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Accuracy of Age-Based Formula to Predict the Size and Depth of Cuffed Oral Preformed Endotracheal Tubes in Children Undergoing Tonsillectomy

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Abstract

Objectives: To retrospectively investigate the reliability of the age-based formula, *year/4 + 3.5 mm* in predicting size and *year/2 + 12 cm* in predicting insertion depth of preformed endotracheal tubes in children and correlate these data with the body mass index. **Patients and Methods:** Patients were classified into 4 groups according to their nutritional status: thinness, normal weight, overweight, and obesity; we then retrospectively compared the actual size of endotracheal tube and insertion depth to the predicting age-based formula and to the respective bend-to-tip distance of the used preformed tubes. **Results:** Altogether, 300 patients were included. The actual endotracheal tube size corresponded with the Motoyama formula (64.7%, 90% CI: 60.0-69.1), except for thin patients, where the calculated size was too large (0.5 mm). The insertion depth could be predicted within the range of the bend-to-tip distance and age-based formula in 85.0% (90% CI: 81.3-88.0) of patients. **Conclusion:** Prediction of the size of cuffed preformed endotracheal tubes using the formula of Motoyama was accurate in most patients, except in thin patients (body mass index < −2 SD). The insertion depth of the tubes was mostly in the range of the age-based-formula to the bend-to-tip distance.

Keywords

pediatrics, preformed cuffed tube, RAE tube, Motoyama formula, tube size, tube insertion depth, age-based, bend-to-tip distance

Introduction

The selection of an appropriately sized endotracheal tube (ETT) is of critical importance, especially in pediatric patients. There are several methods to predict the adequate size of the ETT. One of the most commonly used is the Motoyama formula (MY), which calculates the ETT's internal diameter in millimeters by using the age in years/4 + 3.5 mm.[1] Likewise, the insertion depth of ETT is usually predicted by the age-based formula for depth (AFD), age in years/2 + 12 cm.[2] Other than age, the nutritional status of each child may also play a role in determining the ETT size.

For tonsillectomy, cuffed oral preformed ETT, known as the Ring-Adair-Elwyn (RAE) tube, is widely used. Its bend should avoid the risk of kinking and ease of fixation. However, the fixed bend-to-tip distance (BT), which is specific for each ETT size, has the risk of malposition,[3-5] especially during the application of the Rose position or retractors. Bend-to-tip distance is crucial in choosing ETT size in each patient.

Patients and Methods

After Siriraj Institutional Review Boards' approval (COA no. 062/2020), data were retrospectively collected from the electronic medical records of patients aged 2 to 8 years who underwent tonsillectomy (with or without adenoidectomy) at Siriraj Hospital from 2017 to 2019.

The regular influx of pediatric tonsillectomy in our hospital includes patients undergoing surgery under general anesthesia,

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Figure 1. Preformed Ring-Adair-Elwyn (RAE) tube with fix bent to size relation.

Table 1. Predicted Size and Insertion Depth of ETT as Calculated From Specific Age on Mallinckrodt Cuff Oral Preformed ETT.

Age	Predicted size MY (mm)	Predicted depth	
		AFD (cm)	BT (cm) related to MY
2	4.0	13.0	13.0
3	4.5	13.5	14.5
4	4.5	14.0	14.5
5	5.0	14.5	15.5
6	5.0	15.0	15.5
7	5.5	15.5	16.5
8	5.5	16.0	16.5

Abbreviations: AFD, age-based formula for depth; BT, bend-to-tip distance; ETT, endotracheal tube; MY, Motoyama formula.

with either intravenous or inhalation induction, with an oral tracheal approach for ventilation using a cuffed Mallinckrodt RAE tube (Covidien LC). The RAE tube was preformed (Figure 1) with the BT related to the respective size. Endotracheal tube was placed with the cuff beneath the vocal cord. Cuff inflation pressure was not routinely measured but was observed by tracheal seal (no audible leak) at a peak airway pressure of 20 cm H_2O. Air leak at a ventilating pressure of less than 20 cm H_2O aroused the need to increase cuff inflation or change ETT to a larger size. Equal bilateral breath sounds were auscultated promptly after intubation and the patient placed in the Rose position. The insertion depth was adjusted to ensure a good ETT position and was recorded at the upper incisors and the bend was fixed at the lower lips. Sevoflurane and muscle relaxants were used to maintain anesthesia. Intravenous dexamethasone was administered at the anesthesiologist's discretion. At the end of the surgery, reversal of muscle relaxants was performed. Patients were routinely observed in the post-anesthetic care unit before discharge to the ward where they were staying overnight. They were then examined by anesthesiologist the next day to monitor possible complications.

