PHILIPPINE JOURNAL OF OTOLARYNGOLOGY-HEAD AND NECK SURGERY VOL. 41 NO. 2 JULY – DECEMBER 2026

Concordance of Age-Based, Height-Based and Weight-Based Tracheal Tube Estimates with Actual Tracheal Tube Size in Children Undergoing Tracheostomy

Liza Rowena D. Perdon-Chan, MD
Francis V. Roasa, MD

Department of Otorhinolaryngology
Head and Neck Surgery
Ospital ng Makati

ABSTRACT

Objective: To determine which among an age-based, height-based and weight-based formula most accurately predicts the actual tracheostomy tube sizes used in Filipino children aged 0–18 years including those with malnutrition (Z scores < –2).

Methods:

Design:	Retrospective Review of Records
Setting:	Tertiary Government Training Hospital
Participants:	Medical Records of 31 patients

Results: Records of 31 patients (15 males [48.39%], 16 females [51.61%]; 15 [48.39%] undernourished) were included. The sample had a median age of 1.5 years (IQR, 10.75), a median weight of 9 kg (IQR, 16), and a median length of 77 cm (IQR, 70.5). Age group and nutritional status significantly influenced estimation accuracy. Both height- based and weight- based formulae significantly overestimated tube size, whereas the age- based formula demonstrated better accuracy, correctly predicting 45.16% of cases, with relatively consistent performance across subgroups but reduced reliability in children aged ≥12 years. When one size above and below the predicted age- based formula value were available, coverage improved to 70.97%.

Conclusion: The Khine age-based formula showed the closest agreement with actual tube sizes and may guide the development of population-specific prediction models for Filipino children. Preparing three tube sizes (estimated, one size larger, and one smaller) may improve procedural safety. Prospective, multicenter studies are recommended to validate these findings and account for variations in growth and nutrition.

Keywords: *tracheostomy; airway management; child; infant; anthropometry; malnutrition; tracheal tube size; Filipino children*

Correspondence: Dr. Francis V. Roasa
Department of Otorhinolaryngology
Head and Neck Surgery
Ospital ng Makati
Sampaguita Street, PEMBO, Taguig City 1218
Philippines
Phone: +63 917 621 7979
Email: fvroasa@yahoo.com

The authors declared that this represents original material that is not being considered for publication or has not been published or accepted for publication elsewhere in full or in part, in print or electronic media; that the requirements for authorship have been met by all the authors, and that each author believe that the manuscript represents honest work.

Disclosures: The authors signed a disclosure that there are no financial or other (including personal) relationships, intellectual passion, political or religious beliefs, and institutional affiliations that might lead to a conflict of interest.

Use of Artificial Intelligence: The authors used ChatGPT (OpenAI; GPT-5.4 during initial manuscript preparation and GPT-5.5 during revision) solely to edit author-written text for grammar, clarity, readability, and conciseness. During revision, Gemini Notebook (Google; formerly NotebookLM) was used to organize and track references and for similar language editing. No AI-assisted technologies were used to generate scientific content, analyze or interpret data, perform statistical analyses, generate tables or figures, or write computer code. All scientific content and the final manuscript were reviewed and approved by the authors, who accept full responsibility for the work.

Presented orally as a free paper at the 10th Asia-Pacific Pediatric Otolaryngology Society Conference (APPOS 2025), Seoul, South Korea, November 8-9, 2025, and received a Travel Grant award.

Data Sharing and Availability Statement: Datasets for the study are publicly available in *https://doi.org/10.7910/DVN/UYEF5Y*

Creative Commons (CC BY-NC-ND 4.0)
Attribution - NonCommercial - NoDerivatives 4.0 International

Philipp J Otolaryngol Head Neck Surg 2026; 41 (2): 35-39

©Philippine Society of Otolaryngology – Head and Neck Surgery, Inc.

