



Effect of use of cuffed endotracheal tubes on the occurrence of postoperative extubation-related respiratory adverse events in pediatric patients with airway hypersensitivity: a retrospective cohort study

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Abstract

Purpose Whether endotracheal tube (ETT) configuration (cuffed or uncuffed) influences the occurrence of respiratory adverse events (RAEs) in patients at risk remains largely unknown. We investigated the effects of cuffed ETTs on RAE occurrence after extubation in pediatric patients with airway hypersensitivity.

Methods Children aged < 8 years with increased airway hypersensitivity (defined as upper airway symptoms, recent upper respiratory infection within 2 weeks, or a history of asthma) who underwent general endotracheal anesthesia with inhaled agents between January 2021 and December 2022 were included. We retrospectively examined the patients' background and intraoperative anesthesia conditions by comparing the cuffed and uncuffed ETT groups. Multiple logistic regression analysis was performed to estimate the association between ETT configuration (cuffed vs. uncuffed) and the occurrence of RAEs or respiratory interventions (laryngospasm, peripheral capillary oxygen saturation < 92%, oxygen supplementation, epinephrine inhalation, or reintubation) after extubation.

Results Cuffed ETTs were used in 163 patients and uncuffed ETTs in 143 patients. Apart from the frequency of upper airway surgery and intraoperative fluid balance, no significant differences in background characteristics were observed between the groups. RAEs after extubation were observed in 36 (22.1%) and 28 (19.6%) patients in each cuffed and uncuffed ETT groups. After adjusting for known RAE risk factors, no difference was observed in RAEs or respiratory interventions after extubation between both groups (odds ratio, 1.14; 95% confidence interval: 0.64, 2.06).

Conclusion In pediatric patients with airway hypersensitivity, the use of cuffed ETTs did not increase the occurrence of RAEs or respiratory interventions after extubation.

Keywords Airway hypersensitivity · Children · General anesthesia · Risk factors · Intubation

Introduction

In pediatric patients, the incidence of perioperative respiratory adverse events (RAEs), such as upper airway obstruction, oxygen desaturation, recurrent cough, bronchospasm,

laryngospasm, and apnea, is 15–20% [1]. The incidence of respiratory complications requiring prompt intervention (epinephrine inhalation, dexamethasone administration, supplementary oxygen, or reintubation) immediately after extubation is 3% [2]. Perioperative RAEs constitute a significant cause of severe complications, including reintubation, bradycardia, and cardiac arrest during pediatric anesthesia [1]. Therefore, prevention of these events is of utmost importance.

Several studies have been conducted to identify risk factors for perioperative RAEs in pediatric patients [3, 4]. These risk factors include upper airway symptoms, young age, family history of asthma, atopy, smoking, recent upper respiratory infections within 2 weeks, and upper airway

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surgery [5]. Using cuffed endotracheal tubes (ETTs) in pediatric patients has been a topic of discussion for an extended period. Traditionally, uncuffed ETTs have been frequently used for intubating children aged < 8 years because of the anatomical features of the pediatric larynx and the apprehension that inflating the cuff might harm the airway mucosa and result in subglottic stenosis [6]. The use of cuffed ETTs is believed to lead to acute respiratory complications, such as subglottic edema and stridor, after extubation.

Nonetheless, the use of uncuffed ETTs has disadvantages, including increased tube exchange rates, leakage around the tube, increased costs due to excessive anesthetic gas usage, increased environmental contamination, less reliable end-tidal carbon dioxide monitoring, and an increased risk of aspiration [7]. Recent research has revealed that using cuffed ETTs does not increase the incidence of postoperative RAEs, and textbooks and literature increasingly recommend the use of cuffed ETTs in children [8]. However, evidence supporting the use of cuffed ETTs excludes pediatric patients at a high risk of perioperative RAEs, and to the best of our knowledge, there is no specific report focusing on pediatric patients with airway hypersensitivity.

