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The Use of Minimal Transverse Diameter of Subglottic Airway in Determining the Endotracheal Tube Size in Infants: A Prospective Observational Study

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ABSTRACT

Background: For infants receiving general anesthesia (GA), it is crucial to select the proper endotracheal tube (ETT) size since an unsuitable tube might damage the airway and cause subglottic stenosis. On the other hand, a smaller tracheal tube increases the resistance to gas flow, the danger of aspiration, the requirement for inadequate ventilation, and the necessity of reintubation with a different size tracheal tube.

Objective: The aim of the present study was to investigate the efficacy of the minimum transverse diameter of the subglottic airway (MTDSA) as a reliable method for selection of the tubal size in infants.

Patients and methods: A randomized controlled clinical trial was conducted on infants aged <1 year underwent surgery at Souad Kafafi University Hospital-Misr University of science and Technology. Infants were divided in two equal groups; *Group A* underwent measurement of MTDSA (21 infant), and Group B used the conventional method (internal diameter (ID) of the most frequently used ETT were 3.0 mm for infants less than 1 month old, 3.5 mm for those 1 to 4 months old, 4.0 mm for those 5 to 17 months old) (21 infants).

Results: The use of MTDSA as a method for selection of the tubal size could predict up to 86.7% of correct tube size in contrast to only 47.6% in group B; there was a highly significant difference between the 2 studied groups regarding the internal and external diameters of the selected tubes.

Conclusion: Compared to other approaches, MTDSA using ultrasonography has a higher sensitivity for predicting the size of an ETT. Younger infants have more ultrasonographic sensitivity than older ones.

Keywords: Endotracheal tube, MTDSA, Ultrasonography, Infant.

INTRODUCTION

It can be challenging to determine the ideal endotracheal tube (ETT) size in children and infants [(1)]. A number of formulas and anthropological measures have been made utilizing age, crown-heel length, height, and fifth fingernail width [(2)].

Age-based formulas have a varied effectiveness rate ranging from 47% to 77% and are most frequently employed in pediatric age groups [(3,4)].

A smaller-than-needed ETT causes inadequate ventilation, inaccurate end-tidal gas monitoring, operating room pollution, higher medical gas costs, and a possible aspiration risk. In contrast, a bigger tube may result in subglottic granulomas and stenosis, as well as trauma and postoperative stridor. The patient's hemodynamic condition may be compromised by repeated laryngoscopic efforts to switch to an appropriate-sized tube, which can also lead to airway edema and damage.

The minimum transverse diameter of the subglottic airway (MTDSA) measured by ultrasound (USG) is a relatively new method for estimating the size of the ETT [(5)]. Although having a 90% success record, MTDSA hasn't been the main factor in choosing ETTs [(6)].

Previous studies were done on young children showed a very high success rate to choose the appropriate ETT size when using MTDSA. However, they included, but, did not focus on infants, with their rapidly changing size every month, to determine their ETT size [(6,7)].

The aim of the present study was to investigate the efficacy of MTDSA as a reliable method for selection of the tubal size in infants.

PATIENTS AND METHODS

A randomized controlled clinical trial was conducted on infants aged <1 year underwent surgery at Souad Kafafi University Hospital-Misr University of science and Technology, during the period from June 2022 to December 2022.

Infants were divided in two equal groups; *Group A* underwent measurement of MTDSA (21 infant), and Group B used the conventional method (internal diameter (ID) of the most frequently used ETT were 3.0 mm for infants less than 1 month old, 3.5 mm for those 1 to 4 months old, 4.0 mm for those 5 to 17 months old) (21 infants).

Inclusion criteria: Infants <1 year of age scheduled for surgery underwent general anesthesia (GA) and informed written consent was obtained from parents.

Exclusion criteria: Infant parents refuse. Infants with anticipated difficult airway or congenital malformation of airway (subglottic stenosis, laryngomalacia, choanal atresia, etc.). Bleeding tendency (as hemophilia A). Preterm babies.

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Study Procedures:

Randomization: A computer-generated table was used to randomly assign patients to 1 of the 2 trial groups; the randomization sequence was kept secret by being placed in sealed, opaque envelopes.

