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# Routine use of ultrasonography in prediction of uncuffed endotracheal tube size in pediatric patients

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## Abstract

**Background and aims:** Endotracheal intubation is a crucial skill in anesthesia. Uncuffed pediatric endotracheal tube (ETT) size can be calculated by various methods like age-based formula or by using ultrasound to measure minimal transverse subglottic diameter (MTSD). This study aimed to compare both age-based formula and ultrasound to assess the advantage of routine use of ultrasound to determine pediatric ETT size.

**Materials and methods:** Forty children of 2–10 years of age, ASA class ≤ II, Mallampati airway classes I and II, scheduled for surgery away from the head and neck, were included. Uncuffed ETT size for each child was calculated using age-based formula. After induction of balanced general anesthesia, an ultrasound was done to measure MTSD and an endotracheal tube was selected accordingly. After intubation, an air leak test was done and the ETT was accordingly changed (if needed).

**Results:** ETT size by age-based formula strongly correlated with the size measured by ultrasound (Pearson correlation 0. 913; $P < 0.001$). The percentage of the need to change the endotracheal tube according to the leak test was only 7.5%.

**Conclusion:** The ETT size calculation was similar for both age-based formula and ultrasound. So, we could not justify the routine use of ultrasound for calculating ETT size for intubation in pediatric patients.

**Keywords:** Pediatric anesthesia, Ultrasound in airway management, Endotracheal tube size

## Background

Selection of the proper size of endotracheal tube (ETT) is essential for adequate ventilation and maintenance of general anesthesia (Ellis et al. 2014). An oversized ETT relative to the trachea may damage the tracheal mucosa by friction and by compression causing mucosal ischemia and airway edema, which may lead to post-extubation stridor or subglottic stenosis especially in children (Weiss et al. 2004). On the other hand, an undersized ETT may increase the resistance to gas flow resulting in insufficient ventilation and may increase the risk of aspiration (Gupta et al. 2012). Additionally, an excessive leak of anesthetic gases may lead to loss of anesthetic gases from the circuit and contamination of the anesthetic environment with trace anesthetic gases.

In children below 10 years of age, the cricoid cartilage is the narrowest part of the airway (Litman et al. 2003; Belanger and Kossick 2015). Hence, the traditional recommendation was to use uncuffed ETT in patients younger than 10 years (Fisher 2001). The best fit size of uncuffed ETT is one associated with an audible tracheal air leak at 10–20 $cmH_2O$ (Shibasaki et al. 2010).

Ultrasound (US) is a portable, easy to use, noninvasive tool with a high sensitivity that can be used in combination with other devices for proper airway management (Zamudio-Burbano and Casas-Arroyave 2015).

US has many uses in airway management including the identification of structures, proper positioning, and proper size selection of ETT (Zamudio-Burbano and Casas-Arroyave 2015). Recent studies have documented that US is a reliable, safe, and noninvasive method to estimate the proper size of ETT (Gupta et al. 2012; Shibasaki et al. 2010; Zamudio-Burbano and Casas-Arroyave 2015).

The aim of the work is to check the hypothesis that routine use of airway US will provide a significantly better prediction of the optimal ETT size than a

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conventional age-based formula method. The secondary objective measure was to calculate the percentage of ETT changes necessitated on the basis of an air leak test after US-guided intubation.

## Materials and methods

Our institutional ethical committee approved the study. Written informed consent was obtained from the parents (guardian) of each child. The study was conducted from 1 August 2017 till 1 May 2018 in 40 patients. Patients were prospectively recruited in a cohort fashion. The inclusion criteria were as follows: pediatric patients of both sex, age 2 to 10 years with apparently normal airway, American Society of Anesthesiologists (ASA) class less than III, Mallampati airway classes I and II, and scheduled for surgery away from the head and neck requiring general anesthesia with muscle relaxation and endotracheal intubation. Exclusion criteria included known allergy to ultrasound gel. The uncuffed (according to our institutional pediatric anesthesia protocol) ETT size was calculated for each patient on the basis of the modified Cole's age-based formula (age/4 + 4) (Cole 1957). ETTs 0.5 and 1 mm size larger and smaller were also kept ready and available.

After 10 min of oral midazolam (0.5 mg/kg) for sedation, an IV cannula was inserted. General anesthesia was induced using fentanyl (2 μg/kg), propofol (2 mg/kg), and rocuronium (0.6 mg/kg). After 2 min (onset of effect of muscle relaxant), US examination of the subglottic region was done by one of the two authors (both are well trained in the use of airway US) while the other author maintained face mask ventilation with sevoflurane 4% in100% $O_2$.

US was done in the midline of the neck while the patient was supine in the sniffing position (extended head and flexed neck) with high-resolution B-mode US (SonoSite®, Global Technology, USA) with a linear probe of small footprint (38 mm length, frequencies 6–13 MHz). The true vocal cords were localized (seen as paired hyperechoic linear structures), and then the probe was moved caudally to visualize the cricoid arch. By US, the minimal transverse subglottic diameter (MTSD) was measured during the expiratory phase of the respiratory cycle (Berkow and Ariyo 2015; Sutagatti et al. 2017; Schramm et al. 2012).

