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The evaluation of endotracheal tube cuff pressure in pediatric patients by subjective inflation techniques: a prospective observational study

Darunee Sripadungkul[1], Nawaporn Tanasoontornsut[1], Prathana Wittayapairoch[1*], Thitinuch Ruenhunsa[1], Peerapong Sangsungnern[1], Cattleya Kasemsiri[1], Nathee Maneewan[1] and Sutida Boonkamjad[1]

Abstract

Background Cuffed endotracheal tubes (ETTs) are commonly used in pediatric patients, with the gold standard for measuring cuff pressure being a cuff pressure manometer. However, this equipment is not always available in every operating room. Subjective inflation techniques, such as the minimal occluding volume (MOV) technique and the stethoscope-guided (Steth) technique, offer convenient and safe alternatives to standard methods but do not provide quantitative measurements. This study aimed to evaluate ETT cuff pressures and volumes of air inflated using the two subjective techniques (MOV and Steth) in pediatric patients.

Methods This prospective observational study was conducted at the Department of Anesthesiology, Faculty of Medicine, Khon Kaen University, Thailand. We included healthy pediatric patients aged 2 to 7 years undergoing elective surgeries under general anesthesia with a cuffed ETT. The primary objective of this study was to compare the mean ETT cuff pressures and volumes of air inflated using the two subjective inflation techniques (MOV and Steth method). The secondary objectives include identifying factors associated with inappropriate inflation and evaluating post-intubation complications.

Results Sixty-four pediatric patients were analyzed. The overall mean ETT cuff pressure was 26.52 ± 8.68 cmH_2O. The target was achieved in 46.88% of patients, with overinflation in 32.81% and underinflation in 20.31%. The mean ETT cuff pressure in the MOV group was 27.77 ± 8.89 cmH_2O and in the Steth group was 25.33 ± 8.34 cmH_2O, with a non-significant mean difference of 2.44 cmH_2O (95% CI [-1.89, 6.77], $p = 0.264$). The mean volume of air inflated in the MOV group was 0.78 ± 0.25 ml, and in the Steth group was 0.68 ± 0.22 ml, with a non-significant mean difference of 0.10 ml (95% CI [-0.01, 0.22], $p = 0.084$). Younger age, lower weight, and shorter height were significantly associated with an increased risk of overinflation. An ETT size with an internal diameter (ID) of 5 mm was significantly associated with an increased risk of underinflation. No post-intubation complications were reported.

*Correspondence:
Prathana Wittayapairoch
prathana@kku.ac.th

Full list of author information is available at the end of the article

Conclusions Subjective inflation techniques (MOV or Steth) achieve target ETT cuff pressures in less than 50%, and carry the risks of both overinflation and underinflation, even without post-intubation complications.

Trial registration TCTR20211016001 (registered with the Thai Clinical Trials Registry on October 16, 2021).

Keywords Anesthesia, Children, Cuffed endotracheal tube, Cuff pressure, Inflation, Pediatrics

Introduction

Cuffed endotracheal tubes (ETTs) are commonly used in pediatric patients [1–4]. The safety of using a cuffed ETT requires selecting the appropriate size and depth for the pediatric patient, measuring the ETT cuff pressure, and maintaining an optimal intracuff pressure of 20–30 cmH_2O [2, 5–7]. Overinflation in the cuff can cause airway complications such as sore throat, hoarseness, cough, edema, inflammation, nerve injury, granulations, tracheal stenosis, fistulas, ulcerations, and tracheal rupture [6–9]. Underinflation can lead to aspiration and inadequate ventilation [6, 9, 10]. The gold standard for measuring ETT cuff pressure is using a cuff pressure manometer [6, 11]. However, this equipment may not be available in every operating room and presents challenges such as unintentional leaks, increased costs, and the need for cleaning between patients [6]. Previous studies offer limited data on mean cuff pressure in pediatric patients, with inconsistent results on targeted inflation, underinflation, and overinflation [11–13]. These variations may be due to different ETT types, age ranges, and data collected from various settings like operating rooms, emergency departments, and intensive care units [11–13]. In our hospital, a cuff pressure manometer is not available in every operating room. We commonly use two subjective inflation techniques: the minimal occluding volume technique (MOV) [12] and the stethoscope-guided technique (Steth) [14, 15]. In adult patients, the MOV is a convenient, safe alternative to standard cuff inflation, preventing air leaks and reducing sore throat by maintaining target pressure [16]. However, the Steth is more effective than the MOV in achieving proper ETT cuff pressure and reducing complications [14, 15]. However, the results of comparing these techniques in pediatric patients are not yet available.

