Ultrasound evaluation of subglottic diameter and endotracheal tube in children

Eun Jung Kim

Department of Medicine

The Graduate School, Yonsei University

Ultrasound evaluation of subglottic diameter and endotracheal tube in children

Directed by Professor Hae Keum Kil

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Eun Jung Kim is approved

Thesis Supervisor : Hae Keum Kil

Won Oak Kim

Byoung Wook Choi

The Graduate School

Yonsei University

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Abstract

Ultrasound evaluation of subglottic diameter and endotracheal tube in children

Eun Jung Kim

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Choosing the proper sized endotracheal tube (ETT) is an important task for airway management under general anesthesia in children. Earlier publications presented several methods for selection of ETT using patients' demographic data, such as age, weight, and height, but it has a limitation in accuracy and overlooks the individual differences.[1-5] Recently, Shibasaki et al., have reported the high correlation between the ultrasound-measured subglottic diameter and the outer diameter of ETT according to the age-based formulas.[6] The purpose of this study is to see whether ultrasound-measured transverse diameter of subglottis can give precise information for selecting proper ETT size prior to tracheal intubation.

After loss of consciousness with anesthetic induction, axial images of ultrasound on area of vocal cords and subglottis were obtained 3 times on expiratory phase during

mask ventilation. After tracheal intubation with cuffed-ETT according to the age-based recommended size, an axial image was obtained from the thyroid level to measure the outer diameter (OD) of the inserted ETT. To assess the reliability of ultrasound-measured distance, the agreement of the ultrasound-measured OD of ETT in trachea and actual OD of the ETT were analyzed. The relationship between subglottic diameter and biographic data (age, height, weight, 5th fingernail width, and body-surface area) were analyzed.

Ultrasound-measured outer diameter of ETT following the tracheal intubation, and the actual outer diameter of ETT showed good agreement, suggesting that ultrasound-measurement of subglottic diameter prior to intubation can be valuable information for proper ETT size selection. The biographic data and the ultrasound-measured subglottic diameter showed little correlation among the patients less than 12 months old, but showed good correlation with age, height in the patients older than 12 months.

Subglottic diameter measurement using ultrasound can be a convenient and precise method in predicting the proper ETT size in pediatric patients. Our study reveals the statistical relationship between the subglottic diameter and the biographical data of each patients, which enables health care providers to apply the adequate and fit ETT size in children without the inconvenience of using ultrasound every time to measure the subglottic diameter.

Keywords: Ultrasonography, endotracheal tube, subglottic diameter, child

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The Graduate School, Yonsei University

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I. INTRODUCTION

Choosing the proper sized endotracheal tube (ETT) for pediatric patient for intubation, is an important task. Inappropriate sized ETT, whether too small or too large, can either disrupt efficient ventilation, or cause soft tissue damage of the airway.

Anatomically, the narrowest part of children's larynx is the subglottic level near the cricoids cartilage; unlike adults, which is at the vocal cords.[7] A Study using MRI and CT proved that the subglottic area is the narrowest portion of the airway in young (<2 years) children.[8] Such anatomical difference could explain the possibility of tightened ETT below the cord level even though the tube passes easily through the cords.

The subglottic area can be assessed with ultrasound which is known for its superior accuracy, accessibility, and non-invasive nature when observing anatomical structure.[9-10] Although the anterior-posterior diameter of subglottis cannot be measured due to the acoustic shadow generated by the air column, the transverse diameter can be assessed clearly.[11-12] The ultrasonographical morphometric measurement has been confirmed as a reliable tool in laryngeal assessment in several studies.[10,13] Shibasaki et al. have recently reported that ultrasound-measured subglottic diameter showed high correlation with the outer diameter of ETT according to the

age-based formulas.[1-2,6,14] But, Husein et al. have pointed out that ultrasound measurements of subglottis in children are measured less than videobronchoscopic measurement, and suggested the subglottic diameter will always be underestimated by ultrasound.[13]

The goal of this study is to observe the validity of ultrasound-measured transverse diameter of subglottis prior to tracheal intubation in giving out the precise information in selecting the proper ETT size, and to verify the correlation between the ultrasound-measured diameter and the biographical parameters such as age, weight, height.

II. MATERIALS AND METHODS

1. Ultrasound evaluation of airway

After an approval of the IRB of Yonsei University Health System (IRB number: 4-2009-0723) and registering at www.ClinicalTrials.com (NCT: 01227161), we recruited 227 children aged 1-72 months old who underwent urological surgery with general endotracheal anesthesia. Written informed consent was obtained from the parents of the patients. Patients with previous tracheostomy history, known airway obstruction or other airway anatomical abnormalities, and patients expected to be difficult to intubate were excluded.