Despite the evolution in reported surgical indications, pediatric tracheostomy remains a commonly performed procedure, primarily due to the need for prolonged mechanical ventilation and the management of upper airway obstruction.[1] In pediatric airway management, selecting the appropriate tracheal tube size represents a critical size window, as overestimation may lead to tracheolaryngeal injury, while underestimation may result in inadequate ventilation. Over time, several methods and formulae have been developed to estimate the appropriate tracheal tube size, mostly based on endotracheal tube data. Beginning with the age-based formula proposed by Cole in 1957,[2] this has since undergone modifications and refinements, leading to widely used age-based formulae we know today such as those by Khine, Motoyama and Duracher.[3] By the 1990s, alternative approaches incorporating anthropometric measurements were explored including finger measurements, height-based and weight-based formulae.[4-6] Predictive accuracy was also noted to vary across different populations. For instance, height-based methods were noted to perform better in some studies among Chinese, Korean, Indonesian and European children.[7-10]

In the Filipino pediatric population, published data remain limited. Two studies from 1992 examined correlations between optimal tube size and anthropometric variables,[4,11] while a more recent study explored radiographic tracheal measurements.[12] Despite these findings, most institutions in the Philippines continue to rely on age-based formulae in pediatric resuscitation and anesthesia. Given established ethnic variations in airway dimensions[4-11] and the potential influence of nutritional status on airway development,[6,9] evaluating which predictive model is most applicable to Filipino children is warranted. To the best of our knowledge, based on a search of Herdin Plus, the WHO Western Pacific Region Index Medicus, the Directory of Open Access Journals (DOAJ), MEDLINE (PubMed) and PubMed Central, using the keywords "Tracheostomy," "Airway Management," "Child," "Infant," "Anthropometry," "Malnutrition," "tracheal tube size," and "Filipino children," no English-language study has directly compared age-based, height-based, and weight-based formulae in the Filipino pediatric population.

This study aims to determine which among an age-based formula (ABF), height-based formula (HBF), and weight-based formula (WBF) most accurately approximates the actual tracheal tube sizes used in Filipino children, to help optimize tube selection and minimize the risk of airway injury.

METHODS

With approval of the Ospital ng Makati Ethics Review Board (OMREB), this retrospective study reviewed inpatient medical charts, anesthetic records, operative techniques, and electronic medical records via the Ospital ng Makati Hospital Information Management System (HIMS). The study focused on pediatric patients who underwent tracheostomy between January 2016 and August 2023, specifically those aged 0 to 18 years and 364 days. Records lacking complete information on age, sex, weight and tracheal tube size were excluded. Records lacking information on length were not excluded because the data could still be used for the age-based and weight-based formulas as well as the nutritional status subgroup analysis which are based on z-scores for weight rather than height.

A minimum sample size of 29 participants per group was calculated using PASS 11 Power Analysis and Sample Size Software. This sample size achieves an any-pair power and an all-pair power of at least 80%, to detect differences between the three treatment groups (age-based, height-based, and weight-based) and the control group (actual tracheal tube size) using Dunnett's Test.[13] The calculation assumed an alternative distribution with an average within-group standard deviation of 1.49, an estimated size mean of 5.01, and an actual tube size mean of 6.46. The target family-wise error rate was capped at 5%, applying an equivalence margin of 1.0.[12]

The data collected included patients' age, sex, weight, length or height, primary diagnosis, and the actual tracheostomy tube size used during the procedure. Additionally, a review of pertinent preoperative medical information was conducted, to include the indication for tracheostomy and whether the procedure was planned or performed in an emergency setting. The nutritional status of the child was also recorded based on the WHO/CDC child growth standards, considering factors such as weight-for-age, length or height-for-age, and BMI-for-age, particularly for patients with conditions predisposing them to malnutrition, such as cerebral palsy, Down syndrome, cleft patients, and congenital heart disease. Undernourished children, defined by WHO, were classified as underweight, stunted, or wasted based on Z scores lower than -2 for the respective growth indicators.

For comparison, each patient's estimated tracheal tube internal diameters were calculated using the three formulae: ABF [ID (mm) = age (years)/4 + 3], HBF [ID (mm) = height (cm)/30 + 2], and WBF [ID (mm) = (weight in kg/10) + 3.5]. The calculated tube sizes were rounded to the next half size, for instance, ID 4.25 mm was considered as ID 4.5 mm, and ID 6.75 mm was considered ID 7mm.

Data Analysis

The clinical profiles of the patients included were summarized using medians and interquartile ranges, and frequencies and percentages, as appropriate. Friedman test was used to assess if there were differences between the actual tracheal tube size used and the different estimation

formulas, while adjusting for age-group and nutritional status. A post-hoc Dunn test was used to make pairwise comparisons between the actual tracheal tube size used versus the different estimation formulas. Data analysis was performed using Stata Statistical Software version 17 (StataCorp LP, College Station, TX, USA). Missing values were neither replaced nor imputed. The normality of distribution of numerical variables were assessed by Shapiro-Wilk test of normality. All tests of hypothesis were evaluated with significance level set at α =0.05.

