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Determination of Correct Size of Endotracheal Tube in Children by Ultrasonographic Measurement of Subglottic Diameter Versus Traditional Formula

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Abstract

Background and Aims: To compare the efficacy of ultrasound devices in determining the correct endotracheal tube size for intubation in children in respect to other traditional formulas.

Materials and Methods: This is a prospective observational cross-sectional study. Patients between ages 1 year to 6 years were categorized into two groups, 35 patients in each group. Ultrasound-guided measurement of subglottic diameter was performed in group A (N=35) and subsequent endotracheal tubes of corresponding internal diameter were inserted. Similarly, sizes of endotracheal tubes calculated based on age-related formula were inserted in group B (N=35). First pass success rate and complications were compared between the above two groups.

Results: The number of attempts of intubation in the ultrasound-guided group (Group A, n=35/70) was lesser than the age-based group (Group B, n=35/70)which was statistically significant [p value is 0.021509] ($p<0.05$). Overall complications arising out of repeated attempts of intubation were also significantly less in the ultrasound group. ($p<0.05$) But individual complications arising out of failed intubations were not statistically significant with no meaningful difference between them ($p=0.303077$).

Conclusion: Ultrasonography seems to be a better option than traditional formulas in predicting the correct size of endotracheal tubes in respect of preventing repeated attempts of intubation and perioperative complications.

Key words: Ultrasonography; Subglottic diameter; Hemodynamic changes; Endotracheal tube; Laryngoscopy; Complications

INTRUDUCTION

Pediatric airway assessment has been a challenging task for so long amongst anesthesiologists. Knowledge of the influence of age of the child on laryngeal dimensions is essential for all practitioners who are dealing with the pediatric airway [1,2]. Moreover, assessment of pediatric airway requires cooperation on part of the patient. Most of the bedside tests for this purpose have a poor interobserver agreement and poor positive predictive value [3] Pediatric patients have a relatively larger head and tongue, narrower nasal passages, anterior and cephalad larynx. In the neonatal period, the trachea is funnel-shaped with the upper end wider than the lower, and as age advances it becomes cylindrical [4]. Some may have relatively longer epiglottis, shorter trachea, and neck, or more prominent adenoids and tonsils. Various formulas had been proposed by researchers in the past based on age, height, the diameter of little fingers of both hands [4,5]. Insertion of a tube that is too small will result in inadequate ventilation, poor reliability of end-tidal gas monitoring, leakage of anesthetic gases into the environment, and risk of aspiration. Conversely, the endotracheal tube that is too large has the probability to cause upper airway injury, airway edema, and subsequent subglottic stenosis. Recently ultrasound measurement

of subglottic diameter had paved the way for accurate estimation of pediatric airway, thus minimizing chances of multiple laryngoscopies and putting appropriately sized endotracheal tubes with acceptable leak and reducing the above-mentioned complications [6]. But most of these studies have been done in western populations who have significant differences in corresponding height, ethnicity, and airway parameters than the Indian population [7,8].

This study was formulated in order to compare the efficacy of ultrasound with traditional formulas for estimation of the correct size of endotracheal tubes in children to decrease perioperative complications of airway manipulation.

MATERIALS AND METHODS

The prospective observational study was conducted on children undergoing elective surgical procedures in the Special Surgery Operation Theatre of R.G. Kar Medical College and Hospital from January 2021 to June 2021. The study was initiated after approval from the Institutional Ethics Committee. Written informed consent was obtained after proper counseling from 70 patients included in the study, 35 in each group, as per inclusion and exclusion criteria. (Inclusion criteria: Children posted for elective surgeries, children between the age of 1 year to 6 years, children without any significant co-morbidities; ASA physical status 1 and 2, and children with normal airway and no anticipated difficult airway, Exclusion criteria: children with a suspected difficult airway, recent upper airway infection and associated co-morbidities).

Sample Size Calculation: One study found that the lifetime prevalence of surgical procedures was 1.77% among children. So

For this study p=0.0177.

Thus, the number of patients required for this study was 69.5, taken to 70 with power 87%.