We hypothesize that the Steth method is more effective than the MOV in ensuring appropriate ETT cuff pressure and volume of air inflated in pediatric patients undergoing elective surgeries under general anesthesia.

Therefore, the primary objective of this study was to compare the mean ETT cuff pressures and volumes of air inflated using the two subjective inflation techniques (MOV and Steth method). The secondary objectives include identifying factors associated with inappropriate inflation and evaluating post-intubation complications.

Methods

Study design and setting

This prospective observational cohort study was conducted at the Department of Anesthesiology, Faculty of Medicine, Khon Kaen University, Khon Kaen, Thailand, and took place between August 9, 2021, and February 22, 2022. Approval was obtained from the Khon Kaen University Ethics Committee in Human Research (HE641376) before the study commenced. The analysis and presentation of the study were conducted following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines (Supplementary Material 1). The trial registration number is TCTR20211016001 from the Thai Clinical Trials Registry.

We included pediatric patients aged 2 to 7 years undergoing elective surgery under general anesthesia with a cuffed ETT and classified as American Society of Anesthesiologists (ASA) physical status I or II in this study. Patients were excluded from the study if they had an expected difficult airway, a history of difficult intubation, a risk of aspiration, tracheal disorders such as tracheal stenosis and tracheomalacia, a history of upper respiratory tract infection, sore throat, or hoarseness within the past two weeks.

Informed written consent was obtained from the legal guardians of all participants included in the study. This consent includes detailed standard guidelines for adverse event management in our hospital. Patients received general anesthesia according to standard practice. The choice of anesthetic technique, maintenance, type of drug, and dosage was determined by the attending staff anesthesiologist. Before the operation, patients' vital signs were monitored, including blood pressure, heart rate, electrocardiogram, pulse oximetry, body temperature, and end-tidal carbon dioxide ($EtCO_2$). Patients were pre-oxygenated using a 100% oxygen mask with a flow rate of 6 L/min for 3–5 min and appropriate premedication was administered before induction. During the induction period, an inhalation induction technique could be used without nitrous oxide, or an intravenous induction technique was employed if the patient already had an intravenous line. Prior to intubation, a muscle relaxant was administered, and the cuffed ETT was checked. For intubation, we used cuffed ETTs (Hi-Contour Oral/Nasal Tracheal Tube Cuffed, Shiley™, Thailand) with a calculated size for pediatric patients using the Motoyama

formula, internal diameter (ID) (mm) = (age/4) + 3.5 [17]. The personnel responsible for performing the intubation procedure included staff anesthesiologists, anesthesiology residents, certified registered nurse anesthetists (CRNA), or student registered nurse anesthetists (SRNA) under the direct supervision of staff anesthesiologist.

Cuff inflation and measurement were performed by one of four pediatric anesthesiologists using either the MOV or Steth method, based on their discretion. The first technique is the MOV [12], which involves inflating the cuff until the leak sound becomes inaudible. The second technique is the Steth [14, 15], which involves inflating the cuff until the leak sound becomes inaudible while using a stethoscope placed at the thyroid cartilage area. The cuff inflation was carried out using a 3-ml syringe connected to a three-way stopcock, which was then connected to a cuff pressure manometer (Hi-Lo Hand Pressure Gauge, Shiley™, Germany) via an extension tube (Supplementary Material 2). The ventilator settings during cuff inflation were set to a peak inspiratory pressure (PIP) of 20 cmH_2O, positive end-expiratory pressure (PEEP) 5 cmH_2O and respiratory rate 20/minutes [18]. During cuff inflation, the ETT cuff pressure was recorded from a cuff pressure manometer by a team of researchers, including two CRNAs and an anesthesiology resident, none of whom performed the cuff inflation. These measurements were taken within 5 min after intubation.