RESULTS

A total of 31 patient records were included in this study from January 2016 to August 2023. Three out of 31 patients had missing data for length. The study included almost an equal number of males (15; 48.39%) and females (16; 51.61%). The age distribution ranged from 1-day-old to 18 years, with a median value of 1.5 years (IQR, 10.75). This wide age range was accompanied by a broad range of patients' weight and height, with medians of 9 kilograms (IQR,16) and 77 centimeters (IQR, 70.5), respectively.

In this institution, more pediatric tracheostomy procedures were planned (19;61.29%), as opposed to those performed on an emergency basis (12; 38.71%). The most common indication for tracheostomy was upper airway obstruction (15; 48.39%), often attributed to conditions such as laryngotracheal stenosis and obstructive masses or abscesses. Prolonged intubation accounted for 9 (29.03%) cases. Notably, 15 children (48.39%) were found to be undernourished.

Figure 1 summarizes the percentage of correct, under-, and over-sized estimates for each formula. Tracheostomy tube sizes calculated by HBF, and WBF generally ended up larger than the actual size used in 23/28 (82.14%) and 23/31 (74.19%), respectively.

In our sample, the Khine age-based formula showed the highest accuracy, correctly predicting the actual tube size in 14/31 (45.16%) of cases versus 4/28 (14.29%) for the height-based and 6/31 (19.35%) for the weight-based formula. However, when considering three sizes of tubes (one above and one below the calculated size) estimated by the ABF, HBF, and WBF, the coverage increased to 22/31 (70.97%), 16/28 (57.14%), and 15/31 (48.39%), respectively. *(Figure 2)*

A Friedman test was conducted to determine whether there were significant differences among the actual tracheal tube size used and the three estimation methods (age-based, weight-based, and height-based formulas) when analyzed according to age group. The results revealed a statistically significant difference in tracheal tube size estimates, $\chi^2(3, N = 28) = 87.64$, $p < .0001$. Post-hoc pairwise comparisons were performed using Dunn's test. *(Table 1)*

Among children aged 0–2 years, the weight-based and height-based formulas resulted in significantly higher tracheal tube size estimates compared with the actual tube size (p = .0001 and p = .0008, respectively), whereas the age-based estimate did not differ significantly from the actual tube size (p = .1209). Among children aged 3–5 years, only the weight-based formula resulted in a significantly higher estimate compared with the actual tube size (p = .0304), while the age-based and height-based estimates did not differ significantly from the actual tube size (p = .2477 and p = .0625, respectively). Among children aged 6–11 years, only the height-based formula resulted in a significantly higher estimate compared with the actual tube size (p = .0479), whereas the age-based and weight-based estimates did not differ significantly from

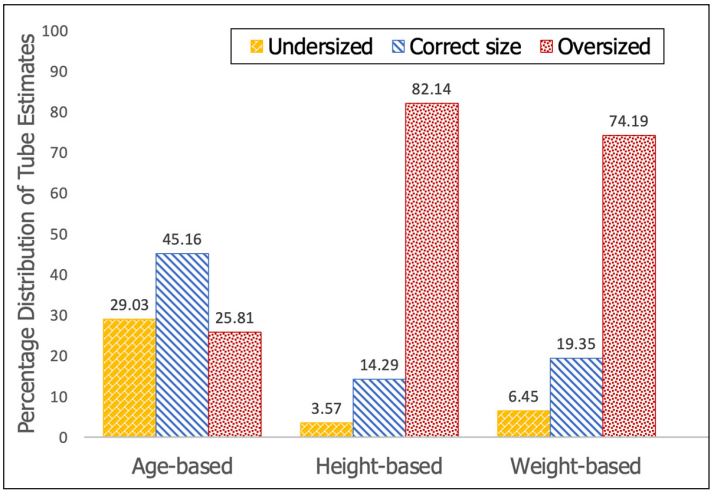


Figure 1. Percentage of Correct Tube Estimates, Undersized and Oversized Estimates Using ABF, HBF and WBF

