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Research Article

Comparative study on prediction of paediatric endotracheal tube size by ultrasonography and by age based formulas

Paul O. Raphael*, Ershad Thasim, Binu P. Simon, Rajagopal P.

Department of Anaesthesiology, Amala Institute of Medical Sciences, Thrissur, Kerala, India

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***Correspondence:**
Dr. Paul O. Raphael,
E-mail: poloralph11@yahoo.com

ABSTRACT

Background: Age-based formulas have been widely used to predict the appropriate size of the endotracheal tube (ETT) for intubation in paediatric age group. These formulas often fail to reliably predict the proper size of ETT. The objective of the study is to determine whether the tracheal internal diameter imaged by ultrasound is a better predictor of ETT size than age based formulas.
Methods: The study included a total of 60 patients of ASA 1 and 2 aged between 2 and 15 years of either sex posted for elective surgery under general anaesthesia. After institutional ethical committee approval and written consent from the parents, anaesthesia was induced as per the protocol. The tracheal diameter was measured after induction of anaesthesia, during mask ventilation prior to intubation. A linear high frequency ultrasound probe (GE venue 40) was used to measure the tracheal diameter. The size of ETT was selected according to the measured tracheal diameter. The leak test and adequate oxygenation/ventilation were the objective tests used to validate the appropriateness of the ETT chosen. The ETT sizes determined by age based formulas and by the use of ultrasound were statistically compared with the appropriate ETT size used clinically for intubation.
Results: The estimation of endotracheal tube size with the aid of ultrasound was found to be superior when compared with age based formulas. Ultrasound tube size determination correlated well with clinically used ETT size.
Conclusions: Determination of endotracheal tube size by ultrasound is a good predictor of proper sized ETT in paediatric age group when compared with age based formulas.

Keywords: Ultrasound imaging, Cricoid cartilage, Endotracheal intubation

INTRODUCTION

Paediatric patients, because of their anatomical differences in airway compared to adult pose many challenges during endotracheal intubation. One such challenge is, in selecting the proper sized endotracheal tube (ETT) for intubation. If ETT is too small it may result in inadequate ventilation, unreliability of end-tidal gas monitoring, leakage of anaesthetic gases into the operating room environment and an enhanced risk of aspiration. If a large ETT is used it can cause upper airway complications like local ischemia, ulceration, scar formation and also increased risk for subsequent subglottic stenosis and post- extubation stridor.[1,2] The prediction of appropriate size of ETT for paediatric age group can be estimated by various methods. These include simple and easy to perform methods like age based formulas like Cole and Motoyama, X-ray neck and comparing the size of ETT diameter with the little finger. The more advanced methods such as CT and MRI are expensive and impractical.[3,4] We usually depend on age based formulas for selecting appropriate sized endotracheal tubes. These formulas which are based on age are often unreliable and may end up in repeated laryngoscopy for selecting the correct sized ETT.[4,5] This could lead to more chances of airway trauma and other complications.

With the help of ultrasonography, the anatomical structures in the supra-glottic, glottic and subglottic regions can be visualised easily. Ultrasound is a reliable, safe and non-invasive pain free modality for evaluation of the upper airways and a useful tool for estimating the proper size of endotracheal tube. The aim of this study was to determine the proper fit ETT using ultrasonography and compare it with those determined by age based formulas.[6,7]

METHODS

After institutional ethical committee approval and with parental consent, 60 ASA I and II patients of either sex between 2 to 15 years of age, undergoing various elective surgeries under general anaesthesia were selected. A detailed history, complete general physical examination and routine investigations were done. Patients belonging to ASA grade III and IV, emergency surgeries, patients with known pulmonary and cardiovascular problems and patients with facial abnormalities and or anticipated difficult intubation were excluded. Those with condition known or suspected to predispose them to laryngeal or tracheal pathology were also excluded.

Procedure

General anesthesia was induced with a dose of 2 mg/kg propofol after appropriate premedication. An intubating dose of vecuronium 0.1 mg/kg was injected to all patients for muscle relaxation. Patient was then mask ventilated with sevoflurane, nitrous oxide and oxygen for 3 minutes for optimal muscle relaxation prior to intubation. During mask ventilation subglottic tracheal diameter was measured using an ultrasound. ETT size as per the age based formula was also calculated. Age based formula (for more than 2 years) used was Motoyama.