The size of an uncuffed endotracheal tube was then re-chosen according to MTSD measured by US and intubation done with this tube size (Rüsch® Safety Clear, Teleflex Medical, Kernen, Germany). After intubation, a leak test was done by gently inflating the lungs to a pressure of 30 $cmH_2O$ then gradually reducing the inflation pressure with head and neck in a neutral position until an audible air leak was detected. The optimal uncuffed ETT size is that which has no audible leakage below a ventilation pressure of 10 $cmH_2O$ and with an audible leakage above 20 $cmH_2O$ (Shibasaki et al. 2010). We changed the ETT to 0.5 mm smaller size if there was no leak at pressure 20 $CmH_2O$ and to 0.5 mm larger size if still there was a leak below pressure 10 $cmH_2O$ (Altun et al. 2016; Altun et al. 2017).

The calculated size by age-based formula was compared to the size chosen by ultrasound (primary outcome). We recorded the number and percentage of times the tube needed to be changed according to the leak test (secondary outcome). Side effects in the form of post-extubation stridor or laryngospasm were recorded after recovery among the studied children.

### Statistical analysis

Based on the previous paper by Schramm et al. (Schramm et al. 2012) the correlation between ultrasound results and the actual diameter of the ETT is 0.86 with margin of equivalence from − 0.3 to 0.3 between them. Using 80% power and 5% significance level, 29 patients were needed. We included 40 patients to compensate for drop outs. Sample size was calculated by PASS 2008 (Blackwelder 1998; Chow et al. 2003).

### Statistical methods

Data was reported as mean ± SD, median + range, or percentage with two-sided 95% confidence intervals. $P < 0.05$ was considered statistically significant. The percentages of irrelevant differences were calculated with two-sided 95% confidence intervals. An irrelevant difference was defined as a difference of ≤ 0.3 mm between the tested methods (ultrasound) and diameter of the correct ETT size (standard). Linear Pearson correlation analysis was used. Paired *t* test was done to determine the difference between the two methods in determining correct tube size selection in all patients. Data was analyzed using SPSS software (Version 22, IBM Chicago, IL, USA) (Devroye 1986; Matsumoto and Nishimura 1998).

## Results

Demographic data (age, body mass index, and sex of the patients) and type of surgery are shown in Table 1.

We found that the estimated ETT size by age formula was strongly correlated to the size measured by US

**Table 1** Demographic data

| | Mean ± SD |
|---|---|
| Age (years) | 6.1 ± 2.3 |
| Body mass index (kg/m$^2$) | 16.6 ± 2 |
| Sex (M to F) | 20: 20 |
| Type of surgery (number, %) | |
| GI surgery | 12 (30) |
| Nephrectomy | 14 (35) |
| Suprarenal mass | 14 (35) |

**Table 2** ETT size by age vs ETT size by US (MTSD)

| | Mean ± SD | *P* value |
|---|---|---|
| Size by age form | 5.52 ± 0.6 | 0.759 |
| Size by US (MTSD) | 5.50 ± 0.6 | |
| | Pearson correlation | *P* value |
| Size by age form and size by US (MTSD) | 0.913 | < 0.001 |

**Table 3** Nearest ETT size by age vs nearest ETT size by US

| | Pearson correlation | *P* value |
|---|---|---|
| Nearest size by age and nearest size by US | 0.891 | < 0.001 |

(Pearson correlation 0.913) with an insignificant difference between the two methods ($P < 0.001$) as shown in Table 2 and scatter diagram in Fig. 1. The nearest commercially available ETT size with 0.5 mm increments by age-based formula was significantly correlated to that determined by US with a Pearson correlation of 0.891 with a significant difference ($P < 0.001$) as shown in Table 3.

The scatter diagram of ETT sizes by both age-based formula and US shows that most results were close to the best fit line as shown in Fig. 1.

Regarding the need to change ETT, after intubation, according to leak test, only two tubes needed to be changed to 0.5 mm larger size ETT, and one tube needed to be changed to 0.5 mm smaller sized ETT as shown in Table 4.

Regarding side effects, there were no reported cases of either post-extubation stridor or laryngospasm after recovery among the studied children.

## Discussion

The results of our study showed that the calculated size of ETT by age-based formula and that by US were strongly correlated with no significant difference between both methods. The need to change ETT according to the leak test was insignificant as ETT changes were required in only three cases (7.5%) among the 40 studied cases.

In our study, we studied US use in pediatric intubation using uncuffed ETT in children aged 2–10 years with the exclusion of infants and younger children less than 2 years as they may have additional age-related anatomical intubation difficulties. Altun et al. (Altun et al. 2016; Altun et al. 2017) studied children of the same age group (1–10 years); however, they used cuffed rather than uncuffed tubes. Schramm et al. (Schramm et al. 2012) had studied uncuffed ETT; however, they studied younger age groups (less than 5 years).

