Usefulness of Ultrasonography for Selection of Correct Size Endotracheal Tube in Paediatric Patients

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ABSTRACT

Introduction: Ultrasonography is fast revolutionising all aspects of practice of anaesthesia. Estimating the correct size of endotracheal tube in paediatric age group has been quite a task in spite of innumerable formulae and thumb rules. This study aims to study the usefulness of ultrasonography in prediction of appropriate size endotracheal tube in paediatric age group.

Material and methods: A prospective clinical observational study was conducted in which, after obtaining ethical committee approval, 60 patients up to the age of 12 years requiring general anaesthesia were studied. Before laryngoscopy, transverse tracheal diameter at the level of cricoid was measured with linear probe [frequency 6-13 Hz] of the portable ultrasound. The attending anaesthesiologist was blinded to the ultrasound measurements. Trachea was then intubated using direct laryngoscopy. Size of the tube was selected as per the age based formulae. Correlation among the study parameters (Optimal endotracheal tube size as per sizing technique, Ultrasound and age based formulae) was assesed with the help of Pearsons correlation coefficient.

Results: Ultrasonography showed better positive predictive value of the correct size endotracheal tube as compared with the age based formulae. Correlation analysis showed higher Pearson's correlation coefficient of 0.977 between ultrasonography determined endotracheal tube size and the optimal size used clinically, as compared to 0.914 with age based formulae method.

Conclusion: Ultrasonography offers a better alternative than the frequently used age-based formulae for Endotracheal tube selection method in paediatric patients.

Key words: Cole's formula, Motoyama's Formula, Paediatric Airway Ultrasound

INTRODUCTION

A formula to predict the correct size of the ETT to be used in the pediatric patient was first proposed by Cole in 1957[1] and this is the most commonly used formula even today. Other age based formulas, like Motoyama's[2], Penlington's[3] were proposedmore than half a century ago. Due to the wide variations in the size of children and the frequent inaccuracy of the calculated ETT size, other complex formulae using multiple variables such as age, height and weight were proposed, but did not gain wideuse in clinical practice. Intubation of paediatric patients with an ETT that is too small may result in insufficient ventilation, poor reliability of end-tidal gas monitoring, leakage of anaesthetic gases into the operating room environment, and an enhanced risk of aspiration.[4-6] In contrast, an ETT that is too large can cause upper airway damage (e.g., laryngeal edema, stridor, local ischaemia, ulceration, granulation, scar formation) and potential for subsequent subglottic stenosis.[7,8] Predictive formulas for appropriate ETT size have also been based on patient's weight and height.[9-11] However, none of these work are accurate and further they do not conform to various ethnic populations across the world. This can result in repeated laryngoscopies and reintubations to identify the appropriate sized tube.

Some recent reports suggest that the diameter of the subglottic upper airway can be determined by ultrasound in healthy young adults and paediatric patients.[12,13] In addition, one 2010 report from a research group in Japan showed that ultrasound can predict optimal ETT size in paediatric patients.[14] Another study published by a Korean group under Baeet al.[15] documented the usefulness of ultrasound for selecting a correct sized uncuffed tracheal tube for intubation of paediatric patients.

Our aim was to study the usefulness of ultrasonography in prediction of appropriate size endotracheal tube in Indian pediatric age group.

MATERIAL AND METHODS

Institutional ethical committee approval was obtained for a prospective clinical observational study. 60 paediatric patients up to the age of 12 years requiring general endotracheal anaesthesia were studied. Written informed consent was obtained from the parents (guardian) of each child.

The inclusion criteria were age upto 12 years, elective surgery requiring general endotracheal anaesthesia, and normal airway.

Exclusion criteria included known allergy to ultrasound gel, age more than 12 years, pre-existing laryngeal pathology and anticipated difficult airway.

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The investigator was trained by performing 15 laryngotracheal ultrasonographic examinations under the guidance of a seniorultrasonologist, before the beginning of the study. The same investigator took all the readings.

