Comparison of Age-Based and Height-Based Formula for Tracheal Tube Size in Cardiac Children

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Objective: *To compare the effectiveness of age-based formula (ABF) and height-based formula (HBF) for pediatric cardiac patients, including patients with failure to thrive (FTT).*

Material and Method: *In a retrospective study of 260 cardiac patients that included those with failure to thrive, aged 2 to 7 years was done. The actual uncuffed endotracheal tube (ETT) size was compared with the predicted one, using both the ABF [ID (mm) = age (years)/4 + 4] and the HBF [ID (mm) = height (cm)/30 + 2].*

Results: *ABF and HBF correctly predicted 50.8% and 50.4% of ETT sizes (p = 1.0), whereas three sizes of tubes (one above and one below the predicted size) cover 95.8% and 93.5% of the patients, respectively (p = 0.24). In patients with FTT, both the ABF and HBF correctly predicted 56.6% of ETT sizes.*

Conclusion: *Age- and height-based formula for estimating tube size in cardio-surgical children is equivalent and independent of physical development. Age-based formula as the simple method can be recommended. The availability of three tube sizes (one smaller, one larger than estimated) should be ensured.*

Keywords: *Age-based formula, Anesthesia, Height-based formula, Pediatric cardiac, Tracheal tube size estimation*

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Selection of the appropriate size of an endotracheal tube (ETT) is important in general anesthesia and critical care practice for children. A too large tube may induce airway trauma, increase the incidence of post-intubation croups, and prolong intubation time by increased intubation attempts. A too-small tube may result in large air leaks, increased risk of aspiration and high airway resistance. Reintubation and tube changes can be associated with moderate to severe airway injury secondary to endotracheal intubation in this population[1].

Growth and development in pediatric patients with congenital heart diseases are impaired[2]. The appropriate size of ETT in these patients who have an already-tenuous cardiovascular system is extremely important because the airway problems may further lead to significant morbidity and mortality.

Over decades, age-based formulae (ABF)[3] have been widely used to predict the proper size of ETT for normal children. More recently, physical characteristics, such as height have been reported to be useful in predicting ETT size more accurately than ABF[4]. The objective of the present study was to compare the accuracy of predicting uncuffed ETT size using ABF and height-based formula (HBF) for pediatric cardiac patients.

Material and Method

After obtaining the Institutional Ethical Review Board approval, the authors performed a retrospective study of the anesthetic records of cardiac patients aged 2 to 7 years old who were orally intubated with a regular uncuffed ETT (Portex, Smith Medical International Limited, Hythe, England) at Siriraj Hospital, Thailand. The present study began on January 1, 2007 until the predetermined sample size was achieved.

The exclusion criteria were history of tracheostomy, upper airway obstruction, and expected difficult intubation, such as Pierre Robin syndrome. Data collected included; age at surgery (years), height (cm), weight (kg) and the final internal diameter (ID) of the ETT (mm) used. For comparative analysis, the actual ID of the ETT was compared with the ID

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predicted using the ABF and HBF detailed as follows: ABF [ID (mm) = age (years)/4 + 4], HBF [ID (mm) = height (cm)/30 + 2]. For the age of the child, a truncated age (age in years, uncounted months) was used. The authors chose a tube-size 0.25 mm larger than the predicted sizes for the patients with age 3, 5, and 7 years. The tube size estimated by HBF was rounded to the nearest half size; ID 4.25-4.74 mm was considered to ID 4.5 mm. The authors also compared these two formulae in children who were sub-classified as failure to thrive (FTT), defined as less than the third percentile for both weight and height for age on the Thai National growth chart[5].

The sample size was calculated based on the comparison of accuracy between ABF and HBF. Our previous study had revealed 48% accuracy of ABF[6]. The authors hypothesized that HBF will be 10% more accurate than ABF. A sample of 260 patients would be adequate to test the difference in accuracy of ABF and HBF (48% vs. 58%), 26% discordant pairs, using 2-sided type I error of 0.05, 90% power and McNemar's test.

Data analysis was done by using SPSS version 17. McNemar's test was used to compare accuracy of ABF and HBF. Pearson's correlation coefficient was applied to test the correlation between actual tube size and age and height. A p-value < 0.05 was considered statistically significant.

Results

The data from 260 cardiac patients were analyzed with a mean age 3.3 of years (SD = 1.4 years) and a height range of 70 to 139 cm (96.3 $\pm$ 11.3 cm). There were 123 boys (47.3%) and 137 girls (52.7%). One hundred twenty one children (46.5%) had cyanotic and 139 children (53.5%) had acyanotic congenital heart disease. Fifty-three children (20.4%) were sub-classified as FTT.

