoring, leakage of anesthetic gases and need for reintubation with appropriate size tube.[2]

In pediatric anesthesia choosing the appropriate size of the ETT is crucial as most of the critical incidents are airway related. The prediction of appropriate size of the ETT for pediatric age group can be estimated by various methods. The traditional formulas used for prediction of appropriate size of ETT are age-based formulas like Cole and Myotome formula, height-based formula, little finger size. All these formulas are poor predictors of the appropriate size of the ETT and resulted in repeated laryngoscopies and reintubations. Recently ultrasound has gained popularity and made a way for consideration of this modality in assessment of pediatric airway.[3]

Aims and objectives

The aim of the present study is to determine the accuracy of ultrasound measurement of subglottic diameter as the best predictor of the size of the endotracheal tube in pediatric surgical cases when compared to conventional age-based formulas to calculate the size of the ETT.

The second objective is to calculate the percentage of reintubations required on the basis of air leak test and the side effects like post extubation stridor or laryngospasm after recovery.

Materials and method

After obtaining approval from institutional ethics committee (Ref no. 799/U/IEC/ESICMC/F0242/12/2020), this study was conducted in the department of Anesthesiology, ESIC Super specialty hospital, ESIC Medical college over a period of one year from December 2020 to November 2021. Based on study done by Gunjan et al.[4] considered sample size for the study was 68 children aged between 2 months to 10 years. Written and informed consent was taken from parent/guardians of all the children, inclusion criteria was ASA Grade I and II Pediatric patients posted for elective surgery requiring general anesthesia. Pediatric patients with anticipated difficult airway, anatomical deformity of the upper airway, previous surgeries involving upper airway, any obvious scars or mass in the neck which will interfere with the USG examination were excluded from the study. All the eligible pediatric patients were examined in pre-anesthetic clinic with detailed history, general and physical examination. Standard fasting guidelines for pediatric age group was followed. Operation theater is kept warm and all necessary drugs for general anesthesia and the intubation equipment was kept ready. Patients once shifted to operation theatre, standard monitors ECG, pulse oximetry, NIBP was connected and the baseline parameters were recorded.

After securing IV cannula with 22G/24G children were premedicated with inj.Atropine 0.02mg/kg,inj.Midazolam 0.05mg/kg. In Group U high resolution B mode USG (MINDRAY M700) with linear probe having frequencies 7-15 MHZ was used to measure subglottic diameter followed by induction with inj.Propofol 2-3mg/kg, muscle relaxant inj.atracurium 0.5mg/kg was given. MICROCUFF(AVANOS) tubes were used for all patients for the first time in our tertiary care population. USG probe was positioned in the midline of the neck with the identification of vocal folds seen as paired hyper echoic linear structures and then moved caudally to visualize the cricoid arch. The cricoid cartilage appears as around hypoechoic structure with hyper echoic edges.

The transverse air column diameter at the cephalic half of cricoid cartilage that is narrower than the caudal part is measured. Based on subglottic diameter measured corresponding ETT was chosen. Standard scanning plane was used to prevent bias and artifacts. Patients were intubated with the selected ETT based on subglottic diameter. In GROUP A, age-based formula was followed to calculate appropriate size of the tube for patients. Age based formula

(Penlington formula) for age <6yrs.: Age/3 +3.5= ID of ETT in mm, age>6yrs.m Age/4 +4.5=ID of ETT in mm. In this the patient was intubated with tube calculated by age based formula. The correct position of the tube is confirmed by capnography (Spacelabs Qube™ Monitor) and by auscultation for bilateral breath sounds. The air leak test was used to measure the best fit ETT. In the presence of resistance to passage of the ETT into trachea, or the absence of air leak at airway pressures at >25cm H_2O the ETT was replaced with a tube of 0.5mm less ID. If leak was audible at airway pressures <10cm.of H_2O or if seal could not be achieved with cuff pressures >25cm. of H_2O the tube was exchanged for one size larger ETT.

