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Dr. Suraj R
Post Graduate, Department of Anaesthesiology and Critical Care, NITTE University, Deralakatte, Mangalore, Karnataka, India

Dr. Ananda Bangera
Professor, Department of Anaesthesiology and Critical Care, NITTE University, Deralakatte, Mangalore, Karnataka, India

Corresponding Author:
Dr. Ananda Bangera
Professor, Department of Anaesthesiology and Critical Care, NITTE University, Deralakatte, Mangalore, Karnataka, India

Endotracheal tube size estimation using ultrasonography in paediatric patients: A prospective randomized controlled study

Dr. Suraj R and Dr. Ananda Bangera

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Abstract
Endotracheal intubation (ETT) is the gold standard for airway management and is one of the most commonly performed procedure. Improper selection of endotracheal tube it results in complications like, inadequate ventilation, poor reliability of end-tidal gas monitoring, leakage of anaesthetic gases into operating room environment and enhanced risk of aspiration. The conventional age-based formulas doesn't reflect the actual tracheal diameter for selection of endotracheal tube. Hence repeated laryngoscopy is often required to place an appropriate sized endotracheal tube especially in paediatric patients. Recent studies have documented that the anatomical structures in supraglottic, glottic and subglottic regions can be evaluated by ultrasound. Therefore, the present study was conducted to determine appropriate endotracheal tube size in paediatric patients by using ultrasound and by comparing it with age based formula.

Keywords: Ultrasonography, paediatric, endotracheal tube size

Introduction
Preamble
Endotracheal intubation is the gold standard for airway management. Airway management in paediatric patients is always a challenge as the paediatric airway differs a lot from the adult airway. The subglottic region at the level of cricoid cartilage conventionally has been described as the most restricted diameter of the upper airway, but this has been challenged recently. The airway exposure in the cricoid region does not remain uniform as the transversal dimension is lesser than the dimension anteroposteriorly. The choice of size of the endotracheal tube is very important, smaller tube may lead to inadequate ventilation, lesser assurance of monitoring end-tidal gas, exposure of anaesthetic gases into operating room environment thereby increasing risk of aspiration. The oversized endotracheal tube relative to the trachea or over-inflated cuff may damage the tracheal mucosa by friction and compression leading to airway edema, post-extubation stridor, ischemic necrosis, and subglottic stenosis at a later stage.
The age-based conventional physical indices do not reflect the actual tracheal diameter for selection of endotracheal tube. Hence repeated laryngoscopy is often required for proper selection of the endotracheal tube for intubation, especially in paediatric patients. To avoid excessive airway instrumentation and minimizing the risk of trauma, the pre-anaesthetic assessment of tracheal diameter by a better technique is essential to select the appropriate endotracheal tube [1].
Recent studies have documented that the anatomical structures in supraglottic, glottis and subglottic regions can be delineated by ultrasonography.
The ultrasonography could be a reliable, safe and non-invasive pain-free modality for evaluation of upper airway's narrowest transverse diameter at the subglottic region and may be helpful to estimate the proper size of the endotracheal tube.
Although, the prediction of ultrasonography for optimal endotracheal tube size in paediatric patients still persists undetermined. Hence, our hypothesis revealed that endotracheal tube size estimation by using ultrasonography assessment of the subglottic region in paediatric patients is more appropriate compared to conventional age-based formula.

Methodology

We studied a total of 131 paediatric patients with age ranging from 1 month to 6 years, who underwent surgery under general anaesthesia with controlled ventilation after the Institutional Ethics Committee clearance and written informed consent from January 2017 to August 2018. The patients were randomly allocated into group A (conventional age-based formula) with 65 patients and group B (ultrasound) with 66 patients by closed envelope method. Comparison of the 2 groups was done in terms of age, sex, weight, ASA-PS, Mallampati classification, ETT cuff leak at 10 cm H_2O, ETT cuff pressure increased to 20 cm H_2O and ETT cuff leak at 20 cm H_2O. Results were statistically analysed using frequencies, percentages and chi-square test. The 'p' value of less than 0.05 is considered statistically significant.