We hypothesized that, compared to uncuffed ETTs, cuffed ETTs would not increase the occurrence of RAEs after extubation in pediatric patients with airway hypersensitivity. To this end, we compared the occurrence of RAEs after extubation of cuffed versus uncuffed ETTs in pediatric patients with airway hypersensitivity. In addition, we performed multivariate analyses to investigate the association between the use of cuffed ETTs and the occurrence of RAEs after extubation in this patient population.

Methods

Ethical approval

This study was approved by the Ethics Committee of Osaka Women's and Children's Hospital (Ethics Committee Approval No. 1622) on March 28, 2023, which waived the requirement for written informed consent owing to the study's retrospective nature. The study complied with the principles of the Declaration of Helsinki (2013) and good clinical practice. This manuscript also adheres to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines.

Study design and participants

This retrospective observational cohort study was conducted in the operating room of the host institution between January 1, 2021, and December 31, 2022. The study included patients aged < 8 years with airway

hypersensitivity who underwent general anesthesia induction with ETT placement, and maintenance using inhaled anesthetics. Airway hypersensitivity was defined as upper airway symptoms such as a runny nose or cough, recent upper respiratory infections within 2 weeks, or a history of asthma. A history of asthma was self-reported by the patients' parents. The exclusion criteria were as follows: a temperature > 37.5 °C, patients already intubated or those returning to the intensive care unit intubated, cardiovascular surgery, cardiac catheterization procedures, and rapid sequence induction. We also excluded cases of total intravenous anesthesia given that propofol reduces the risk of RAEs [1]. We conducted a retrospective analysis of the patients' background and intraoperative anesthesia data by comparing the cuffed and uncuffed ETT groups.

Study outcomes and methodology

The primary outcome was the occurrence of RAEs or respiratory intervention after extubation of cuffed and uncuffed ETTs in pediatric patients with airway hypersensitivity. RAEs after extubation were defined as laryngospasm or peripheral capillary oxygen saturation (SpO_2) < 92%, while respiratory intervention included oxygen administration, epinephrine inhalation, or reintubation.

The following ETTs were used during the study period: cuffed ETTs—a Microcuff pediatric endotracheal tube (Avanos, Alpharetta, GA, USA) (internal diameter ≤ 4.5 mm) and Portex endotracheal tube (Smiths Medical Japan, Tokyo, Japan) (internal diameter ≥ 5.0 mm); uncuffed ETTs—Portex endotracheal tubes (all sizes); and RAE tubes—TaperGuard RAE tracheal tubes (Covidien Japan Inc., Tokyo, Japan). Tube sizes were selected based on Cole and Duracher's inner diameter formula (uncuffed ETTs: $4 + \text{age} \times 1/4$ mm, cuffed ETTs: $3.5 + \text{age} \times 1/4$ mm) [9]. Although the anesthesiologist in charge adjusted for the patients' physique, both cuffed and uncuffed ETTs were changed to smaller ETTs when there was resistance to tube advancement or no leakage. The leakage pressure was checked by applying a continuous positive pressure of 30 cmH_2O .

The following data were retrospectively collected from the patients' electronic medical and anesthesia records: age, height, weight, sex, underlying medical conditions, surgical procedure, preoperative infections, respiratory status, premedication, airway management method, ventilation method, anesthesia technique (general anesthesia/sedation, induction type: intravenous/inhalational, maintenance drugs), anesthesia duration, surgical duration, intraoperative fluid and blood balance, respiratory intervention after extubation, lowest SpO_2 , and laryngospasm.

