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Comparative analysis comparing age-based formulae and ultrasonography for predicting pediatric endotracheal tube size

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ABSTRACT

BACKGROUND: In the pediatric age group, age-based algorithms have been routinely utilized to determine the proper endotracheal tube (ETT) size for intubation. These algorithms frequently fall short of accurately predicting the ideal ETT size. The study's goal is to ascertain whether ultrasonography-derived tracheal internal diameter is a more accurate indicator of ETT size than age-based formulas. In the past, endotracheal tube size was determined using age-based calculations; however, more recently, ultrasound has been utilized to determine the subglottic diameter and select the proper endotracheal tube size. For anesthesiologists, assessing airways in children continues to be the most difficult assignment. The examination of a pediatric airway should now be accurate and informative thanks to recent advancements in ultrasound techniques.

AIM: To examine the accuracy of ultrasonography in determining the size of endotracheal tubes in pediatric patients and compare it with the age-based Motoyama formula for endotracheal tube outer diameter determination.

MATERIAL AND METHOD: Following the institutional ethical committee's clearance, sixty pediatric patients, age three to fourteen years who were scheduled for procedures under general anesthesia with endotracheal intubation and met the requirements ASA I & II, were added to the study. B-mode ultrasonography (USG) with excellent resolution was used to measure the subglottic diameter. The ETT that most closely matched the measured subglottic diameter in terms of OD was selected. The time required for USG scanning to measure the tracheal diameter in seconds, together with the clinically best fit ETT size and the actual ETT size used. The size of each patient's ETT was determined using the age-based Motoyama formula. A comparison was made between the ETT size estimated by USG and the age-based Motoyama formula before it was finally employed therapeutically.

RESULTS: Utilizing the age-based Motoyama formula, the mean endotracheal tube diameter was determined to be 2.66±0.62 mm. 7.1±1.12 mm was the mean subglottic diameter as determined by ultrasonography. 5.1±1.07 mm was the mean of the outside diameter that matched the subglottic diameter as determined by USG. The average ID value that matched the USG-measured OD was 3.12±0.69 mm. Each USG scanning took a total of 9.72±1.22 seconds, which was the meantime taken by USG.Based on the results of the air leak test, the mean of the clinically best-fit ETT was 5.15±0.68 mm. This figure is more than the mean of ETT size determined by the age-based Motoyama formula and nearly identical to the mean of ID corresponding to OD as determined by USG.

CONCLUSION: When compared to the age-based calculation, ultrasonography shown to be a reliable predictor for the assessment of the subglottic diameter of the airway in children in order to establish the appropriate endotracheal tube size for intubation. When choosing the right endotracheal tube size for clinical use, this non-invasive, safe method can help avoid patient trauma from repeated intubation attempts or inadequate ventilation. To further validate, though, larger-scale multicenter trials ought to be carried out.

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KEYWORDS: Ultrasound imaging, Cricoid cartilageand Endotracheal intubation

INTRODUCTION:

Due to the physical variations in their airways from adult patients, pediatric patients present numerous difficulties during endotracheal intubation. Choosing the appropriate endotracheal tube (ETT) size for intubation is one such difficulty. Anesthetic gas leakage into the operating room, poor ventilation, unstable end-tidal gas monitoring, and an increased risk of aspiration can all arise from an ETT that is too tiny. Using a big ETT increases the risk of developing scars, ulcerations, local ischemia, and post-extubation stridor. It can also lead to subglottic stenosis in the future.[1,2]There are several ways to estimate the predicted optimal size of an ETT for the pediatric age group. These include straightforward and basic techniques including using age-based calculations like Cole and Motoyama, taking an X-ray of the neck, and comparing the ETT diameter to the little finger. The more sophisticated techniques, including CT and MRI, are costly and unworkable.[3,4]

Unlike the adult airway, which is cylindrical in shape and has the glottis as its narrowest part, the pediatric airway is funnel-shaped, with the narrowest component being the cricoid cartilage.[5]In pediatric patients, choosing the right ETT size is crucial since improperly sized tubes can lead to issues such as air leaks, aspirations, inadequate ventilation, edema, ulcerations, necrosis of the subglottic region, post-extubation stridor, and subglottic stenosis.[6,7]In the past, many formulas based on factors including finger diameter, height, weight, and age have been used to identify the right size ETT for pediatric patients. The smallest diameter cannot be accurately anticipated by height or weight, and the size of the airway varies greatly amongst patients, thus these methods are not always appropriate.[8]

Understanding how a child's age affects laryngeal dimensions is crucial for any practitioner working with pediatric airway patients. The trachea has a funnel-shaped upper end that is broader than the lower during the newborn stage and eventually becomes cylindrical as the child grows older.[9]The primary factor that determines whether or not to advocate the use of uncuffed endotracheal tubes in kids under the age of eight years old is their growing airway structure.[10]Recently, USG has emerged as a superb real-time, portable, non-invasive imaging method for managing airways. The anatomical structures in the supraglottic, glottic, and subglottic regions can be seen with the aid of USG, and it is possible to anticipate the proper size ETT.[11,12]The anatomical structures in the supraglottic, glottic, and subglottic regions are plainly visible with the aid of ultrasonography. When evaluating the upper airways, ultrasound is a dependable, painless, safe, and non-invasive modality. It can also be a helpful tool for determining the appropriate endotracheal tube size.

