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Comparison of Ultrasonographic Estimation of Endotracheal Tube Size with Age-Based Formula and Diameter of Little Finger in Pediatric Patients

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ABSTRACT

Maintaining a patent airway is the first principle of resuscitation and life support. Successful intubation with the appropriate size endotracheal tube (ETT) is more difficult in children than adults. Use of inappropriate size of ETT can cause significant morbidity and mortality. Visualization of the pediatric airway diameter with the help of ultrasound can enable anesthesiologist to better predict ETT size and it will prevent unnecessary tube changes and airway trauma. Hence, we undertook this study to assess accuracy of USG guided tracheal diameter measurement in predicting ETT size in pediatric patients and its comparison with that determined by age-based formula and diameter of little finger. A total of 50 patients aged between 2 and 6 years were included in this study from July 2017 to June 2018. Agreement between actual ETT inserted and ETT estimation by diameter of little finger, age-based formula and ultrasonography was calculated by using kappa statistics. ETT measurement by diameter of little finger shows an agreement percentage of only 20% (kappa value of 0.05) while the agreement with age-based formula was 56 % (kappa value 0.42). The best agreement was seen between ETT estimated by USG and actual ETT inserted with a kappa value of 0.87 (very good agreement). USG may be considered as a reliable tool for ETT estimation in pediatric patients when compared to age-based formula & diameter of little finger. Age based formula should be preferred over diameter of little finger for ETT estimation when USG is not available.

Key Words: Endotracheal tube, Ultrasound, Tracheal diameter, Kappa statistics

INTRODUCTION

Maintaining a patent airway is the first principle of resuscitation and life support. It is an essential skill for those caring for anesthetized or critically ill patients. Successful intubation with the appropriate size endotracheal tube (ETT) is more difficult in children than adults. The pediatric airway anatomy is different when compared to adults. Their larynx is located higher in the neck with a relatively larger tongue, they have a differently shaped epiglottis; and the vocal cords are angled.[1] Apart from above differences the smaller diameter of pediatric airway makes these patients highly susceptible to laryngeal edema. The effect of 1 millimeter of edema in the cross-sectional area at the level of the cricoid ring in a pediatric airway decreases airway opening by 75 percent (%), whereas in adults airway opening decreases only by 19 %.[2]

Use of inappropriate size of ETT can cause significant morbidity and mortality. A too large ETT tube can cause upper airway damage like ulceration, ischemia, scar

formation, airway edema, sore throat, post extubation stridor, subglottic stenosis.[3,4] On the other hand, a too small ETT can cause large air leak, increased resistance to air flow, increased work of breathing, inadequate ventilation, increased risk of aspiration, increased pollution of operating room, poor monitoring of end tidal gases, difficulty in passing a suction catheter, increased risk of occlusion, increased cost related to increased consumption of volatile agents and need for reintubation.[3,5] To avoid excessive airway instrumentation and minimizing risk of trauma, the preanesthetic assessment of tracheal diameter is important to select appropriate size of ETT. For appropriate ETT size estimation, some anesthesiologists select ETT based on their experience while others use various formulae for calculation of ETT size based on children demographic data like age, weight, height, diameter of child's little finger.[6] The success rate of these demographic data in correct prediction of ETT size is variable. Various studies show that correct ETT size estimation by using age-based formula varies from 31% to 97.5%.[7,8]

Visualization of the pediatric airway diameter with the help of ultrasound can enable anesthesiologist to better predict ETT size and it will prevent unnecessary tube changes and airway trauma. There were very few studies, which we could find in literature, related to USG use in ETT size estimation in pediatric patients and none which compared its efficacy to classical measures of ETT size estimation, which are age-based formula and diameter of little finger method. Hence, we undertook this study to assess accuracy of USG guided tracheal diameter measurement in predicting ETT size in pediatric patients and its comparison with that determined by age-based formula and diameter of little finger.