When using the Motoyama formula [17] for pediatric ETT sizing, if the cuffed ETT is too small to seal the trachea with a small volume of air, it is advisable to replace it with the next larger size rather than over-inflating the cuff. Conversely, if the cuffed ETT is so large that there is no air leak before inflating the cuff, it should be replaced with the next smaller size. The decision to replace the cuffed ETT, considering the risks of repeating direct laryngoscopy and tracheal reintubation, is made by the attending staff anesthesiologist.

Data collection

All study data was documented by a team of researchers (comprising two CRNAs and an anesthesiology resident) who were not assigned to the operating room on the day of data collection.

The first section assessed patient characteristics, including gender, age, weight, height, and ASA physical status classification. The second section assessed the ETT cuff pressure recorded from the cuff pressure manometer, along with the method of inflation (MOV or Steth), percentage of patients achieving targeted inflation (20–30 cmH_2O) [12], underinflation (< 20 cmH_2O), and overinflation (> 30 cmH_2O) and volume of air inflated. The third section assessed data on cuff inflation and intubation, including the personnel who performed the intubation procedure (staff anesthesiologist, anesthesiology resident, CRNA, or SRNA), the ETT size, the number of intubation attempts, and the duration of intubation. The duration of intubation was defined as the difference in minutes between the moment of intubation and the moment of extubation. The fourth section assessed the mean volume of air inflated to achieve targeted inflation for the overall group and for each ETT size (ID). The fifth section assessed factors associated with inappropriate inflation and targeted inflation, including gender, age, weight, height, ASA physical status classification, method of inflation, ETT size, volume of air inflated, and the number of intubation attempts. The sixth section assessed post-intubation complications within 24 h, such as sore throat, hoarseness, aspiration, and other complications.

Statistical analysis

The demographic data of the participants was presented using frequency and percentage for categorical variables, and mean ± standard deviation (SD) or median with interquartile range (IQR) for continuous variables. Categorical data was evaluated using the Chi-squared test or Fisher's exact test and presented as numbers and percentages. The Shapiro-Wilk test was employed to test for normality in continuous data. Continuous data that followed a normal distribution were analyzed using the independent sample T-test and presented as mean ± SD. For data with a non-normal distribution, the Mann-Whitney U test was applied, with results presented as median (IQR). The magnitude of the mean difference in ETT cuff pressure between the MOV and Steth techniques was reported with a 95% confidence interval (CI), and statistical significance was considered for $p < 0.05$. Ordered logistic regression was employed to examine the association between factors and inappropriate inflation (underinflation, overinflation) and the targeted inflation of ETT cuff pressure. All analyses were conducted using STATA version 10.1 (StataCorp, Texas, USA).

Sample size

The estimated required sample size for the study was determined using the formula for estimating a finite population mean [19]. This calculation was based on a previous study that reported a mean cuff pressure of 23 cmH_2O with a standard deviation of 22 [11]. Our population consisted of 77 patients from the hospital database over a three-month period. To detect a 10% of mean difference in ETT cuff pressure (type I error of 0.05) with a power of 80%, we determined that a sample size of 64 participants was required for this study.

Results

A total of 64 patients were identified as having undergoing elective surgery under general anesthesia with a cuffed ETT. Sixty-four patients were enrolled and included for analysis (Fig. 1). There were no patients who withdrew from the study, and there was no missing data.

Patient characteristics

In our study, we enrolled 64 pediatric patients: 31 (48.44%) in the MOV group and 33 (51.56%) in the Steth group. Of these, 40 (62.50%) were male. The mean age was 4.56±1.64 years, with a median weight of 17 (14, 22.45) kg and mean height of 106.86±13.33 cm. ASA physical status classification was I for 73.44% and II for 26.56% of patients. There were no significant demographic differences between the MOV and Steth groups in terms of gender, age, weight, height, and ASA physical status classification (Table 1).