Results

131 Paediatric patients from 1-6 years undergoing elective surgeries under general anaesthesia with controlled ventilation were included in the study. They were divided into two groups, in which group A (conventional age-based formula) includes 65 patients and group B (ultrasound) includes 66 patients.

Table 1: Comparison of Age distribution

Age (in months)	Group-A		Group-B	
	Count	%	Count	%
1 - 24	14	21.5%	25	37.9%
24 - 48	25	38.5%	15	22.7%
48 - 72	26	40.0%	26	39.4%
Total	65	100.0%	66	100.0%
Chi-square value = 5.15; P = 0.06				

Comparison of age distribution was done by Chi-square test. In group A 21.5% of all subjects fall in age group 1-2 year, while group B it 37.9%. In Group A 38.5% of all subjects fall in age group 2-4 years, while in group B 22.7%. In group A 40 of all subjects fall in age group 4-6 year, while in group B 39.4%. The two groups are comparable as the difference was statistically non-significant (P value = 0.06).

Table 2: Comparison of Gender distribution

Sex	Group-A		Group-B	
	Count	%	Count	%
Male	33	50.8%	33	50.0%
Female	32	49.2%	33	50.0%
Total	65	100.0%	66	100.0%
P = 1				

In group A 50.8% were males and 49.2% were females. In group B 50% were males and 50% were females.

These two groups were comparable in terms of gender distribution and statistically non-significant with (P value = 1).

Table 3: Comparison of weight distribution

Weight						P-value
Group	N	Minimum	Maximum	Mean	SD	
Group-A	65	4	36	14.91	8.11	0.11
Group-B	66	4	31	12.67	7.78	

The mean weight in group A was 14.9, while in group B was 12.67. The difference among two groups was statistically non-significant (P value= 0.11).

Table 4: Comparison of ASA-PS distribution

ASA PS	Group-A		Group-B	
	Count	%	Count	%
I	45	69.2%	44	66.7%
II	20	30.8%	22	33.3%
Total	65	100.0%	66	100.0%
P=0.85				

In group A, 69.2% were ASA-PS I and 30.8% were ASA-PS II. In group B, 66.7% were ASA-PS I and 33.3% were ASA-PS II.

Among the two groups ASA-PS distribution was comparable and statistically non-significant (P value= 0.85).

Table 5: Analysis of incidence of audible leak around the ETT cuff

	Group A (Age-based formula)	Group B (USG guided)
Audible leak around the ETT cuff at 10 cm H_2O	47	41
Audible leak around the ETT cuff at 20 cm H_2O	28	8

Out of 65 patients in group A (age-based formula) 47 showed audible leak at 10cm H_2O, where as in group B 41 out of 66 patients showed audible leak at 10 cm H_2O.

In group A, ETT cuff pressure was increased in 47 patients out of 65 to 20 cm H_2O. In group B, 41 patients required increase in ETT cuff pressure to 20 cm H_2O.

In group A, out of 65 patients 28 required endotracheal tube was exchange to a larger tube by 0.5mm ID. Whereas, in group B only 8 patients needed endotracheal tube change to larger tube by 0.5mm ID.

Table 6: Predicting audible leak around the ETT cuff at 20 cm H_2O

Leak	Group-A		Group-B	
	Count	%	Count	%
Yes	28	43.1%	8	12.1%
No	37	56.9%	58	87.9%
Total	65	100.0%	66	100.0%
$p<0.001$				

Overall, group A and group B were comparable. The endotracheal tube was changed to larger size by 0.5mm ID in 43.07% (28) in group A patients, While in 12.1% (8) patients the endotracheal tube was changed to larger size by 0.5 mm ID in group B patients, which showed statistical significance with p value < 0.001.

