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Relationship Between USG Guided Subglottic Diameter, Age-Based Formula and Little Finger Breadth with Outer Diameter of Endotracheal Tube in Pediatric Patients for the Estimation of Appropriate Size of Endotracheal Tube

[1]Akhil Shekar, [2]N. Suvina, [3]Y. Prajwala and [4]Swati Bisht

[1]Department of Anesthesiology, East Point College of Medical Sciences, Bangalore, Karnataka, India

[2]Department of Anesthesiology, Dr. B. R. Ambedkar Medical College, Bangalore, Karnataka, India

[3,4]Department of Anesthesiology, Vydehi Institute of Medical Sciences, Bangalore, Karnataka, India

ABSTRACT

Children are not the small size adults and have the distinct physiology of their own, distinct from adult which makes the pediatric anaesthesia diverse from adult anaesthesia and mainstay of anesthetic management in this pediatric age group in general anesthesia. This study was designed to correlate ultra-sonography (USG) guided subglottic diameter, age based formula and little finger breadth (LFB) for the estimation of appropriate size of the uncuffed endotracheal (ET) tube in pediatric patients in view to decrease the repeated attempts of intubation and the consequences following it. To correlate USG guided subglottic diameter, age based formula and LFB(Little Finger Breadth) for the estimation of appropriate size of the uncuffed ET-tube in pediatric patients in view to decrease the repeated attempts of intubation. This Prospective study was conducted among Pediatric patients falling into age group 6months-6 years age group undergoing elective surgery under general anesthesia in Vydehi Institute of Medical Sciences and Research Centre, Bangalore. One year from October 2019 to October 2020. Fifty children with mean age of 38 months (SD 22.2 range-Three Months to 72 months) were recruited for this prospective observational study after the informed written consent from the parents. Agreement between calculated ETT(Endotracheal tube) and correct ETT size shows that the age based formula provided better prediction of ETT size in children (40% of children). Ultrasound was correct in 16% of the cases. A difference of ≤0.3 mm between the tested methods (USG, LFB) and the OD of the correct ETT size was considered as an acceptable difference. In conclusion, USG measured subglottic diameter correlates with the actual tracheal tube used and may be useful in choosing the appropriate size ETT. Age based formulae are more reliable. Therefore, it is our opinion that there is no advantage in ultrasound measurement of subglottic diameter.

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Key Words

Ultra-sonography, (USG) guided subglottic diameter, LFB (little finger breadth)

Corresponding Author

Swati Bisht,
Department of Anesthesiology, Vydehi Institute of Medical Sciences, Bangalore, Karnataka India
suvi11492@gmail.com

Author Designation

[1]Senior Resident
[2]Associate Professor
[3]Assistant Professor
[4]Professor

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INTRODUCTION

Pediatric airway assessment is often challenging to the anaesthesiologists. Children are not the small size adults and have the distinct physiology of their own, distinct from adult which makes the pediatric anaesthesia diverse from adult anaesthesia and mainstay of anesthetic management in this pediatric age group in general anesthesia[1]. Insight about the influence of the age of the child on laryngeal dimensions becomes essential in this assessment[2]. The progression of airway anatomy plays main factor for the use of uncuffed ET tube in paediatric patients <6 years[3]. Next vital step would be selection of appropriate size of endotracheal (ET) tube in paediatric patient. Larger size tube may result in complications like ulceration, glottis edema, subglottic stenosis, local ischemia and post-operative sore throat. Conversely a smaller size tube may result in inadequate delivery of tidal volume, increased risk of aspiration, increased OT pollution and accidental extubation[4]. Different methods are used for prediction of ET-tube size which includes physical indices based formulae[5,6] like age based formula[7] [Age/4+4] i.e. modified Cole's formula, body length based formula[8], multi variate formula[9], little finger breadth (LFB) measurement[10]. Age based formulae are most commonly used and show a variable success rate ranging from 47-77%[7]. In most of the cases, it requires using formulas but have led to poor prediction of tracheal diameter, requiring repeated laryngoscopies[2]. Nowadays advancements which help us for measuring this tracheal diameter are video bronchoscopy, MRI (Magnetic Resonance Imaging) and USG (Ultra Sonography). Due to easy availability of ultrasound devices, high sensitivity and familiarity of anaesthesiologists to ultrasound devices, it this modality has been considered in the assessment of pediatric airway. Despite a success rate of about 90%, minimal transverse diameter of subglottic airway (MTDSA) has not been used as a primary criterion for ETT selection[11,12]. Hence, this study was designed to correlate USG guided subglottic diameter, age based formula and LFB(Little Finger Breadth) for the estimation of appropriate size of the uncuffed ET-tube in pediatric patients in view to decrease the repeated attempts of intubation and the consequences following it.