Endotracheal tube cuff pressure and volume of air inflated

The overall mean ETT cuff pressure observed was 26.52±8.68 cmH_2O. The mean cuff pressure in the MOV group was 27.77±8.89 cmH_2O, and in the Steth group, it was 25.33±8.34 cmH_2O, with a non-significant mean difference of 2.44 cmH_2O (95% CI [-1.89, 6.77], $p=0.264$). The ETT cuff pressure that achieved the targeted inflation range of 20–30 cmH_2O was found in 46.88% of the patients, while inappropriate inflation was observed in 53.12% of the patients, with underinflation occurring in 20.31% and overinflation in 32.81%. There were no significant differences between the MOV group and the Steth group in ETT cuff pressure, including targeted inflation, underinflation, and overinflation. The overall mean volume of air inflated was 0.73±0.24 ml. The mean volume of air inflated in the MOV group was 0.78±0.25 ml, and in the Steth group, it was 0.68±0.22 ml, with a non-significant mean difference of 0.10 ml (95% CI [-0.01, 0.22], $p=0.084$) (Table 2).

Data of cuff inflation and intubation

Anesthesiology residents were responsible for intubating 37.50% of the patients, SRNA for 26.50%, staff anesthesiologists for 23.44%, and CRNA for 12.50%, respectively. There were no significant differences between the MOV