Statistical analysis

Statistical analyses were performed using EZR 1.61 (Saitama Medical Centre, Jichi Medical University, Saitama, Japan). Multivariable regression models were used because there were several independent variables for the dependent variable. Characteristics were compared between the cuffed and uncuffed ETT groups using the Fisher exact test or Chi-square test for categorical variables and the Mann–Whitney *U* test for continuous variables. Multiple logistic regression analysis was performed using RAEs or respiratory interventions after extubation as dependent variables. We selected seven independent variables (use of cuffed ETTs, age < 4 years, American Society of Anesthesiologists physical status ≥ 2 , preoperative oxygen administration, midazolam use as premedication, upper airway surgery, and intraoperative fluid balance) with reference to the results of the univariate analysis and those of reported studies [3–6]. In this study, upper airway surgery included otolaryngology and oral surgeries. Otolaryngology surgeries mainly included adenotonsillectomy, while oral surgeries included palatoplasty, plastic surgery of the lip, and lingual frenectomy. Intraoperative fluid balance was treated as a continuous variable, while the other independent variables

were treated as binary categorical variables. Statistical significance was set at $p < 0.05$.

Results

A total of 320 patients met the criteria for inclusion in this study. Among them, 14 lacked cuff use data; consequently, the data of the remaining 306 patients were analyzed. Among these participants, cuffed ETTs were used in 163 patients (cuffed ETT group) and uncuffed ETTs in 143 patients (uncuffed ETT group) (Fig. 1). The distribution of the patients is shown in Table 1.

Univariate analysis revealed no significant differences in patient characteristics between the groups, except for the following two factors. The frequency of upper airway surgery was higher in the uncuffed ETT group than in the cuffed ETT group (28.0% [95% confidence interval {CI}: 20.8, 36.1] vs. 12.3% [95% CI: 7.7, 18.3], $p = 0.001$). The intraoperative fluid balance was lower in the uncuffed ETT group than in the cuffed ETT group (median [interquartile range]: 4.7 [3.8–6.2] mL/kg/h vs. 5.1 [4.1–7.1] mL/kg/h, $p = 0.03$) (Table 2). The incidence of RAEs or respiratory interventions after extubation was not

Fig. 1 Flowchart of participant selection

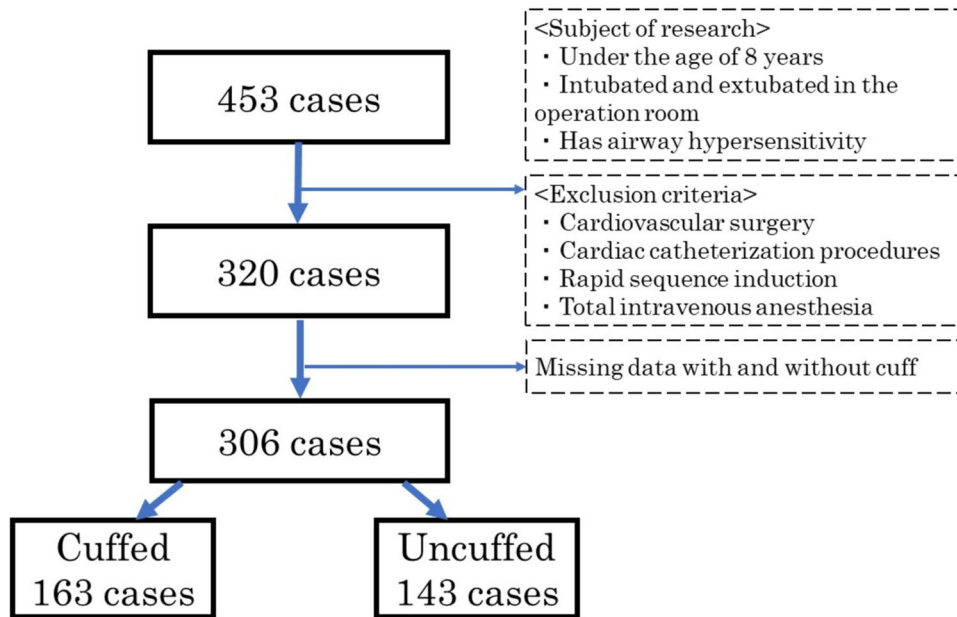


Table 1 Endotracheal tube use by age

Age	< 1 month	1–12 months	1–4 years	4–8 years	Total (n = 306)
Cuffed	0 (0)	17 (11.9)	79 (55.2)	47 (32.9)	143
Uncuffed	0 (0)	21 (12.9)	78 (47.9)	64 (39.3)	163