After confirming starvation, consent and clinical findings, patients were induced with inhalational / intravenous agents. Patients were paralyzed with a non-depolarizing muscle relaxant (atracurium 0.5 mg/kg after excluding any known allergies) and before laryngoscopy, using ultrasonography, transverse tracheal diameter at the level of cricoid (subglottis) was measured in supine position with head in slight extension with linear hockey stick probe [frequency 6 -13 Hz] of portable ultrasound system .Reading was taken at the highest possible resolution and with the probe placed in midline of anterior neck. Figure 1 shows an illustration of the ultrasonographic view of the cricoid arch and the air column. From the measured reading 0.5 mm was subtracted to avoid a very snugly fitting tube.The attending anaesthesiologist was blinded to the results of the ultrasound measurement. The trachea was then intubated using direct laryngoscopy. Size of the ETT was selected as follows:

1. UncuffedETT, with the Cole's formula
   ID (inner diameter) in mm = 0.25 x (age in years) + 4;
2. Cuffed ETT in children aged ≥ 5 years, with the Motoyama's formula:
   ID (inner diameter)in mm = 0.25 x (age in years) + 3.5;

ETT sizing technique was used to determine the optimal sized ETT. This technique utilizes leak pressure to identify optimum sized ETT in pediatric patients. The leak pressure (pressure at which leak occurs around the tube) was measured with the help of stethoscope placed in the suprasternal notch and manometer was observed for the pressure at which leak was auscultated on ventilation. In case of cuffed endotracheal tube, leak pressure was checked before inflating the cuff. Endotracheal tube size was considered optimal when the tracheal leak was detected at an inflation pressure of 10 to 25 cm H_2O. If the leak was detected at pressure > 25cm H_2O the tube was exchanged with one that was 0.5 mm smaller, but if the leak occurred at inflation pressure < 10 cm H_2O the tube was exchanged with 0.5 mm larger tube.

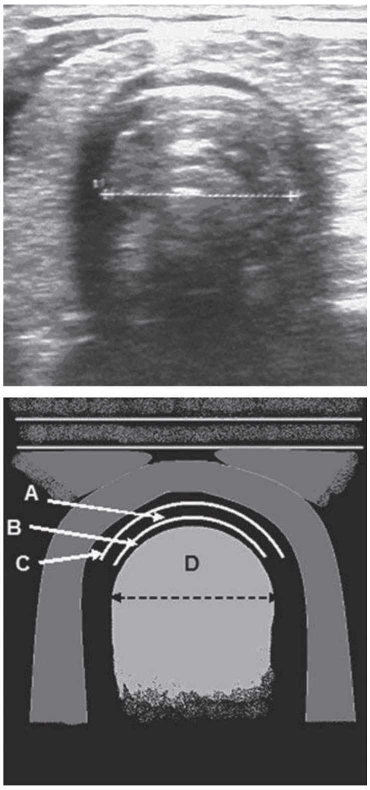

Figure-1: The cricoid arch and the air-column, ultrasonography view12. Cricoid cartilage is a round hypoechoic structure (the medulla (A) with hyperechoic edges (the internal (B) and external (C) perichondrium). The air-column (D) appearedhyperechoic and created a posterior acoustic shadow. The mucosa–air interface, a hypoechoic edge, was easily recognized.

A comparison was made between calculated external diameters of the endotracheal tube from

1 Physical indices of age based formulas,
2 Predetermined by ultrasound
3 Actual clinically used ETT for intubation during general anesthesia

Choice of ETT was determined as correct if deviations were ≤ 0.3 mm from the outer diameter of the correct ETT size as decided by ETT sizing technique.

As the consecutive outer diameters of many different types and manufacturers of ETT differ by approximately 0.7 mm, hence the error of measurement must be ≤ 0.3 mm to predict the correct tube size. For example, the outer diameter of the Ruesch Safety Clear ETT (Teleflex Medical) sizes 4.5 and 5.0 are 6.0 and 6.7 mm respectively.

The dotted line represents the measured air-column width.[14]

STATISTICAL ANALYSIS

After data collecetion, data entry was done in Excel.

Data analysis was done with the help of SPSS Softwear ver 15, Sigmaplot Ver 11 and MedCalc Ver 10.

Quantitative data is presented with the help of Mean, Std Dev, Mean and Interquartile range.

Correlation among the study parameters was assesed with the help of Pearsons correlation coefficient.

P value less than 0.05 was taken as significant.

RESULTS

The demographic data (age, sex, and weight) was comparable between the two groups.

Sixty children were recruited for the study, 29 male and 31 female. The mean age was 4.98 ± 3.34 years (range 1 day to 12 years), mean height was 99.65 ± 24.57 cm (range 45 to 142 cm) and mean body weight was 17.18 ± 9.14 kg (range 1 to 37 kg).

Out of the total 60 cases cuffed ETT was used in 23 cases and uncuffed ETT in 37 cases.

The rate of irrelevant differences between the correctly sized ETT and Ultrasound determined ETT size with a maximum allowed deviation of ≤ 0.3 mm was (Table-1).