With this in mind, a prospective observational study was designed to examine the accuracy of ultrasonography in determining the size of endotracheal tubes in pediatric patients, as well as how it compares to the age-based Motoyama formula for determining endotracheal tube outer diameter.

MATERIAL AND METHODS

Sixty pediatric subjects, ages three to fourteen, who were scheduled for surgeries under general anesthesia with endotracheal intubation and who fit the American Society of Anesthesiologists Physical Status I & II, were enrolled in the study following approval from the institutional ethics committee and written informed consent from parents or guardians. In this study, we have taken into account a sample size of sixty patients. Patients who were expected to have a difficult airway, had an upper airway anatomical deformity, had a scar, ulcer, or lump in their neck, had had prior neck surgery, or had an upper respiratory tract infection were not accepted.Pre-anesthetic evaluations included a thorough history and physical examination of each patient. Prior to surgery, patients were kept at zero percent for six hours for meals and two hours for clear fluids.

On the day of the surgery, the patient was taken into the operating room and routine monitoring was established for heart rate (HR), electrocardiography (ECG), pulse oximetry (SpO_2), non-invasive blood pressure (NIBP) and end-tidal CO_2 ($EtCO_2$) and baseline readings were recorded. General anesthesia was induced at the discretion of the attending anesthesiologist. After the loss of consciousness and confirmation of bag and mask ventilation, a loading dose of neuromuscular blocking agent, injection atracurium 0.5−1mg/kgwas given and the patient was ventilated for 3 minutes, using the close circuit. The ultrasonography of subglottic space was performed with temporary cessation of respiration and this apnoea interval was also noted.

Procedure

General anesthesia was induced with a dose of 2 mg/kg propofol after appropriate premedication. An intubating dose of atracurium 0.5 mg/kg was injected for muscle relaxation. Before being intubated, the patient was mask ventilated for three minutes using nitrous oxide, oxygen, and sevoflurane to promote maximum muscular relaxation. Using ultrasonography, the subglottic tracheal diameter was determined during mask ventilation. The ETT size was also chosen using the age-based approach. Motoyama was the age basis formula (for more than two years) that was applied.

Ultrasonography technique

Using a high-resolution linear probe of an ultrasound machine (GE Healthcare Venue 40) placed on the anterior neck's midline while the patient's head was extended and neck was flexed during mask ventilation, the subglottic diameter was measured. The standard scanning plane was upheld to avoid bias and artifacts. An anesthesiologist with ultrasonography experience carried out the procedure. A spherical, hypoechoic structure with hyperechoic margins is how the cricoid arch is seen. The lower border of the cricoid cartilage, which is regarded as the subglottic tracheal diameter, is where the transverse air-column diameter was measured.The endotracheal tube with a comparable outer diameter was chosen based on the measured subglottic tracheal diameter. Since different manufacturers' ETTs have varying outside diameters, we utilized Teleflex Rusch endotracheal tubes for our investigation. The tubes that were chosen were measured for their corresponding inner diameter. To avoid causing damage to the airways, an endotracheal tube with an outer diameter that is consistently smaller than the tracheal diameter was used. These measurements were taken while tracheal diameter fluctuation was at its lowest by briefly stopping manual ventilation.[14,15]

Statistical analysis

The data analysis was performed using IBM SPSS version 20.0 software. Quantitative variables were expressed as mean± SD and compared across follow-ups using paired t-tests. A $p<0.05$ is considered statistically significant.

RESULT: -

Table 1:Comparable pattern was seen in the demographic and physical characteristics of all 60 patients

	Frequency N=60
Meanage±SD	3.85±2.11year
Male: Female	43:21(67%malesand33%females)
MeanWeight± SD	14.55±5.65kg
MeanHeight±SD	104.19±14.15cm
BMI±SD	11.43±1.62kg/m^2

Table 2: Haemodynamic parameters HR, NIBP (systolic), NIBP (Diastolic), Spo2 and EtCo2 when compared at different times, no significant changes were observed after ET intubation and at other timepoints.