Study Protocol: After receiving clearance from the Anesthesia Department's Research and Ethical Committee at Northwestern University's Faculty of Medicine, before entering the operating room, baseline data for continuous ECG, pulse oximetry, and noninvasive arterial blood pressure were taken. 8% sevoflurane and 50% oxygen were then used to produce GA. When the patient loses consciousness, a peripheral venous cannula will be placed. Fentanyl was administered at a dose of 2 mg/kg to eliminate the stress response associated with intubation, and atracurium was administered intravenously at a dose of 0.5 mg/kg to assist endotracheal intubation. Atracurium top-ups at a dosage of 0.1 mg/kg and 1–1.5% isoflurane in a 50/50 combination of oxygen and air were used to maintain anesthesia, each 30 minutes.

A technique for acquiring images and predicting endotracheal tube sizes:

To identify cricoid cartilage, a linear array high-frequency transducer (Mindray) model: DC-N2 was used. The probe was positioned longitudinally first. The probe was rotated transversely and the MTDSA was measured at the level of the lower border of the cricoid cartilage at the conclusion of inspiration (10 cm H2O airway pressure). The outer diameter (OD) that is closest to MTDSA and does not exceed MTDSA was used to determine the ETT. To avoid bias, the MTDSA was measured by a person who was not aware of the infant's age.

Sevoflurane, fentanyl were used for induction of anesthesia in all children, and atraciurium was used for neuromuscular paralysis. During the end-inhalation phase, MTDSA was assessed independently by an anesthesiologist with experience in airway ultrasonography (USG).

The attending consultant anaesthetist received the measured value and used the MTDSA data to determine the ETT. A 0.5 mm smaller ETT was employed and the end tidal CO2 was attached in the event that there was resistance to passing the ETT through the vocal chords. In each instance, an uncuffed tube was utilized. While evaluating air loss following intubation, the researcher was blind to both age and MTDSA measurements (with head in neutral position). When a minor tracheal leak was observed at a pressure of 20 cm H2O, the tube size was regarded best fit. A bigger tube was inserted if there was an audible leak at 10 cm H2O. Downsizing was required when there was no or only a little leak at 30 cm H2O. The number of ETT changes attempted, ultrasonography accuracy in different age groups, and agreement between the best-fit endotracheal tube and the prediction based on the subglottic airway's minimum transverse diameter was recorded. Complications (croup, stridor, airway damage, and hypoventilation) and patient characteristics (monthly age, gender, and weight) was documented, compared, and statistically assessed.

Study outcomes:

Primary outcome: The least transverse diameter of the subglottic airway prediction and the best-fit endotracheal tube were found to be in agreement.

Secondary outcome(s): The number of attempts to change ETT to achieve correct size. The accuracy of ultrasound in relation to age per month, gender, and weight. The incidence of complications (croup, stridor, injury)

Ethical Considerations:

This study was ethically approved by the Institutional Review Board of the Faculty of Medicine, Misr University for Science and Technology. Before enrolling any children in the study, parents of all potential participants were given the opportunity to give their written agreement after being informed of the study's goals. This study was executed according to the code of ethics of the World Medical Association (Declaration of Helsinki) for studies on humans.

Statistical Analysis

The collected data were introduced and statistically analyzed by utilizing the Statistical Package for Social Sciences (SPSS IBM Inc., Armonk, New York) version 20 for windows. Qualitative data were defined as numbers and percentages. Chi-Square test and Fisher’s exact test were used for comparison between categorical variables as appropriate. Quantitative data were tested for normality by Kolmogorov-Smirnov test. Normal distribution of variables was described as mean and SD, and median (range) if not normally distributed. If the data were regularly distributed, the Student t-test was employed to compare them; otherwise, the Mann-Whitney U test was applied. The tube size and MTDSA measurement was correlated using a Spearman association. P value ≤0.05 was considered to be statistically significant.

RESULTS

Demographic data and weight showed statistically insignificant difference between the 2 studied groups (**Table 1**).

Table (1): Comparison between two studied groups regarding the demographic characteristics and weight.

Variable		**Group**				**P-value**
		Group A (n=21)		**Group B (n=21)**		
		Count	**%**	**Count**	**%**	
Age (months)	**Mean ± SD**	4.71 ± 2.12		4.61 ± 2.09		0.76
Weight (kg)	**Mean ± SD**	6.60 ± 1.49		6.41 ± 1.60		0.2
Gender	**Female**	9	42.9%	9	42.9%	1.000
	Male	12	57.1%	12	57.1%	

Data are expressed as mean ± standard deviation (SD), numbers and percentage (%). P ≤0.05 is significant.