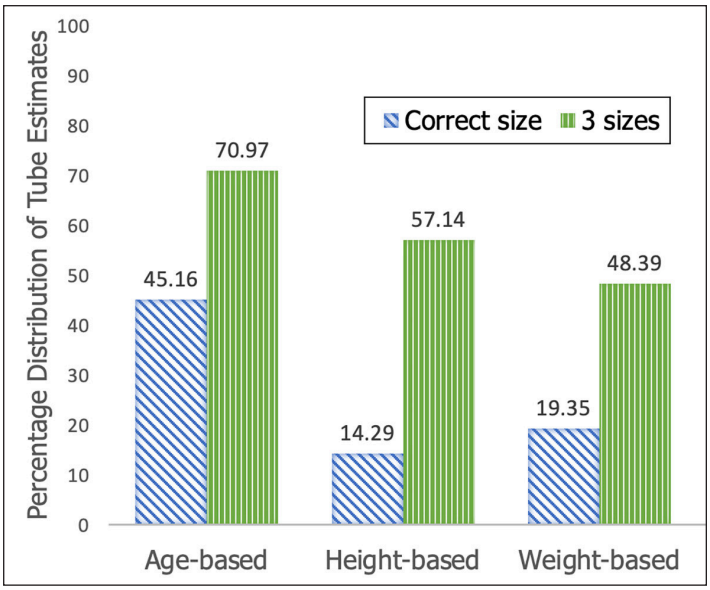


Figure 2. Percentage of Correct Tube Sizes and Three Sizes of Tracheostomy Tube Across 3 Formulae

Table 1. Comparison between the actual tube size used and the different estimation methods with adjustments for age

Tube size	Age group* Age 0-2 years n = 18 Median (IQR)	p-value†	Age 3-5 years n = 3 Median (IQR)	p-value†	Age 6-11 years n = 5 Median (IQR)	p-value†	Age 12-18 years n = 5 Median (IQR)	p-value†
Actual	3.5 (0.5)		4.5 (1)		5.5 (0.5)		6 (1)	
Age-based estimate	3.5 (0.25)	.1209	4.5 (0.5)	.2477	6.25 (0.25)	.3144	7.25 (0.5)	.0083
Weight-based estimate	3.8 (0.5)	.0001	6.3 (1.9)	.0304	5.2 (1.8)	.1668	5.5 (4.1)	.0881
Height-based estimate	3.75 (0.8)	.0008	5.7 (0.4)	.0625	6 (0.4)	.0479	6.7 (0.95)	.0218

* Friedman test to compare the actual vs estimates accounting for age group, p-value < .0001.
† Post-hoc Dunn test to compare with actual size.

Table 2. Comparison between the actual tube size used and the different estimation methods with adjustments for nutritional status

Tube size	Nutritional status* Z < -2 n = 15 Median (IQR)	p-value †	Z ≥ -2 n = 16 Median (IQR)	p-value †
Actual	3.5 (1.0)		4.25 (1.75)	
Age-based estimate	3.5 (2.75)	.3080	4.13 (1.88)	.2124
Weight-based estimate	3.8 (1.4)	.0184	4.8 (2.7)	.0352
Height-based estimate	3.75 (2.5)	.0315	4.7 (1.9)	.0406

* Friedman test to compare the actual vs. estimates accounting for nutritional status, p-value = .0003.
† Post-hoc Dunn test to compare with actual size.

the actual tube size (p = .3144 and p = .1668, respectively). Among children aged 12–18 years, the age-based and height-based formulas resulted in significantly higher estimates compared with the actual tube size (p = .0083 and p = .0218, respectively), whereas the weight-based estimate did not differ significantly from the actual tube size (p = .0881).

A Friedman test was also conducted to determine whether there were significant differences among the actual tracheal tube size used and the three estimation methods when analyzed according to nutritional status. The results revealed a statistically significant difference in tracheal tube size estimates, $\chi^2(1, N = 28) = 13.82$, p = .0003. Post-hoc pairwise comparisons were performed using Dunn's test. *(Table 2)*

Among children with growth failure (Z-score < –2), the weight-based and height-based formulas resulted in significantly higher estimates compared with the actual tube size (p = .0184 and p = .0315, respectively), whereas the age-based estimate did not differ significantly from the actual tube size (p = .3080). Among children without growth failure (Z-score ≥ –2), the weight-based and height-based formulas also resulted in significantly higher estimates compared with the actual tube size (p = .0352 and p = .0406, respectively), whereas the age-based estimate did not differ significantly from the actual tube size (p = .2124).

DISCUSSION

In this sample, height- and weight-based formulas consistently produced larger estimates than the tube sizes ultimately used, in contrast to studies reporting superior accuracy of height-based methods over age-based formulas.[8-10] This consistent overestimation raises important clinical considerations, as oversized tubes may increase the risk of airway injury, including laryngotracheal trauma and stenosis, particularly with repeated or prolonged intubation.[3] This is especially relevant in emergency and operative settings where rapid decision-making is required.