Anesthesia was induced with sevoflurane inhalation or intravenous administration of propofol 2 – 2.5 mg/kg. Patients were laid in supine position, with the neck extended using 3 cm rolled-surgical cotton pad. After loss of consciousness, atracurium 0.4 mg/kg was given to all children for muscle relaxation. While the anesthesiologist mask-ventilates the patient before the intubation, ultrasonography was performed on the midline of anterior neck by a highly-experienced anesthesiologist. The evaluation began with identification of hyoid cartilage. Then the probe was then moved caudally each by each to localize the true vocal cords (paired symmetrical hyperechoic structures) (Fig. 1, 2) and the cricoids arch round hypoechoic shadow with hyperechoic edges) (Fig. 3). During the image requirements, anesthesiologist stops

mask-ventilation to acquire clear still images on expiratory phase of ventilation but each measuring time was not to be over 5 seconds to avoid possible hypoxic events.

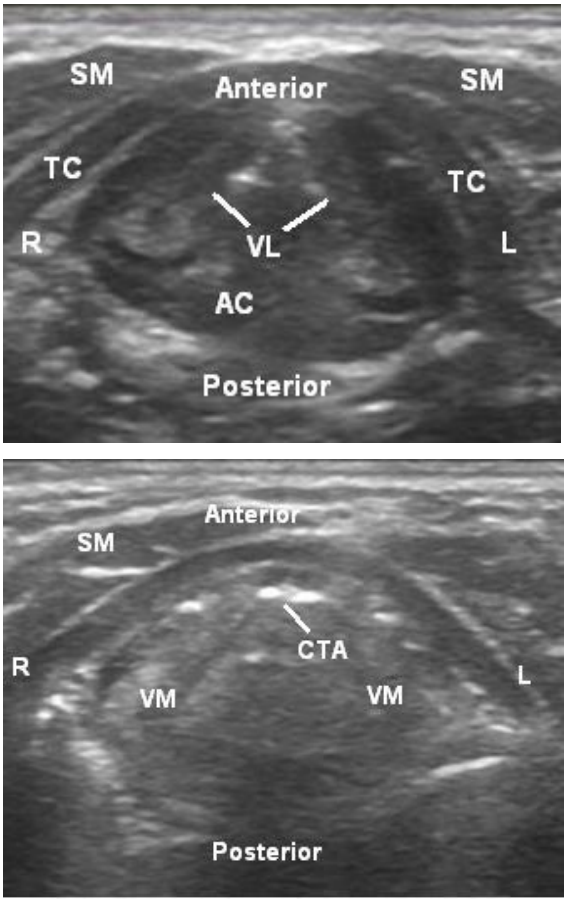

Fig. 1, 2 Images of airway at the vocal cord level, using ultrasonography
SM indicates strap muscle; TC, thyroid cartilage; VL, vocal ligaments; AC, arytenoids cartilage; VM, vocalis muscle; and CTA, comet tail artifacts

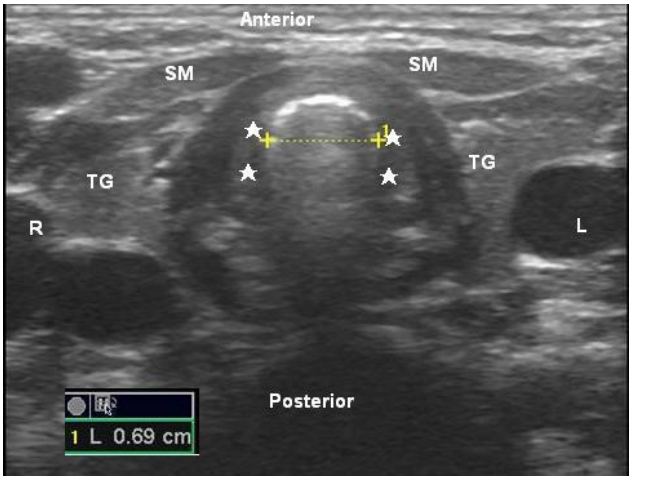

Fig. 3 Transverse diameter of airway at the cricoids cartilage level in this patients measures 0.69 cm by ultrasonographic measurement. SM indicates strap muscle; TG, thyroid gland; asterix, cricoids cartilage.

The measurements were performed in B-mode of ultrasound (LOGIQe™, GE Healthcare, Wauwatosa, WI, USA) with an adjustable-frequency linear probe (8-13 MHz) placed on the midline of the anterior neck.