ID in mm=0.25 x (age in years) + 3.5

Ultrasonography technique

The subglottic diameter was determined using a high resolution linear probe of ultrasound machine (GE healthcare venue 40) placed on the midline of the anterior neck with the head extended and neck flexed during mask ventilation. To prevent artefact and bias, standard plane of scanning was maintained. Procedure was performed by an anaesthesiologist experienced in using ultrasound. The cricoid arch is visualised as a round hypoechoic structure with hyperechoic edges (Figure 1). The transverse air-column diameter was measured at the lower edge of the cricoid cartilage which is considered as the subglottic tracheal diameter. Subglottic tracheal diameter measured was used to select the endotracheal tube with similar outer diameter. Since the outer diameter of ETT differs among different manufacturers, we used Rusch endotracheal tube (teleflex) for our study. Corresponding inner diameter of the selected tubes were recorded. The endotracheal tube with an outer diameter always less than the measured tracheal diameter was selected to prevent trauma to the airways. These measurements were performed when manual ventilation was stopped briefly to minimize fluctuation in tracheal diameter.[8-11]

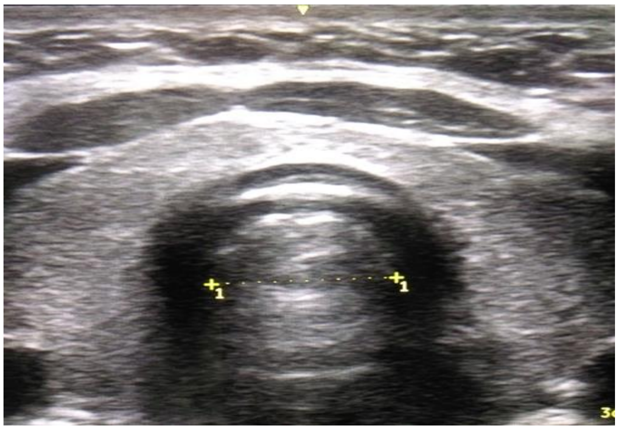

Figure 1: Ultrasound measurement of subglottic diameter of trachea.

The endotracheal tube size estimated by ultrasonography was used for endotracheal intubation. Endotracheal tube size was confirmed by performing leak test by one of the investigator. ETT size was considered optimal when the tracheal leak was detected at an inflation pressure of 10-20 cm of H_2O. If there was no audible leak when the lungs were inflated to a pressure of 20 to 30 cm of H_2O or when there was a resistance to the passage of ETT into the trachea, the tube was exchanged with 0.5 mm smaller tube. But if a leak occurred at an inflation pressure of less than 10 cm of H_2O the ETT was exchanged with a 0.5 mm larger tube.[12-14] The recorded data include internal diameter of the ETT from the age-based formula, ETT determined by ultrasound imaging and the clinically used ETT for intubation during general anaesthesia.

Statistical analysis

The results were tabulated and analysed using Microsoft Excel 2007 and SPSS 23 for windows. Statistical significance in mean difference was done using student t-test. The Bland Altman method and linear regression were used to compare the ETT diameter predicted from age-based formula, estimated tracheal diameter by ultrasound and clinically used ETT diameter. Data was reported as mean SD unless otherwise indicated. $P < 0.05$ was considered statistically significant.

RESULTS

Demographic characteristic of 60 patients are shown in Figure 2 and are comparable. Ultrasound determination of tracheal diameter was done in all patients without any difficulty. The time required for ultrasound estimation of

ETT was less than 2 minutes in all patients. In patients who are aged <5 years mean internal diameter of ETT derived by age based formula was 4.3±0.24 and by ultrasound was 4.28±0.30. In ages between 6 to 10, mean internal diameter of ETT for age based formula and by ultrasound was 5.3±0.39 and 5.3±0.37 respectively. In patients above 10 years mean internal diameter of ETT for age based formula was 6.5±0.41 and by ultrasound was 6.3±0.27.

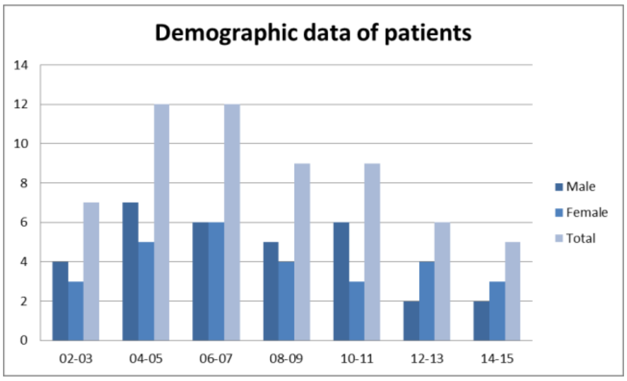

Figure 2: Age and gender distribution of patients studied.

