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ORIGINAL RESEARCH

Airway ultrasound predicts endotracheal tube size more accurately than Cole's age-based formula in paediatric patients

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Background: Age-based formulas (ABFs) are commonly used in paediatric anaesthesia to determine the correct size of an endotracheal tube (ETT). However, these formulas often predict an incorrect size. The aim of this study was to determine if the tracheal internal diameter as determined on axial ultrasound images better predicts paediatric ETT size than Cole's ABF.

Methods: This study is a prospective observational study that involved 106 paediatric patients aged 1–10 years classified as ASA I and ASA II according to the American Society of Anesthesiologists Classification of Physical Status. These paediatric patients were scheduled for elective surgery and required general anaesthesia. They were randomly allocated to one of two groups by blind balloting. There were 53 participants in each group: the ultrasound-predicted endotracheal tube size (UPE) group and the (age-based) formula-predicted endotracheal tube size (FPE) group. For both groups, the actual ETT size used for intubation was noted and compared to the predicted size.

Results: The two groups (UPE and FPE) were comparable with respect to demographic and clinical variables. Airway ultrasound scans predicted the appropriate ETT size in 52 out of the 53 participants in the UPE group. This is a better prediction than the Cole's ABF, which accurately predicted appropriate ETT size in 35 out of the 53 participants in the FPE group ($p < 0.001$).

Conclusion: Data from this study shows that an airway ultrasound scan predicted the ETT size more accurately than Cole's ABF in paediatric patients.

Keywords: ultrasound, Cole's age-based formula, endotracheal tube size, children

Introduction

The choice of an appropriately sized endotracheal tube (ETT) has been a challenge in paediatric anaesthesia. Different methods have been used to determine ETT size, including the width of the little finger, use of Broselow tape, weight-based formula (WBF), age-based formula (ABF), neck x-ray and magnetic resonance imaging (MRI). Each of these methods, however, has demonstrated differing degrees of inaccuracy.

The ABFs are widely used to predict the appropriate size of the ETT in children.[1] Different ABFs have been used to predict the size of ETT in paediatric anaesthesia in different settings but the commonly used ABF in the West African subregion is Cole's ABF. The choice of an appropriately sized ETT is important in paediatric anaesthesia because of the peculiarity of the paediatric airway compared to the adult airway. An additional factor is the presence of congenital anomalies that affect the airway (e.g. Pierre Robin and Treacher Collins syndromes). Choosing an inappropriate paediatric ETT could lead to an increase in the need for re-intubation.[2] Using an ETT size which is larger than required or an over-inflated cuff between the endotracheal tube and the anatomic structures of the airway may damage the tracheal mucosa through friction and compressions. This can result in airway oedema, post-extubation stridor, subglottic stenosis or cartilaginous ischaemia, especially in children.[3] On the other hand, using a smaller ETT will increase the resistance to flow of gas and increase the risk of aspiration, insufficient ventilation and poor monitoring of the end-tidal gases.

Previous studies have suggested that the accuracy of ABFs in predicting correct ETT size is 47–77%.[4] In recent times, there have been advances in the use of ultrasound in anaesthesia. The ultrasound scan (USS) has also been found useful in airway management. It is a non-invasive tool that can be used to measure the diameter of the trachea. Measurement of the subglottic diameter (narrowest portion of the paediatric airway) on an axial ultrasound image can be used to determine the appropriate paediatric ETT size. Lakhal et al.[5] measured the tracheal internal diameter and correlated this with similar measurement taken with an MRI. The findings of their study suggested a strong correlation between the measurement by USS and MRI.[5] They, therefore, concluded that ultrasound is a good predictor of correct cuffed and uncuffed ETT sizes. Similarly, in a recent study, Gehlaut et al.[6] reported that USS is more reliable for assessing the subglottic diameter in a paediatric airway and predicted the appropriate ETT size better than physical indices-based formulas for cuffed and uncuffed tubes. We determined whether the tracheal internal diameter imaged by airway ultrasound is a better predictor of ETT size compared to Cole's ABF.

Methods

This study is a prospective observational study conducted that involved 106 paediatric patients aged 1–10 years, classified as ASA I or ASA II according to the American Society of Anesthesiologists (ASA) Physical Status classification. These paediatric patients were scheduled for elective surgeries requiring intubation as part of the anaesthetic technique between February 2020 and September 2020. Written informed consent was obtained from the parents or guardians of the patients.