After the measurement has been done, patients were intubated with cuffed endotracheal tube (ETT) (Hi-Contour™, Mallinckrodt, Nellcor, Pleasanton, CA, USA) which was selected by age-based recommendation (Table 1).[15] None of patients showed resistance during the passage of cuffed ETT. Leak test was not performed. Ultrasound was then performed to measure the OD of placed ETT at the thyroid level (Fig. 4). The image requirements were made three times at each level (vocal cords level, cricoids level, and thyroid level) and saved on ultrasound machine for later analysis.

Age of Patient	Internal Diameter of Endotracheal Tube (mm)	Recommended Size of Laryngoscope Straight Blade	Distance of Insertion (cm)
Preterm (<1250g)	2.5 uncuffed	0	6-7
Full term	3.0 uncuffed	0-1	8-10
1 yr	3.5-4.0 cuffed	1	11
2 yr	4.5-5.0 cuffed	1-1.5	12
6 yr	5.0-5.5 cuffed	1.5-2	15
10 yr	6.0-6.5 cuffed	2-3	17
18 yr	7-8 cuffed	3	19

Table 1 Recommended Sizes and Distance of Insertion of Endotracheal Tubes and Laryngoscope Blades for Use in pediatric Patients[15]

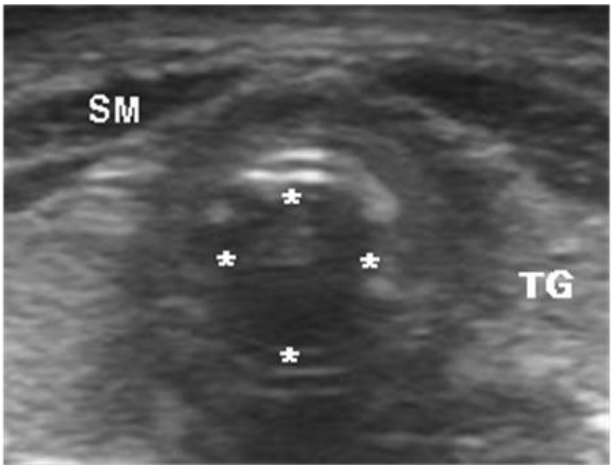

Fig. 4 Transverse diameter of airway at the thyroid level after intubation. TG indicates thyroid gland; astrix, Endotracheal tube

2. Statistical Analysis

Data analysis was performed using PASW Statistics 18 (SPSS® for Windows, Rel. 18.0.0.2009. Chicago: SPSS Inc.) The primary end-point of this study was to obtain the agreement between the ultrasound-measured outer diameter (OD) of ETT placed in trachea and the actual OD of ETT using Bland-Altmann method to verify the degree of accuracy of ultrasonographic measurement.

The secondary end-point of this study was to assess the relationship between the patient's biographical parameters (age, weight, and height) and the subglottic diameter. Pearson coefficient and simple/multiple linear regression analysis were used to derive such statistical relationships.

III. RESULTS

During the ultrasound evaluation, every patients tolerated well, without any apnea or hypoxic events.

Total 227 children aged 1 to 72 months were recruited. Among those patients, 10 were excluded in the screening step due to missing of either biographical or ultrasonographic data, and 2 were dropped out for not being intubated because of changes in surgical plan. Consequently, data of 215 children were analyzed for the study.

In 14 of 215 patients (0.74%), ultrasound (US)-measured subglottic diameters were little larger than the ODs of selected ETT retrospectively, but none of the cases showed resistance during the passage of the ETT through the cricoids level at the time of tracheal intubation. The US-measured OD of ETT (OD-ETT) placed in trachea showed a close agreement with the actual OD-ETT in Bland-Altmann precision analyses (Fig. 5). The 95.3% of differences of US-measured OD-ETT and actual OD-ETT was distributed in a limit of agreement (mean difference ± 1.96 SD) (Fig . 5).

The US-measured subglottic diameter also showed good correlation of Pearson correlation coefficient 0.635 with the OD-ETT selected according to the age-based recommendation for ETT tube size (p-value < 0.0001).

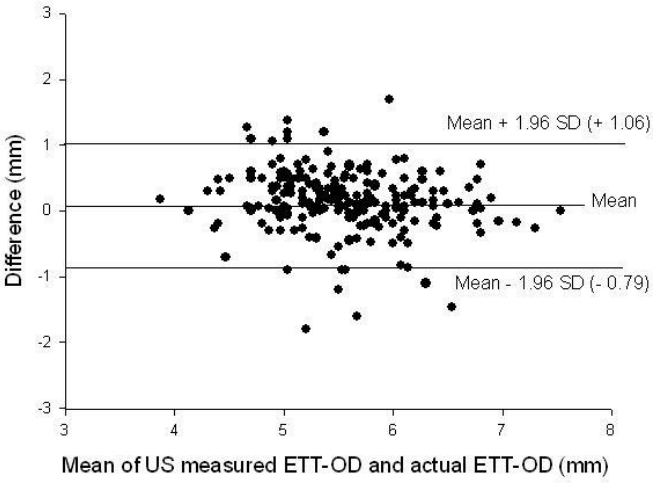

Fig. 5 Bland-Altman precision analysis of the differences between US-measured OD-ETT placed in trachea and actual OD-ETT.