MATERIAL AND METHODS

After approval by the research ethics committee and written informed consent of parents, this study was carried out in pediatric patients of either sex, between 2 to 6 years of age, coming for various surgeries under general anesthesia (GA) at Indira Gandhi Medical College, Shimla. The study was conducted from 1st July, 2017 to 30th June, 2018. The sample size was 50 pediatric patients calculated by using professional statistical software with a power of 80%, alfa error of 5%, mean difference of 0.5mm and standard deviation of 1. Difference between two paired measurements was analyzed using paired T test. Agreement between ETT size measurement using age based formula, diameter of little finger and ultrasonography with actual ETT inserted was calculated by using Kappa statistics.

Study Protocol

All patients were subjected to a routine pre anesthetic check-up. During this, thorough history, general examination and routine investigations of the patient were carried out.

Children were premedicated with oral midazolam (0.5 mg/kg) or nasal midazolam spray (0.3 mg/kg).

ETT size was measured by the investigator using:

1. USG guided tracheal diameter during induction. The detail of method is mentioned in subsequent paragraphs.
2. ETT size as per age based formula was calculated as follows and noted
   ETT Size as per age based formula (2-6 yr) (Penlington's formula)
   ID in mm = age (yr) /3 +3.5
3. Diameter of the little finger was measured which gave us the outer diameter of ETT. We measured side to side diameter of the little finger with the help of vernier caliper.

As this was an observational study, the Anesthetist incharge in the operation theater (OT) used the ETT as per his or her discretion. For study, cases done by Anesthetist having greater than five years of experience were included. The size of the ETT which was used by the anesthetist was noted. This ETT size was correlated with

the sizes estimated using above three techniques. For correlation internal diameter of the tubes were used.

Ultrasonography Technique:

Subglottic diameter was determined by using high resolution linear probe (40 mm length , frequencies 6-13 MHz) of USG machine placed on midline of anterior neck with head extended and neck flexed (sniffing position). Standard scanning plane was used to prevent any examination bias and artifacts.

Cricoid cartilage and vocal cords were visualized. Transverse air column diameter was measured at lower edge of cricoid cartilage which is considered as subglottic tracheal diameter. Tracheal diameter leads to estimation of outer diameter of the ETT, the corresponding inner diameter was calculated for comparison. For standardization, only uncuffed Portex endotracheal tube was used in our study.

OBSERVATIONS AND RESULTS

A total of 50 patients aged between 2 and 6 years were included in this study from July 2017 to June 2018.

Demographic Characteristics

In our study, 32.0 % of patients were female children (Fch) while remaining 68.0 % patients were male children (Mch) belonging to different age groups (ranging from 2 to 6 years).

Table 1: outer and inner diameters of uncuffed endotracheal tubes of the used brand

OUTER DIAMETER OF ETT(mm)	INNER DIAMETER OF ETT (mm)
4.8	3.5
5.5	4
6.1	4.5
6.7	5.0
7.3	5.5

The same brand of uncuffed ETT (Portex) was used for all children. The manufacturer-provided ETT outer diameter (Table 1) was used to convert the measured subglottic airway diameter to the ETT internal diameter (ID) with which the trachea was intubated.

Table 2: comparison of ETT size (in mm) estimated by diameter of little finger with ETT size used clinically by paired t-test.

VARIABLE	MEAN	STANDARD DEVIATION (SD)	MEAN DIFFERENCE	P VALUE
ETT measured by diameter of little finger	5.31	0.8		
Actual ETT inserted	4.52	0.6	0.79	<0.001

The mean difference between ETT estimated by diameter of little finger and actual ETT inserted was 0.79. There was a statistically significant difference (p value < 0.001) between ETT estimated by diameter of little finger and actual ETT inserted. (Table 2)

Table 3: comparison of ETT size (in mm) estimated by age based formula with ETT size used clinically by paired t-test.