Sample size determination

The sample size was calculated to be 106 using the formula for the comparison of two means.[7]

$$n = \frac{(u+v)^2 (SD_1^2+SD_2^2)}{(\mu_1-\mu_2)^2}$$

Selection criteria

Inclusion criteria

Patients who are 1–10 years old, scheduled for elective surgery requiring endotracheal intubation, and classified as ASA I or ASA II were included in this study. The funnel shaped larynx is said to assume the conical shape in children between the ages of 8 and 10 years. We, therefore, decided to adopt the upper limit of 10 years for this study.

Exclusion criteria

Excluded from this study are patients who are at risk of gastric aspiration, with risk factors for difficult intubation, with history of relevant drug allergies and who are asthmatic. We decided to be cautious by excluding difficult airways because, to the best of our knowledge, this is the first study of its kind in the West African subregion. It is, therefore, prudent to conduct the study first in patients with normal airways and plan a follow-up study including patients with anticipated difficult airways later.

Preoperative protocol

Standard preoperative assessment, investigation and fasting were done based on the hospital's guidelines. Fitness of patient for surgery was assessed using the ASA physical status classification system. Patients who were ASA I or ASA II were recruited for the study. The ETT size was initially determined for all 106 participants using the standard paediatric ABF described by Cole ((age in years/4) + 4 mm).[8] Participants were randomly allocated to one of two groups of 53 participants each through blind balloting using a sealed envelope technique by the anaesthetic technician, as follows:

a. Group UPE (ultrasound-predicted endotracheal tube size) were intubated with ultrasound determined endotracheal tube size; this was determined 5 minutes after the administration of muscle relaxant.
b. Group FPE (formula-predicted endotracheal tube size) were intubated with Cole's ABF determined endotracheal tube size.

The ballot picked determined the group a participant was assigned to and the manner in which the ETT was chosen. Bias was eliminated largely by measuring the subglottic diameter and calculating the ETT size using Cole's ABF in all the participants, ensuring that the researcher/anaesthetist was blinded to this randomisation. Only the anaesthetic technician who was involved with the blind balloting, knew which group each participant belonged to. The ETT was selected based upon the group the participant belonged to, and then given to the anaesthetist who intubated the participant. The researcher conducting the study was not privy to the size determined either by the ABF or by USS.

On arrival in the theatre, standard monitors were attached (including electrocardiogram [ECG], non-invasive blood pressure [NIBP], peripheral oxygen saturation [SpO_2] and temperature) and baseline vital signs were recorded. Intravenous access was secured for the administration of fluids and drugs. Pain from cannulation was prevented by the application of EMLA cream at least 30 minutes before cannulation. Induction of anaesthesia was with intravenous propofol (3 mg/kg) and endotracheal intubation was facilitated with intravenous atracurium (0.5 mg/kg). While waiting for the onset of action of atracurium, participants were mask ventilated with isoflurane at a minimal alveolar concentration (MAC) of 1.2 in oxygen for 5 minutes. This was done to prevent participants from becoming light under anaesthesia, hence preventing awareness. The standard operating procedure of the institution was followed in the conduct of anaesthesia in all participants.

During the period of mask ventilation, the high-frequency linear probe of a Sonosite iLook ultrasound scanner (serial no.: P03014-02 09/02, Sonosite Inc., Bothell, WA, USA) was placed by the researcher (an expert in airway ultrasonography) at the side of the neck of all eligible participants to identify the correct landmarks; trachea and oesophagus. Axial images were then obtained by placing the USS probe transversely, at the midline of the anterior neck, with the head extended and neck flexed. The subglottic diameter was then determined from the axial images. Standard plane of scanning was maintained to prevent artefact and bias. The cricoid arch was visualised as a round hypoechoic structure with hyperechoic edges. The transverse air column diameter was measured at the lower edge of the cricoid cartilage and considered the subglottic tracheal diameter (Figure 1). The subglottic tracheal internal diameter was then used to select the ETT size, rounded up to the nearest 0.5 mm or whole number (rounded off as the external diameter of the endotracheal tube) for the UPE group. ETT size for the FPE group was determined using Cole's ABF. Endotracheal intubation was done and only cuffed Portex endotracheal tubes were used. The ETT size was confirmed as adequate by the performance of leak test by the first research assistant. ETT size was considered optimal when tracheal leak was detected at an inflation pressure of 10–20 cm of H_2O using a Posey cufflator (Endotracheal tube inflator and manometer, serial no.: 8199X1229860, manufactured by J.T. Posey Company, Arcadia, USA). Absence of an audible leak