According to the backward stepwise multiple regression analysis, US-measured subglottic diameter and biographic data (age, height, and weight) showed little correlation among patients less than 12 months old, but showed good correlation with age, height among patients older than 12 months. (Table 2)

Variables	≤ 12 months		12 months <	
	β ± SE	p value	β ± SE	p value
Age (ms)	-0.017 ± 0.024	0.485	0.008 ± 0.003	0.010
Weight (kg)	0.054 ± 0.042	0.201	0.019 ± 0.020	0.326
Height (cm)	0.019 ± 0.011	0.093	0.019 ± 0.005	0.000

Table 2 Association of subglottic diameter with biographical parameters by backward stepwise multiple regression analyses

IV. DISCUSSION

Endotracheal tubes employed in this study were all cuffed ETT. Previous studies proclaimed that uncuffed ETT are recommended for children under age 6, and cuffed ETT for older children for the possibility of airway mucosa damage of younger children caused by cuffed ETT.[16] But, nowadays many studies showed that neither cuffed nor uncuffed induce the airway damage.[14,17] This study was designed to use only cuffed ETT for children aged 1 to 72 months in the same context, and also due to the possibility of ETT misplacement during the positional change of caudal or epidural block which are used for postoperative analgesia.

ETT sizes were chosen according to the recommendation for each age. (Table 1) Such sizes of ETT were intubated more smoothly, easy to ventilate, and problems as gas leakage could be prevented.[14]

Ultrasound was used as an imaging instrument of the airway and measuring tool for the subglottic diameter.[6,11,18] A previous study has already proved the expediency of ultrasound in assessing the subglottic diameter, and a strong correlation with MRI measurements of the transverse subglottic diameter, suggesting that ultrasonographic measurement could adequately assess the subglottic diameter.[19] Although ultrasonography is an operator-dependent technique, it is relatively simple to attain. A total of approximately 15 procedures are required for operators to obtain reliable and reproducible measurements.[11] Ultrasonographer for this study was a pediatric anesthesiologist, who had been experienced ultrasound for several years. Vocal cords had been used as anatomical landmark in each measurement for their unique structure which makes them easy to distinguish. Although inadequate calcification of pediatric laryngeal cartilaginous structures may induce the visual limitation with ultrasound, but it does not change the result dramatically and above all, cannot be disregarded for its many virtues such as non-invasiveness, portability, easy accessibility compared with other imaging devices, such as MRI, CT, or x-ray.[20]

The primary end-point of this study is to confirm the accuracy of ultrasound-measured subglottic diameter. For that, we have evaluated the agreement between the ultrasound measured-outer diameter of ETT placed in the trachea and the actual outer

diameter of ETT. As a result, 95.3% of mean difference between the two measurements are placed within the limit of agreement, which shows the reliability of ultrasound measurement of airway distance. In other words, with the availability of ultrasound, measurement of subglottic diameter prior to intubation can help choose the individual-appropriate sized ETT.

Determination of proper sized ETT is very important for pediatric patients in anesthesia because too large tube may result in subglottic edema followed by respiratory difficulty. In comparison to this, too small ETT can cause inappropriate ventilation, underestimation of end-tidal CO2, or leakage of anesthetic gas. Predictive formulas using biographical parameters such as age, weight, or height has been used to select ETT in children.[1-3,5,14] Of these, age-based formulas are commonly used for its convenience.[1-2,14] However, previous studies suggested that those methods to determine the size of ETT according to age, such as Cole, Khine, or Motoyama formula, have their limitation in accuracy.[6] Thus, age-based formulas obtain the internal diameter of ETT, meaning that such methods have tendency to predict larger size than the clinically optimal size.[6] Moreover, these methods required frequent repeated laryngoscopies to indentify the fitted ETT in individual child.

