

Comparison of Ultrasonography with Cole's Formula to Determine Appropriate Endotracheal Tube Size in Pediatric Population

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ABSTRACT

Introduction

Recently, ultrasonography (USG) has gained popularity in perioperative airway management. One of the commonest method to select endotracheal tube in pediatric patients is Cole's formula. Our study was conducted to assess if there was a measurable difference in the appropriateness of the endotracheal tubes as selected by the two methods.

Methods

The study group included 68 children scheduled for elective surgeries under general anesthesia with endotracheal intubation in a randomized prospective manner. The size of endotracheal tube was calculated using Cole's formula in group A. In group B, ultrasound was done to measure the subglottic transverse diameter at the level of cricoid to find the largest outer diameter of tube.

Results

Ultrasonography group measuring the subglottic diameter was found to have more appropriately sized tubes than age-based Cole's formula (76.5% Vs 58.8% p=0.007). The pressure equilibrated measured (13.2 ± 5.2 cm of H₂O in age based group and 17 ± 4.5 cm of H₂O in ultrasonography group) was statistically significant (p=0.002). Also the incidence of selecting an inappropriately small sized ET tube was lower in the ultrasound group (5.9% Vs 35.3%). There were no significant differences in the number of intubation attempts and mean time required for intubation between the two groups.

Conclusion

Ultrasonographic method is a suitable alternative tool in predicting the size of uncuffed endotracheal tube in pediatric population than age-based Cole's formula.

Keywords

Age-based formula, cricoid ring, pediatric, subglottic diameter, tracheal intubation

INTRODUCTION

Under general anesthesia, airway management in children is achieved either with a supraglottic airway or by means of an endotracheal tube. An endotracheal tube is often employed for this purpose.¹ There are noticeable differences between the adult and the pediatric airways. It is conical in shape and narrowest in the subglottis at the level of the cricoid ring in contrast to the cylindrical shaped adult airway, where the narrowest portion is at the glottis.²

Traditionally, the size of the endotracheal tube used in children has been estimated based on their age or an anthropometric measurement like weight, height and finger diameter. Cole's formula based on children's age (ET tube size in mm = Age of the child/4 +4)^{3,4} is widely used. Inappropriate sizes like larger tube can lead to airway trauma, oedema, ulceration, necrosis of subglottic region, post-extubation stridor and subglottic stenosis while an undersized tube can lead to leakage around the tube leading to inadequate ventilation and risk of aspiration.

Recently, point of care ultrasonography (POCUS) has come up as an excellent, non-invasive, portable and real time imaging modality for airway management with a short learning curve. Various studies have validated its appropriateness in measuring the airway dimensions compared to CT or MRI measurements.⁵ Appropriateness of an endotracheal tube used can be estimated by listening to audible air leak around the tube or by quantifying the pressure equilibration after connecting the endotracheal tube to a closed circuit. Keeping this in mind, a prospective observational study was planned to compare ultrasonography with age based formula for determination of endotracheal tube size in pediatric patients.

METHODS

After Institutional Review Committee (IRC) of Institute of Medicine (IOM) approval, a randomized interventional study was conducted in Tribhuvan University Teaching Hospital (TUTH) and Manmohan Cardiothoracic Vascular and Transplant Centre (MCVTC) operation theatres from February to July 2019. Data was collected from a total of 68 enrolled patients with 34 in each of the group. American Society of Anesthesiologists (ASA) physical status (PS) III and above, emergency surgery, anticipated difficult airway, any anatomical deformity of upper airway, previous surgery involving upper airway and any scars, mass or ulcer in the neck which will interfere with the ultrasound examination were excluded. The enrolled patients posted for surgery were randomly distributed into two groups by computer generated random numbers, which

was then drawn as sequentially numbered opaque sealed envelopes (SNOSE):

- Group A: Size of the ET tube selected based on the age-based Cole's formula.
- Group B: Size of the ET tube selected based on the ultrasound measurement of the transverse diameter of the cricoid ring.

After induction of anesthesia and muscle relaxation direct laryngoscopy was carried out and intubation was done with the tube selected as per Cole's formula in group A and on the basis of point of care ultrasonography (USG) on children in group B where the calipers were then used to measure the internal transverse diameter of the cricoid ring. The measured value was noted and communicated to airway assistant, who immediately determined the endotracheal tube with the largest possible external diameter that could be negotiated. A premade table was used to determine the corresponding internal diameter size of the endotracheal tube. The number of intubations attempts, the time taken for ultrasonography and intubation was noted and recorded.