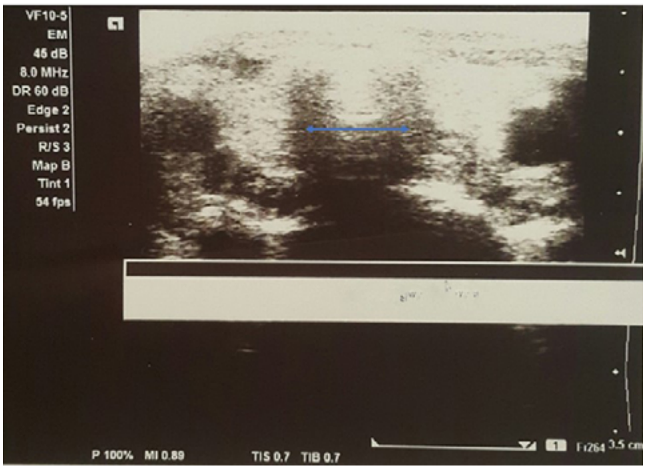

Figure 1: Ultrasound view of the subglottic diameter
Note: The blue arrow (⟷) indicates the dimension of the subglottic diameter

when the lungs were inflated to a pressure of 20–30 cm of H_2O or resistance to the passage of the ETT into the trachea, necessitated an ETT change to a 0.5 mm smaller ETT. The ETT was changed to a 0.5 mm larger ETT when a leak occurred at an inflation pressure of less than 10 cm of H_2O.[9] The recorded data were the internal diameter of the ETT from the ABF, ETT size determined by ultrasound imaging and the size of ETT that the participant was intubated with. The same sonographer conducted the USS for all the participants in order to eliminate or reduce discrepancies to the bare minimum.

Statistical analysis

The variables that were analysed for each participant include the ETT size estimated based on Cole's ABF, ultrasound-determined subglottic diameter and the size of the ETT that the participant was intubated with. Data entry and statistical analysis were performed using Statistical Product and Service Solutions (SPSS) version 23 computer software (IBM SPSS Statistics, IBM Corp. NY, USA). Categorical variables were presented using frequency and percentage. Numerical data were presented as mean ± standard deviation (SD). Mean comparison of numeric variables between the two groups (UPE and FPE) was carried out using the independent Student's t-test. Linear regression to predict actual tube using UPE and FPE was also formulated. A p-value of less than 0.05 was considered statistically significant.

Results

Table I shows the demographic profile between the two groups. There was no significant difference in the demographic profile between the two groups. The age range of the entire study population was 1–10 years, with a mean of 4.67 ± 1.9 years. The age range of participants in the FPE group was 1–10 years with a mean of 4.68 ± 1.9 years, while that of the UPE group was 1–10 years with a mean of 4.66 ± 1.8 years (p = 0.973).

Table I: Comparison of demographic profile between groups

	FPE (n = 53)	UPE (n = 53)	Total	p-value
Age (years) (mean ± SD)	4.68 ± 1.9	4.66 ± 1.8		0.973
Gender *n* (%)				
Male	38 (71.7)	42 (79.2)	80 (75.5)	0.367
Female	15 (28.3)	11 (20.8)	26 (24.5)	
ASA *n* (%)				
ASA I	45 (84.9)	44 (83.0)	89 (84.0)	0.791
ASA II	8 (15.1)	9 (17.0)	17 (16.0)	
Weight (kg) (mean ± SD)	18.82 ± 7.3	19.07 ± 7.2	18.95 ± 7.3	0.878

FPE – age-based formula-predicted endotracheal tube, UPE – ultrasound-predicted endotracheal tube, ASA – American Society of Anesthesiologists, SD – standard deviation