MATERIALS AND METHODS

This Prospective study was conducted among Pediatric patients falling into age group 6months-6 years age group undergoing elective surgery under general anesthesia in Vydehi Institute of Medical Sciences and Research Centre, Bangalore. One year from October 2019 to October 2020. Ethical clearance was obtained before conducting the study from the Institutional Ethical Committee.

Inclusion Criteria:

- Written and informed consent from parents/ guardians.
- ASA-I and II pediatric patients.
- Pediatric patients for elective surgeries who require endo tracheal intubation.

Exclusion Criteria:

- Patients suffering from any respiratory diseases which cause airway narrowing.
- Pre-existing tracheal and laryngeal pathology.
- ASA-III and IV patients.
- Airway deformity.
- Anticipated difficult airway.

Sample Size: According to the previous study, estimation of appropriate size of endotracheal tube by preoperative assessment of subglottic region by ultrasonography in children was found to be 88%. Therefore, assuming (p)=88% as the accuracy of estimated size of endotracheal tube with 10% margin of error, the minimum required sample size at 5% level of significance is 43 patients. For our convenience, we will enroll 50 patients in the study who fulfill the inclusion criteria.

Method of Collection of Data: All the patients under the study underwent pre-anaesthetic checkup (PAC), the day before surgery. During PAC, by the help of age-based formula, Internal diameter (ID) of ET tube was calculated and corresponding OD was noted. Pre-operatively breadth of distal phalanx of little finger at the level of distal inter phalangeal groove of all the enrolled patients was measured with the help of Vernier calliper. On the day of surgery, inside OT after giving premeditation, all the patients were induced as per our institution protocol. Patient was kept in supine position with head in extension to avoid possibility of respiratory induced changes in airway dimensions. USG was done using linear probe (Frequency of 7-15 MHz) and measurements was be taken in B-mode. The probe was placed on the middle of anterior neck and at first true vocal folds were located and identified as paired hyper echoic linear structures moving with respiration. Later cricoid arch was identified by moving the probe caudally. Cricoid arch appears as round hypo echoic structure with hyper echoic edge. The air column appears hyper echoic. The subglottic diameter was measured by transverse measurement of air column obtained in cephaloid half of cricoid arch. The anesthesiologist who intubates was blinded to the results of USG and LFB measurement values. The size of uncuffed ET tube for intubation for that particular patient was selected. If any resistance at the time of intubation, a smaller size tube by 0.5mm was chosen. Besides that, a larger size tube by 0.5mm was chosen

if there is an air leak at 20cmH2O of peak airway pressure and low expired tidal volume of <7ml/Kg body weight. In order to avoid manufacture related discrepancies in OD measurements of ET tube, we used ET tubes from one manufacturer for all patients involved in this study.

Statistical Analysis: Data was entered in MS Excel and analyzed using SPSS software version 17. Qualitative data was expressed using range, frequencies and percentages whereas quantitative data was expressed mean and standard deviation. Pearson correlation coefficient, Chi-square test and necessary statistical tests were applied. All statistical analysis was carried out at 5% level of significance and p value <0.05 was considered as significant.

RESULTS AND DISCUSSIONS

Fifty children with mean age of 38 months (SD 22.2 range- Three Months to 72 months) were recruited for this prospective observational study after the informed written consent from the parents. Out of 50 children recruited, 41 (82 %) were boys and 9 (18%) were girls. 12 (24%) children were <or equal to one year of age at the time of procedure. Mean weight of the 66 children recruited, was 14.02 kg (SD 3.8, range 6.4-21 kg). Eleven (22%) out of fifty children had body weight <ten Kg. 48 (96%) children were classified as ASA grade I while 2 children were ASA grade II (4%).

Size of ETT by Age Based Formula: Mean of size of ETT diameter, calculated using age based formula (Cole's formula) was 4. 7mm (SD 0.47, range 3.5-5.5 mm). Mean sub-glottic diameter as measured using ultrasound was 6.9 mm (SD 0.78, range 3.8-8.2). Mean of size of these ETT was 4.5 mm (SD 0.57, range 3-5.5). Mean of the correct size ETT was 4.7 (SD 0.51, range 3 -5.5). This value is more than the means of both ETT calculation using USG method and age related formula.

