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Original Article

Comparison of Ultrasound and Motoyama Formula for Estimation of Endotracheal Tube Diameter in Pediatric Patients

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ABSTRACT

Objective: To assess the comparative effectiveness of Ultrasound and Motoyama formula for the calculation of endotracheal tube diameter in pediatric patients.

Study Design: Quasi-experimental study

Place and Duration of Study: The study was carried out at Department of Anesthesia Combined Military Hospital Quetta, Pakistan from May-Nov 2022.

Methodology: The quasi experimental study was carried out at Anesthesia Department of Combined Military hospital Quetta from May to Nov 2022. A sample size of 40 patients was calculated with the aid of WHO sample size calculator. The patients were then divided into two equal groups of 20 patients each. Twenty patients were placed in group-U in which internal diameter of cuffed endotracheal tube was estimated through ultrasonography whereas 20 patients were placed in group-M in which age related Motoyama formula was used as guide to calculate the internal diameter of cuffed endotracheal tube. The intubation attempt was considered successful if tube was passed in first attempt. Statistical Package of Social Science (SPSS) version 26.0 was used to analyze and interpret data.

Results: Both groups were similar in distribution of gender and ASA status. The intubation was successful in first attempt in 19(95%) of group-U patients while only 1(5%) patient had unsuccessful intubation at first attempt. While in group-M patients 13(65%) had successful intubation in first attempt and 7(35%) patients were not intubated at first attempt which showed that the ultrasound guided calculation of tube diameter was superior (p value <0.02).

Conclusion: The ultrasonographic estimation of endotracheal tube diameter is more reliable as compared to the Motoyama formula for estimation of ETT diameter in peadiatric patients.

Keywords: Endotracheal tube, Motoyama formula, Ultrasonography for ETT

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INTRODUCTION

The selection of properly sized endotracheal tube for pediatric patients is very important and tricky as compared to adults.[1] The children of different age groups have different tracheal diameters and selection of endotracheal tube is not as straight forward as adults. We have to choose among a wide array of pediatric cuffed and un-cuffed tubes. The pediatric airway is dissimilar to adult's airway. The glottis opening visualization is not enough for endotracheal tube diameter estimation in pediatric patient as the narrowing is encountered in sub-cricoid region[2] due to which intubation is not very simple is it sounds. The seasoned anesthetists mostly rely on their intuition which they acquire over years but it is subjected to human error and miscalculation. There are certain formulas which have been used to help calculate the diameter of endotracheal tube like Cole's formula. In this formula inner diameter of endotracheal tube is computed by diving age by two and adding three to it but it over-estimates cuffed endotracheal tube diameter and used only as rough guide.[3] The Motoyama Formula has better standing among age based endotracheal tube estimation formulas.[4]

The use of upsized or down sized tube in a pediatric patient who is already anesthetized on hit and trial basis is taxing for patient and puts extra pressure on anesthesiologist specially when the induction is rapid sequence and child desaturates quickly.[5] Anesthesiologist who routinely work with pediatric patients develop more apt judgement regarding tube selection but those who do not encounter pediatric cases daily or work in remote locations, face problems in judgment. Therefore, the quest for appropriately fitted tube is still ongoing and there is no gold standard in this regard. The formulas which correlate age to diameter and length of tube are least helpful when body habitus of child is not

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according to age. In our part of world, there are a large number of malnourished kids who do not attain their full height (stunting) and weight according to age (wasting). According to a review article of Pakistani pediatric population forty-eight percent children suffered growth stunting and 10 percent suffered wasting due to malnutition[6]. Body surface area is used for pediatric population for calculation of drug dosage but it has been proposed as unreliable tool for estimation of ETT diameter.[7] The use of little finger which is still in use underestimates the diameter and air leak leading to risk of aspiration making it a less attractive substitute.[8] The length of middle finger has been used by Ritchie-McLean *et al.*,[9] in their study to calculate the internal diameter of endotracheal tube but they used it for un-cuffed endotracheal tube but the focus of our study was cuffed endotracheal tube. Ultrasound has been suggested to have utility in estimation of size of endotracheal tube by some international publications; Therefore we wanted to check its reliability by comparing it to formula-based calculation of endotracheal tube diameter in our local pediatric population.

METHODOLOGY

The quasi-experimental study was initiated after grant of permission from Combined Military Hospital (CMH) Quetta ethical committee which endorsed the IERB ERC/82/2022. After addressing ethical issues, the study was conducted in anesthesia department of CMH Quetta from May to November 2022. The sample size was calculated by making use of WHO sample size calculator. The parameters used for sample size calculation were: expected estimated of tube diameter with ultrasound to be 0.9810 and tube diameter with Motoyama formula to be 0.4810. The sample size was calculated to be 40 patients. Purposive sampling was done to recruit the participants. After informed consent two equal groups (n= 20) were formulated and named as group-U in which cuffed endotracheal tube diameter was estimated through ultrasonography and group-M in which age related Motoyama formula was used as a guide to calculate the internal diameter of endotracheal tube.