1. 89.18% for uncuffed tubes,
2. 86.95% for cuffed tubes.

The rate of irrelevant differences between the correctly sized ETT and ETT size determined by Age based formulae with a maximum allowed deviation of ≤ 0.3 mm was (table-2).

1. 75.67%as per Cole's formula for uncuffed tube.
2. 34.78% as per Motoyama's formula for cuffed tube.
3. 60% as per Age based formulae as a whole for cuffed and uncuffed tubes.

As a whole the age based formulas predicted the correct size of ETT in 36 out of 60 cases i.e. 60% as compared to 88.33% by Ultrasonography (53 out of 60).

Correlation Analysis

Virtual Effect of Ultrasound on the number ofreintubations required

During this study, the primary choice of ETT [based on age based formulae] was incorrect in 24 of 60 patients and a different size ETT had to be inserted. In patients whom uncuffed tube was put and Cole's formula was used to decide the appropriate tube size, 9 patients required reintubation while when cuffed tube was put and Motoyama's formula was used to decide the appropriate tube size, 15patients required reintubation. This resulted in a mean number of 1.38 intubations per child. If the attending anesthesiologists, who were blinded to the results of the ultrasound measurement, had known the size of ETT according to Ultrasound, there would have been a need for reintubation in only 7 cases with a mean number of 1.11 intubations per child (Table-3, 4, 5)

DISCUSSION

This study has revealed the potential utility of ultrasound to measure the transverse diameter of upper airway at subglottic region for selection of the appropriate sized ETT.

Shibasaki et al.[14] tested the hypothesis that subglotticdiameter, as determined by ultrasonography, betterpredicts optimal ETT size than existing methods.A total of 192 patients, aged 1 month to 6 yr,who were scheduled for surgery and undergoing general

anesthesia were enrolled and divided into developmentand validation phases. In the development group, the optimalETT size was selected according to standard agebased

formulas for cuffed and uncuffed tubes. Tubes werereplaced as necessary until a good clinical fit was obtained.*Via* ultrasonography, the subglottic upper airway diameterwas

Method	Correct tube size	Overestimations	Underestimations	Positive Predictive Value
Ultrasonography for uncuffed tubes	33/37	2/37	2/37	89.18%
Ultrasonography for cuffed tubes	20/23	2/23	1/23	86.95%
UltrasonographyTotal	53/60	4/60	3/60	88.33%

Table-1: Comparison of Ultrasonography guided technique with the ETT of the correct size Choice of ETT was determined as correct if deviations were ≤ 0.3 mm from the outer diameter of the correct ETT size as decided by ETT sizing technique.

Method	Correct tube size	Overestimations	Underestimations	Positive Predictive Value
Cole's formula for uncuffed ETT	28/37	4/37	5/37	75.67%
Motoyama's formula for cuffed ETT	8/23	1/23	14/23	34.78%
Age based Formulae for cuffed / uncuffed ETT	36/60	5/60	19/60	60%

Table-2: Comparison of Age based formulae with the ETT of the correct size Choice of ETT was determined as adequate if deviations were ≤ 0.3 mm from the outer diameter of the correct ETT size as decided by ETT sizing technique.

Study variables	External diameter of ETT used(mm)		
	Pearson Correlation (R)	P Value	N
ETT size by formula	0.914	< 0.001	Significant
ETT size by USG	0.977	<0.001	Significant
ETT used (Sizing technique)	1		

Table-3: Correlation among USG and age based formulae for determination of ETT size

Uncuffed tubes	Ext diameter of ETT used(mm)		
	Pearson Correlation(R)	P value	Correlation is
ETT size by USG	0.965	< 0.01	Significant
ETT size by Formula	0.917	< 0.01	Significant

Table-4: Correlation among USG and age based formulae for determination ofuncuffed ETT size

Cuffed ETT	Ext diameter of ETT used(mm)		
	Pearson Correlation(R)	P value	Correlation is
ETT size by USG	0.948	< 0.01	Significant
ETT size by Formula	0.769	< 0.01	Significant

Table-5: Correlation among USG and age based formulae for determination ofcuffed ETT size determined before tracheal intubation. They constructeda regression equation between the subglottic upperairway diameter and the outer diameter of the ETTfinally selected. In the validation group, ETT size wasselected after ultrasonography using this regression equation.

The primary outcome was the fraction of initialcuffed and uncuffed tube sizes, as selected through theregression formula, that proved clinically optimal.Subglottic upper airway diameter highly correlatedwith outer ETT diameter deemed optimal on clinicalgrounds. The rate of agreement between the predicted ETTsize based on ultrasonic measurement and the final ETT sizeselected clinically was 98% for cuffed ETTs and 96% foruncuffed ETTs. Thus this study validated the usefulness of ultrasonography in determining the ETT size as in our study.