Agreement Between Two Methods of Tube Size Calculation and Correct ETT: Agreement between calculated ETT and correct ETT size shows that the age provided better prediction of ETT size in children (40% of children), ultrasound was correct in 16 % of the cases. A difference of $\leq$0.3 mm between the tested methods (USG, LFB) and the OD of the correct ETT size was considered as an acceptable difference. Size of correct ETT matched with ETT size calculated using USG method is 22 patients (44%), whereas the age-based method selected the correct tracheal tube size in 34 (68%) patients. The two-tailed P value equals 0.0376.This difference was statistically significant (p <0.05 using McNemars test) proving the superiority of age based method over ultrasound method. Comparisons of means of sizes of correct ETT with age based formula and with USG guided size was carried out separately using paired t test which had the statistically significant association.

Reliability Agreement of Age Based Formula and Correct Tube Size: Intra class correlation coefficient (ICC) was calculated to know the reliability agreement for the size of ETT which was used for the patient with the size of ETT calculated using age based formula. Agreement of ultrasound based method with the correct size tube was 0.954 is considered as excellent also supported by good 95% confidence limit. However the same ICC for agreement for age based formula method and correct ETT was also 0.854 which is considered good. These values suggest that USG based methods is better than age based formula in children. The mean USG based tube size and mean age based tube size was similar to the mean correct tube size in females (4.7). However it was more in males (5.1). Mean age base tube size was found to be different from the mean correct tube size in both males and females. Agreement between USG based tube size and correct tube size was greater than age based tube size in boys. (Table 6). However agreement between USG based tube size and correct tube size was less in females (0.05).

Body Weight and Calculation of Correct Size ETT: The mean age based tube size was near to the mean correct tube size in children weighing 5-10 kg. In children weighing >10 kg, the mean of age based tube was similar to mean of correct tube. However, the mean of USG based tube size was greater to the mean correct tube size. Agreement between USG based tube size and age based tube size with correct tube size, stratified by weight was also analyzed. The agreement between age based tube size and correct tube size was more in children >10 kg weight. In children having weight ranging from 5-10 kg, the USG based tube size showed a better agreement with correct tube size than the age based one.

Age and Correct ETT Size: Mean of correct ETT used was almost same that of age based method and less than that of ultrasound method in both the age groups. However the ETT diameter of used tube matches very closely with age based method in both age groups. ICC value for agreement shows excellent correlation between correct ETT size and USG method especially in children with one year or less. In children more than one year of age, agreement for correct ETT size versus age based method was 0.797, whereas agreement for correct ETT and USG method is0.375.

Lin's Concordance Correlation Coefficient: Lin's concordance correlation coefficient (ρc) is a measure

of how well a set of bivariate data (Y) compares to a "gold standard" measurement or test (X). (ρc)measures both precision (ρ) and accuracy (Cβ). McBride (2005) suggests the following descriptive scale for values of the concordance correlation coefficient (for continuous variables):

- ρc <0.90 is poor strength of agreement.
- ρc 0.90-0.95 is moderate strength of agreement.
- ρc 0.95-0.99 is substantial strength of agreement.
- ρc >0.99 is almost perfect strength of agreement.

Lin's concordance correlation coefficient for comparison of USGD and LFB measurements with OD of the correct ETT between different methods is depicted in (table 11) which shows poor agreement.