Number of cardiac patients is shown in relations between calculated tube-size by ABF, HBF, and actual tube-size in Fig.1 (a) and (b), respectively. One size predicted by the ABF and HBF was used in 50.8% and 50.4% of the patients. There was no significant difference between both groups (p = 1.0). Whereas three sizes of tubes (one above and one below the predicted size) predicted by the ABF and HBF covered 95.8% and 93.5% of the patients, respectively (p = 0.24) (Fig. 2).

The ETT size calculated by ABF and HBF was smaller than the size actually used in 35.8% and 12.3%, and was larger in 13.5% and 37.3%, respectively (Fig. 3). The Pearson's correlation between the size

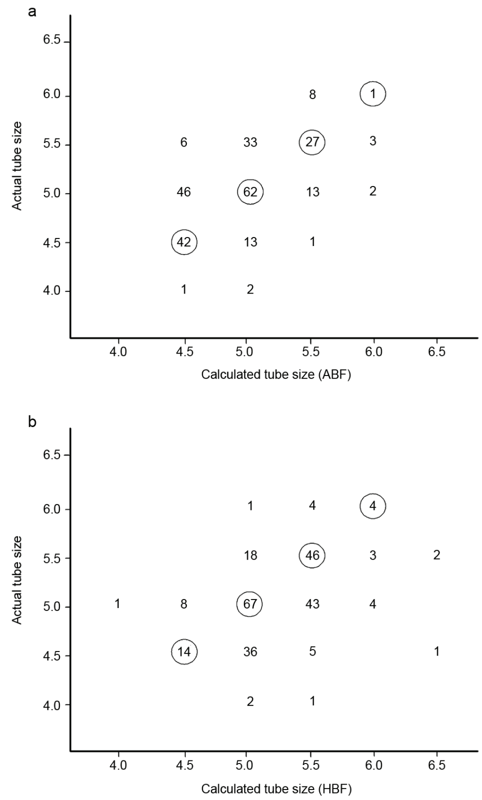

Fig. 1 Relations between calculated tube size by
a: age-based formula (ABF)
b: height-based formula (HBF) and the actual tube size. Numbers of patients circled represent those with guideline-appropriate endotracheal tube

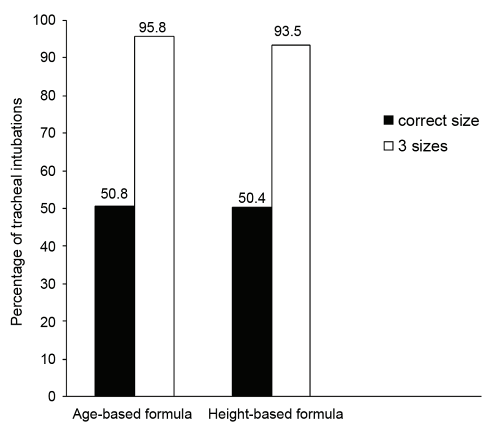

Fig. 2 Percentages of correct tube-size and three sizes of endotracheal tube (correct size, one 0.5 mm smaller, one 0.5 mm larger than the predicted size) predictions by the age-based and height-based formula

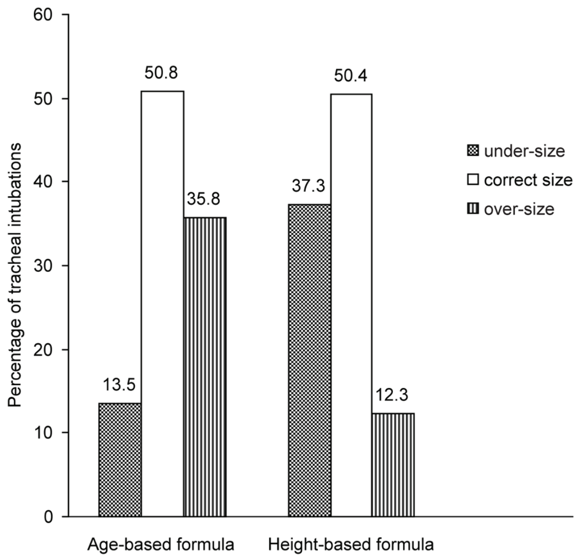

Fig. 3 Comparison of percentages of correct tube-size, under-size (endotracheal tube $\leq$ 0.5 mm smaller than guideline), over-size (endotracheal tube $\geq$ 0.5 mm larger than guideline) predictions between the age-based and height-based formula ($p < 0.001$)