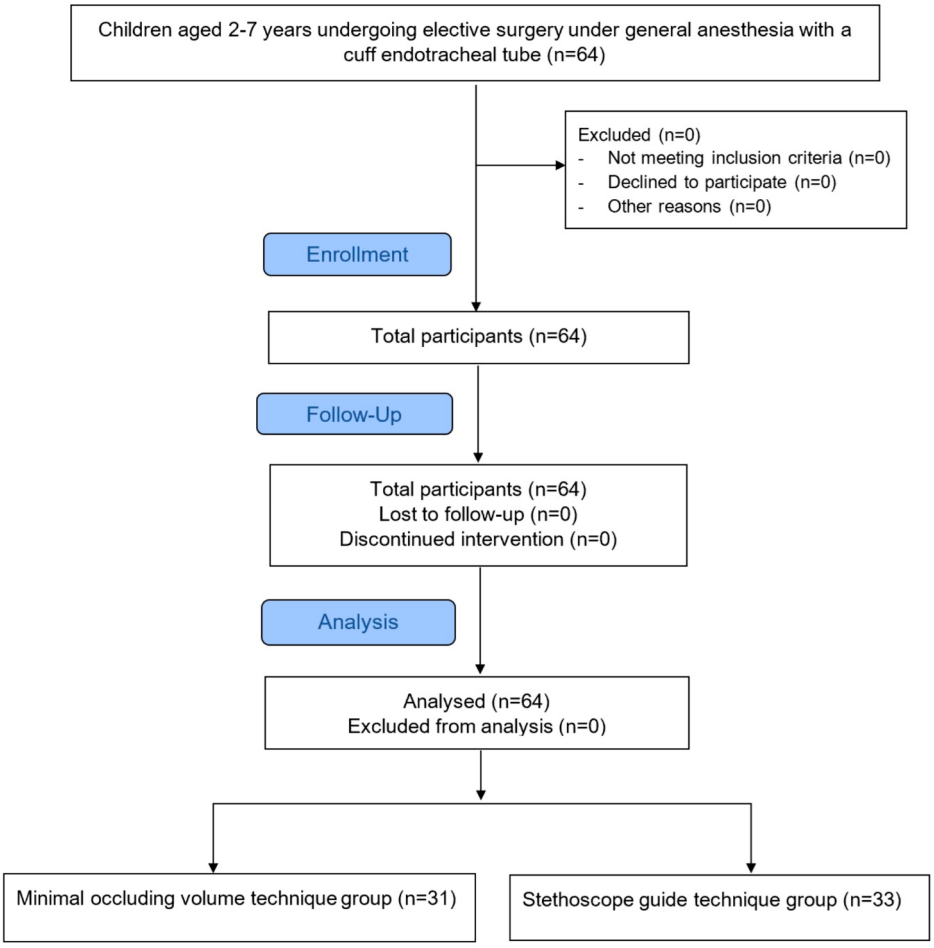

Fig. 1 Study flow diagram

Table 1 Demographic data

Variables	Total ($n=64$)	MOV ($n=31$)	Steth ($n=33$)	*p*-value
Gender (n (%))				
Male	40 (62.50)	22 (70.97)	18 (54.55)	0.175
Female	24 (37.50)	9 (29.03)	15 (45.45)	
Age (year; mean ± SD)	4.56 ± 1.64	4.23 ± 1.63	4.88 ± 1.62	0.112
Weight (kg; median (IQR))	17 (14, 22.45)	16.2 (13.5, 19.2)	17.5 (15, 24)	0.265
Height (cm; mean ± SD)	106.86 ± 13.33	105.84 ± 14.74	107.82 ± 12.00	0.557
ASA physical status classification (n (%))				
I	47 (73.44)	23 (74.19)	24 (72.73)	0.894
II	17 (26.56)	8 (25.81)	9 (27.27)	

MOV, Minimal occluding volume technique; Steth, Stethoscope-guided technique; SD, standard deviation; IQR, interquartile range; ASA, American Society of Anesthesiologists

Table 2 Endotracheal tube cuff pressure and volume of air inflated

Variables	Total ($n=64$)	MOV ($n=31$)	Steth ($n=33$)	*p*-value
Mean ETT cuff pressure (cmH_2O; mean ± SD)	26.52 ± 8.68	27.77 ± 8.98	25.33 ± 8.34	0.264
Targeted inflation (n (%))	30 (46.88)	16 (51.61)	14 (42.42)	0.462
Underinflation (n (%))	13 (20.31)	5 (16.13)	8 (24.24)	0.420
Overinflation (n (%))	21 (32.81)	10 (32.26)	11 (33.33)	0.927
Volume of air inflated (ml; mean ± SD)	0.73 ± 0.24	0.78 ± 0.25	0.68 ± 0.22	0.084

Targeted inflation, 20–30 cmH_2O; Underinflation, < 20 cmH_2O; Overinflation, > 30 cmH_2O; MOV, Minimal occluding volume technique; Steth, Stethoscope-guided technique; ETT, endotracheal tube; SD, standard deviation

group and the Steth group in terms of the intubator, the ETT size, the number of intubation attempts, and the duration of intubation (Supplementary Material 3).

The volume of air inflated for targeted inflation

The overall of mean volume of air inflated for targeted inflation was 0.68±0.23 ml. The mean volumes of air inflated for targeted inflation were 0.65±0.19 ml, 0.78±0.29 ml, and 0.57±0.14 ml for the ETT sizes (ID) 4.0 mm, 4.5 mm, and 5.0 mm, respectively.

Factors associated with inappropriate inflation

The factors associated with inappropriate inflation (underinflation and overinflation) were age (odds ratio, OR 0.51, 95% CI [0.37, 0.72], $p<0.001$), weight (OR 0.89, 95% CI [0.82, 0.96], $p=0.004$), height (OR 0.94, 95% CI [0.91, 0.98], $p=0.003$), and ETT size (ID) 5.0 mm (OR 0.02, 95% CI [0.00, 0.15], $p<0.001$), all of which were significant (Supplementary Material 4). Younger age, lower weight, and shorter height were significantly associated with an increased risk of overinflation. An ETT size (ID) of 5 mm was significantly associated with an increased risk of underinflation.

Post-intubation complications

There were no post-intubation complications reported within 24 h, such as sore throat, hoarseness, aspiration, or other complications in this study.