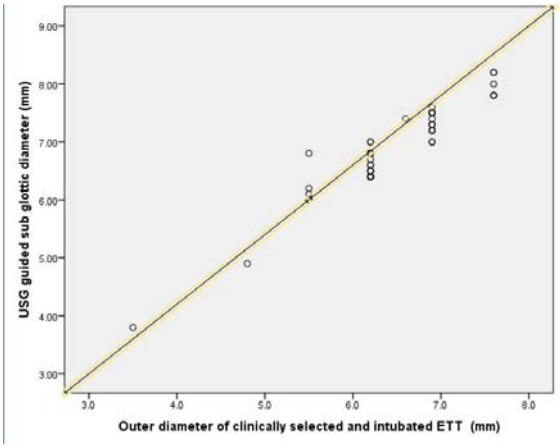

Fig. 1: Scatter Plot Between USGD with OD of ETT Used

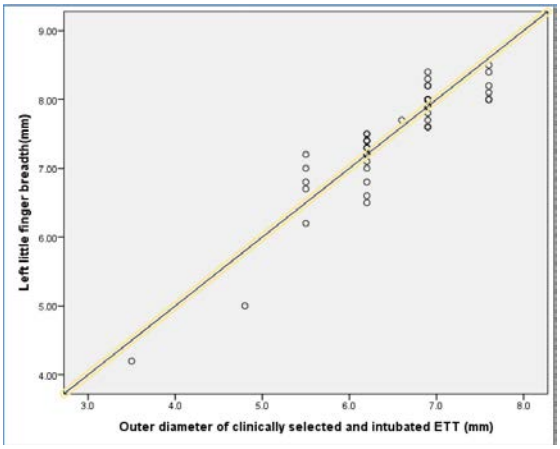

Fig. 2: Scatter plot Between LFB with OD of ETT Used

Bland and Altman analysis plot of LFB and OD of actual ETT used shows a mean difference of -0.98mm (CI -1.07 to -0.88). The upper and lower limits of agreement (2 SD) were -0.33 and -1.62, respectively (P value=0.52). Similarly, the plot of USG measured OD and OD of actual ETT showed a mean difference of 0.44 mm (CI-0.51to-0.3). The upper and lower limits of agreement (2 SD) were 0.02 and -0.9, respectively. This was not statistically significant (P value of 0.53). Values of LFB and USG appear to be distributed in almost a similar range of distribution (±1.96 for LFB and ±1.6 for USG).

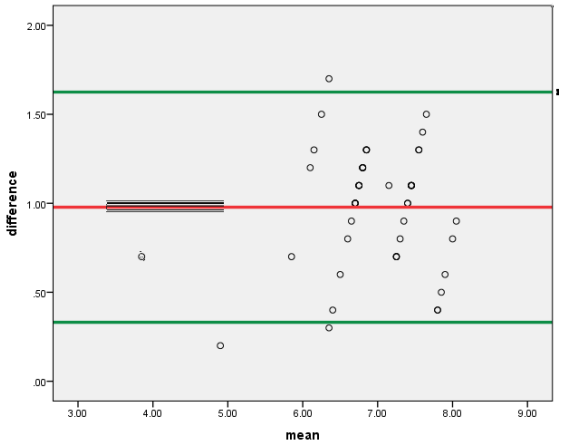

Fig. 3: Bland and Altman Analysis Plot of LFB and OD of Actual ETT(in mm)

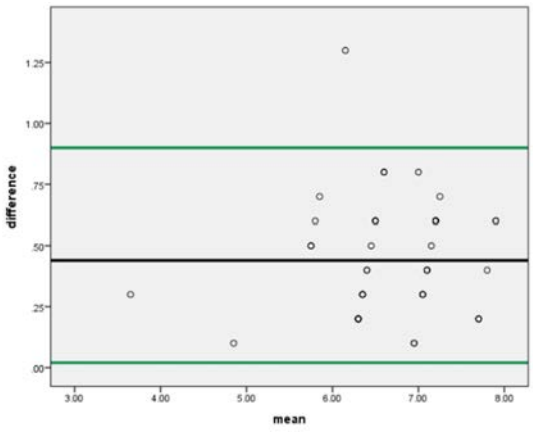

Fig. 4: Bland and Altman Analysis Plot of USG and OD of Actual ETT(in mm)

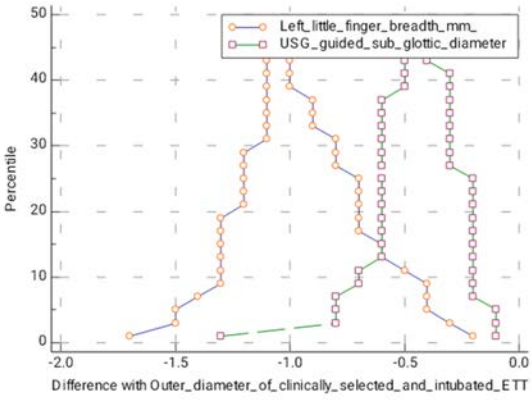

Fig. 5: Mountain Plot Showing Curves for USG Subglottic Diameter, LFB and OD of ETT Values

Table 1: Details of the Sub-Glottic Diameter and ETT Using Age Based Formula, USG Methods and Correct ETT Tube