VARIABLE	MEAN	Standard deviation (SD)	Mean difference	P value
ETT measured by age based formula	4.66	0.6		
Actual ETT inserted	4.52	0.6	0.14	0.002

ETT inserted by age based formula had a mean of 4.66 whereas actual ETT inserted had a mean of 4.52. The mean difference between these two was 0.14. The p value was 0.002, which indicates a significant difference between ETT estimated by age based formula and actual ETT inserted. (Table 3)

Table 4: comparison of ETT size (in mm) estimated by ultrasonography with ETT size used clinically by paired t-test.

VARIABLE	Mean	Standard deviation (SD)	Mean difference	P value
ETT measured by ultrasonography	4.53	0.6		
Actual ETT inserted	4.52	0.6	0.01	0.659

There was no statistically significant difference in ETT estimated by ultrasonography and actual ETT inserted (p value >0.05). (Table 4)

Table 5: Agreement between actual ETT inserted with ETT measured by diameter of little finger, age-based formula and ultrasonography.

VARIABLE	AGREEMENT PERCENTAGE (%)	KAPPA VALUE (k value)	P VALUE
ETT measured by diameter of little finger	20	0.05	0.160
ETT measured by age based formula	56	0.42	< 0.001
ETT measured by ultrasonography	90	0.87	< 0.001

Agreement between actual ETT inserted and ETT estimation by diameter of little finger, age-based formula and ultrasonography was calculated by using kappa statistics. ETT measurement by diameter of little finger shows an agreement percentage of only 20% with a kappa value of 0.05, which indicated a poor agreement between ETT estimation by diameter of little finger and actual ETT inserted. The agreement was not statistically significant (p value >0.05). The agreement between ETT estimation by age-based formula and actual ETT inserted was 56 %. There was a moderate agreement between these two methods (kappa value 0.42). This agreement was statistically significant (p value <0.001). The best agreement was seen between ETT estimated by USG and actual ETT inserted with a kappa value of 0.87 (very good agreement) and agreement percentage of 90. This agreement was statistically significant (p value <0.001). (Table 5)

DISCUSSION

The selection of the appropriate endotracheal tube size during pediatric anesthesia remains one of the most important and challenging task for the anesthesiologist. The most commonly used method for determination of ETT size is age based formulae. Time to time various age based formulae has been used, the most common among them are Cole's, modified Cole's, Motoyoma, Penlington's and Khine's age based formulae.[9,10,11] We used Penlington's formula for estimation of ETT by age based formula. In our study, age based formula predicted correct ETT size in only 56 % of pediatric patients. In the majority of cases the tube size was differing by 0.5 mm, with the major difference being overestimation of the correct tube size by one tube size, which was in 36% of cases. Similar results were seen in a study conducted by Davis et al. 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.[12] Thus this study strongly corroborates the findings of our study.

Turkistani and coworkers compared age based formula, length based formula, width of the fifth fingernail and multivariate formulae for estimation of correct ETT size in fifty pediatric patients aged between 2 to 10 years. The correct ETT predicted by age based formula was only 22 %. It was also seen that in 58% of patients best ETT was less than the size predicted by age based formula, which strongly correlates with our study.[13] Contrary to our study, Shih and team found that age based formula predicted the accurate size in 82.4% of Chinese children, in the age group of 1.5 months to 6 years. These contrary results could be due to geographical variation and different population characteristics.[14] Another method which is commonly used for estimation of ETT size in pediatric patients in emergency situations is diameter of little finger.[8] It is stated that the external diameter of the correct ETT is the same as the size of the distal phalanx of the little finger. Our study estimated the correct ETT size in only 20% of pediatric patients when using diameter of little finger, while age based formula predicted the ETT size in 56 %. Age based formula was significantly better than the diameter of little finger for the estimation of ETT size.