The formula used for sample size calculation was as follows: -

N=4pq/(L^2)

Where, n=required sample size,

P=0.0177 (as per the study by Bhasin SK et al),

Q=1-p,

L=Loss % (Loss of information)

Calculation:

Here p=0.0177,

Q=1-p=1-0.0177=0.9823,

4pq=4×0.0177×0.9823=0.0695

L^2=0.0010

n=4pq/(L^2) =0.0695/0.0010=69.5=70

Study Group:

70 patients were taken and divided into two groups

Group A=35 patients

Group B=35 patients

Patients entered the Operation Theatre after the proper pre-anesthetic check-ups. Patients were positioned supine with their head and neck at the optimum position for intubation. Monitors were attached as per ASA guidelines for checking heart rate, electrocardiogram tracing, non-invasive blood pressure, saturation, and temperature. Patients in each group [ultrasound (group A) and age-based (group B)] were chosen randomly. They were kept nil per oral from 6 hours prior to surgery for solid food and clear fluid was allowed till 2 hours prior to surgery. The patients in group A were premedicated with intranasal dexmedetomidine 2 microgram/kg after securing intravenous access and subglottic diameter was assessed with head extended and neck flexed with high-resolution B mode ultrasonography with a small footprint linear probe having frequencies 7 to 15 MHz and length 40 mm. A predetermined standard scanning plane was used to prevent any examination bias and artifacts. True vocal cord localization was done which is seen as paired hyperechoic linear structures which move on respiration and swallowing. Then the probe was moved caudally to visualize the cricoid arch in order to avoid any confusion between the cricoid cartilage and the tracheal ring. The measure of tracheal diameter was taken as the transverse air column diameter measurement done at the cephalic half of the cricoid cartilage which is narrower than the caudal part. (Ultrasonographic measurement of endotracheal tube diameter which corresponds to minimal transverse diameter of the subglottic airway (MTDSA).

The estimated internal diameter in patients of group B was calculated on the standard formula (Age/4 +4), and a 0.5 mm smaller internal diameter cuffed endotracheal tube was chosen. After checking the pre-anesthesia checklist, patients were pre-oxygenated with 100% oxygen. Fentanyl (2μg/kg) and Midazolam (0.05mg/kg) were administered after securing the intravenous line followed by an appropriate induction agent (incremental concentrations of sevoflurane via Jackson Rees

Modification of Ayre's T piece]. After achieving adequate relaxation with atracurium (0.6mg/kg), tracheal intubation was done with a cuffed endotracheal tube of corresponding internal diameter as had been obtained on pre-operative assessment from estimated outer diameter and position confirmed by capnography and auscultation of bilateral equal breath sounds. Heart rate, saturation, and mean arterial blood pressure were monitored at the following intervals: baseline (before induction), 1 minute, and 5 minutes after intubation. Hemodynamic changes, number of attempts of intubation, and complications like postoperative sore throat, stridor, mucosal injury, and bronchospasm arising out of the process were taken into consideration for the analysis of the study.

For statistical analysis, data were entered into a Microsoft Excel spreadsheet and then analyzed by SPSS (version 20.0; SPSS Inc, Chicago IL, USA). Data has been summarized as mean and standard deviation for numerical variables and count percentage for categorical variables. Using independent t-test and chi-square test p-value was calculated. P-value <0.05 was considered significant.

RESULTS

Table 1: Demographic data analysis in between two groups (Group A ultrasound group, n=35 and Group B, conventional age-based group, n=35)

	Mean ± SD		p-value
Parameters	**Group A**	**Group B**	
Age	2.45 ± 1.22	2.8 ± 1.47	0.292
Sex(M/F)	22/13	22/13	1

Table 2: ASA grade wise distribution in between two groups (Group A ultrasound group, n=35 and Group B conventional age-based group, n=35)

	GROUP A	GROUP B	Marginal row total
ASA Grade 1	22	34.2	46
% of total population	31.4	11	65.60%
ASA Grade 2	13	15.8	24
% of total population	18.6	35	34.40%
Marginal column total	35	50	70
%TOTAL		50	100.00%

p- value =0.614535

The chi-square statistic is 0.2536. The p-value is .614535. Not significant at p < .05.

The chi-square statistic with Yates correction is 0.0634.

The p-value is .801192. Not significant at p < .05.

Table 3: MPG grade wise distribution in between two groups (Group A ultrasound group, n=35 and Group B conventional age-based group, n=35)

	GROUP A	GROUP B	Marginal row total
MPG Grade 1	18	20	38
% of total population	25.71	28.57	54.08
MPG Grade 2	16	15	31
% of total population	22.85	21.42	44.27
MPG grade 3	1	0	1
% of total population	1.42	0	1.42
Marginal column total	35	35	70
%TOTAL	50	50	100%

p- value = 0.725745

The chi-square statistic is 0.1231. The p-value is .725745. Not significant at p < .05.