As regards the use of MTDSA as a method for selection of the tubal size could predict up to 86.7% of correct tube size in contrast to only 47.6% in group B, there was a highly significant difference between both groups as regards the internal and external diameters of the selected tubes. The number of attempts according to leak was significantly decreased in the MTDSA group (**Table 2**).

Table (2): Comparison between two studied groups regarding the clinical data.

Variable		**Group A (n=21)**	**Group B (n=21)**	**P-value**
Measurements predicted tube size	No	3 (14.3%)	11 (52.4%)	0.035
	Yes	18(85.7%)	10 (47.6%)	
MTDSA Measurement (mm)	Median (Range)	5.3 (4 - 6.3)		
Tube size (internal diameter) (mm)	Mean ± Standard deviation	3.74 ± 0.48	4 ± 0.35	0.007
Tube size (external diameter)(mm)	Mean ± standard deviation	5.15 ± 0.64	5.22 ± 0.91	0.008
Number of attempts according to leak	**1** Numbers (%)	19 (90.5%)	13 (61.9%)	0.043
	2 Numbers (%)	2 (9.5%)	8 (38.1%)	

Data are expressed as mean ± standard deviation (SD), numbers and percentage (%), median (range). P ≤0.05 is significant.

Also, there was strong correlation between MTDSA measurement and tube size with P value <0.001 (**Table 3**).

Table (3): Correlation between MTDSA measurement and tube size in Group A.

Variable			**MTDSA Measurement**
Spearman's Correlation	**Tube size**	**r-value**	0.952**
		P-value	**<0.001**
		N	21

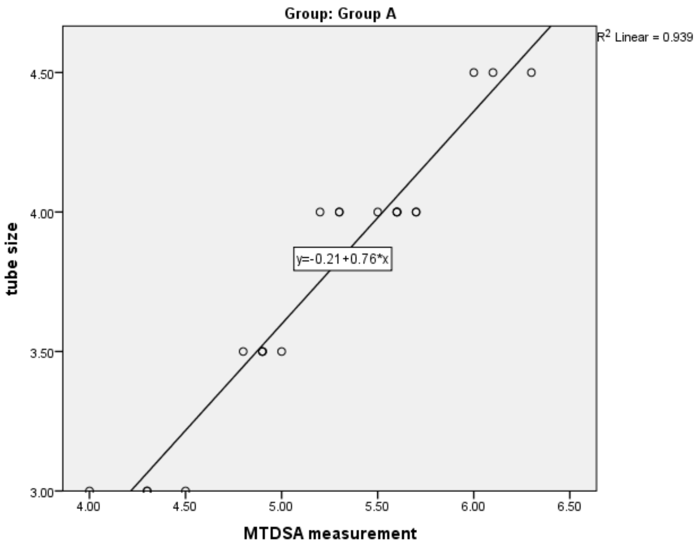

Figure (1): Correlation between MTDSA measurement and tube size

As regards the complications encountered in both groups, there was a higher incidence of croup and airway injury in group B with statistically significant difference between both groups (**Table 4**). These results come in favor for the use of MTDSA for tube size selection in infants.

Table (4): Comparison of complications among the 2 study groups:

Variable		**Group**				**P-value**
		Group A (n=21)		**Group B (n=21)**		
		Count	**%**	**Count**	**%**	
Croup	**No**	19	90.5%	12	57.2%	0.036
	Yes	2	9.5%	9	42.8%	
Stridor	**No**	21	100%	19	90.5%	0.71
	Yes	0	0.0%	2	9.5%	
Airway injury	**No**	20	95.2%	11	52.4%	0.02
	Yes	1	4.8%	10	47.6%	
Hypoventilation	**No**	21	100%	18	85.7%	0.3
	Yes	0	0.0%	3	14.3%	

*: Significant at P ≤ 0.05. Fisher`s Exact test.

DISCUSSION

MTDSA was used in this randomized controlled clinical trial to estimate the size of the EET for babies. In the pediatric population, determining the proper EET size can be challenging, and if the size is improperly selected, it could lead to a number of complications. Although some previous studies investigated the ability of MTDSA to choose the appropriate ETT size in pediatrics and these studies showed a high predictability of MTDSA to select the appropriate ETT size. However, the infants, with their rapidly changing size every month, were not the primary targets of investigations of these studies [(7-9)]. So in our study we focused on the use of MTDSA for selection of ETT size in infants.