			Range	
Diameter (mm)	**Mean**	**SD**	**Minimum**	**Maximum**
Sub-glottic diameter	6.88	0.78	3.8	8.2
ETT by age based formula	4.72	0.47	3.5	5.5
ETT by USG	4.56	0.57	3	5.5
Correct ETT	4.69	0.51	3	5.5

Table 2: Match Between Correct ETT Used Versus ETT Calculated by USG and ETT Calculated by Age Based Formula Tube Formula ET Tube with Correct ETT Size

N=50		**USG based ET tube match with correct tube size**		
		Yes	**No**	**Total**
Age based formula ET tube	**Yes**	14 (28)	20 (40)	34 (68%)
match with correct tube size	**No**	8 (16)	8 (16)	16 (32%)
	Total	22 (44%)	28 (56%)	50 (100)

Table 3: Paired T Test for USG Based and Age Based Method with the Correct Size ETT

	Paired difference				
	Difference of means	**SD**	**Std. error Means**	**95% confidence limit**	**p-value**
Pair 1-Age based ETT and aETT size used	-0.20	0.285	0.04	-0.1 to-0.06	0.622
Pair 2-USG based ETT and aETT Size used	0.44	0.23	0.03	0.37 to0.506	<0.001

Table 4: Intra Class Correlation Coefficient(ICC) Values for Agreement of Correct ETT Size and Both Methods

	ICC	**95% confidence limit**
Agreement of USG and correct ETT size	0.954	0.92-0.97
Agreement of age based formula and correct ETT size	0.854	0.75-0.91

Subgroup analysis-boys vs. girls:

Table 5: Mean Age Based and USG Based Correct Tube Size

N=50	**Mean correct tube size**	**Mean age base tube size**	**Mean USG base tube size**
Male (n=41)	4.7	4.6	5.1
Female (n=9)	4.7	4.8	4.8

Table 6: Agreement Between Age Based and USG Based ET Tube with Correct Tube Size with ICC

N=50	**Agreement between age based and correct tube size**	**Agreement between USG and correct tube size**
Male (n=41)	0.848 0.911	
Female (n=9)	0.915 0.053	

Table 7: Mean Age Based and USG Based Tube Size, According to Weight of Children

Weight (N=50)	**Mean of correct ETT size**	**ETT with age based formula**	**ETT with USG method**
5-10 kg (n=11)	4.13	3.9	4.6
>10 kg (n=39)	4.84	4.9	5.2

Table 8: ICC Value Suggesting the Agreement for Correct ETT Size and Both the Methods

Weight(N=50)	**Agreement for correct ETT vs. age based method**	**Agreement for correct ETT size vs. USG method**
5-10 kg (n=11)	0.600 0.876	
>10 kg (n=39)	0.814 0.382	

Table 9: Means of the Sizes of Correct ETT, with Age Based Formula USG Method According to Age

Weight (N=50)	**Mean of correct ETT size**	**ETT with age based formula**	**ETT with USG method**
<=1 year (n=12)	4.17	4	4.7
>1year (n=38)	4.9	4.9	5.3

Table 10: Agreement with ICC Values Between Correct Tube Used and USG Based Method

Age (N=66)	**Agreement for correct ETT size vs. age based method**	**Agreement for correct ETT vs. USG method**
<= 1 year (n=21)	0.682 0.88	
>1year (n=45)	0.797 0.375	

Table 11: Lin's Concordance Correlation Coefficient for Comparison of USGD and LFB Measurements with OD of the Correct ETT

	Lin's concordance correlation coefficient	**Confidence Interval**	**Measures of precision**	**Measures of accuracy**
USG-OD-ETT	0.818	0.73-0.88	0.95	0.856
LFB-OD-ETT	0.5	0.38-0.61	0.91	0.55

Table 12: Comparison Between the Best Fit and Predicted Size of Endotracheal Tube by Various Modalities

	Frequency (%)			**Pearson correlation**
	"Best fit"< size predicted	**"Best fit"= size predicted**	**"Best fit"> size predicted**	**with best fit tube**
Predicted size by age based formula	0	43	7	0.855
Predicted size by comparison to left finger breadth	2	0	48	0.910
Predicted size by ultrasonography	1	22	27	0.954

Mountain plot gives a visual correlation of agreement and inter changeability between techniques. Observations were made based on the comparison of shape of one mountain with the other. The median between actual OD ETT and LFB OD and USG OD as assessed by mountain plots was -1.05 and -0.4,

respectively. The methods of measurement would be classified in the decreasing order of accuracy as follows: actual OD ETT >LFB OD >USG OD. Absence of inter changeability, which occurred with the techniques, was seen at the base of the mountain not aligning exactly with each other.