Values are expressed as numbers (%)

Table 2 Patient characteristics and anesthesia conditions

Variables	Uncuffed (<i>n</i> = 143)	Cuffed (<i>n</i> = 163)	<i>p</i> value
Age (years) 0–3	96 (67.1)	99 (60.7)	0.30
4–7	47 (32.9)	64 (39.3)	
Male sex	97 (67.8)	110 (67.5)	1
Height (cm)	84.2 [75.5, 102.8]	90.7 [77.0, 107.0]	0.30
Weight (kg)	11.3 [9.4, 16.0]	12.0 [9.2, 16.9]	0.48
ASA-PS 1	102 (71.3)	113 (69.3)	0.80
ASA-PS ≥ 2	41 (28.7)	50 (30.7)	
Upper airway symptoms	106 (74.1)	122 (74.8)	0.99
History of upper airway symptoms within 2 weeks	21 (14.7)	29 (17.8)	0.56
Asthma	23 (16.1)	25 (15.3)	0.98
Oxygen administration by nasal cannula	2 (1.4)	4 (2.5)	0.69
Oxygen administration by high-flow nasal cannula	0 (0.0)	1 (0.6)	
Midazolam use as premedication	124 (86.7)	141 (86.5)	1
Rapid induction	11 (7.7)	17 (10.4)	0.53
Number of intubation procedures ≥ 2	21 (14.7)	16 (9.8)	0.26
Upper airway surgery	40 (28.0)	20 (12.3)	0.01
Anesthesia time (min)	107 [80.0, 151.5]	108 [89.0, 174.0]	0.12
Intraoperative fluid balance (mL/kg/h)	4.7 [3.8, 6.2]	5.1 [4.1, 7.1]	0.03

Values are expressed as median [interquartile range] or number (%)

ASA-PS, American Society of Anesthesiologists physical status

Table 3 Post-extubation results

Outcome variables	Uncuffed (<i>n</i> = 143)	Cuffed (<i>n</i> = 163)	<i>p</i> value
RAEs* or respiratory interventions† after extubation	28 (19.6)	36 (22.1)	0.69
Laryngospasm	1 (0.7)	7 (4.3)	0.11
SpO ₂ < 92%	24 (17.6)	27 (18.5)	0.98
Respiratory intervention	9 (6.3)	21 (12.9)	0.08
Oxygen administration	9	21	
Epinephrine inhalation	0	0	
Reintubation	0	0	

Values are expressed as numbers (%)

*Respiratory adverse events were defined as laryngospasm or peripheral capillary oxygen saturation < 92%

†Respiratory interventions were defined as oxygen administration, epinephrine inhalation, or reintubation

significantly different between the groups (19.6% [95% CI: 13.4, 27.0] vs. 22.1% [95% CI: 16.0, 29.2], *p* = 0.69) (Table 3).

Multivariate logistic regression analysis revealed that using cuffed ETTs was not an independent predictor for the occurrence of RAEs or respiratory interventions after extubation after adjusting for young age (< 4 years), an American Society of Anesthesiologists physical status classification

Table 4 Association between tube type and occurrence of respiratory adverse events or respiratory interventions after extubation with analysis of confounders using multivariable logistic regression analysis

	OR (95% CI)	<i>p</i> value
Use of cuffed ETTs	1.14 (0.64, 2.06)	0.65
Age < 4 years	1.13 (0.62, 2.08)	0.68
ASA-PS ≥ 2	0.97 (0.51, 1.86)	0.93
Preoperative oxygen administration (by nasal cannula or high-flow nasal cannula)	25.10 (2.65, 238.00)	0.005
Midazolam use as premedication	0.98 (0.40, 2.39)	0.97
Upper airway surgery	1.24 (0.61, 2.54)	0.55
Intraoperative fluid balance (mL/kg/h)	1.00 (1.00, 1.01)	0.39

Respiratory adverse events were defined as laryngospasm or peripheral capillary oxygen saturation < 92%

Respiratory interventions were defined as oxygen administration, epinephrine inhalation, or reintubation

ASA-PS, American Society of Anesthesiologists physical status; CI, confidence interval; OR, odds ratio

score ≥ 2, midazolam use as a premedication, and upper airway surgery (odds ratio, 1.14 [95% CI: 0.64, 2.06], *p* = 0.65) (Table 4).

