Original Research Article

Ultrasound measurement of subglottic diameter for determination of microcuff endotracheal tube size and intubation outcome in paediatric cases: An observational study

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Abstract

Introduction: One of the biggest achievements of medical science is safe anaesthesia especially for children. Management of airway takes priority over any other intraoperative intervention during anaesthesia .Determination of "best -fit" endotracheal tube (ETT) is important in children to provide optimum ventilation without causing any laryngotracheal morbidity[1-4]. **Aim:** To investigate the 1st attempt success rate of intubation using best fit Micro cuff ETT (MCETT) size, determined by ultrasound measured subglottic diameter in paediatric population and to compare the result with age based size table of micro cuff endotracheal tube. **Materials and methods:** 66 paediatric patients aged between 1-10 year, undergoing various elective surgeries under general anaesthesia were included in the study .The subglottic airway transverse diameter was measured in the brightness (B) mode using the linear probe (range 6-13 MHz) of the USG device with the child in the supine and neutral head position. Best-fit tube ID is considered as the one with satisfactory air leak at an airway pressure of 15-20cm H2O. 1st attempt success rate of intubation using best fit MCETT size, determined by ultrasound measured subglottic diameter in paediatric population were compared with the result with age based size table of micro cuff endotracheal tube. **Results and Conclusion**: Comparisons of means of sizes of correct MCETT with age based table and with USG guided method revealed that both methods are good predictors for the correct MCETT size estimation (p-value<0.05). However, size of correct MCETT matched with MCETT size calculated using USG method was in 56 patients (84.8%), whereas the MCETT by age-based table selected the correct tracheal tube size in 42 (63.6%) patients with the difference being statistically significant (p=0.026). Furthermore, reliability agreement calculated by Intraclass correlation coefficient suggested that USG based methods are better than age based formulas in children with k- values of 0.939 and 0.887 respectively. **Conclusion:** We conclude that ultrasound appears to be a reliable predictor for the assessment of the subglottic diameter of the airway in children to estimate the appropriate size of microcuff endotracheal tube.

Keywords: Paediatric microcuff endotracheal tube, subglottic diameter, ultrasound.

Introduction

Determination of "best -fit" endotracheal tube (ETT) is important in children to provide optimum ventilation without causing any laryngotracheal morbidity. For this purpose, various formulae based on the demographic characteristics (weight, age, height, and finger size) have been developed, but none of them has been fully successful in predicting the optimum endotracheal tube (ETT) size.As these formulas do not reflect individual variations in internal organ growth[1-4].

Measurement of subglottic diameter (SD) at the cricoid cartilage level by ultrasound is gaining importance and the results have shown that it is a better method for determining the appropriate ETT size. There are several studies using ultrasonographic measurement of subglottic diameter for calculation of uncuffed and cuffed tube size selection in paediatric patients but most of the studies utilised the initial ETT size selection according to age-based formulas[9,2].

This study was planned to investigate the 1st attempt success rate of intubation using best fit Micro cuff ETT size, determined by ultrasound measured subglottic diameter in paediatric population and to compare the result with age based size table of micro cuff endotracheal tube[5,6,7,8].

Materials and Methods

After approval from Institute`s Ethics and Research committee (35/MC/EC/2019) and written and informed consent from parents/guardians, 66 pediatric patients belonging to American society of anaesthesiologist (ASA) grade I, II, aged between 1-10 years undergoing various elective surgeries under general anaesthesia and requiring endotracheal intubation were included in the study.

Patients having any anatomical deformity of upper airway, recent history of the upper respiratory infection, requiring fiberoptic intubation or alternate intubation technique, having any obvious scar, mass or ulcer in the neck , with body mass indices above the 85th percentile (overweight) and below the 5th percentile (underweight) and were excluded from the study.

A detailed pre anaesthetic checkup including history taking, clinical examination and routine investigations were done preoperatively. On the day of surgery the patient is taken into OT after checking written informed consent, PAC and confirming nil by mouth status. Calculated volume of intravenous fluid startedthrough an already

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secured IV line as per hospital protocol. Baseline pulse rate (PR), mean arterial blood pressure (MAP), oxygen saturation (SpO2) and electrocardiogram (ECG) were recorded.