A total of 80 (75.5%) males and 26 (24.5%) females were studied, with a M:F ratio of 1:0.3. There were 38 (71.7%) males and 15 (28.3%) females in the FPE group with a M:F ratio of 1:0.4, while 42 (79.2%) males and 11 (20.8%) females were studied in the UPE group with a M:F ratio of 1:0.3 (p = 0.367). A total of 89 (84.0%) ASA I and 17 (16.0%) ASA II participants were studied. There were 45 (84.9%) ASA I and eight (15.1%) ASA II participants in the FPE group, while the UPE group had 44 (83.0%) ASA I and nine (17.0%) ASA II participants (p = 0.791). The weight of the study population ranged between 8 kg and 50 kg, with a mean weight of 18.94 ± 8.23 kg. The range of weight and mean weight for the FPE group was 8.4–43 kg and 18.82 ± 7.3 kg, respectively. The UPE group's weight and mean weight was 8–50 kg and 19.07 ± 7.2 kg, respectively. The mean weights were comparable (p = 0.878).

Table II shows the basic clinical characteristics of participants. There was no statistical difference between the two groups. The mean ETT cuff pressure for the FPE group was 16.60 ± 6.3 and 15.94 ± 3.5 cm of H_2O for the UPE group (p = 0.505). The mean dose of propofol at 3 mg/kg for the FPE group was 63.91 ± 27.8 mg and 64.13 ± 26.6 mg for the UPE group (p = 0.966). The mean dose of atracurium at 0.5 mg/kg for the FPE group was 9.59 ± 3.1 mg and 9.90 ± 3.3 mg for the UPE group (p = 0.711). The mean subglottic diameter for the FPE group was 0.49 ± 0.1 cm and 0.48 ± 0.1 cm for the UPE group (p = 0.933).

Figure 2 shows the correlation between the ABF and the ultrasound-based estimate of ETT size. The ABF and the ultrasound-based estimation of ETT size showed a positive linear correlation (r = 0.845, p < 0.001).

Table II: Induction and ETT characteristics of participants

	FPE (n = 53) mean ± SD	UPE (n = 53) mean ± SD	p-value
ETT cuff pressure (cm H_2O)	16.60 ± 6.3	15.94 ± 3.5	0.505
Internal tracheal/subglottic diameter (cm)	0.49 ± 0.1	0.48 ± 0.1	0.933

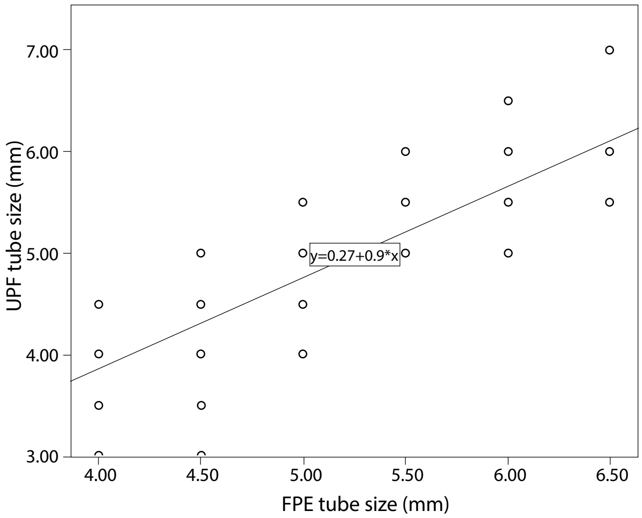

Figure 2: Correlation between ultrasound-predicted and age-based endotracheal tube size estimate (Pearson correlation coefficient = 0.845, $p < 0.001$*)

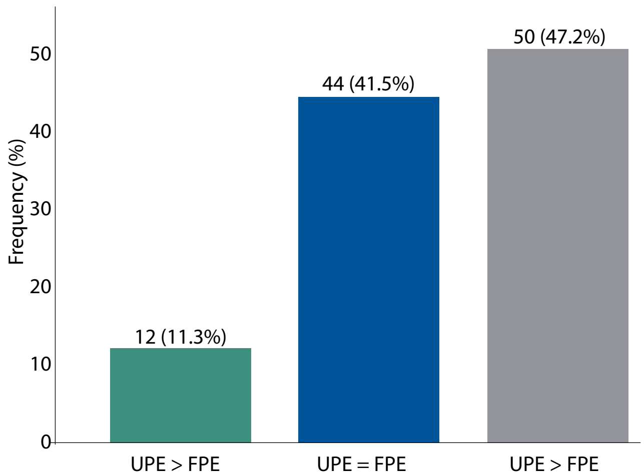

Figure 3: Agreement between age and ultrasound predicted endotracheal tube sizes ($p < 0.001$*)