Discussion

This retrospective cohort study demonstrated that cuffed ETTs did not increase the incidence of RAEs or respiratory interventions after extubation in pediatric patients with airway hypersensitivity.

Although the use of cuffed ETTs is increasing in pediatric patients, uncuffed ETTs are still often the choice for neonates and infants. Young age is a risk factor for RAEs after extubation, with the risk decreasing by 8% for each additional year [3]. Therefore, age has been a major confounding factor in previous cohort studies on the use of cuffs. Most studies have performed analyses with fine age stratifications to eliminate this confounding factor [10, 11]. The cohort study by de Wit et al. [12] involved an analysis of 6796 cases, which allowed them to maintain a large sample size even when stratifying for age and performing a multivariate analysis adjusting for risk factors such as age and procedure.

More uncuffed ETTs were used in upper airway surgery because we used uncuffed RAE tubes in certain oral surgeries, such as cleft palate or lip repair. The bend of the RAE tubes was fixed at the mandibular median, and the depth of the cuffed RAE tube insertion from the bend was often insufficient. To ensure tube insertion depth, we used one-size-up uncuffed RAE tubes. In the multivariate analysis, upper airway surgery was included as an independent variable to account for potential confounding factors. We also found that the uncuffed ETT group had a significantly lower intraoperative fluid balance than did the cuffed ETT group. Therefore, we included intraoperative fluid balance as an independent variable.

The disadvantages of using uncuffed ETTs indicate the benefits of cuffed ETTs. Furthermore, there are benefits to using cuffed ETTs during the intraoperative phase. Sealing the airway with a cuff allows accurate capnograms and high internal airway pressure [13]. In addition, humidification is enhanced when a heat and moisture exchanger is used [14]. Early detection of airway problems is possible because the capnogram shows abnormal waveforms in patients with asthma [15] and an abnormal tracheal tube position. Even when secretions accumulate and cause atelectasis due to airway infection, or when thoracopulmonary compliance decreases during thoracoscopy or laparoscopy, it is possible to ensure ventilation volume and alveolar recruitment while caring for pressure injury. Changes, such as atelectasis, increased airway resistance, or those resulting from surgical procedures, could easily aggravate respiratory conditions in children. Therefore, the use of cuffed ETTs may be more effective in pediatric patients with airway hypersensitivity.

This study had some limitations. First, we could not evaluate all the RAEs that have been assessed in previous

studies—such as cough, stridor, and airway obstruction—because our study extracted data from anesthesia records and a proprietary anesthesia evaluation chart. Accordingly, the presence of laryngospasm was determined by the anesthesiologist in charge. Further, a decrease in SpO₂ does not necessarily indicate an RAE. For instance, central apnea can also lead to a reduction in SpO₂. Second, the severity of asthma was unclear because a history of asthma was self-reported by the patients' parents. Third, no prior sample size was calculated due to its retrospective nature. Fourth, some patients in the cuffed ETT group did not undergo cuff pressure measurements. Fifth, some patients were treated with drugs that affect the airway, such as steroids. Finally, since different brands of ETTs were used at our institution, we are unsure what role, if any, the cuff material may have played in our results. Further comprehensive prospective studies should be conducted to improve the generalizability of the results.

Conclusion

The use of cuffed ETTs did not increase the occurrence of RAEs or respiratory interventions after extubation in pediatric patients with airway hypersensitivity. Therefore, the use of cuffed ETTs could be considered given their advantages, even for pediatric patients with airway hypersensitivity.

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Data availability The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest The authors report no conflicts of interest.

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