The chi-square statistic with Yates correction is 0.0118.

The p-value is .913405. Not significant at p < .05.

MPG 3 was not taken under the calculation due to insufficient marginal value in group 2.

The calculation was performed with n= 69.

Table 4: Comparison of preinduction and post-intubation (at 1 minutes) Heart rate, SPO_2 and MAP in between group A and B.

	GROUP A			GROUP B		
	Mean	**SD**	**p value**	**Mean**	**SD**	**p value**
Preinduction HR	84.82	10.13	0.953	82.74	6.58	0.84
Post-intubation HR at 1 minutes	90	10.87		87.54	9.08	
Preinduction SPO_2	99.51	0.61	1	99.11	0.67	1
Post-intubation SPO_2 at 1 minutes	99	1.3		97.82	2.88	
Preinduction MAP	77.37	8.77	0.993	78	7.21	0.96

Table 5: Comparison of preinduction and post-intubation (at 5 minutes) Heart rate, SPO_2 and MAP in between group A and B

	GROUP A			GROUP B		
	Mean	**SD**	**p value**	**Mean**	**SD**	**p value**
Preinduction HR	84.83	10.14	0.98	82.74	6.58	1
Post-intubation HR at 5 minutes	88.97	9.93		85.71	6.74	
Preinduction SPO_2	99.51	0.612	1	99.11	0.676	1
Post-intubation SPO_2 at 5 minutes	99.63	0.547		99.62	0.49	
Preinduction MAP	77.37	8.77	0.99	78	7.21	0.99
Post-intubation MAP at 5 minutes	78.2	9.57		81.71	8.91	

Table 6: Complicacy arises wise distribution in between two groups (Group A ultrasound-based group, n=35 and Group B age-based group, n=35)

	GROUP A	GROUP B	TOTAL
YES response	2	9	11
% of total population	2.85714	12.8571	65.60%
NO response	33	26	59
% of total population	47.1429	37.1429	34.40%
TOTAL	35	35	70
%TOTAL	50	50	100.00%

p- value = 0.021509*
The chi-square statistic is 5.2851. The p-value is .021509. Significant at p < .05
The chi-square statistic with Yates correction is 3.8829.
The p-value is .04878. Significant at p < .05.

Table 7: Number of attempts wise distribution in between two groups (Group A ultrasound-based group, n=35 and Group B conventional age-based group, n =35).

	GROUP A	GROUP B	TOTAL
No of attempt 2	2	9	11
% of total population	2.85714	12.8571	65.60%
No of attempt 1	33	26	59
% of total population	47.1429	37.1429	34.40%
TOTAL	35	35	70
%TOTAL	50	50	100.00%

p-value = 0.021509*
The chi-square statistic is 5.2851. The p-value is .021509. Significant at p < .05
The chi-square statistic with Yates correction is 3.8829.
The p-value is .04878. Significant at p < .05.

Table 8: Number of HOARSENESS arises in between Group A and Group B.

	GROUP A	GROUP B	TOTAL
YES response	1	3	4
% of total population	1.42857	4.28571	65.60%
NO response	34	32	66
% of total population	48.5714	45.7143	34.40%
TOTAL	35	35	70
%TOTAL	50	50	100.00%

p-value =.303077
The chi-square statistic is 1.0606. The p-value is .303077. Not significant at p < .05.
The chi-square statistic with Yates correction is 0.2652.
The p-value is .606603. Not significant at p < .05.

Table 9: Number of STRIDOR arises in between Group A and Group B.

	GROUP A	GROUP B	TOTAL
YES response	1	3	4
% of total population	1.42857	4.28571	65.60%
NO response	34	32	66
% of total population	48.5714	45.7143	34.40%
TOTAL	35	35	70
%TOTAL	50	50	100.00%

p-value =.303077
The chi-square statistic is 1.0606. The p-value is .303077. Not significant at p < .05.
The chi-square statistic with Yates correction is 0.2652.
The p-value is .606603. Not significant at p < .05.

Table 10: Number of TRACHEAL MUCOSAL INJURY arises in between Group A and Group B.

	GROUP A	GROUP B	TOTAL
YES response	0	4	4
% of total population	0	5.71429	65.60%
NO response	35	31	66
% of total population	50	44.2857	34.40%
TOTAL	35	35	70
%TOTAL	50	50	100.00%

p-value =0.0621

Chi squared equals 2.386 with 1 degrees of freedom.