Similarly in a study conducted by King et al, in June 1993 in Philadelphia in 237 pediatric patients, ETT size estimation by age based formula was found to be significantly better than diameter of little finger.[8] Van den berg and Mphanza in their study found that the use of the diameter of

little finger as a guide for tracheal tube insertion in pediatric patients lead to selection of a larger tube in majority of cases.[15] In our study we also found that ETT estimation by diameter of little finger overestimates correct ETT size in almost 80 % of cases which was similar to their findings. The use of USG to predict appropriate ETT size in pediatric patients has been studied previously. 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 et al., and they reported the usefulness of measuring the subglottic diameter by ultrasonography in 10 pediatric patients.[16] Various studies have shown that transverse diameter is smaller than anteroposterior diameter at the cricoid level, so transverse diameter measured by USG may be used to choose correct size of ETT owing to its convenience of measurement and narrowness.[17,18]

In our study, the USG estimated correct ETT size of uncuffed tubes in 90% of pediatric patients which was reflected in another study conducted by Shibaski et al in Japan. Shibaski et al found correct cuffed and uncuffed ETT size estimation by USG in 98% and 96% patients respectively.[19] Bae et al, also found USG to be better predictor of ETT size estimation than age based formula in their study conducted in children less than 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 90% of pediatric patients.[7] These differences could be due to different measurement location of trachea. They measured subglottic diameter at the level of mid cricoid, whereas we measured subglottic diameter at the lower edge of cricoid cartilage.[20] Also there might be difference in expertise of using USG for the same, as we took guidance of senior radiologist in the same. The present study shows that ultrasonography offers a more accurate means of selecting a correctly sized uncuffed tracheal tube in children. This concurs with the findings of Gupta and coworkers study in Meerut, Uttar Pradesh, India. They also found that USG guided selection of ETT has estimated the appropriate sized ETT better than physical indices based formulae in 98% of pediatric patients under eighteen year of age.[21] However, their study does not clearly indicated whether cuffed or uncuffed ETT was used.

Schramm and colleagues, reported that USG estimation of ETT was associated with reduced repeated intubation attempts compared to that determined by age based formula in pediatric patients below 5 yrs of age.[22] The results of our study were comparable to the study conducted by Altun et al, who also found that subglottic diameter measured by USG was a better predictor for estimation of appropriate ETT size. The success rate with USG for prediction of accurate tracheal size was 86 %. But they used cuffed ETT for their study.[20] Another point of deliberations which we found in our study results was that, there was significant difference in success rate of size estimations when we considered gender based pediatric patients. In Male children (Mch), ETT estimation by diameter of little finger selected the correct tracheal tube size in 23%, whereas in Female children (Fch) diameter of little finger selected the correct tracheal tube size in only12.5%. Age based formula predicted the accurate size in 64 % of male children, whereas in female children age based formula selected accurate size in only 37% of female children. In comparison to these two methods, USG estimation of ETT size correlated with actual ETT size in 88 % of male children and 93% of female children. We were searching in the literature for the same, but none of the study has demarcated the results according to gender of the patients. As in our study, number of pediatric patients was limited; hence further

comments regarding the same can be made only after larger study looking into the same. USG offers a number of advantages compared to other competitive imaging modalities (CT, MRI). Apart from being comparable to above radiological methods in assessment of subglottic airway, the use of USG requires minimal training & do not require complete immobility or sedation which is invariably required for CT or MRI scan for producing better image quality.[18] The use of USG also avoids radiation exposure which is not the case with CT scan. Also, high quality laryngeal images of CT and MRI cannot be routinely obtained because of the high cost and feasibility. Subglottic stenosis can also be evaluated by USG, a common complication in neonatal or pediatric anesthesia.[23]

CONCLUSION

USG may be considered as a reliable tool for ETT estimation in pediatric patients when compared to age based formula & diameter of little finger. Age based formula should be preferred over diameter of little finger for ETT estimation when USG is not available. The major limitation of our study was the limited sample size of 50 patients, dispersed between the ages of two years and six years, limited the number of patients within each age group.

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