Inclusion Criteria: Pediatric patients (age 2 to 12 years) with ASA status I to II were included.

Exclusion Criteria: Neonates, infants, ASA III & IV, patients with subglottic stenosis, difficult airway, patients with full stomach or congenital airway disorders were excluded.

The patients were booked through children OPD for various surgeries and pre-anesthesia assessment was done in pre-anesthesia clinic. The purpose of study was explained to parents/guardians and written informed consent was taken. In operation theatre, all patients were given Sevoflurane with overpressure technique and intravenous access was achieved. Standard monitoring was attached and standard general anesthesia was given with Propofol (2.5mg/kg) and Atracurium (0.5mg/kg). After that bag- mask- ventilation was done in both groups for three minutes. In group-U patients during bag mask ventilation a liner array high frequency probe (Canon medical systems, xario 100) was placed parallel to mandible in the middle of neck. At first the sono anatomy of glottis was visualized as hyperechoic structure making isosceles triangle with trachea in the centre appearing as hypoechoic shadow and the probe was then gently slided caudually to identify cricoid arch which appeared as a hypo-echoic area with hyper-echoic margins. The sub-cricoid region was identified as hypoechoic air column in the cephalad part of this arch with air column inside. The transverse diameter of this air column was calculated, and Ultrasound probe was removed. The measurement attained was in millimeter. Intubation was attempted through tube with outer diameter corresponding to the calculated rounded off to the nearest and lowest 0.5mm. The outer diameter was converted to internal diameter according to manufacturer's guidelines. The appropriately sized tube was the one which passed through sub glottis without any problem and there was air leak at 20cm of water. The tube which showed hindrance at sub glottis or which had no air leak at 20cm of water was not passed. Successful attempt was marked when the appropriately sized tube was able to pass in the first attempt. In group-M patients, the internal diameter of tube was calculated with Motoyama formula, in which age was divided by two and 4cm was added to it. The intubation was attempted with the tube corresponding to Motoyama formula. The appropriately sized tube was marked as the one which passed through sub epiglottis smoothly without any hindrance and there was air leak at 20cm of water. The tube which showed hindrance at sub glottis or which had no air leak at 20cm of water was not passed. The intubation attempt was considered successful if tube was passed in first attempt. Primary outcome was successful intubation at first attempt with appropriately sized tube.

Statistical Package of Social Science (SPSS) version 26.0 was used to analyze and interpret data. Mean±SD was computed for quantitative variables and frequency was computed for qualitative variables. Chi-square analysis was employed for comparison of efficacy between both groups. The demographics were also compared by t-test to compute *p* value. The *p* value less than and equal to 0.05 was considered to be significant.

RESULTS

Demographic features were analogous in both study groups. The primary outcome was the successful intubation at first attempt with both techniques. The demographics included age, weight, height, ASA status and gender distribution. The mean age of group-U was 9.30±2.00 years and mean age in group-M was 8.75±1.65 years. The mean height was 104.25±41.645 cm and mean weight was 21.80±4.27 in group-U patients while mean height and mean weight was 122.35±19.65 cm and 20.70±3.79kg in group-M respectively. Both groups were similar in distribution of gender and ASA status. There were 12(60%) males and 8(40%) females in group-U and 11(55%) males and 9(45%) females in group M. There were 13(65%) ASA-I patients in group-U and 7(35%) ASA-II patients while there were 13(65%) ASA-I patients and 7(35%) ASA-II patients in group-M as shown in Table-I.

The primary outcome was the successful intubation at first attempt. The intubation was successful in first attempt in 19(95%) group-U patients while only 1(5%) patient had unsuccessful intubation at first attempt. While in group-M patients 13(65%) had successful intubation in first attempt and 7(35%) patients failed to be intubated in first attempt which showed that the ultrasound guided calculation of tube diameter was better (p value <0.02) as presented Table-II.

Table-I: Demographic characteristics of both Study Groups (n=40)

Parameter		Group-U (n=20) MEAN±SD	Group-M (n=20) MEAN±SD	*p*-value
Age (years)		9.30±2.00	8.75±1.65	0.60
Weight (kg)		21.80±4.27	20.70±3.79	0.33
Height (cm)		104.25±41.64	122.35±19.65	0.22
		Frequency (%)	Frequency (%)	
ASA	ASA-I	13(65.0)	13(65)	0.62
	ASA-II	7(35)	7(35)	
Gender	Male	12(60.0)	11(55.0)	0.50
	Female	8(40.0)	9(45.0)	

Table-II: Frequency of Successful Intubation in Both Study Groups (n=40)