Figure 3 shows the agreement between the ABF and ultrasound-based estimation of ETT sizes. A total of 44 participants out of 106 (41.5%) had ABF and ultrasound-based estimations of the same size ETT. Ultrasound-based estimations gave a smaller ETT size in 50 participants out of 106 (47.2%) compared to ABF estimations. For 12 participants (11.3%), the ultrasound-based estimation gave a larger ETT size than the ABF ($p < 0.001$).

Table III presents the difference between the tube size predicted by each group (UPE and FPE) and the actual tube size intubated with. In the UPE group, 52 out of the 53 participants (98.1%) had their tube size accurately estimated. However, one participant (1.9%) had a smaller ETT size estimated than appropriate. In the FPE group, 35 out of the 53 participants (66.0%) had the ETT size accurately estimated. In 17 participants (32.1%), the FPE estimated ETT size was larger than the actual intubated size. In one participant (1.9%), the estimated size was smaller than the accurate size for intubation ($p < 0.001$).

Table III: Disparity in age-based formula- and ultrasound-predicted tube size with actual tube used

	FPE ***n*** **(%)**	**UPE** ***n*** **(%)**	**Mc-nemar test**	***p*****-value**
Lower	1 (1.9)	1 (1.9)	8.941	**< 0.001***
Same	35 (66.0)	52 (98.1)		
Larger	17 (32.1)	0 (0.0)		

*$p < 0.05$

Discussion

The findings from this study revealed that ultrasound estimated a significantly more accurate ETT size for intubation in the paediatric age group compared to Cole's ABF. The results obtained in this study are similar to the findings reported in other studies in terms of ultrasound being more accurate than Cole's ABF.[9-11] Notwithstanding, we observed that there were some differences in the level of accuracy of the ultrasound in our study compared to other studies referenced. These disparities may be attributed to differences in the sample size of the study population as well as the type of ABF used. The effect of muscle paralysis and the types of tube used may also have contributed to the differences observed.

In this study, ETT size was accurately predicted in 98.1% of participants intubated with ultrasound-based estimated ETT size, compared to 66% of participants intubated with the accurate ETT size as estimated through the ABF ($p < 0.001$). The estimation of a smaller size ETT than required for intubation was similar in both groups (1.9%). No participant in the UPE group had a larger size of ETT estimated, whereas Cole's ABF estimated a larger size ETT in 32.1% of patients ($p < 0.001$). Observations from this study revealed that the ABF significantly overestimated the tube size compared to ultrasound. The significantly more accurate rate of prediction of correct ETT size using the ultrasound may be attributed to a direct view and measurement of the subglottic diameter compared to Cole's ABF that uses the patient's age to estimate the tube size. Some researchers have reported that the tube size predicted by Cole's ABF may not accurately match the subglottic opening.[12,13] Confounding factors that have been postulated to affect the accuracy of an ABF in estimating ETT size include the type of tube used (either cuffed or uncuffed), brand of ETT and the exact ABF used. These factors were controlled in this study and would therefore not have influenced the accuracy obtained for estimations with the aged-based formula, as observed here.

Some studies have also found the estimation of the ETT size by ultrasound to be significantly more accurate than the estimation by Cole's ABF.[12,14] Raphael et al.[9] reported that the use of ultrasound was more accurate in estimating an appropriate ETT size compared to an ABF, which is similar to the finding of this study. They studied patients in the age range of 2–15 years and measured the tracheal diameter at the level of the cricoid cartilage after induction of anaesthesia and muscle relaxation, as was done in the index study. However, in the present study, the accuracy of ABF is comparably lower (66% vs 95.9%) than that reported by Raphael et al.[9] The difference may be accounted for by the fact that Cole's ABF was used in this study while Raphael et al.[9] employed Motoyama's ABF ((Age/4) + 3.5 mm) and suggested that Indians might require smaller tube sizes compared to the Caucasians. A calculated smaller tube size that would result from the use of Motoyama's ABF could be responsible for the more accurate estimation by the ABF reported in their study. Cole's ABF in this study was found to have over-estimated the actual tube size in 17 participants.