A leak test was performed to determine the appropriateness of the endotracheal tube. For this, anesthesia machine was set in manual mode of ventilation. Initially, fresh gas flow of 5 L/min was set with the adjustable pressure-limiting valve closed to fill up and pressurize the circuit to a pressure of 30 cm of water (H₂O). The flow meter was closed fully left for 10s for the circuit pressure to equilibrate to a new value. This new value of circuit pressure at the end of 10 seconds was used to decide whether the used endotracheal tube was of an appropriate size, large for the child or small. This was noted in the proforma.

1. (A) Appropriate if the circuit pressure equilibrated to 10–20 cmH₂O after 10 seconds.
2. (L) Large if the circuit pressure equilibrated to >20 cmH₂O.
3. (S) Small if the circuit pressure equilibrated to <10 cmH₂O.

When the tube size was found to be inappropriate, it was left at the discretion of the primary intubating person to change the tube to a more appropriate size.

Data were analyzed by IBM SPSS software version 21 and values presented as mean (standard deviation SD or range) or number. Demographic data and data relating to endotracheal tubes used was analyzed using 2-tailed independent t-test for intergroup comparison. Nominal categorical data were analyzed with Chi-square test. For all determinations p-value <0.05 was considered significant.

Table 1. Age distribution between groups A and B

Age (in years)	Group A		Group B		p-value
	No. of patients	Mean age ± SD	No. of patients	Mean age ± SD	
2	3	4.5 ± 1.3	7	4.4 ± 1.6	0.80
3	5		3		
4	7		4		
5	9		8		
6	10		12		
Total	34		34		

RESULTS

All the demographic data were comparable in both the groups. All patients recruited were between the age groups 2 and 6 years. The average age of the patients in group A was 4.5 ± 1.3 years and in group B was 4.4 ± 1.6 years which was found to be comparable (p=0.80). A total of 41.2 % in group A and 32.4% in group B were females which was comparable (p= 0.45).

The total intubation attempts made for successful intubation were also comparable in the two groups. Single attempt of intubation was successful in group A in 94.1% of the cases as compared to 91.2% in group B (p= 1). Similarly, 5.9% in group A and 8.8% in group B required two attempts at intubation which was not statistically significant. No patients in either of the two groups required more than two attempts at intubation.

The average size of the ET tube used as per the estimation by the age based Cole's formula was found to be 5.0 ± 0.4 mm (internal diameter) as compared to 5.2 ± 0.6 mm (internal diameter) that was used in the ultrasonography group, which was not statistically significant (p=0.10).

The mean times required for the intubation was 22.1 ± 5.5 seconds in group A, while it was 20.1 ± 3.3 seconds in group B (p= 0.08) which was not statistically significant. The pressure equilibrated was also measured which was found to be 13.2 ± 5.2 cm of H₂O in group A and 17 ± 4.5 cm of H₂O in group B (Figure 1) which was statistically significant (p= 0.002).

The incidence of appropriateness of the ET tube was compared in the two groups. The incidence of appropriately (A) sized estimation was found to be significantly higher in the ultrasound group than in Cole's formula group (76.5% Vs 58.8%, p=0.007). Also the incidence of selecting an inappropriately small sized ET tube (S) was lower in the ultrasound group (5.9% Vs 35.3%). However, this study found that the use of ultrasound would inappropriately estimate a larger ET tube (L) in 17.6% of cases as

Table 2. Intubation attempts comparison between the groups

Intubation attempts	Group A n (%)	Group B n (%)	p-value
1	32 (94.1)	31 (91.2)	1
2	2 (5.9)	3 (8.8)	
Total	34 (100)	34 (100)	

Table 3. Appropriateness comparison between the groups

Appropriateness of size	Group A n (%)	Group B n (%)	p-value
Appropriate	20 (58.8)	26 (76.5)	0.007
Large	2 (5.9)	6 (17.6)	
Small	12 (35.3)	2 (5.9)	
Total	34	34	

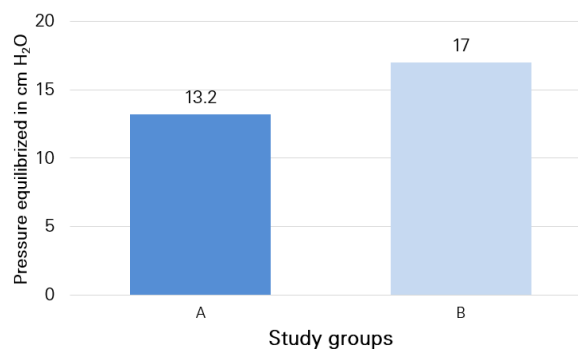


Figure 1. Pressure equilibrated in groups A and B

compared to 5.9% in the age based estimation group, which was statistically significant.