Discussion

In our study of 64 pediatric patients aged 2 to 7 years undergoing elective surgeries with cuffed ETTs and using routine subjective inflation techniques (MOV or Steth), we found that the overall mean ETT cuff pressure achieved the targeted inflation in 46.88% of cases. Subjective inflation techniques can effectively achieve the targeted cuff pressure during short intubation periods without post-intubation complications. Younger age, lower weight, and shorter height were significantly associated with an increased risk of overinflation. An ETT size (ID) of 5 mm was significantly associated with an increased risk of underinflation.

The previous study in pediatric patients reported mean ETT cuff pressures of 23±22 cmH_2O, with 23% of measurements in the targeted range, 53.5% underinflation, and 23.5% overinflation, conducted under general anesthesia similar as our study [11]. However, another study in the pediatric intensive care unit (PICU) found a mean cuff pressure of 17.95±3.92 cmH_2O, which is lower than the targeted range, with underinflation in 45% of cases and no overinflation [12]. This differs from our findings, possibly due to the PICU patient population (non-surgical or non-anesthesia patients) and the routine ETT cuff pressure estimation by respiratory therapists [12].

The mean ETT cuff pressure in the Steth group was 2.44 cmH_2O lower than in the MOV group. A previous adult study found the Steth method significantly more effective than MOV in maintaining appropriate cuff pressure [14]. In pediatric patients, the Steth method achieved lower-than-target cuff pressure in the PICU

[12], while the MOV method produced higher-than-target pressures (38 cmH_2O) in an emergency department setting [13]. However, data comparing these two techniques in pediatric patients are still lacking. The trend toward lower ETT cuff pressure with the Steth method may be due to its greater accuracy in detecting when the leak sound becomes inaudible with a stethoscope in pediatric patients, similar to adult patients.

For the mean volumes of air inflated, a previous study reported higher mean volumes of air inflated, specifically 1.7±0.3 ml for ETT size (ID) 4.5 mm and 1.9±0.3 ml for 5.0 mm [20]. This difference suggests variations in the type of ETT and the method of cuff inflation used between studies.

Age, weight, and height were significantly associated with overinflation. This is consistent with a prior study that found age, weight, and the person inflating the ETT cuff were significantly associated with overinflation [13]. In contrast, another study found no significant association between cuff pressure and ETT size [12].

Our study did not encounter any post-intubation complications, likely due to the short duration of intubation (88.5 min) and the high success rate on the first attempt of intubation (93.75%), which reduces the risk of airway injury. Similar to the previous study that found no immediate post-intubation complications [11]. Although some patients experienced cuff pressures above 60 cmH_2O, no immediate problems occurred, likely due to the operation time being under one hour and the administration of intraoperative dexamethasone to many patients to prevent postoperative nausea and vomiting [11]. This aligns with other research showing that shorter duration of intubation [11, 21], intubation by experienced senior anesthetists [21], and intraoperative dexamethasone administration can decrease post-intubation complications [21]. In contrast, a prior study found that cuffed ETTs resulted in a sore throat in 19.4% of patients, with an overall median pain score of 1 (range 0–7) on a scale of 1 to 10. Additionally, the incidence of sore throat increased with higher ETT cuff pressures: 68% at 31–40 cmH_2O and 96% at over 40 cmH_2O [8]. Several confounding factors, such as ETT size, surgery duration, intubator experience, and the use of drugs like dexamethasone or nitrous oxide, were not examined [8]. Nevertheless, the high percentage of inappropriate inflation, particularly overinflation, may lead to long-term complications such as tracheal ischemia and stenosis if patients undergo prolonged intubation, such as in major operations or extended mechanical ventilation in the intensive care unit [12].

In resource-limited environments where a cuff pressure manometer is not available in every operating room, cuff inflation using subjective techniques (MOV or Steth) may serve as an indirect guide to achieve targeted cuff inflation during short intubation durations. However, while our study showed that 46.88% of the mean ETT cuff pressures were within the targeted range, 53.12% exhibited inappropriate inflation.