Discussion

Endotracheal intubation is the most commonly performed procedure for airway management. Due to the improper size of endotracheal tube (ETT), it results in complications like inadequate ventilation, weak reliability of end-tidal gas monitoring, leakage of anaesthetic gases into operating room environment and enhanced risk of aspiration. The smaller diameter tubes are easier to insert and need less force to adapt to the patient's airway. However, they are associated with higher resistance, difficulty in passing a suction tube and enhanced risk of occlusion, aspiration and kinking with inadequate ventilation [1].

The larger tubes have a higher incidence of a postoperative sore throat, may cause injury to the tracheal mucosa and may also cause airway edema, post-extubation stridor and subglottic stenosis because of the over-inflated cuff. However, there is a huge difference in size and shapes of the trachea, thus the correlation between age, height, weight, body surface area and tracheal shape or size, is poor.

Currently, the ETT is selected according to age and height based formulas, which generally predicted either smaller or larger sizes than proved clinically optimal [2].

The current study was conducted to determine the suitable ETT size in young patients. The tube size was calculated based on either a conventional age-based formula or by ultrasound guidance. A comparison was done in order to choose the appropriate method to select ETT.

We studied 131 patients with ASA-PS I and II between age group of 1month to 6 years who were undergoing surgery requiring general anaesthesia with endotracheal intubation. The patients were randomly divided into two groups by closed envelope method.

1. **Group A:** A total of 65 patients were selected in whom ETT size was determined by conventional age-based formula and were allotted age appropriate microcuffed oral ETT which were selected as follows: 0-6 months- 3.5 mmID, 6-12 months- 4 mm ID and in children >1 year, with the formula, Internal Diameter (ID) = (age in years/3) +3.5.
2. **Group B:** A total of 66 patients were selected in whom ETT size was determined by ultrasound.

Both groups were comparable with respect to age, gender, weight and ASA-PS. No patients were excluded from the study.

We used a conventional age-based formula and found no audible leak at 10 cm H_2O in 27.7% patients and we have increased the ETT cuff pressure to 20 cm H_2O in rest of (72.3%) patients as there was an audible leak after the first attempt. Furthermore, we increased tube size as there was an audible leak present at 20 cm H_2O in 59.9% patients.

Shibasaki *et al.*, evaluated 48 patients belonging to the age group of 1 month to 6 years for the selection of appropriate ETT size by using conventional age-based formula. Any hinderance to ETT path or absence of audible leak when lungs were expanded 20-30 cm H_2O pressure, the tube was switched to one which was smaller by 0.5 mm ID. In contrast, ETT was exchanged for one that was 0.5mm ID larger if a leak happened at an inflation pressure < 10 cm H_2O. They reported a success rate of 35% when there was absence of audible leak at 10 cm H_2O. The ETT was exchanged to that of a larger size in 60% patients [2].

Bae *et al.*, evaluated 69 patients belonging to age group of <8 years for the selection of appropriate ETT size by using conventional age-based formula. They found that 31 patients showed leak at <15 cm H_2O and 9 patients showed leak at >30 cm H_2O. They have changed the ETT size to a larger one in 31% patients and to smaller size ETT in 9% patients [5]. Though the criteria used for changing ETT by them was different, they too reported gross in accuracy in predicting appropriate sized tube.

The purpose of ultrasound to estimate suitable ETT size in children has been reported previously. Shibasaki *et al.* and Schramm *et al.*, used conventional age-based formula for the initial tube size selection [2]. An appropriate size of the tube within pre-determined leak thresholds was used leading to ETT tube changes repeatedly. These studies then correlated the appropriate tube size with ultrasonographic measurement and formulas devised rather than directly implicating the measured subglottic diameter [5].

Kim *et al.* also used the age based formula for initial tube size selection and reckoned a positive correlation between subglottic diameter (measured) and actual ETT outer diameter. But, they did not calculate based on ultrasonographic measurements instead, used demographic variables [5].