According to this study, subglottic diameter becomes wider as age, weight, and height increases, but US-measured subglottic diameter and such parameters doesn't show the siginificant correlation among the patients less than 12 months old. But, there has been meaningful correlation between US-measured subglottic diameter and age, height among the patients older than 12 months old. When backward stepwise multiple regression analysis was applied to the relationship between subglottic diameter and each parameters in children older than 12 months old, the equation of "cuffed ETT OD = 0.01 x age (ms) + 0.02 x height (cm) + 4.4" were derived (R^2=0.52). This study results showed good correlation between the US-measured subglottic diameter and the recommend sized-ETT according to the age (R^2 = 0.635). As a results, with the availability of ultrasound, US-measured subglottic diameter can help choose the most optimal sized ETT, if not, choosing the age-specific ETT size according to the previous methods could be more convenient.

V. CONCLUSION

Previously used age-based formulas for choosing proper endotracheal tube size in pediatric patients is useful for its simplicity but, has its limitation on accuracy. However, direct measurement of subglottic airway diameter by using ultrasound can be an accurate measure and helps to determine the proper ETT size in pediatric patients. Moreover, such ultrasonographic measurement of the airway could be calculated using age and height in patients over 12 months of age, suggesting that such information can be used as a variable for deciding ETT size, without the hustle to directly measuring the airway diameter.

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< ABSTRACT (IN KOREAN)>

소아에서 성대하 기관내경과 기관삽관튜브의 초음파적 측정

<지도교수 길 혜 금>

연세대학교 대학원 의학과

김 은 정

영유아 및 소아의 기도관리에 있어 적절한 기관 튜브의 선택은 매우 중요한 일이다. 기관 튜브의 경우 그 크기가 기관의 내경에 비해 작다면 적절한 환기가 이루어지지 않으며, 그 크기가 클 경우 기관 내부의 조직에 압력을 가해 손상을 입힐 수 있으므로 적절한 크기의 기관 튜브를 결정하는 것은 임상적으로 큰 의미가 있다. 해부학적으로 성인과는 달리 소아의 기도는 성대하부의 윤상연골부가 가장 좁기 때문에 튜브의 선택은 이 부위의 내경에 의존되어야 한다. 기존의 알려져 있는 소아의 기관 튜브 크기 결정 방법으로는 환아의 역학적 정보 및 신체 부위의 크기를 바탕으로 하는 계산 방법들이 있다. 하지만 이러한 방법들은 정확성이 떨어지며, 개개인의 차이를 간과한다는 한계가 있다. 최근에 나이를 적용한 공식을 통해 결정된 기관 튜브의 외측 너비와 초음파를 통해 측정한 기관내경이 높은 연관성을 가진다는 연구가 발표되었다. 따라서 본 연구는 초음파를 이용함으로서 성대하부 윤상연골부를 관찰하고 이를 통해 측정된 성대하부 윤상연골부의 너비가 기관 삽관 이전에 기관 튜브 크기를 결정하는 데 정확한 정보를 제공할 수 있는 지 알아보고자 한다.

전신마취를 유도 한 후 마스크 환기를 시행하며, 성대, 성대하방의 윤상연골부에서의 가로단면 초음파 영상을 호기 기간 동안 각기 3 회씩 얻는다. 연령에 따른 공식에 의해 선택한 크기의 기관 튜브를 이용한 기관내 삽관 후 얻은 갑상연골 위치에서 기관내 튜브가 보이는 가로단면 영상을 저장한다. 초음파 측정을 통해 얻은 값의 효용성을 파악하기 위해 실제로 사용된 기관 튜브의 바깥 너비와 초음파를 통해 측정된 기관내 기관 튜브의 바깥 너비를 확인한다. 이렇게 얻어진 성대하방 너비와 환아의 역학적 정보 및 신체 부위의 크기와의 연관성에 대해 조사해보았다.

기관 삽관 후 초음파를 이용하여 측정된 기관 튜브의 외측 너비와 실제 사용된 기관 튜브의 외측 너비는 유의한 상관관계를 보이며, 따라서 적절한 기관 튜브 크기 선택을 하는 데 있어서 기관 삽관 전, 초음파를 이용한 성대하방의 윤상연골부 관찰이 중요함을 확인해볼 수 있다.

초음파를 이용한 성대하방의 윤상연골부의 너비 측정은 소아 환자에서 적절한 기관 튜브 크기를 결정하는 데 매우 정확하며 편리한 방법이라 할 수 있다. 본 연구를 통해 성대 하방 너비와 환자 개개인의 역학적 정보 및 신체 부위의 크기와의 통계학적 상관관계를 확인해볼 수 있었으며, 실제로 매번 초음파를 이용한 성대 하방의 너비 측정이 없이도 적절하고 정확한 기관 튜브 크기를 정할 수 있게 도와준다.

핵심되는 말 : 초음파, 기관 튜브, 성대 하방 너비, 소아