The tube size calculated based on the USG diameter measurement and actual size of the ETT used for the patient was recorded in the group U. In group A, ETT size calculated based on the age formula and the actual ETT used for the patients were recorded. Correlation between age based ETT, USG measured subglottic diameter based ETT with the actual ETT used for the patients were done in both the groups. Correctly predicted ETT size, overestimated ETT size and under estimated ETT sizes were compared. Post operative patients were observed for post extubation respiratory complications like cough, sore throat, stridor.

Statistics was analysed by using Graphpad InStat version 3.0. Demographic data was represented as mean ± standard deviation. USG based ETT and age based ETT sizes comparative analysis was calculated by independent samples t-test. Pearson's correlation coefficient (R) test was performed for age-based ETT, USG-based ETT with the actual ET Tube used. To check the reintubation percentage and post-op complications Chi-squared test was performed. $P < 0.005$ considered as statistically significant.

Results

The demographic data of the present study was enrolled with 34 patients in each group, and there were no dropouts recorded in this trial. In Group A, mean age of the study group was 5.65 ± 2.77, males were 29 whereas female patients were 5, and the mean weight of the children was 18.47 ± 5.22. Similarly, the mean age in group U was 5.97 ± 2.77, males were 27 and females were 7, and the mean weight of this study group was 19.06 ± 6.35(Table 1).

Table 1: *Demographic data of participants (n=34)*

Parameters	**GROUP A (Age-based ETT)**	**Group U (USG-based ETT)**
Age (mean ± SD)	5.65 ± 2.77	5.97 ± 3.26
Males: Females	29 : 5	27 : 7
Weight	18.47 ± 5.22	19.06 ± 6.35

SD: Standard deviation, ETT: Endotracheal Tube, USG: UltrasonographyAge groups of the study was further categorized to 1 to 4, 5 to 8 and 9 to 12 years. The difference in ages, number of male and female children, mean weights of both the groups was calculated, tabulated in table 2. Mean weights were noted from 13.5±2.06 kgs to 27±4.63kg

Table 2: *Different age groups in both groups.*

	GROUP A (Age-based ETT)			**Group U (USG-based ETT)**		
	1 – 4 years	**5 – 8 years**	**9 – 12 years**	**1 – 4 years**	**5 – 8 years**	**9 – 12 years**
Number of patients	14	13	7	13	14	7
Males : Females	13 : 1	9 : 4	7 : 0	13 : 0	8 : 6	6 : 1
Weight (mean ± SD)	13.57 ± 2.06	20.23 ± 2.91	25.0 ± 3.37	14.3 ± 4.66	19.4 ± 3.80	27.1 ± 4.63

SD: Standard deviation, ETT: Endotracheal Tube, USG: UltrasonographyThe difference between the ETT size estimated by USG and actual ETT used was statistically significant with a P-value (P=0.0460). But there is no statistical significance observed (P=0.0911) in the difference of the ETT tube size between age based ETT size and actual ETT used during surgery (Table 3)

Table 3: *ETT size by age Vs ETT size by USG.*

Measurements (mm)	**Mean ± SD**	**P-value**
ETT size estimated by USG	5.2 ± 1.1	**0.0460***
ETT size used actually on table	4.8 ± 0.8	
ETT size derived from age-based formula	5.5 ± 0.7	0.0911
ETT size used actually on table	5.2 ± 0.5	

*Independent Samples t-test, SD: Standard deviation, There is a strong positive correlation (R=0.960) between USG-estimated ETT size and actual ETT size used which infers that the difference in the diameter of the ET tube estimated using USG and the diameter of the actual ET tube used is There is a positive correlation (R=0.799) between age-based ETT size and actual ETT size used. The estimated

ETT size by age formula was moderately correlated (0.577) to the size measured by USG).