The Khine age-based formula correctly predicted the exact tube size in 45.16% of cases, with improved performance in children younger than 12 years (53.85%). These findings are comparable to reports from Canadian, Thai, Japanese, and Indian pediatric populations, where accuracy ranges from approximately 50% to 60%.[6,14-16] From a practical standpoint, preparing one size above and one below the predicted value increased coverage to 70.97%, reinforcing the clinical utility of the age-based approach. This emphasizes flexibility in tube selection rather than reliance on a single estimate, a principle supported in both early and contemporary literature.[2,14,15]

While age-based formulas remain widely used, variability exists among different formulations. The Khine formula, which tends to yield smaller estimates, may better reflect the anthropometric characteristics of Filipino children, given the observed tendency of other formulas to overestimate tube size. Notably, both age group and nutritional status significantly influenced estimation accuracy in this sample, with age-based formulas demonstrating relatively consistent performance across subgroups but reduced reliability in older children. These findings highlight the continued relevance of population-specific validation when applying predictive formulae.

This study is limited by its retrospective design, single institution nature, and relatively small sample size, which may affect the generalizability of findings and introduce variability in patient characteristics. Larger, multicenter prospective studies are needed to

validate these findings. The inclusion of standardized air leak testing may provide a more objective assessment of tube fit, which can be performed intraoperatively with the help of an anesthesia machine for both endotracheal and tracheostomy tubes, though it has been more widely used in the former.[15, 17,18] Innovations in tracheal tube cuff materials and design, such as high-volume, low-pressure polyvinyl chloride and ultrathin polyurethane (e.g., Microcuff ETTs), have also been utilized to maintain a secure seal at low pressures, minimizing the risk of injury to the subglottic area;[19] however, their widespread use and distribution are restricted by high procurement costs.[18,19]

Emerging methods for tube size estimation, including ultrasound, radiographic measurements, and patient-specific modeling, offer more individualized approaches but remain limited by cost, accessibility, and time constraints.[12,17-19] Despite these advances, variability in tube size estimation persists, influenced by differences in growth patterns, nutritional status, and population-specific characteristics.[5,6,9,11,16]

In conclusion, the Khine age-based formula showed the closest agreement with actual tube sizes and may guide the development of population-specific prediction models for Filipino children. Preparing three tube sizes (estimated, one size larger, and one smaller) may improve procedural safety. While predictive formulas provide useful guidance, clinical judgment remains essential, and intraoperative verification of tube fit is recommended.

ACKNOWLEDGEMENTS

We wish to express our gratitude to Dr. Emilio Q. Villanueva III, our biostatistician who helped us with data analysis and interpretation, as well as Dr. A. V. Santos, Department Chairman, and Dr. C. A. Nofuente, Program Director, for their guidance and unwavering support throughout the course of this work.