Bae *et al.* compares the success of a conventional age-based formula with ultrasonographic dependent selection of tube size in uncuffed tubes. But, this study also recognised a linear regression formula from 41 children to approximate ultrasonographic measurement predicted tube size [5].

Unlike others, we used ultrasound to measure the subglottic diameter to identify cuffed tube size which showed an initial attempt success rate of 87.9% and then compared it with conventional age-based formula.

When compared to studies conducted by Bae *et al.* and Schramm *et al.*, our initial attempt of rate of success with direct measurement was higher but lower than Shibasaki *et al.* study [2]. Bae *et al.* found 60% success in the selection of correct uncuffed ETT size [5]. Schramm *et al.* also examined uncuffed ETT and showed a lower success rate of 48% [3]. Shibasaki *et al.* attained a higher success rate of 98% for cuffed tubes when a regression equation was applied to the directly measured subglottic diameters [2]. However in contrast to the above two studies here we have increased the ETT cuff pressure to 20 cm H_2O and looked for leak among USG group.

Kim *et al.* also concluded that measurement using ultrasound was helpful in selection of the correct ETT size, though they did not try to predict appropriate sized tubes and therefore did not achieve a success rate [5]. The difference in our results from the other studies is clearly portrayed by several factors including measurement location, precision, and air leak test limits.

Bae *et al.*, positioned the ultrasound probe at mid cricoid level and Shibasaki *et al.* positioned at lower cricoid level [5]. However recent assessment of the larynx has revealed that cricoid is not the narrowest portion as demonstrated by Litman *et al.* who has shown that the constriction is at the vocal cord, followed by the sub-vocal cord and the cricoid level, in sedated, unparalysed children with magnetic resonance imaging (MRI). The ratio of the transverse to anteroposterior diameter of the trachea was found to be around 0.4 at vocal cord level, 0.5 at the sub-cricoid level and 0.8 at cricoid level [4].

Shibasaki *et al.* explained this fact to discuss the results of the measured diameter to a relatively smaller ETT outer diameter with blurred image of vocal cords obtained via ultrasound [2].

In current study, we found minimal transverse diameter of the subglottic airway (MTDSA) of the subglottis is the one which is used to determine the appropriate size of the ETT in paediatric patients.

Schramm *et al.*, found that MTDSA of subglottis is the narrowest portion and hence ETT size is determined from it [3].

Ultrasound can precisely calculate the transverse diameter of the airway. However, this is not the case with anteroposterior diameter. This is due to the unclear visualization of the trachea's posterior part by the air's acoustic shadow. The tracheal diameter in anteroposterior direction is greater when compared to the diameter in the transverse direction. This causes misjudgments of the original tracheal diameter and leads to the selection of an ETT of smaller size [1-2].

Bae *et al.* showed that ETT size was often underestimated by USG in individuals where the technique failed to be successful in 31 (77.5%) out of 40 patients, as the outer diameter of ETT does not take into account the mass of the deflated cuff during the USG guided measurement of tracheal diameter. However, there can be certain drawbacks to this such as high resistance and increased pressures of the airway. Overestimating is another problem which leads to choosing of an ETT of larger diameter which in turn can cause trauma of the airway and laryngotracheal damage [5].

In our study, we did overcome both overestimation and underestimation by observing leak pressure thresholds and peak airway pressure. As the thickness of the wall of ETT may influence the tube size ID for a specified outer diameter of the tube, which in turn influence the peak airway pressure, Hence in our study, only one brand of ETT was used. Thus, ultrasonography may be more useful in predicting appropriate ETT size in paediatric patients [1].

Conclusion

The ultrasonography offers a better alternative than commonly used conventional age-based formula in predicting appropriate ETT size in paediatric patients.

Conflict of Interest

Not available

Financial Support

Not available

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