On correlation using Pearson's correlation coefficient, it was observed that there was a moderate correlation of best fit Endotracheal tube with endotracheal tube size by age based formula (r=0.855) and strong correlation was seen with left finger breadth and ultrasonography (r=0.910 and r=0.954 respectively).

Mean of size of ETT diameter, calculated using age based formula (Cole's formula) was 4.7 mm (SD 0.47, range 3.5-5.5 mm). Similarly Neha Bharadwaj[13] reported 4.66mm (SD 0.6). We reported agreement of 85.4% by age based formula and this was 56% by Neha Bharadwaj[13] and 65.8% in Rekha Makireddy[14] Similar results were seen in a study conducted by Davis[7] in North Carolina where they found that age based formula selected the correct ETT size in only 68% of pediatric patients. They also found that ETT size estimated by age based formula was larger in 61% of patients. With the help of ultrasonography we could measure the subglottic diameter and we could estimate the ETT size without taking significant time, hence it is an aid in routine as well in emergencies. In literature, the first study using USG to estimate subglottic diameter was done by Husein[11] and they reported the usefulness of measuring the subglottic diameter by ultrasonography in 10 pediatric patients. In our study, mean sub-glottic diameter as measured using ultrasound was 6.9 mm (SD 0.78, range 3.8-8.2). As per the recommendations (ref) the USG tube size was calculated following the sub-glottic diameter. Mean of size of these ETT was 4.5 mm (SD 0.57, range 3-5.5). Ultrasound had agreement of 95.4% of the cases. Rekha Makireddy[14] reported this as 70.7% and Neha Bharadwaj[13] and Shibaski[15] in Japan as 90%. Bae[12], also found USG to be better predictor of ETT size estimation than age based formula in their study conducted in children <8 years. In their study, they found that USG method of tube selection allowed correct size ETT selection in 60% of patients, which was quite contrasting to the results of our study which shows that USG predicted correct ETT size in 95.4% of pediatric patients. These differences could be due to different measurement location of trachea. Also there might be difference in expertise of using USG for the same. Most of the recent studies emphasized that the ultrasound was a reliable tool in measuring subglottic diameter, thereby predicting the OD of ETT. A study by Schramm[16] which was claimed to be the first European study to examine the role of ultrasound for prediction of correct uncuffed tube sizes reported that ultrasound measurement of minimal transverse diameter of the subglottic airway correctly predicted ETT in 48% of the cases. Agreement between calculated ETT and correct ETT size shows that the age provided better prediction of ETT size in children (40% of children), ultrasound was correct in 16% of the cases but however ICC for agreement of USG was 0.954 and agreement of age based formula was 0.854. Size of correct ETT matched with ETT size calculated using USG method is 22 patients (44%), whereas the age-based method selected the correct tracheal tube size in 34 (68%) patients. The two-tailed P value equals 0.0376.

Little Finger Breadth and Outer Diameter of ETT: Most of the results from studies involving LFB measurements to predict the ETT size were in agreement with the observations in our present study. Study by van den Berg[17] in 1997 has shown that the diameter of the terminal phalanx of little or index finger was a poor predictor of the external diameter of ETT that provided the best fit. King[10] have also made similar conclusions that neither fifth finger breadth nor fifth finger diameter accurately predicts proper ETT size in most children. Their study suggested that a more accurate estimation can be made using the age based formula. However, breadth of the fifth finger nail can be of help when the child's age is unknown or when calculation is awkward or impossible. In our study, mountain plot figure displayed a better correlation of actual OD ETT with LFB compared to USG in our study. Hence, LFB may be useful as it is cost effective, especially in patients where age is unknown.

CONCLUSION

Neither USG nor LFB methods for measurement ofETT can be used as a reliable tool to predict the OD of ETT. USG has a definite advantage over age based formulas in children less than one year of age and less than five kg of body weight for calculations of ETT size. USG may be considered as a reliable tool for ETT estimation in pediatric patients when compared to diameter of little finger. Age based formula should be preferred over diameter of little finger for ETT estimation when USG is not available. In conclusion, US measured subglottic diameter correlates with the actual tracheal tube used and may be useful in choosing the appropriate size ETT. Age based formulae are more reliable. Therefore, it is our opinion that there is no advantage in ultrasound measurement of sub-glottic diameter.

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