Shibashaki et al.[10] reported the accuracy of ultrasound in the estimation of the cuffed ETT size to be 98% which is similar to this present study. However, they observed the accuracy of the ABF to be 35%, which is lower when compared to what was observed in the present study (66%). It is noteworthy that Shibashaki et al.[10] used different formulas (Motoyama and Khine (age in years/4) + 3 mm) that could predict a smaller tube size compared to Cole's formula used in the present study. In addition, the authors found that the ABF estimated a larger size of ETT, sometimes two or three times the actual size required in some participants. In this study, the tube sizes estimated by Cole's ABF were also larger in 32.1% of the participants. The lower accuracy compared to the index study (38% vs 66%) could, however, not be explained as all the confounding factors that were controlled in the index study were also controlled in the study by Shibashaki et al.[10]

The accuracy of the ultrasound-based estimation of ETT size is comparable to that obtained by Gupta et al.[11] Even though the exact ABF employed by Gupta et al.[11] was not specified, it had a lower accuracy rate of 35% compared to 66% obtained in this study. In addition, they did not mention if the tube used was cuffed or uncuffed. Cuffed ETTs have a larger outer diameter compared to an uncuffed ETT which might have affected their results.

Some authors, however, have reported lower accuracy in using ultrasound to estimate the appropriate ETT sizes compared to what was obtained in the present study. Sutagatti et al.[15] and Makireddy et al.[16] reported accuracies of 89.3% and 70.7%, respectively, using ultrasound. The lower accuracy reported could be due to the fact that the measurement of the subglottic diameter was done in non-sedated and non-paralysed patients in contrast to anaesthetised and paralysed patients used in the index study. Crying and different phases of respiration at the time of measurement might have affected the accuracy of their measurements. It has been shown that subglottic diameter is best measured when the patient is paralysed as the phase of respiration affects the diameter.[13] The trachea diameter is widest at the expiratory phase and it may be challenging to get the measurement at this phase in a self-ventilating patient. The lower accuracy reported by Sutagatti et al.[15] compared to this study could also be due to the adjustment made on the ultrasound-based estimated tube size. They chose a tube size that was 1 mm smaller than the estimated measurement for cuffed tubes.

Furthermore, Bae et al.[17] reported that ultrasound-based ETT size estimations were correct in only 60% of their patients, while the ABF estimated the correct ETT sizes in 31%. Though they took the measurement at the cricoid cartilage and measured the transverse diameter as done in the present study, it was observed that they used uncuffed tubes in their study as opposed to this study which used cuffed ETTs. Out of the 69 incorrect ETT size by ABF, 63 were smaller sizes while six were larger sizes. They, however, attributed the low accuracy of the ultrasound-based estimations to the shortcomings of ultrasound which only measures the transverse diameter. They predicted that the lack of information on anteroposterior (AP) diameter may allow for discrepancies in the size of ETT estimated with ultrasound. However, AP measurement is not routinely done as it is deemed more difficult than the transverse diameter. They also noted that the variations in the actual diameter of the ETT used could result in inaccuracy.

Conclusion

Data from the present study show that ultrasound estimated endotracheal tube sizes more accurately than Cole's ABF. Taken together, our study suggest that ultrasound may be an effective tool in measuring the subglottic diameter of the trachea and estimating the appropriate size of paediatric endotracheal tubes.

Conflict of interest

The authors declare no conflict of interest.

Funding source

No funding was required.

Ethical approval

The study was approved by the Lagos University Teaching Hospital Health Research Ethics Committee (LUTH HREC) and the Health Research and Ethics Committee of Lagos State University Teaching Hospital (LREC) with reference numbers ADM/DCST/HREC/APP/3100 and LREC/06/10/1251, respectively.