	Baseline	After Induction	After ET intubation	After10min	After20min	After30min
HR± SD	87.47±5.44	98.66±5.8	105.18±4.77	95.38±2.27	89.24±2.3	85.13±4.64
SBP± SD(mmHg)	108.81±2.04	104.49±1.44	112.88±2.57	103.17±1.38	103.12±2.38	109.87±2.77
DBP± SD(mmHg)	66.37±2.15	63.38±2.5	71.55±2.16	71.77±1.18	73.37±1.87	70.64±1.72
Spo2±SD	90±0	90±0	90±0	90±0	90±0	90±0
EtCo2 ± SD(mmHg)	25.32±1.55	33.05±1.23	34.88±1.47	35.73±1.82	35.74±2.2	36.28±1.17

Utilizing the age-based Motoyama formula, the mean endotracheal tube diameter was determined to be 2.66±0.62 mm. 7.1±1.12 mm was the mean subglottic diameter as determined by ultrasonography. 5.1±1.07 mm was the mean of the outside diameter that matched the subglottic diameter as determined by USG. The average ID value that matched the USG-measured OD was 3.12±0.69 mm. Each USG scanning took a total of 9.72±1.22 seconds, which was the meantime taken by USG. Based on the results of the air leak test, the mean of the clinically best-fit ETT was 5.15±0.68 mm.This figure is more than the mean of ETT size determined by the age-based Motoyama formula and nearly identical to the mean of ID corresponding to OD as determined by USG.

DISCUSSION

The formula based on age Motoyama is frequently used to measure children's ETT sizes who are older than two years old. According to earlier research, the Cole formula's age-based ETT size selection has an agreement rate as low as 47–77.[5]A height-based method, like Broselow tape, can be applied to account for growth variations among individuals. However, because these calculations cannot account for variations in the growth of different internal organs, these techniques have numerous drawbacks. Unlike CT and MRI, ultrasonography (USG) does not require a patient to be immobile. USG is reasonably easy to learn, but it does take training.[16]When assessing the upper airway's narrowest transverse diameter at the subglottic area, USG is dependable and can be useful in determining the appropriate ETT size.

The results of USG have been compared with Magnetic Resonance Imaging (MRI) for the purpose of subglottic diameter measurement in 19 adult patients by **Lakhal et al2007**[14] and the results were found comparable. They came to the conclusion that ultrasonography seems to be a good method for determining the subglottic upper airway diameter in young, healthy adults. In light of this, a prospective observational study was designed with the purpose of estimating the ETT size and comparing it to the current age-based equations, as well as determining the narrowest transverse width of the trachea in the subglottic area in pediatric patients using USG. On the other hand, an MRI scan can provide more details regarding the anterior-posterior measurement of tracheal diameter.[17]Because the posterior wall of the trachea is hidden by the acoustic shadow created by the air column, anterior posterior diameter cannot be seen with ultrasonography. High-quality pictures from an MRI enable precise larynx measuring. As a result, MRI is regarded as the gold standard non-invasive technique for determining subglottic diameter.

However, because to their high cost and practicality, high-quality laryngeal images from CT and MRI cannot be frequently obtained in clinical settings.

Research on the viability of using ultrasonography to assess the subglottic diameter revealed a good agreement between transverse subglottic diameter measurements obtained by ultrasonography and magnetic resonance imaging (MRI), leading to the conclusion that ultrasonography was a suitable method for measuring the subglottic diameter.[18]Unlike CT and MRI, which require absolute immobility, ultrasound does not, especially in newborns. Ultrasonography is relatively easy to learn, although it depends on the operator's skill and so requires training. Subglottic stenosis is a common problem in newborn or pediatric anesthesia that can be evaluated using ultrasound.[19,20]An notable restriction of ultrasonography in older patients is age-related physiological laryngeal calcification, which is typically found in adults and results in an acoustic shadow in the ultrasound image.[21]

In another study by **Shibasaki et al. 2010**[21] a low incidence of a need to change the tube was reported, as their success rate of placing a correct fitting ETT was 96%. A bigger multicentric prospective investigation would be able to validate the results of the present study, which has limitations in that it was a descriptive study conducted in a single hospital environment. The transverse diameter of the trachea is measured at a single level by ultrasonography, which has limits because tissue pressure can cause fluctuations in this measurement. Because transverse diameter can be challenging to measure in these situations, we did not include patients who were less than two years old, nor did we include kids who already had anatomical anomalies or required difficult intubation.

CONCLUSION:

When compared to the age-based calculation, ultrasonography shown to be a reliable predictor for the assessment of the subglottic diameter of the airway in children in order to establish the appropriate endotracheal tube size for intubation. When choosing the right endotracheal tube size for clinical use, this non-invasive, safe method can help avoid patient trauma from repeated intubation attempts or inadequate ventilation. To further validate, though, larger-scale multicenter trials ought to be carried out. A non-invasive, safe, and dependable method for choosing the right endotracheal tube size for clinical use is ultrasound.The accuracy of ultrasonography in measuring subglottic diameter, which prevents intubation-related problems from trauma or ineffective ventilation, is confirmed by our research.

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