DISCUSSION

Selection of an appropriately sized endotracheal tube is important in children in order to avoid

problems and complications like airway trauma and aspiration pneumonitis for large and small tubes respectively relative to the size of the airway.⁶

Many empirical formulas and techniques have been devised, from the estimation of the endotracheal diameter by correlating with the diameter of the little finger to radiological (CT/MRI) based estimations.⁷ However the most commonly used technique the age-based formula also has been found to be unreliable in estimating an appropriately sized endotracheal tube size in children by various authors.^{4,8,9,10}

The appropriateness of tube size has been defined in several ways. We have used the maintenance of airway pressure to determine the appropriateness based on the amount of air leak around the tube. We believe that this method is more objective and reproducible as compared to other methods. The audibility of the leak could be subjected to various confounding factors including the shape of the pediatric airway, use of neuromuscular blocking agents, depth of anesthesia and the position of the neck.^{11,12}

In our study, the assessment of the amount of leak around the tube was done for both groups. The size of the endotracheal tube as determined by the two methods, the time and number of attempts required for intubation was also not statistically significant. However, the incidence of selecting an appropriately sized endotracheal tube was high in the ultrasonographically determined group (76.5% Vs 58.8%, $p=0.007$), which was statistically significant. In a very similar study done by Ganaprakasam in 2017 among 150 children of the age group 2-6 years, they had found a strong correlation between the outer diameter as assessed by the airway ultrasound and the optimal endotracheal tube. They had been successful in estimating an appropriately sized tube in 74.7% of the cases which was statistically significant than the age based formula which was successful in only 45.3%.⁹ Similar study done in the same age group patients comparing the age based formula and the clinical fit had found a similar lower accuracy at only 48% in cardiac and 54.4% in non-cardiac patients which is in accordance with our study.¹³

Among the inappropriately sized tubes, USG determined endotracheal tube was found to have an incidence of being larger than the ones determined by weight based Cole's formula (17.6% Vs 5.9%). In clinical practice, there is a very widespread practice of still decreasing the size of the endotracheal tube by 0.5mm to account for the outer diameter of the ET tube. Though the aim of this research was not to study the outcomes of the patient, there are evidences that have shown negative outcomes related to using a smaller sized tube, especially in the perioperative setup. Based

on the diagnosis and the type of surgery, there are increased chances of inadequate airway protection, micro and even macro- aspiration of the gastric contents and increased work of breathing as per the Hagen-Poiseuille's equation.^{11,12} This study was also not designed to answer the age long question of whether to use a cuffed or an uncuffed tube but to only help to estimate the ET tube size accurately. However, there has been some evidence in this study that the age based formula underestimates the actual airway size. If an inappropriate tube size was selected using the age based formula, the incidence of it being smaller was found to be higher than as compared to the USG based ET tube size determination (35.3% Vs 5.9%). In literature, this incidence has been found to be as high as 70%.¹⁴ In summation with the practice of downsizing the endotracheal tube, this could have significant clinical implications.

Another finding consistent with a higher accuracy is the higher pressure of equilibrium seen in the USG guided determination group. An average pressure of 17 cm H₂O was statistically higher than the 13.2 cm H₂O pressure in the age based group. The recommended pressure required for the sealing of the airway is 15-20 cm H₂O.¹⁵ Inadequate sealing pressures cause increased chances of micro and macro aspiration leading to pneumonitic changes. At the same time, high sealing pressures could lead to decrease in the mucosal perfusion causing ciliary damage, necrosis and even trachea-oesophageal fistula.¹⁶ The sealing pressure needs to be low enough to maintain the adequate capillary perfusion pressure. The capillary perfusion pressure depends not only on the pressure exerted by the endotracheal tube but also on the mean arterial pressure of the patient. Considering the patient to be haemodynamically stable, the pressure of equilibrium with the use of airway ultrasound has been found in our study to be in accordance with the current recommendations of 15-25 cm of H₂O.^{15,17} This is thus, a strong evidence in our opinion, for the routine use of airway ultrasound to determine the ET tube size in the pediatric population

There are some limitations of our study. The incidence of postoperative morbidities associated with endotracheal intubation was not studied. This was a study performed in a single centre, so, a larger multicentric prospective study would be able to validate the results. We did not include the subjects below two years of age because transverse diameter is difficult to measure in these cases.

CONCLUSION

Ultrasonographic method is a suitable alternative tool in predicting the size of uncuffed endotracheal tube in pediatric population than age-based Cole's formula.

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CONFLICT OF INTEREST

The author(s) declare that they do not have any conflicts of interest with respect to the research, authorship, and/or publication of this article.

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