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References

1. Takita K, Morimoto Y, Okamura A, Kemmotsu O. Do age-based formulae predict the appropriate endotracheal tube sizes in Japanese children? J Anesth. 2001;15(3):145-8. https://doi.org/10.1007/s005400170016.
2. Schramm C, Knop J, Jensen K, Plaschke K. Role of ultrasound compared to age-related formulas for uncuffed endotracheal intubation in a pediatric population. Pediatr Anesth. 2012;22(8):781-6. https://doi.org/10.1111/j.1460-9592.2012.03889.x.
3. Weiss M, Dullenkopf A, Gysin C, et al. Shortcomings of cuffed paediatric tracheal tubes. Br J Anaesth. 2004;92(1):78-88. https://doi.org/10.1093/bja/aeh023.
4. Khine HH, Corddry DH, Kettrick RG, et al. Comparison of cuffed and uncuffed endotracheal tubes in young children during general anesthesia. Anesthesiology. 1997;86(3):627-31. https://doi.org/10.1097/00000542-199703000-00015.
5. Lakhal K, Delplace X, Cottier J-P, et al. The feasibility of ultrasound to assess subglottic diameter. Anesth Analg. 2007;104(3):611-4. https://doi.org/10.1213/01.ane.0000260136.53694.fe.

6. Gehlaut P, Golhar M, Johar S, Kumar P, Nain R. A comparative evaluation of age-based formula and ultrasonography to predict endotracheal tube size in paediatric patients. Indian J Clin Anaesth. 2020;7(3):477-82.
7. Kirkwood BR, Sterne JAC. Calculation of required sample size. In: Goodgame F, Pinder V, Moore K, editors. Essential medical statistics. 2nd ed. Massachusetts, USA: Blackwell Publishing Ltd; 2003. p. 413-28.
8. Cole F. Pediatric formulas for the anesthesiologist. AMA J Dis Child. 1957;94:672-3. https://doi.org/10.1001/archpedi.1957.04030070084009.
9. Raphael P, Thasim E, Simon B, Rajagopal P. Comparative study on prediction of paediatric endotracheal tube size by ultrasonography and by age based formulas. Int J Res Med Sci. 2016;4(7):2528-32. https://doi.org/10.18203/2320-6012.ijrms20161889.
10. Shibasaki M, Nakajima Y, Ishii S, et al. Prediction of pediatric endotracheal tube size by ultrasonography. Anesthesiology. 2010;113(4):819-24. https://doi.org/10.1097/ALN.0b013e3181ef6757.
11. Gupta K, Gupta P, Rastogi B, et al. Assessment of the subglottic region by ultrasonography for estimation of appropriate size endotracheal tube: A clinical prospective study. Anesth Essays Res. 2012;6(2):157. https://doi.org/10.4103/0259-1162.108298.
12. Tantri AR, Kapuangan C, Rohmana A. The accuracy in predicting endotracheal tube size for Malayan pediatric patients: A comparison between ultrasonography and Cole formula. Adv Sci Lett. 2018;24(9):6893-96. https://doi.org/10.1166/asl.2018.12875.
13. Pillai R, Kumaran S, Jeyaseelan L, George SP, Sahajanandan R. Usefulness of ultrasound-guided measurement of minimal transverse diameter of subglottic airway in determining the endotracheal tube size in children with congenital heart disease: A prospective observational study. Ann Card Anaesth. 2018;21(4):382-7. https://doi.org/10.4103/aca.ACA_220_17.
14. Abdelghany A, Nasr N, Talaat S, Mansour M, Shabana T. Ultrasound compared to age related formulas for prediction of pediatric endotracheal tube size. QJM Ann Int J Med. 2020;113(1):3-5. https://doi.org/10.1093/qjmed/hcaa039.
15. Sutagatti JG, Raja R, Kurdi MS. Ultrasonographic estimation of endotracheal tube size in paediatric patients and its comparison with physical indices based formulae: A prospective study. J Clin Diagnostic Res. 2017;11(5):UC05-UC08. https://doi.org/10.7860/JCDR/2017/25905.9838.
16. Makireddy R, Cherian A, Elakkumanan L, et al. Correlation between correctly sized uncuffed endotracheal tube and ultrasonographically determined subglottic diameter in paediatric population. Indian J Anaesth. 2020;64(2):103-8. https://doi.org/10.4103/ija.IJA_619_19.
17. Bae JY, Byon HJ, Han SS, Kim HS, Kim JT. Usefulness of ultrasound for selecting a correctly sized uncuffed tracheal tube for paediatric patients. Anaesthesia. 2011;66(11):994-8. https://doi.org/10.1111/j.1365-2044.2011.06900.x.