By the Bland Altman analysis, the rate of agreement between clinically optimal and ultrasound guided endotracheal tube was 98.5% (P <0.0001) when compared to the rate of agreement between clinically used and age based formula derived tube which was 95.9% (Table 1-3).

Our results shows a strong correlation between ultrasound determined tube size and clinically used ETT.

Table 1: Comparison of mean internal diameter based on age based formula and ultrasound method with endotracheal tube used.

Age	Internal diameter (age based formula)	Internal diameter (clinical)	Internal diameter (ultrasound)
<5	4.3±0.24	4.2±0.31	4.28±0.30
6-10	5.3±0.39	5.28±0.4	5.3±0.37
>10	6.5±0.41	6.4±0.28	6.3±0.27

Table 2: Comparison between ETT derived by age based formula and by ultrasound to the clinically used ETT (ID=Internal diameter of endotracheal tube).

Variable	Beta	Confidence interval		Adjusted R	P value
		Upper	Lower		
I.D formula and I.D clinical	0.981	0.972	0.877	0.963	0.0001
I.D ultrasound and I.D clinical	0.995	1.028	0.973	0.989	0.00001

Table 3: Correlation between ETT derived by age based formula and by ultrasound to the clinically used ETT (ID=internal diameter of endotracheal tube).

Variable	Kendall's tau-b correlation	P- value
I.D formula and I.D clinical	0.959	0.0001
I.D ultrasound and I.D clinical	0.985	0.0001

DISCUSSION

The age based formula Motoyama is commonly used for determining ETT size in children who are older than 2 years. Previous studies shows that the rate of agreement of age-based ETT size selection using the Cole formula is as low as 47-77.[5] Height-based technique such as Broselow tape can be used to compensate for individual variation in growth. However, these methods have many limitations because these formulas cannot consider variation in the growth of various internal organs.

Our study showed that ultrasound measurement of subglottic diameter has significant advantage in predicting optimal paediatric ETT size. In a pilot study, role of ultrasound and its usefulness in predicting the tracheal diameter in paediatric patients were studied.[5] In the study, a prospective clinical study like the pilot study showed a higher correlation between ETT used clinically and ETT determined by ultrasound than between ETT used clinically and ETT determined by age based formula. With the aid of ultrasonography we could measure the air-column width at the level of the cricoid and select the optimal sized ETT for intubation in less than 2 minutes. ETT was selected according to the measured diameter of the air column which was considered as the inner diameter of trachea. Teleflex-Ruch ETT was used in all cases to prevent bias, as the outer diameter of ETT varies with different manufactures. We preferred to measure the subglottic diameter as this was the narrowest part of trachea thus preventing trauma due to insertion of a large sized endotracheal tube.

Non-invasive techniques for measurement of tracheal diameter are chest X-ray, CT, MRI, ultrasonography and the invasive methods are flexible or rigid endoscopy. Various studies have shown that optimal ETT size could be selected from tracheal measurement on chest radiography. Some studies show a good tracheal diameter correlation between computed tomography and chest radiography and also conclude that the CT scan could give a representative measurement of tracheal diameter.[15,16] MRI scan on the other hand can give additional information on the anterior posterior measurement of tracheal diameter.[17] Anterior posterior diameter cannot be visualised with an ultrasound because the acoustic shadow generated by the air column obscures the location of posterior wall of trachea. MRI provides high quality images allowing accurate measurements of larynx. Hence MRI is considered as a non-invasive gold standard method for measurement of subglottic diameter. But in the clinical settings the high-quality laryngeal images of CT and MRI cannot be routinely obtained because of the high cost and feasibility.

Studies done on the feasibility of ultrasonography to examine the subglottic diameter showed a strong correlation between ultrasonography and MRI measurements of the transverse subglottic diameter and concluded that ultrasound could determine the subglottic diameter adequately.[18] Ultrasonography unlike CT and MRI does not require strict immobility, especially in infants. Ultrasonography depends on the operator skill and hence requires training, yet relatively simple to learn. Ultrasound may also be useful to evaluate patients with subglottic stenosis, a common complication in neonatal or paediatric anaesthesia.[19-21] Age related physiological laryngeal calcification usually seen in adults is an important limitation of ultrasonography in geriatric patients as it creates an acoustic shadow in ultrasound image.[22]

CONCLUSION

Ultrasound is a safe, reliable, non-invasive tool for selection of appropriately sized endotracheal tube for clinical use. Our study validates the reliability of ultrasound to measure subglottic diameter which avoids intubation related complications of either trauma or inefficient ventilation.

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