The exclusion criteria were previous or current tracheostomy, tracheal stenosis, anticipated difficult intubation, or Down syndrome. Extracted data included age, sex, indication for surgery, actual ETT size and insertion depth, volume of air blown into the cuff, and complications (ie, reintubation and number of attempts, abnormal lung sounds, and use of inhaled racemic epinephrine or bronchodilators).

According to the World Health Organization (WHO) growth reference criteria for body mass index (BMI) at a specific age,[6,7] thinness was defined as BMI < -2 SD of the WHO Growth Reference median, normal BMI as BMI between -2 SD and $+1$ SD, overweight as BMI between $+1$ SD and $+2$ SD, and obese as BMI $> +2$ SD.

The MY was used to calculate the tube size in millimeters and rounded up to the nearest 0.5 mm. Predicting insertion depth was calculated using the AFD and BT according to the size calculated by MY. These predicting parameters were compared to the patient's actual ETT as shown in Table 1.

Sample Size Calculation

Previous studies have shown an accurate tube size calculation using MY of 72.5% in noncardiac pediatric patients[8] and the accuracy of AFD of 67.9%.[9] With an acceptable error of 4.5% (2-sided, 90% CI), the calculated sample size was 294 patients.

Statistical Analysis

Frequencies were reported as percentage, range, mean $\pm$ SD, or median (min, max). The accuracy of ETT size and insertion depth were documented in percentage with 90% CI.[10]

Comparisons between groups were performed using the Pearson χ^2 test, χ^2 test for trend, Bonferroni method, and independent *t* test (multiple comparison). All statistical data analyses were performed using PASW Statistics version 18 (SPSS, Inc).

Results

Three hundred seventy-six patients aged 2 to 8 years who underwent tonsillectomy between January 2017 and September 2019 were initially included. A total of 76 patients were excluded (46 did not meet the inclusion criteria, while 30 did not have complete data), leaving 300 pediatric patients in the study. Demographic data and patient characteristics are shown in Table 2.

We found that the actual ETT size corresponded with MY-based prediction in 64.7% (90% CI: 60.0-69.1). A comparison among the nutritional groups is shown in Figure 2. The actual size of ETT corresponded with MY in 65.8% (90% CI: 59.2-71.8) in normal BMI patients and 67.2% (90% CI: 60.2-73.4) in overweight and obese patients. The cuff had to be inflated in 107 patients (35.7%), with the range of air blown from 0.2 to 5 mL.

The prediction accuracy of the MY formula did not differ statistically between the BMI-related groups. However, in cases where the actual tube size was not correctly predicted by MY, smaller ETTs were preferred in normal-weight patients

Table 2. Demographic Data and Characteristics of the Study Population (n = 300).

Parameters	n = 300
Sex; male	202 (67.3)
Age (years)	5.2 ± 1.5
ASA physical status	
I	140 (46.7)
II	150 (50.0)
III	10 (3.3)
BMI (kg/m^2)	17.5 ± 4.2
BMI-for-age[a]	
Thinness	14 (4.7)
Normal	152 (50.7)
Overweight	46 (15.3)
Obese	88 (29.3)
Indication for tonsillectomy	
RI	12 (4.0)
OSDB	205 (68.3)
RI and OSDB	83 (27.7)

Abbreviations: ASA, American Society of Anesthesiologists; BMI, body mass index; OSDB, obstructive sleep-disordered breathing; RI, recurrent infection.
[a]According to World Health Organization (WHO) growth reference median.

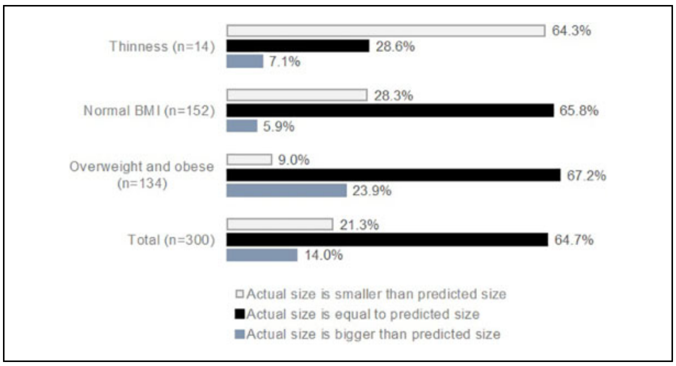

Figure 2. Actual and predicted endotracheal tube size in different body mass index-for-age groups. Tube size prediction according to Motoyama formula; year/4 + 3.5 mm.