Table 4: *Correlation between age-based ETT, USG-based ETT with the actual ET Tube used*

** Independent Samples t-test, R: Pearson's Correlation Coefficient, ETT: Endotracheal Tube, USG: Ultrasonography*

	Pearson's correlation coefficient (R)	**P-value**
USG-based ETT vs Actual ETT used	0.960	**<0.001***
Age-based ETT vs Actual ETT used	0.799	**<0.001***
USG-based ETT vs Age-based ETT	0.577	**0.0003***

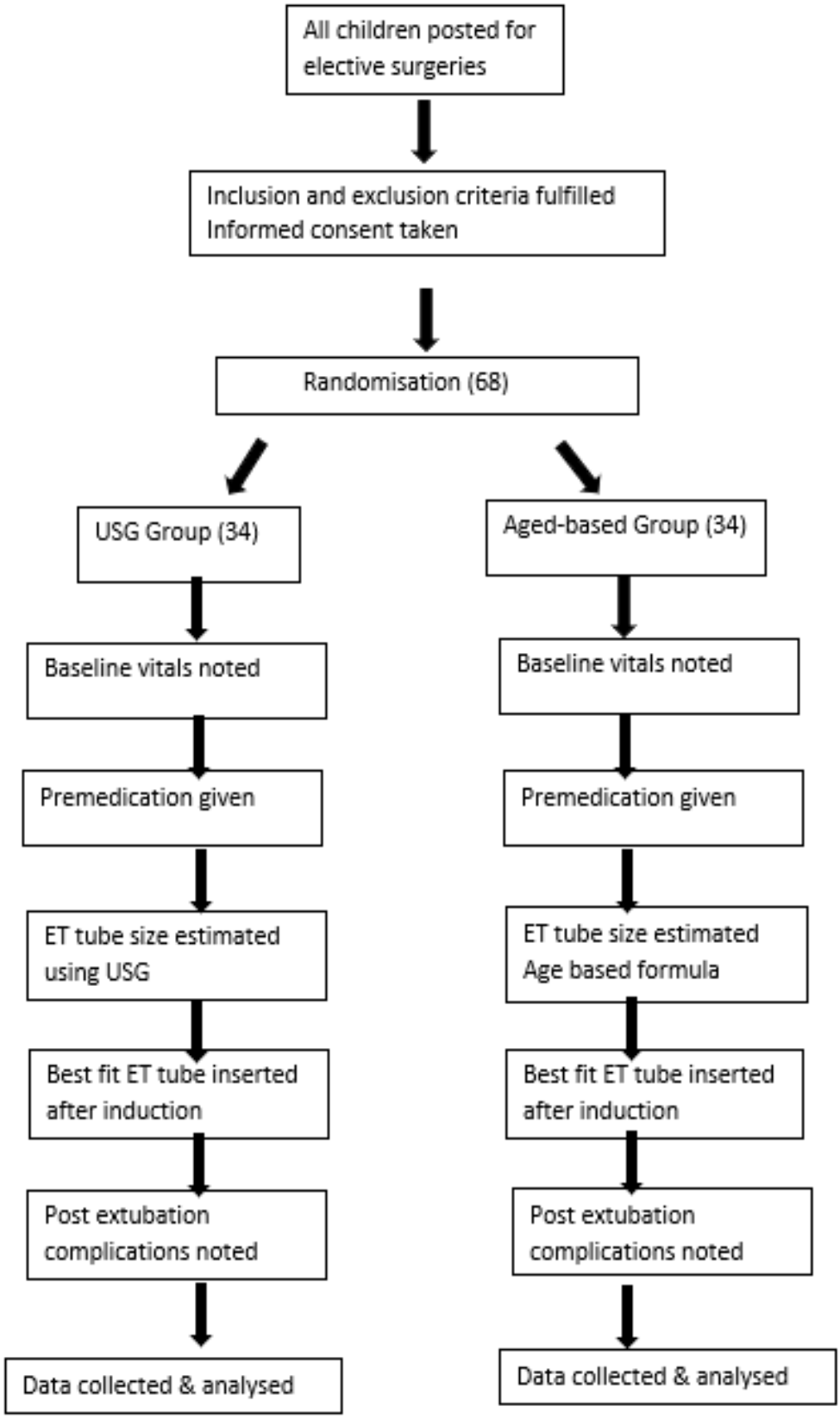
A comparison of reintubations and post-op complications was done between group A and U. The difference in reintubations and post-op complications between group A and group U were statistically significant with $P < 0.002$ and $P < 0.002$ respectively.