We found that the nearest ETT size with 0.5 mm increments by age was also significantly correlated to that by US. These results concur with those of Sutagatti et al. (Sutagatti et al. 2017) who found that comparing the ETT size estimated by US with the ETT used clinically did not show any significant difference ($P = 1.000$). Their study differed in that they used both cuffed and uncuffed ETT in a wider age range of children (1–14 years). Bae et al. (Bae et al. 2011) found that US selected the correct ETT size in 60% of patients compared to only 31% with the age-based method ($P = 1.000$). These different results may have been attributed to a failure to standardize the time of the respiratory cycle at which US measurement was done, and they used continuous positive airway pressure of 10 $cmH_2O$ during their measurements. The difference between our results and those of Bae et al.'s

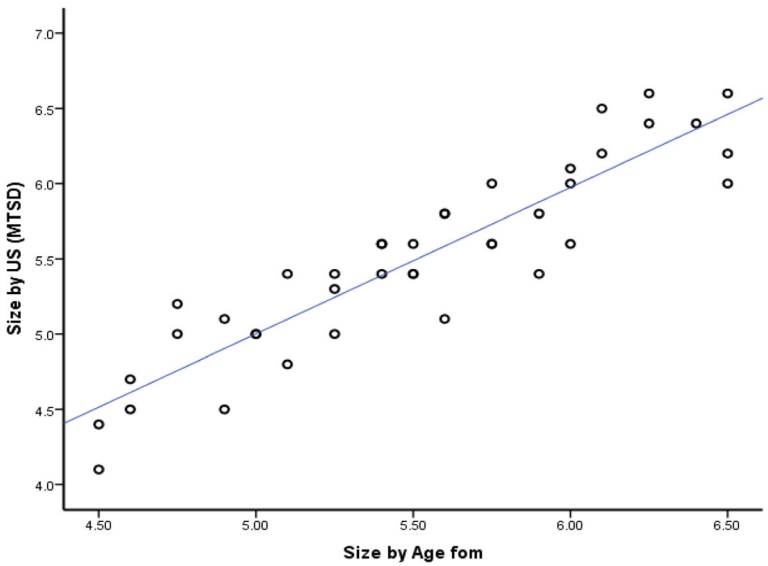


**Fig. 1** Scatter diagram of ETT size by US (MTSD) and by age form shows that most results lie close to the best fit line

**Table 4** Frequency and percentage of ETT change according to air leak test

| | | Frequency | Percent |
|---|---|---|---|
| Need to change by air leak test | No | 37 | 92.5 |
| | Yes to larger tube | 2 | 5 |
| | Yes to smaller tube | 1 | 2.5 |
| | Total | 40 | 100 |

may also be related to their inclusion of neonates and infants in their study (Bae et al. 2011).

Our study's low incidence of a need to change the ETT correlated to those of Shibasaki et al. (Shibasaki et al. 2010) who found a correct fitting of uncuffed ETTs in 96% of subjects ($P < 0.001$) and that of Altun et al. (Altun et al. 2017) who found an ultrasound determined best ETT tube fit in 88% of children.

We have studied patients undergoing surgeries away from head and neck (Table 2) to exclude the possibility of additional airway difficulty and shared the origin of post-intubation complications (if any). While Altun et al. (Altun et al. 2016; Altun et al. 2017) had studied pediatric patients undergoing adenotonsillectomy, Schramm et al. (Schramm et al. 2012) studied children undergoing multiple types of surgery including ENT surgeries with shared airway.

We have done US after induction of balanced general anesthesia including muscle relaxation as the tracheal diameter changes after muscle relaxation (Sutagatti et al. 2017). Our US measurements were taken during the expiratory phase of the respiratory cycle to avoid fluctuations in tracheal diameters, while Schramm et al. (Schramm et al. 2012) had measured the MTSD preoperatively before induction of anesthesia without muscle relaxation, and this may explain their different results.

The limitations of our study include the relatively low number of patients (40 patients), so we recommend larger sized multi-center studies to get results that are more applicable for general guidelines. The second limitation is that US measures the transverse (the smaller) rather than the antero-posterior tracheal diameter as posterior tracheal wall visualization is usually difficult.

## Conclusion

Our study concludes that although ultrasound airway measurements may be more accurate for determining endotracheal tube size than simple age-based formula; the difference is still insignificant and the correlation between the two methods is strong. Therefore, the routine use of ultrasound in pediatric endotracheal tube size estimation could not be justified.

### Abbreviations

ASA: American Society of Anesthesiologists; ETT: Endotracheal tube; MTSD: Minimal transverse subglottic diameter; SD: Standard deviation; US: Ultrasound

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### Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

### Authors' contributions

EM analyzed and interpreted the patient data. SA was a major contributor in writing the manuscript. Both authors shared in the immediate preoperative ultrasound, face mask ventilation, and intubation. Both also read and approved the final manuscript.

### Competing interest

The authors declare that they have no competing interests.

### Ethics approval and consent to participate

This study was approved by institutional review board of National Cancer Institute – Cairo University on session 116 dated 30/5/2017
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### Consent for publication

Not applicable.

### Competing interests

The authors declare that they have no competing interests.

## Publisher's Note



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