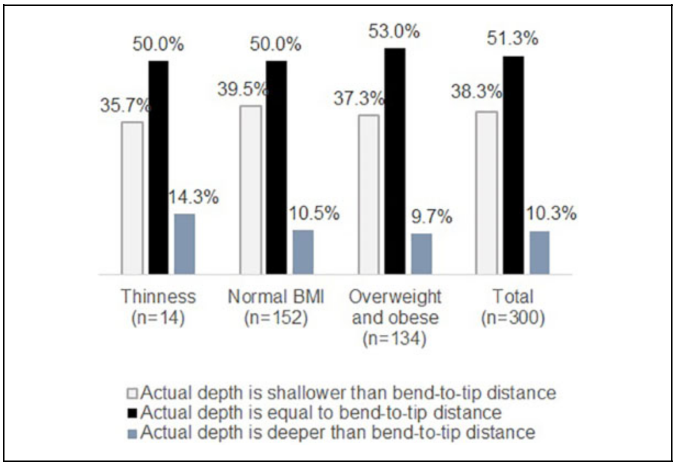

Figure 3. Actual endotracheal tube insertion depth and bend-to-tip distance in different body mass index-for-age groups.

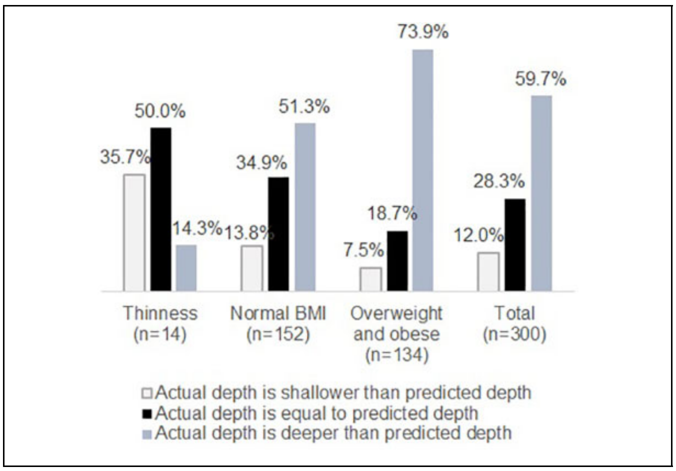

Figure 4. Actual and predicted endotracheal tube insertion depth in different body mass index-for-age groups. Prediction according to age-based formula; year/2 + 12 cm.

and larger ETTs in overweight/obese as compared to Motoyama prediction (P < .001). Also, Also, in the MY correctly predicted group (n = 194), 68.0% were male with the height of 112.3 ± 10.8 cm, compared to the incorrectly predicted group (n = 106), of which 67.9 % were male with the height of 113.0 ± 10.4 cm. So, neither sex (P = .98) nor height (P = .62) influenced the accuracy of the MY formula.

Eight patients (2.67%) had to be reintubated. All were finally intubated with the size predicted by MY. Dexamethasone was routinely administered intraoperatively in 148 patients (49.3%). No dexamethasone was administered as a rescue drug after surgery, although there was a postoperative stridor in 1 patient; an overweight girl had been intubated with an ETT 1.0 mm larger than MY.

The insertion depth was mostly found to be in the range of BT and AFD in 85.0% of the patients. In all groups, the majority of tubes (51.3%) were placed according to BT, which is usually deeper than AFD as shown in Figures 3 and 4 (except for ET size 4.0 mm). In a few cases, insertion depth did not correspond with BT and AFD, being either shorter or deeper than predicted (6.7% and 8.3%, respectively).

Regarding depth prediction, there was no inadvertent extubation or endobronchial intubation. The tube moved out after Rose positioning in one case because of miscalculation.

Discussion

Our study found that MY could predict the accurate size of cuffed oral ETT in 64.7% of the patients. The size of oral preformed tubes is associated with a certain BT, which must be considered when choosing the tube. This is comparable to the study of Hunyady and Jonmarker, demonstrating that in noncardiac pediatric patients in accordance with 72.5% between MY predicted and actual tube size, the predicted size was bigger in 18% and smaller in 8.7%.[4] In contrast to our patients, cardiac pediatric patients generally required larger tubes, although they had less body weight. Another study in normal-weight children aged 1 to 10 years showed a lower correspondence rate of MY with the actual ETT size (47.4%)[11] than in our study. The inconsistent results might be due to the different ages of the study participants and the unmentioned rounding method of ETT size after calculation.