The hypothesis of this study was that USG-derived MTDSA would be a good predictor for ETT size in infants. This hypothesis was supported by the results of this work which showed that MTDSA could predict up to 86.7% in comparison to the conventional group that showed prediction of only 47.6% of correct tube size with a highly significant difference from the conventional method as regards the internal and external diameters of the selected tubes. Also, the number of attempts according to leak was significantly decreased in the MTDSA group and there was strong correlation between MTDSA measurement and tube size with P value <0.001. The incidence of croup and airway injury was significantly reduced in the MTDSA group. These results signify the safer use of MTDSA for tube size selection in infants.

Compared to the others, age-based equations are the easiest for doctors to use. Nevertheless, prior research found that the Cole formula's age-based correlation for choosing the paediatric ETT size was only 47-77% [(8,9)]. ETT sizes that are too small are frequently predicted using age-based formulas [(10)].

Children's sonographic appearance is characterised by homogeneous cartilage rings without calcification and a hyperechoic air-mucosal contact. They may be precisely assessed with USG since they are bordered by isoechoic thyroid tissue and hypoechoic constrictor muscles [(11)]. The transverse diameter near the vocal cord, in both spontaneously breathing and paralysed juvenile airways, has been found to be the smallest part in studies [(12-13)].

At the cricoid and vocal cord levels, the transverse dimensions are less than the equivalent anteroposterior diameters [(14)]. The motionless voice cords in paralysed patients are challenging to image, and angulation of the probe to enhance cord resolution can cause inaccuracies in the assessment of the glottic transverse diameter. The cricoid should, in theory, be the limiting and, hence, predictive component in choosing ETT size since it is a relatively hard, full cartilaginous ring in comparison to the vocal cords. At the point of end inspiration, the MTDSA was measured at the level of the lower cricoid cartilage boundary.

In agreement with our results, **Pillai *et al.*** [(15)] conducted a research on 51 kids who were scheduled for heart surgery and ranged in age from 1 day to 5 years, where the ETT size was determined based on the MTDSA. They demonstrated that as compared to the traditional method's accuracy (27.5%) in predicting ETT size, MTDSA had a much higher global score (87.8%). MTDSA had a baby success rate of 82.1% whereas age-based formulas had a success rate of 14.3% (4/28). None in the research group of kids had difficulties. The research by **Pillai *et al.*** [(15)]**,** in contrast, comprised kids from 1 day to 5 years old who were scheduled for heart surgery. In contrast to age, weight, and sex, **Chen *et al.*** [(16)] discovered that height is the best accurate criterion for estimating tracheal diameter in CT scan pictures of children with congenital cardiac disease.

In a research by **Shibasaki *et al.*** [(17)] including 192 children between the ages of 1 month and 6 years, it was discovered that ultrasound assessment of the subglottic airway diameter was more accurate at predicting the size of an adequate endotracheal tube than age and height-based formulae. The rate of agreement between the final ETT size chosen clinically and the projected ETT size based on ultrasonic measurement was 98% for cuffed ETTs and 96% for uncuffed ETTs. Although they employed both cuffed and uncuffed ETTs and covered patients aged 1 month to 6 years, their study differs from ours in that some ODs tended to be smaller in cuffed than in uncuffed ETTs.

In a research done in children, **Deekiatphaiboon *et al.*** [(18)] looked at the relationship between the outer diameter of ETT and the mid-glottic transverse diameter/subglottic diameter. A total of 95 general anaesthetic patients between the ages of 1 and 8 were included. For predicting the OD of uncuffed ETT size in children, they discovered a moderate connection between USG measures of the glottic area (r values of 0.46 for glottic transverse diameter and 0.47 for mid-glottic transverse diameter).

In comparison to the link between subglottic diameter and ETT size, the relationship between glottic/mid-glottic transverse diameter and ETT size was not different**.** However, because of the tiny airway, particularly in novice performers, USG of the subglottic area may be simpler to examine than that of the glottic region. Compared to the patients in our research, they were older patients [(18)].

CONCLUSION

Compared to other approaches, USG has a higher sensitivity for predicting the size of an ETT. Younger infants have more ultrasonographic sensitivity than older ones.

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