Table 5: *Comparison of the percentage of reintubations or post-op complications.*

	GROUP A	**Group U**	**P-value**
Reintubations			
(No./Total cases)	10/34	6/34	0.002*
Percentage	**29.4%**	**17.65%**	
Post-op complications (No./Total cases)	6/34	3/34	0.002*
Percentage	**17.65%**	**8.82%**	

***** Chi-squared test

Figure 1: *Study flow chart as per the CONSORT guidelines*



Discussion

Pediatric intubations are difficult for most of the anesthesiologists because of their anatomical differences of the airway compared to adult. There are several formulas like age based, height based, and weight based are in practice for calculation of ETT. With advancement in technology medical devices like ultrasonography is helping in estimating ETT size. One such attempt was made in the present randomized controlled study in south Indian population to compare the ultrasonography with age-based formula and percentage of reintubations as well as post-op complications.

A study done by Gupta K, et al. a comparison between the ETT size derived by ultrasonography and by age-based formula with the clinically used ETT.[5] They observed that a strong correlation between predetermined ETT by USG with clinically used ETT over age-based formula. Similarly, in the present study results are comparable with their estimated ETT by USG with our estimated ETT by USG (P<0.0460*) but they did not mention on the ETT type they used either cuffed or uncuffed. In the present study we used micro-cuff ETT tube successfully. The main advantage with the micro-cuff tube is having high volume with low-pressure that seals the trachea at lower pressures than the mucosal capillary perfusion pressure.[6,7] The anatomical designs of microcuff ET tubes avoids damage to the sensitive subglottic region. Most of these micro-cuff ETT tube studies with its tube size appropriateness and sovereignty over uncuffed tubes were done in western population.[6,7,8,9] However, there is a difference in the airway anatomy of Indian and western pediatric populations.[10] The present study of USG micro-cuff ETT over age-based formula is giving significant results (table 3 and 5) to use it effectively without any side effects.

In another clinical study i.e. tracheal tube sizes were selected based on two methods performed by Bae JY, et al. concluded that the ETT size estimated via USG have useful means of selecting correct tracheal tube size when compared with age based ETT calculation in pediatric patients.[2] But in their study, they have used only uncuffed tubes whereas in our present study micro-cuffs were used. Moreover, in our study USG was done on operation table when the patient was awake(sedated) and estimated the ETT size to choose the correct sized micro-cuff tube; which is a totally contrast over Bae JY's study where they took USG on table after anesthesia.

All the traditional methods were used only for predicting ETT size and provide inner diameter, the advantage of using USG technique is minimally invasive and has proven airway anatomy value for assessing the size. In our study, table 4 shows a strong positive correlation between USG-based ETT size and actual ETT size and also have shown strong correlation between age-based ETT size and actual ETT size. A moderate correlation was observed between age-based formula and USG. A similar correlation was observed in Makireddy R, et al study when comparing the USG-measured subglottic diameter and the actual size ETT.[11] This study also used uncuffed tubes which were different from the microcuff tubes used in our study.

Additionally, in the present study, we estimated the percentage of reintubations and post-op complications which brought out the uniqueness in this study and was not seen in most of the research. The percentage of reintubations were reduced to 17.65% in USG when compared to the age-based group (29.4%), there is also statistical significance between the groups. As we mentioned the advantages of USG in the above paragraphs, this reduction in reintubation percentage used in USG is another example to suggest that this technique is used by anesthesiologists when the patient is awake on operation table. Post operative complications also significantly reduced in the USG group from 17.65% to

8.82% when compared to the age-based formula group. The number of reintubations are directly proportional to number of post operative complications.[12] The only limitation for this technique is operator dependent, but however it can be overcome by routine practice and sample size may be small to generalize.

Conclusion

The present study revealed that the USG is a non-invasive, safe, and reliable tool. Furthermore, subglottic diameter measured by USG is an accurate and effective method to measure ETT size for micro cuff tubes. To conclude the present study, the subglottis diameter measured by USG is a good predictor for the correct size of the micro cuff ET tube.

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Conflicts of Interest

None of the authors have conflicts in preparing or submitting the manuscript.

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