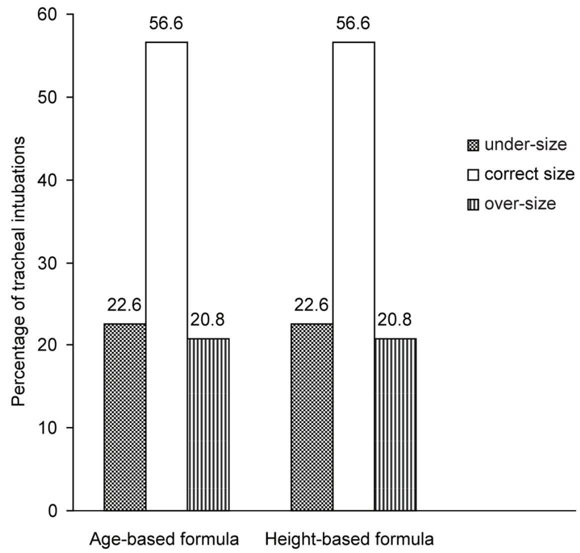

Fig. 4 Percentages of correct tube-size, under-size (endotracheal tube $\leq$ 0.5 mm smaller than guideline), over-size (endotracheal tube $\geq$ 0.5 mm larger than guideline) predictions of the age-based and height-based formula in cardiac patients with failure to thrive

of ETT with age and height were 0.58 and 0.54, respectively. In fifty-three cardiac patients with FTT, there were 54.7% boys and 45.3% girls with a mean age $\pm$ SD of 3.4 $\pm$ 1.5 years and a mean height $\pm$ SD of 88.7 $\pm$ 10.3 cm. 54.7% of them had cyanotic and 45.3% had acyanotic heart diseases. Both the ABF and HBF correctly predicted 56.6% of ETT sizes, whereas three sizes of tubes covered 100% and 96% of the patients, respectively. In 22.6%, the ETT size calculated by both formulae was smaller than the size actually used, and larger in 20.8% (Fig. 4). The Pearson's correlation between the size of ETT with age and height were 0.74.

Discussion

The present study shows that age- and height-related formula both correctly estimated half of the ETT size used in cardiac patients. The ABF tended to underestimate the tube-size, whereas the HBF tended to overestimate it. In patients with failure to thrive (FTT), proportions of the under- and over-estimation were similar. The authors' age-based estimation of ETT size (50.8%) is comparable to those in Japanese children (53.5%) under eight years old[7], Canadian children (51.3%) aged 1 to 18 years[8], and Thai children (54.4%) aged 2 to 7 years[6]. Three tubes (including one above and one below the predicted size) covered 95.8% of cardiac patients, which is similar to the Japanese study (97.2%), and the authors' previous study (96.9%).

Though a reasonable number of studies about this issue exist, data and conclusions are still conflicting. Different formulae have been proposed to choose the appropriate size of the ETT for pediatric patients. Pediatric anesthesiologists preferred modified Cole's (age-based) formula for tube estimation, though this formula is not appropriate in all ethnic groups[9]. The recently published review of von Rettberg et al[10] found out that currently 22 different formulae are used, 19 of them for uncuffed and three for cuffed tubes. The majority of these formulae were age related, secondly came length/height related formulae.

Obviously, the age- or length-related formulae are preferred in clinical routine, whereas weight-related formulae do not play any role[8,10]. Several studies could demonstrate that height/length of the children estimated ETT size better than the ABF[4,9,11,12]. Shih et al[12] commented on their results with an impressive high accuracy (82.4%) using HBF in healthy Chinese children aged 1.5 months to 6 years. Contrasted to their findings, the authors' results revealed that only 50.4% of cardiac patients were accurately predicted by this formula. Of their patients with need for reintubation, 83.1% needed a larger ETT size than predicted. As the authors adjusted the ETT size upward, Shih et al adjusted it downward.

In complete opposition to Shih and his group are the data of Bunchungmongkol et al[13] comparing the ABF and length-based (using the Broselow tape) formula (LBF) in 2 to 8 years old Thai children with FTT who underwent cardiac surgery. They found that the age-predicted ETT size matched the actual size exactly in 61.7%, whereas LBF could do so in only 11.7%. The accuracy of the Broselow tape is estimated 55% to 86.9%[14]. It was developed on the basis of data from a U.S. population, which may partly explain the significant differences described.

Trying a more accurate approach, considering the individual patient, Shibasaki et al[15] measured subglottic airway diameter using ultrasonography producing better results than standard age- and height-based formulae. Though this method seems to be a good predictor of correct ETT sizes, it is a quite sophisticated and operator-dependent technique that cannot be routinely performed everywhere. On the other hand, et al[16] analyzing digital x-ray images found out that the age-related formula predicted the correct tube size better (62.2%) than the radiologic method (42.8% at sixth cervical vertebra, 43.7% at second thoracic vertebra), thus providing a strong argument for the age related formula.