After preoxygenation with 100% oxygen, premedication was given in the form of inj. glycopyrrolate 0.005mg/kg, inj. midazolam 0.05mg/kg, inj. fentanyl 2 micro gm/kg. Induction was done by inj. propofol 2.5mg/kg i.v., followed by inj. atracurium 0.6mg/kg i.v . Intermittent positive pressure ventilation (IPPV) with 100% oxygen via face mask done. After 3 min, trained investigators measured the subglottic airway transverse diameter in the brightness (B) mode using the linear probe (range 6-13 MHz) of the USG device (Sonosite micromax) with the child in the supine and neutral head position.

The patients were ventilated via a facemask during the measurement. The probe is placed on the anterior neck; then, proceeds in the caudal direction, the vocal cords and cricoid cartilage visualized. In apnoeic phase, the narrowest portion of subglottic airway diameter is measured as the hyperechoic air column diameter (figure 1). Tracheal intubation was performed with the same brand of microcuff ETT, the outer diameter (OD) of which match to the closest size (by table 2) measured subglottic airway diameter. If there was any resistance to passage of the tube into the trachea or absence of audible leak at airway pressure >25 cmH20, the tube was replaced with internal diameter (ID) 0.5 mm smaller prior to inflation of the cuff. If an audible leak is present at airway pressure <10 cmH2O, or a cuff pressure >15 cmH2O (as measured by cuff manometer) was required to seal the trachea, the tube was changed to the nearest larger size (0.5 mm larger ID). Best-fit tube ID is defined as the tube ID that fulfil all aforementioned criteria. The need for ETT replacement was recorded.

Patients were maintained on O_2, N_2O, inj atracurium 0.15 mg/kg and sevoflurane 2 %. At the end of surgery patients were extubated after giving reversal with inj. neostigmine and inj. glycopyrrolate, cuff deflation and oral suctioning. The patient was observed for any postoperative airway complication, if present then the need for reintubation assessed. If no postoperative complication (croup, cough, sore throat, dyspnoea, dysphonia or stridor) was observed, the child was shifted to recovery room.

For Microcuff tracheal tubes size selection is done by following

Table 1:ID and Age

ID (mm)	3	3.5	4	4.5	5	5.5
AGE	Birth(<3kg) to <8month	8month to <2 year	2 to <4year	4 to <6 year	6 to <8 year	8 to <10 year

Figure 1.USG midline transverse image of subglottic diameter at cricoid level

Table 2.Outer diameter (OD) and inner diameter(ID) of microcuff endotracheal tube (Kimberly Clark)

ID (mm)	3	3.5	4	4.5	5	5.5
OD (mm)	4.3	5	5.6	6.3	6.7	7.3

Ultrasonography is a operator dependent technique, all the measurements were carried out by the investigator trained by a radiologist for two weeks for measuring cricoid dimension and related anatomy, to rule out any bias in the accuracy of measurement with ultrasonography. A pilot analysis was carried out to measure the subglottic diameter in the operation theatre over 15 patients following the same technique with the radiologist present and supervising during scanning.

Based on a previous study[7] the sample size was calculated as 66 participants at 95% confidence interval & 10% relative error to verify 86% successful intubation on first attempt with best fit cuffed endotracheal tube based on ultra-sonographic measurement of subglottic diameter.

Statistical analysis was done using Microsoft Excel and was analyzed using SPSS statistical software (version 20.0) (IBM Corporation, NY, USA). Numerical variables (e.g. age, weight, HR and BP) were presented as mean ± SD and categorical variables (e.g., sex and adverse effects) were presented in numbers and percentage (%). Mean and standard deviations were calculated for the agreement for correct MCETT used with each ultrasound MCETT and age based table method. MCETT was assessed using Intra class correlation (ICC).Comparisons of means of sizes of correct MCETT with age based table and with USG guided size was carried out using paired t test. Proportion of correct MCETT used with the age based table method and with that of ultrasound is compared using McNemar's test.