Approach our findings with caution due to various limitations. Ethical considerations influenced our prospective observational study design, possibly introducing confounding factors. The single-setting nature of the study may limit its generalizability. Additionally, we measured ETT cuff pressure only once (post-intubation), without accounting for changes over time, which could be significant for prolonged intubation. Further research in diverse settings using randomized controlled trials is recommended to minimize bias and enhance validity.

Conclusions

Subjective inflation techniques (MOV or Steth) achieve target ETT cuff pressures in less than 50%, and carry the risks of both overinflation and underinflation, even without post-intubation complications.

Abbreviations

ETT	Endotracheal tube
MOV	Minimal occluding volume technique
Steth	Stethoscope-guided technique
ASA	American Society of Anesthesiologists
$EtCO_2$	End-tidal carbon dioxide
ID	Internal diameter
CRNA	Certified registered nurse anesthetists
SRNA	Student registered nurse anesthetists
PIP	Peak inspiratory pressure
PEEP	Positive end-expiratory pressure
SD	Standard deviation
IQR	Interquartile range
CI	Confidence interval
PICU	Pediatric intensive care unit

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12871-024-02780-7.

Supplementary Material 1: Supplementary Table 1. STROBE Statement—Checklist of items that should be included in reports of cohort studies

Supplementary Material 2: Supplementary Fig 1. Setup for monitoring endotracheal tube cuff pressure

Supplementary Material 3: Supplementary Table 2. Data of cuff inflation and intubation

Supplementary Material 4: Supplementary Table 3. Factors associated with inappropriate inflation

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Author contributions
Darunee Sripadungkul (Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing). Nawaporn Tanasoontornsut (Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Writing – original draft). Prathana Wittayapairoch (Conceptualization; Data curation; Formal analysis; Funding acquisition; Investigation; Methodology; Project administration; Resources; Software; Supervision; Validation; Visualization; Writing – original draft; Writing – review & editing). Thitinuch Ruenhunsa (Conceptualization; Data curation; Investigation; Methodology; Project administration; Resources; Writing – review & editing). Peerapong Sangsungnern (Conceptualization; Data curation; Investigation; Methodology; Project administration; Resources; Writing – review & editing). Cattleya Kasemsiri (Conceptualization; Data curation; Methodology; Project administration; Resources; Supervision; Visualization; Writing – review & editing). Nathee Maneewan (Conceptualization; Investigation; Methodology; Resources; Validation). Sutida Boonkamjad (Conceptualization; Investigation; Methodology; Resources; Validation).

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Data availability
Data is provided within supplementary material.

Declarations

Ethics approval and consent to participate
The study protocol was approved by the Khon Kaen University Ethics Committee for Human Research (HE641376) before the study commenced on July 23, 2021. The trial registration number is TCTR20211016001, registered with the Thai Clinical Trials Registry on October 16, 2021. This study adhered to the principles outlined in the Declaration of Helsinki, and written informed consent was obtained from all subjects participating in this trial before enrollment.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Department of Anesthesiology, Faculty of Medicine, Khon Kaen University, Khon Kaen 40002, Thailand