Children with heart abnormalities often are underdeveloped in weight and height. Samadi et al reported that reduced weight and height was detected in 66.7% and 65.8% of children with congenital heart disease and bone age delay was seen in fifty five percent of them[17]. Weight retardation was more frequent and more marked than retardation in height[18]. Up to now, only some few studies have investigated ETT size in these patients[6,13,19]. Daugherty et al compared length-based using the Broselow tape and age-based formula in normal and pathologically short children and found that they were equivalent in predicting tube size[19]. In agreement with their findings, the authors' results show that ABF is as accurate as HBF in pediatric cardiac patients and in a subset of patients with FTT. The present study describes FTT as weight and height both being below the third percentile for the age in question. The present study is the first testing the HBF in this population. As ABF predicted the correct tube size quite well even in this group of children, the authors wonder if the development of the trachea is independent from retardation or under-development.

This question is substantiated by the already mentioned data of Furuya[16], but also by other studies. In 1993, King et al[20] compared four methods for endotracheal tube selection in a prospective blinded design. Two hundred and thirty-seven children aged 1 month to 9 years old were investigated. The age formula: (age in years + 16)/4 had an accuracy of 97.5%, whereas the width of the fifth fingernail predicted the tube size with 91% accuracy. The width and the diameter of the fifth finger underestimated the tube size needed. A length related formula was not included. A study from 2009 has reconsidered the data of King et al widely confirming their findings. Turkistani et al[21] investigated four different methods including length based formula in healthy children 2 to 10 years of age. The best predictors of the correct tube size were the age related formula, which was identical to the formula used by King et al, and the width of the fifth fingernail. As these two studies illustrate, the debate on the ideal formula to predict the optimal tube size for uncuffed intubation in infants and children is still open.

Conclusion

The present study showed that ABF was as accurate as HBF in pediatric patients with cardiac surgery including a subset of children with failure to thrive (FTT). According to the authors' results the authors recommend three tube sizes (the predicted size, one 0.5 mm smaller and one 0.5 mm larger) should be available before tracheal intubation. As the authors' results have been obtained retrospectively without control of the anesthetic procedure and with no follow-up regarding postoperative airway complications, prospective studies still need to be done. This is also suggested by conflicting data in the literature. Pediatric cardiac patients with FTT will be of special interest in this matter.

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Potential conflicts of interest

None.

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การเปรียบเทียบสูตรการใช้อายุและความสูงในการคำนวณขนาดท่อหายใจในเด็กโรคหัวใจ

เสาวภาคย์ จำปาทอง, สายพิณ เมืองแมน, Benno von Bormann, กำแหง วัชรักษะ

วัตถุประสงค์: *เพื่อศึกษาเปรียบเทียบสูตรการใช้อายุ และความสูงในการคำนวณขนาดท่อหายใจในเด็กโรคหัวใจ*
วัสดุและวิธีการ: *การศึกษาย้อนหลังในผู้ป่วยโรคหัวใจ 260 ราย อายุระหว่าง 2-7 ปี โดยเปรียบเทียบขนาดท่อหายใจชนิด uncuffed ที่ใช้จริงกับขนาดที่คำนวณได้โดยสูตรการใช้อายุ [เส้นผ่าศูนย์กลางท่อ (มม.) = อายุ (ปี) / 4 + 4] และสูตรการใช้ความสูง [เส้นผ่าศูนย์กลางท่อ (มม.) = ความสูง (ซม.) / 30 + 2]*
ผลการศึกษา: *สูตรการใช้อายุและความสูงคำนวณขนาดท่อหายใจได้ถูกต้อง 50.8% และ 50.4% (p = 1.0) ขณะที่ขนาดท่อหายใจ 3 ขนาด (หนึ่งขนาดใหญ่กว่า และหนึ่งขนาดเล็กกว่าที่คำนวณได้) ครอบคลุม 95.8% และ 93.5% ของผู้ป่วยตามลำดับ (p = 0.24) ในผู้ป่วย failure to thrive ทั้งสูตรการใช้อายุและความสูงคำนวณขนาดท่อหายใจได้ถูกต้อง 56.6%*
สรุป: *สูตรการใช้อายุและความสูงสามารถใช้คำนวณขนาดท่อหายใจในเด็กโรคหัวใจได้ไม่ต่างกัน แนะนำสูตรการใช้อายุเพราะเป็นวิธีที่ทำได้ง่ายกว่าและในการใส่ท่อหายใจควรเตรียมขนาดท่อให้พร้อมไว้ทั้ง 3 ขนาด (ขนาดที่คำนวณได้และขนาดที่เล็กกว่า และใหญ่กว่าหนึ่งขนาด)*