Results

In this study, all 66 enrolled patients completed it successfully. Comparable pattern was seen in the demographic and physical characteristics of all 66 patients. (Table-3). The durations of measurement using USG, the measured USG-OD, USG ID and the best-fit IDs of the 66 included paediatric patients are given in Table 4. The success rate at the first attempt with USG was 86%; the ETT was changed in one patient to a tube one size larger and in nine patients to a tube one size smaller.

Table 3: Demographic and physical profile of the subjects

	Frequency n=66
Age , mean ± SD (years)	4.6 ±2.5 (1 to 10)
Male : Female	49:17
Weight, mean) ± SD (Kg)	14.77±5.86 (6.8 to 32)
ASA Grading I :II	53:13

Table 4: The duration of measurement, USG OD, measured (USG-ID) and inserted tube ID and MCETT size by age based table

	Mean±SD (min-max)
USG duration (s)	36.03 ±6.04 (26-50)
USG-OD (mm)	6.42 ±0.69 (5.2-8.1)
USG-ID (mm)	4.57±0.63 (3.5-5.5)
Best-fit ID (mm)	4.51 ±0.635 (3.5-5.5)
MCETT by age based table	4.43 ±0.66 (3.5-5.5)

Comparison between the Best fit and predicted size of Microcuff Endotracheal tube by age based table was done by Paired t test to know that there is significant relation between paired values of both the methods (USG based and age based table method with the correct size MCETT) and is statistically significant.(P value<0.05)
Size of correct MCETT matched with MCETT size calculated using USG method is 56 patients (84.8%), whereas the MCETT by age-based table selected the correct tracheal tube size in 63.6% (42) patients. This difference was statistically significant (p=0.026 using McNemar's test) proving the superiority of ultrasound method over age based table method.

Intraclass correlation coefficient (ICC) was calculated to know the reliability agreement for the size of MCETT which was used for the patient with the size of MCETT calculated using age based table. Agreement of ultrasound based method with the correct size tube was 0.939 is considered as excellent and also supported by a good 95% confidence limit. However the same ICC for agreement for age based table method and correct MCETT was also 0.887 which is considered good. These values suggest that USG based methods are better than age based table formulas in children. (table 5)

Table 5: Reliability Agreement of age based formula and correct tube size

	ICC	**95% confidence limit**
Agreement of USG and correct MCETT size	0.939	0.897- 0.963
Agreement of age based table and correct MCETT size	0.887	0.819- 0.930

Children were observed in the recovery room to see post operative complication.Out of 66 children, only 3 (4.5%) children had mild laryngospasm.