In contrast, a recent study proposed a technique using the middle finger length to predict ETT size. They found only 32.2% correct placement using MY.[12] This might be affected by the use of both cuffed and noncuffed tubes in their study and the different ages.

Ultrasound is suggested to be better than the formula for ETT size prediction,[13] tailoring ETT individually to each patient, and reflects the ETT outer diameter, which is more relevant than the internal diameter, since there are manufacturing differences between the wall thickness and ETT material.[14] The size was usually found to be smaller when predicting with ultrasound compared to MY.[11,13] Chest radiography was also thought to have a good correlation in tracheal diameter compared to computed tomography but did not reflect the subglottic diameter, the narrowest part of the pediatric larynx.[13]

The length-based approach has been an alternative for the selection of ETT size, either with the respective formula or a Broselow tape. It showed adequate accuracy and should be considered[15,16] especially in an emergency situation when age or weight are not assessable.

There are various methods for classifying the nutritional status of children. Despite the debate as to which single growth reference is the most appropriate, our study was based on WHO growth reference using BMI, which has been recommended in the assessment of growth in children and adolescents above 5 years of age.[17] However, in children aged 0 to 5 years, the accuracy of its use remains uncertain.[6]

Anthropomorphic measurements have shown that obese adult patients may have smaller airways due to airway compression from adiposity and cephalic compression of the diaphragm.[18] Fenley et al suggested this correlation for obese pediatric patients too.[19] Our data do not support their conclusions, as we did not find obese children having a smaller tube size as predicted. About 25% of obese patients require a larger ETT than MY. This may be due to the inclusion of 1- to 20-year-old patients in their sample, as compared to 2 to 8 years in our study. In addition, they measured the cross-sectional area of the trachea rather than the subglottic diameter, which is the narrowest part in children.

Pek et al suggested that for proper insertion depths, the tip should be placed at the vertebral level of T2-T4 vertebral bodies, and AFD was correctly predicted in 67.9% in their study.[9] However, we observed that AFD was not appropriate when patients were in the Rose position, with the possibility of moving the tube outward up to 0.5 to 1.2 cm.[20]

The BT of a preformed tube is a function of its size, making adequate selection a crucial matter. However, prediction of the preformed tube size following MY does not always correspond to BT with the expected depth from AFD; a difference of up to 1 cm is noticed, especially at patient ages 3, 5, and 7, as shown in Table 1. As a consequence, even the best formula does not replace a thorough clinical inspection after intubation.

We did not apply ultrasound, which was reported to visualize ETT tip in more than 80%.[21] However, its superiority over conventional intubation techniques among children has not yet been proven comprehensively.

This study design varied from other similar trials: (1) We did not apply ultrasound, as suggested by Shibasaki et al,[13] because the required experience and expertise could not be consistently provided. (2) Patients' necks were extended in the Rose position. (3) Our patients stayed overnight so we could monitor possible short-term complications. (4) The number of patients with thinness was too small for statistical significance. (5) Finally, this was a retrospective study, with its specific limitations, such as missing data due to either sloppy documentation or lack of standards. As a consequence, we had to assume that reintubation attempts, postoperative coughing, or sore throat were not always recorded or may have been masked by the effect of dexamethasone. There was generally no measurement of airway or ETT cuff pressure. Future prospective randomized controlled trials may obtain more comprehensive results.

Conclusions

In most patients, aged 2 to 8 years, undergoing tonsillectomy, the size of the cuffed preformed ETT could be predicted by the MY. An exception was a small group of thin children, needing a slightly smaller tube (0.5 mm). More than 80% of the tube insertion depth could be correctly predicted in the range of BT and age-based formula.

Authors' Note

Clinical trial registry: Accuracy of cuffed oral preformed tracheal tube size using Motoyama's formula and depth using age based formula in children undergoing tonsillectomy and/or adenoidectomy: A retrospective study. Study ID: TCTR20200409008. http://www.clinicaltrials.in.th/index.php?tp=regtrials&menu=trialsearch&smenu=fulltext&task=search&task2=view1&id=6021.

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