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References

1. Shi F, Xiao Y, Xiong W, Zhou Q, Huang X. Cuffed versus uncuffed endotracheal tubes in children: a meta-analysis. J Anesth. 2016;30(1):3–11.
2. Bhardwaj N. Pediatric cuffed endotracheal tubes. J Anaesthesiol Clin Pharmacol. 2013;29(1):13–8.
3. Park S, Shin SW, Kim HJ, Yoon JU, Byeon GJ, Kim EJ, et al. Choice of the correct size of endotracheal tube in pediatric patients. Anesth Pain Med. 2022;17(4):352–60.
4. De Orange FA, Andrade RG, Lemos A, Borges PS, Figueiroa JN, Kovatsis PG. Cuffed versus uncuffed endotracheal tubes for general anaesthesia in children aged eight years and under. Cochrane Database Syst Rev. 2017;11(11):CD011954.
5. Tobias JD. Pediatric airway anatomy may not be what we thought: implications for clinical practice and the use of cuffed endotracheal tubes. Paediatr Anaesth. 2015;25(1):9–19.
6. Moon KM, Donaworth S, Hagele MS, Kim SS, Willer BL, Tobias JD. Endotracheal tube Cuff pressures in the operating room of a Pediatric Hospital: a Quality Improvement Initiative. Pediatr Qual Saf. 2022;7(6):e619.
7. Holzman RS. Airway management. In: Davis PJ, Cladis FP, editors. Smith's anesthesia for infants and children. 9th ed. St. Louis, Missouri: Elsevier; 2017. p. 349–69.
8. Calder A, Hegarty M, Erb TO, von Ungern-Sternberg BS. Predictors of postoperative sore throat in intubated children. Paediatr Anaesth. 2012;22(3):239–43.
9. Hockey CA, van Zundert Aa, Paratz J. Does objective measurement of tracheal tube cuff pressures minimise adverse effects and maintain accurate cuff pressures? A systematic review and meta-analysis. Anaesth Intensive Care. 2016;44(5):560–70.
10. Krishna SG, Hakim M, Sebastian R, Dellinger HL, Tumin D, Tobias JD. Cuffed endotracheal tubes in children: the effect of the size of the cuffed endotracheal tube on intracuff pressure. Paediatr Anaesth. 2017;27(5):494–500.
11. Tobias JD, Schwartz L, Rice J, Jatana K, Kang DR. Cuffed endotracheal tubes in infants and children: should we routinely measure the cuff pressure? Int J Pediatr Otorhinolaryngol. 2012;76(1):61–3.
12. Wettstein RW, Gardner DD, Wiatrek S, Ramirez KE, Restrepo RD. Endotracheal cuff pressures in the PICU: incidence of underinflation and overinflation. Can J Respir Ther. 2020;56:1–4.
13. Ferenczy ED, Stoner MJ, Spencer SP, Gee SW, Scherzer DJ, Tobias JD. Elevated endotracheal tube cuff pressure in the pediatric emergency department. Int J Pediatr Otorhinolaryngol. 2018;113:289–91.
14. Kumar RDC, Hirsch NP. Clinical evaluation of stethoscope-guided inflation of tracheal tube cuffs. Anaesthesia. 2011;66(11):1012–6.
15. Borhazowal R, Harde M, Bhadade R, Dave S, Aswar SG. Comparison between two endotracheal tube Cuff inflation methods; just-seal Vs. Stethoscope-Guided. J Clin Diagn Res JCDR. 2017;11(6):UC01–3.
16. Al-Metwalli RR, Al-Ghamdi AA, Mowafi HA, Sadek S, Abdulshafi M, Mousa WF. Is sealing cuff pressure, easy, reliable and safe technique for endotracheal tube cuff inflation? A comparative study. Saudi J Anaesth. 2011;5(2):185–9.
17. Motoyama EK. Endotracheal intubation. In: Smith's Anesthesia for Infants and Children. 5th ed. Edited by Motoyama EK, Davis PJ: St Louis, MO, C.V. Mosby. 1990, p. 269–75.
18. Dullenkopf A, Schmitz A, Gerber AC, Weiss M. Tracheal sealing characteristics of pediatric cuffed tracheal tubes. Paediatr Anaesth. 2004;14(10):825–30.
19. Daniel WW, Cross CL, Biostatistics. A Foundation for Analysis in the Health Sciences. 10th ed. Hoboken, NJ: Wiley; 2013. p. 190.
20. Güneş K, Sever F, Özmert S. Determining optimal cuff volume for cuffed endotracheal tubes commonly used in pediatric patients: a prospective observational study. Saudi Med J. 2024;45(2):147–53.
21. Molla MT, Bizuneh YB, Nigatu YA, Melesse DY. High incidence rate of postoperative sore throat in intubated children at Northwest Amhara Comprehensive Specialized Hospitals, Ethiopia. A multicenter study. Front Pediatr. 2023;11:1037238.

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