Discussion

Estimating tracheal tube size in children is most crucial; ideally, the optimum endotracheal tube size should be estimated with simple measurements rather than using cumbersome formulas derived from measurements of demographic data such as age and height. Moreover these methods are not accurate and may produce conflicting results. Recently ultrasound has been shown as a reliable noninvasive method to evaluate the airway diameter and several studies have investigated the role of ultrasound to guide ETT size selection in pediatric population.
We found many studies in the literature investigating the success of ultrasound in pediatric patients in determining the appropriate sized cuffed and uncuffed endotracheal tube and their association with conventional formulae. However, no literature was found using microcuff tubes and comparing USG with age based tables available for MCETT.
In this study, our first attempt success rate was 84.85% with direct measurement is higher than two previous studies done by Bae et al[11]. they reported 60% success and Schramm et al[12]. who reported 48% success in a younger population by use of uncuffed ETT. Shibasaki et al[9]. attained higher success (98%) for cuffed tubes when a regression equation was applied to directly measured subglottic diameters. The difference between our results and those of other studies can be explained by several factors, such as measurement location, precision and predetermined air leak test limits.
In terms of location, the probe was positioned at the cricoid cartilage level, either at the lower end of the cricoid ring or at mid point, in all previous studies[8,9,11], but in our study measurement was taken at transverse diameter of cricoid cartilage at air mucosa interface. This measure represents a reliable and consistent value that can be comparable among the patients.
In all the patients the transverse airway column was measured as previous study[11] have reported that ultrasound can accurately measure airway diameter in the transverse, which is not possible in the anteroposterior direction. As the anteroposterior diameter of the trachea is larger than its transverse diameter, and leads to underestimation of the actual tracheal diameter and the selection of a smaller endotracheal tube.
We avoided both underestimation and overestimation in our study by monitoring audible leak and peak airway pressures. Ultrasound measurement revealed airway diameter and hence tube ODs and needs to be converted to tube ID. As the tube OD for a given ID differs among varying brands so we used microcuff tube of the same standard brand.
In this study we observed direct ultrasonography measurements of the subglottic diameter to identify microcuff endotracheal tube size with 84.85% first attempt success rate. Whereas the success rate with age-based tables selecting the correct microcuff endotracheal tube size is 63.6%. patients with the difference being statistically significant (p=0.026). Furthermore, reliability agreement calculated by Intra-class correlation coefficient suggested that USG based methods is better than age based formula in children with k- values of 0.939 and 0.887 respectively (k- value more than 0.9 -excellent, more than 0.8 -good, more than 0.7 -average).
Although doing measurement by ultrasound depend on experience of investigator doing USG, time taken for measuring the subglottic diameter by ultrasound in our study was 36.03 sec which is quite similar to studies done by Shibasaki et al[9] **(** 30 second**)** and Demat etal [7] (37.8 second**).**
In our study only 3 patients had laryngospasm which was relieved by bag and mask ventilation. No other complication was seen due to the procedure.

Limitations

Limitations of our study, we did not include the subjects below one year of age because transverse diameter is difficult to measure in this age group due to anatomical variations.Kim et al [8] had already observed a poor correlation between demographic parameters and ultrasound measurements at this age population. We also excluded patients with anticipated difficult intubation.
Limitations of ultrasonography should also be considered as it measures the transverse diameter of the trachea at one level which is subject to variations.

The use of ultrasonography to predict appropriate uncuffed endotracheal tube size in children has been previously studied. The results of these studies[8,9,10,11,12] are comparable to our study as shown in Table 6.

Table 6: showing studies examining the appropriate paediatric ETT with ultrasonographic measurements

Author	Population	Initial tube size selection	Type of tube	condition	Allowed leak pressure	Measurement level
Shibasaki et al[9].	n=192 1 month-6 years	Age and height based formulas versus ultrasonography	Cuffed and uncuffed	Apnoea with no continuous positive airway pressure	10-20 cm H20 for uncuffed ETT 20-30 cm H2O for cuffed ETT	At lower edge of the cricoid cartilage
Bae et al[10]	n=141<8 years	Age based formulas versus ultrasonography	Uncuffed	10 cm H2O continuous positive airway pressure	15-30 cm H2O	At the mid cricoid cartilage level
Schramm et al[11].	n=50<5 years	Age based formulas versus ultrasonography	Uncuffed	Apnoea with continuous positive airway pressure	15.3-25.5 cm H2O	At the narrowest portion of the subglottic airway (MTDSA)
Kim et al[8]	n=215 1-72 months	Age based recommendation versus ultrasonography	Cuffed	Apnoea	No air leak test	At the mid-cricoid cartilage level
Gupta et al[12]	n=112 3-18 years	Physical indices versus ultrasonography	Cuffed and uncuffed	Awake	20-30 cm of water	Cephalic half of the cricoid cartilage
In our study	n = 66 1-10 years	Age based table versus ultrasonography	Microcuff endotracheal tube	Apnoea	No air leak test	At mid cricoid cartilage lavel

Conclusion

We conclude that ultrasound appears to be a reliable predictor for the assessment of the subglottic diameter of the airway in children to estimate the appropriate size of microcuff endotracheal tube. It offers a better alternative than the frequently used age based table for microcuff endotracheal tube.

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