Shibasakistandardized the location and respiratoryparameters for ultrasound measurement. Conditions of known or suspected laryngeal or trachealdiseases were excluded. This criterion was considered in the study ofShibasakiand in our study.

This study does not describe the term clinical fit in detail. In our study we determined optimal size of ETT by sizing technique.

Bae et al.[15] examined 141 children below the ageof 8 years. In all patients, after anesthesiainduction andmuscle relaxation, the ultrasound measurement of thetransverse diameter of the airway at the cricoid cartilage was done with8- to 13-MHz linearprobe under a constant airway pressure of 10 cmH_2O. Using standardized leaktest (15–30 cmH_2O), ultrasound method predicted the correct uncuffed ETT in only 60% and age-basedmethod predicted the correct tube in 31% cases (P = 0.001).

Christoph Schramm et al[16] evaluated the role of ultrasound in pediatric patients to compare the correct size of an uncuffed (ETT) with the minimal transverse diameter of the subglottic airway (MTDSA) measured by ultrasound and with tube size predicted by different age-related formulas.A total of 50 pediatric patients ≤ 5 years were enrolled. As a standard, they defined the adequate ETT size with no audible leakage below a ventilation pressure of 15 mbar and with an audible leakage above 25 mbar. The maximum allowed difference between the prediction method result and the ETT that fit was defined as 0.3 mm. Ultrasound was performed before the intubation procedure; the intubating anesthesiologists were blinded to the results of the ultrasound measurement. Agreement between the two age-based formulas most commonly used at the department and MTDSA with the correct ETT size (standard) was analyzed using a Bland-Altman plot. Correlation and regression analyses were performed and the numbers of correct intubation trials recorded.The frequency of bias ≤ 0.3 mm between each method and the correct ETT in the first attempt was <50% and the mean number of reintubations 1.6 ± 1.3. In contrast to age-related formulas, however, the ultrasonographically determined MTDSA was not significantly different from the correct ETT. MTDSA was highly associated with the outer diameter of the ETT (r = 0.869, R(2) = 0.754)

In our study optimum ETT size was determined by Sizing technique i.e leak pressure 10-25 cm H_2O. Also the above study was done only for uncuffed ETT while in our study we used both cuffed as well as uncuffed tubes.

The measurement of tracheal diameter may be performed using non-invasive methods such as Chest X ray, CT, MRI or ultrasonography and invasively by endoscopy. High quality laryngeal images provided by CT and MRI are not routinely obtained because of cost and feasibility and the assessment of laryngeal dimensions may be overestimated as shape of the subglottic area is frequently not cylindrical.[17] Also they require immobile child for which they may require sedation or anaesthesia.

Recent report showed thatairway ultrasonography has a strong correlation with magnetic resonance image (MRI) for measurements of the transverse subglottic diameter.[18] Ultrasonography is operator dependent technique but is relatively simple to learn. Unlike adults, laryngeal calcification is not encountered in children.[19] Therefore, laryngealcalcification, one of the limitations of performingultrasonographic measurements of the larynx, doesnot influence ultrasonographic findings in paediatricpatients. Thus, ultrasonography may be moreuseful for the selection of tracheal tube size inchildren.

Our study did not include any patient with a laryngealpathology. Literature indicates that pre-emptive airway sonography may help in planning the airway management in cases with anticipated difficult airway, stridor, past history of tracheostomy.[20-23] During the period of our study we used USG to correctly determine double lumen ETT size for one of our paediatric patients.

CONCLUSION

Ultrasonography is a very useful, safe,quick, reliable noninvasive reproducible method for estimation of the subglottic tracheal diameter for selection of appropriate sizedETT in children. Our study validates the superiority of ultrasound to predict the appropriate ETT size as compared to age based formulae both for cuffed and uncuffed ETT in children.Children withpolytrauma cases in which FAST (Focussed Assessment with Sonography for Trauma) forms an integral part of initial evaluation would be also benefitted with airway sonography as they may require ET intubation Ultrasonography of airway can have special indications in children exposed to airway radiation.

Limitations

Although we found Ultrasonography superior as compared to formula based methods in predicting the ETT size for pediatric patients it is not a foolproof method. Also it cannot become a routinely used method because of the cost involved and finally is a subjective method in which the investigator has to be first trained to a particular skill level.

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