REFERENCES

1. Carron JD, Derkay CS, Strope GL, Nosonchuk JE, Darrow DH. Pediatric tracheotomies: Changing indications and outcomes. *Laryngoscope.* 2000 Jul;110(7):1099-1104. DOI:10.1097/00005537-200007000-00006; PubMed PMID: 10892677.
2. Cole F. Pediatric formulas for the anesthesiologist. *AMA J Dis Child.* 1957 Dec;94(6):672–673. DOI:10.1001/archpedi.1957.04030070084009; PubMed PMID: 13478300.
3. Reynolds P, Scattoloni JA, Gadepalli SK, Ehrlich P, Cladis FP, Davis PJ. Anesthesia for the pediatric trauma patient. In: Davis PJ, Cladis FP, editors. Smith's Anesthesia for Infants and Children. 9th ed. St. Louis: Elsevier; 2017. p. 969-999.
4. Bautista R. The value of anthropometric data in airway management among Filipino infants and children. *Philipp J Otolaryngol Head Neck Surg*. 1992;7:112-123. Available from: https://pjohns.pso-hns.org/index.php/pjohns/issue/view/85/33.
5. Wang TK, Wu RS, Chen C, Chang TC, Hseih FS, Tan PP. Endotracheal tube size selection guidelines for Chinese children: prospective study of 533 cases. *J Formos Med Assoc.* 1997 May;96(5):325-329. PubMed PMID: 9170819.
6. Eipe N, Barrowman N, Writer H, Doherty D. A weight-based formula for tracheal tube size in children. *Paediatr Anaesth.* 2009 Apr;19(4):343-8. DOI: 10.1111/j.1460-9592.2008.02916.x; PubMed PMID: 19178655.
7. Shih MH, Chung CY, Su BC, Hung CT, Wong SY, Wong TKM. Accuracy of a new body height-based formula for predicting tracheal tube size in Chinese children. *Chang Gung Med J.* 2008 May-Jun;31(3):276–280. PubMed PMID: 18782950.
8. Jang HY, Shin SD, Kwak YH. Can the Broselow tape be used to estimate weight and endotracheal tube size in Korean Children? *Acad Emerg Med.* 2007 May;14(5):489-91. DOI: 10.1197/j.aem.2006.12.014; PubMed PMID: 17384410.
9. Kapuangan C, Tantri AR, Zakaria GS. Accuracy of Broselow Tape and Cole Formulation in Predicting Uncuffed Endotracheal Tube Size in Pediatric Patients. *Teikyo Med J.* 2021 Oct;44(5):1653-1658. [Accessed 2026 April 5]. Available from: https://www.teikyomedicaljournal.com/public/volume/TMJ/44/05/accuracy-of-broselow-tape-and-cole-formulation-in-predicting-uncuffed-endotracheal-tube-size-in-pediatric-patients-615ed9ebe295f.pdf.
10. Hofer CK, Ganter M, Tucci M, Klaghofer R, Zollinger A. How reliable is length-based determination of body weight and tracheal tube size in the pediatric age group? The Broselow tape reconsidered. *Br J Anaesth.* 2002;88(2):283-285. DOI: 10.1093/bja/88.2.283; PubMed PMID: 11878662.
11. Macapinlac MH, Bautista RM, Calimag MP. Validation of indices for predicting optimal tube size and length among Filipino infants and children. *Santo Tomas J Med.* 1992 Sep;1(2):17–25. Available from: https://www.researchgate.net/publication/331891961_Validation_of_indices_for_predicting_optimal_tube_size_and_length_among_Filipino_infants_and_children.
12. De Guzman ICS. Tracheal diameter estimates using age-related formula versus radiographic findings: which approximates the actual tracheostomy tube in pediatric patients? *Philipp J Otolaryngol Head Neck Surg.* 2018 Nov;33(2):32-36, DOI:10.32412/pjohns.v33i2.271.
13. NCSS, LLC. PASS 11 Power Analysis and Sample Size Software [computer program]. Kaysville (UT): NCSS; 2011. Available from: https://www.ncss.com/.
14. Chumpathong S, Muangman S, von Bormann B, Vacharaksa K. Comparison of age-based and height-based formula for tracheal tube size in cardiac children. *J Med Assoc Thai.* 2012 Apr;95(4):544–549. PubMed PMID: 22612009.
15. Takita K, Morimoto Y, Okamura A, Kemmotsu O. Do age-based formulae predict the appropriate endotracheal tube sizes in Japanese children?. *J Anesth.* 2001;15(3):145-148 DOI: 10.1007/s005400170016; PubMed PMID: 14566512.
16. Subramanian S, Nishtala M, Ramavakoda CY, Kothari G. Predicting endotracheal tube size from length: Evaluation of the Broselow tape in Indian children. *J Anaesthesiol Clin Pharmacol.* 2018 Jan-Mar;34(1):73-77. DOI:10.4103/joacp.JOACP_317_16; PubMed PMID: 29643627; PubMed Central PMCID: PMC5885454.
17. Shibasaki M, Nakajima Y, Ishii S, Shimizu F, Shime N, Sessler DI. Prediction of pediatric endotracheal tube size by ultrasonography. *Anesthesiology*. 2010 Oct;113(4):819-24. DOI:10.1097/ALN.0b013e3181ef6757; PubMed PMID: 20808208.
18. Hanamoto H, Maegawa H, Inoue M, Oyamaguchi A, Kudo C, Niwa H. Age-based prediction of uncuffed tracheal tube size in children to prevent inappropriately large tube selection: a retrospective analysis. *BMC Anesthesiol*. 2019 Aug;19(1):141. DOI:10.1186/s12871-019-0818-3; PubMed PMID: 31390987.
19. Park S, Shin SW, Kim HJ, Byeon GJ, Yoon JU, Kim EJ, et al. Choice of the correct size of endotracheal tube in pediatric patients. *Anesth Pain Med (Seoul)*. 2022 Oct;17(4):352-360. DOI:10.17085/apm.22215; PubMed PMID: 36317427.