The one-tailed P value equals 0.0612

The association between rows (groups) and columns (outcomes) is considered to be not quite statistically significant.

Table 11: Number of BRONCHOSPASM arises in between Group A and Group B.

	GROUP A	GROUP B	TOTAL
YES response	0	1	1
% of total population	0	1.42857	65.60%
NO response	35	34	69
% of total population	50	48.5714	34.40%
TOTAL	35	35	70
%TOTAL	50	50	100.00%

p-value =0.1569
Chi squared equals 1.014 with 1 degrees of freedom.
The one-tailed P value equals 0.1569
The association between rows (groups) and columns (outcomes) is considered to be not statistically significant.

DISCUSSION

The present study shows that ultrasonography offers a more accurate means of selecting a correctly sized endotracheal tube in children than the age-based formula. The number of attempts of intubation was significantly less in an ultrasound-based group than the age-based group. Similarly, complications arising out of repeated attempts of laryngoscopy were also more in the age-based group. But the individual complications like postoperative sore throat, stridor, tracheal mucosal injury, aspiration giving rise to bronchospasm were compared among both the groups and were not statistically significant.

In some previous studies, like in a cross-sectional study by Dr. Shubh Singh et al, out of 100 children taken up for a study, the ultrasonographic assessment was accurate in 100%of patients, in comparison to 95% success in age-based formulas, 97% in right little finger-based and 98% in the left little finger-based formula.

In another prospective study done by Dr. Shibasaki et al. in a total of 192 children of age between 1 month and 6 years, the rate of agreement between the predicted endotracheal tube size based on the ultrasonic measurement and the final tube size selected clinically was 98% for cuffed tubes and 96 % for un-cuffed tubes. We have used only cuffed tubes for our study.

Dr. Schramm et al conducted a study on 50 children of age less than 5 years and found that measurement of the minimal transverse diameter of the subglottic airway (MTDSA) by ultrasound facilitates selection of correct endotracheal tube in pediatric patients and minimize the number of re-intubations [10], similar to our study.

Kim et al, in their study on 215 children of age between 1-72 months, showed that ultrasound-guided endotracheal tube size at subglottic diameter was more accurate than age or height-based formulas [11], which conforms to our study.

Ultrasonography thus has recently found a place in anesthesiology and is a newer modality in airway assessment [9,10]. Though it is an operator dependant technique, it is relatively easy to learn and with adequate expertise, can produce reliable results [11]. Other modes of airway assessment like chest X-Ray, Computed Tomography scan, Magnetic Resonance Imaging are comparatively expensive and require much co-operation on the patient's behalf as well as sedation which can be easily avoided in ultrasonography [12,13].

As ultrasound cannot measure anteroposterior diameter in pediatric airway accurately and can lead to underestimation of correct endotracheal tube size, the transverse airway column was measured in the first group (Group A) [2,14,15]. The ultrasonography probe was placed either at the lower end of the cricoid ring or at the midpoint (as feasible), and the lower edge of hypoechoic cricoid cartilage was taken as a reference point for measurement of subglottic diameter. Endotracheal tubes of the same brand were selected for all the patients to avoid disparity in comparison groups. In the second group, endotracheal tube size was selected based on the patient's age (Age/4+4). As cuffed tubes were used, 0.5 mm smaller internal diameter tubes were inserted which is used conventionally in pediatric patients [3,6] Among the patients in group A, only 5.7% patients had undergone repeated attempts of intubation, whereas, in 25% patients of group B, repeated laryngoscopy had to be performed. A number of attempts of intubation, as well as complications, were thus higher in group B. But, among the individual complications like mucosal injury, bronchospasm, sore throat, no significant association was noted. Hemodynamic alterations noted in all failed intubations were also tabulated but showed no significant difference.

Several limitations to be considered in this study include manufacturer-based differences in endotracheal tube diameters and material. Also, this study was conducted in a single center, an urban academic Institute, so generalization of the results obtained from this study may not be feasible in other scenarios [1,3].

CONCLUSION

Ultrasound is found to be a better tool in predicting correct endotracheal tube size in children in comparison to age-based formula. Perioperative complications and repeated attempts were significantly reduced on the use of ultrasound. Thus, this study might promote the use of ultrasound in the institutes wherever feasible to improve the first pass success rate in children.

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