		Group-U (n=20) Frequency (%)	Group-M (n=20) Frequency (%)	*p*-value
Success	Yes	19(95)	13(65.0)	<0.02
	No	1(5.0)	7(35.0)	

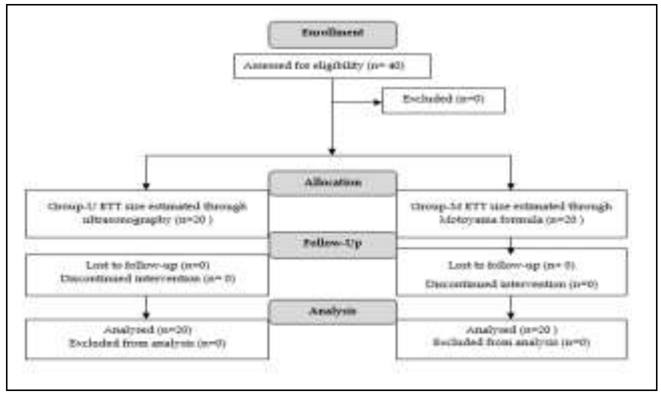

Figure: Flow Diagram of Patients

DISCUSSION

This study supports the use of ultrasonographic estimation of endotracheal tube diameter. Ultrasonographic estimation of endotracheal tube diameter is more reliable than age based formulas.

Ultrasound has become an important imaging modality for practice of anesthesiology which has utility in many anesthetic interventions. Recently its role has been highlighted in calculation of tracheal diameter for pediatric patients. One of the recent studies showed that ultrasonography guided visualization of subglottic area helped in estimation of diameter of tracheal tube[11]. This is of particular importance as pediatric endotracheal tube size estimation is still a debatable issue. Before ultrasound, doctors relied upon the age based formulas for estimation of tube diameter and went for an up-sized or down-sized tube in case of failure. Children are not merely small adults. They have reduced functional residual capacity and have immature alveoli and desaturate quickly[12] especially when they have not been adequately pre-oxygenated due their non-cooperative behavior before induction of anesthesia. The multiple intubation attempts not only prolongs apnea time and promotes desaturation but also induces trauma to airway that can culminate into adverse effects of laryngospasm and croup post-operatively[13]. This problem gets more serious when intubation is rapid sequence with substantial risk of aspiration. Every failed attempt multiplies risk and places child in a dangerous situation. Therefore any means of knowing the size of tube with reasonable accuracy prior to intubation attempt is welcomed.

Deekiatphaiboon *et al.*, found a coherence of transverse diameter of subglottis with outer diameter of un-cuffed endotracheal tube and pleaded that ultrasound was more reliable as there was great inter-individual inconsistency[14]. However, the results were projected in the form of formulas which is not very practical. In this study use of subglottis transverse diameter was used and directly correlated the external diameter of cuffed endotracheal tube.

Ye *et al.*, measured the outer transverse diameter of porcine trachea with electronic vernier caliper under ultrasonographic guidance and found that it correlated well. However, in this study measurement of the sub-cricoid region in its transverse diameter was done as it's the narrowest part in children[15], since the focus of study was pediatric population. Study of Bae *et al.*, is also worth mentioning who demonstrated a direct relation between un-cuffed tube diameter with sub-glottic transverse diameter without involving any formulas but it was done for un-cuffed tube in contrast to cuffed endotracheal tube which was the focus in this study as these are more desirable in terms of clinical consequences and are more economical.[16] Transverse diameter of sub-glottis was taken, rounded up and the tube was selected correlating to external diameter to keep the study simple. It was found that there is a reasonably good correlation of sub-glottic diameter with external diameter of cuffed endo-tracheal tube with 95% success rate. Anthropometric measures proved to be an unreliable guide in comparison to ultrasound for ETT diameter calculation. They over-estimated the ETT diameter as in case Motoyama formula under discussion.

The possibility of time consumption for Ultrasound was addressed by taking measurement during bag mask ventilation which didn't result in prolongation of anesthesia time.[17] Point of care ultrasonography has also been used for confirmation of endotracheal intubation but it was beyond the scope of this study.[18]

LIMITATIONS OF STUDY

Neonates, infants and adults were not studied in this study. There should be a larger scale randomized controlled trial on this topic.

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CONCLUSION

The Ultrasonographic estimation of endotracheal tube diameter is more reliable as compared to the Motoyama formula for estimation of ETT diameter in peadiatric patients.

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Authors' Contribution

Following authors have made substantial contributions to the manuscript as under:

TA & SQ: Data acquisition, data analysis, critical review, approval of the final version to be published.

CAA & AH: Study design, data interpretation, drafting the manuscript, critical review, approval of the final version to be published.

KM & AQ: Conception, data acquisition, drafting the manuscript, approval of the final version to be published.

Authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated andAcknow resolved.

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