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Assessment of early paediatric airway sequelae after using cuffed or uncuffed endotracheal tubes with ultrasound and flexible endoscopy

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ABSTRACT

Background: Cuffed tracheal tubes (CTT) emerge to prevent air leakage despite that most anaesthesiologists prefer the uncuffed tracheal tubes (UTT) in the paediatrics. Using recent tools for evaluation of endotracheal intubation sequelae may help to prevent airway injury and determine the appropriate type and size of endotracheal tube (ETT).

Purpose: The study aimed to detect the early airway changes after using CTT or UTT in paediatrics. Also, to find out the correlation between the endoscopic and ultrasonographic findings in detection of post intubation sequelae in paediatrics.

Methods: A prospective, randomized study was performed over 80 children aged from two to five years, scheduled for abdominal surgeries under the effect of general anaesthesia. Patients were assigned into two equal groups: Group C: CTT and Group U: UTT.

Results: There was less statistically significant ETT exchange in the group C ($p = 0.020$). No significant difference could be found as regard to the change in the subglottic diameter, the incidence of stridor, laryngospasm and croup, and the occurrence of airway injuries. There was a positive correlation between the change in the subglottic diameter and the prevalence of airway injuries ($P = 0.014$). The duration of the endotracheal intubation could not influence the incidence of neither the stridor nor the airway injuries in both groups.

Conclusion: There were no difference between the use of CTT or UTT in the paediatrics in terms of early airway changes. However, the rate of tube exchange is significantly lower when using CTT. A positive correlation is found between the endoscopic and ultrasound findings in the detection of post intubation sequelae in paediatrics. Short-term endotracheal intubation neither affects the incidence nor the severity of airway injuries. Using the external diameter of the endotracheal tube instead of the inner diameter is crucial for proper sizing in paediatrics.

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1. Introduction

Nearly 4.7% of the children had surgical procedures annually (average of 3.9 million) [1]. However, cuffed tracheal tubes (CTT) emerge for their special ability to prevent air leakage; most anaesthesiologists prefer the uncuffed tracheal tubes (UTT) especially in the paediatric age group based on the concept that the cuff may induce airway mucosal damage, tissue edema, and fibrosis, which could produce a life-threatening outcome [2,3].

Most of the researchers compared cuffed and uncuffed ETT using stridor as the primary end measure following extubation. Stridor was considered to represent all pertinent airway injuries. Moreover, no standard best practice for assessing laryngeal injury, dysphonia, or dysphagia after extubation has been established yet [4–7].

Recently, authors recommended endoscopic airway examination which demonstrated a comparable reliability to 4D-computed tomography examination of the upper airway. Also, ultrasonography is being used in a widespread manner in the evaluation of the airway [8].

Using recent tools for objective airway evaluation like flexible endoscopy and ultrasonography might help to prevent airway injury and determine the appropriate type and size of endotracheal tube.

2. Aim of the work

The primary outcome of this study was to detect the early airway changes after using cuffed or uncuffed endotracheal tubes in paediatrics.

The secondary outcome of this study was to find out the correlation of endoscopic and ultrasound findings in detection of post intubation sequelae in paediatrics.

3. Patient and methods

The study was authorized by the Alexandria Faculty of Medicine's Ethical Committee. A signed informed

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consent was obtained from parents or guardians. A prospective, randomized study was performed within the Hospitals of Alexandria University on 80 children aged from two to five years of both sexes, with physical status classification ASA I or II and scheduled for abdominal surgeries lasting from 2 to 4 hours under general anaesthesia with endotracheal intubation (Figure 1).

Evaluation of the patients preoperatively through proper history taking and clinical examination including COPUR score.

Patients with known airway anomalies, who expected difficult intubation (COPUR score > 12), more than one direct laryngoscopy trial to insert the endotracheal tube, were excluded.

Oral 0.5 mg/kg of midazolam was given 20–30 minutes prior to the procedure to facilitate parental separation.

When the patient entered the operating room, a multi-channel monitor had been secured to them. Inhalational induction of general anaesthesia using incremental concentrations of sevoflurane was given. Intravenous line was inserted and secured. Fentanyl 1 µg/kg and Rocuronium 0.5 mg/kg were given intravenously (IV).

The transverse subglottic diameter was estimated by a secondary investigator using a high-resolution B mode ultrasonography. The measured subglottic diameter was used to determine the size of the ETT that was used for intubation. In group C, patients received a CTT 2 mm less than the measured subglottic diameter. In group U, patients received an UTT 1 mm less than the measured subglottic diameter [9–11].

A proper sized lubricated standard laryngeal mask airway (LMA) was inserted. A flexible endoscope (KARL STORZ ENDOSKOPE, Germany) was inserted through the previously inserted LMA to examine the airway to exclude congenital anomalies or previous injuries. The LMA was removed, and tracheal intubation was performed using direct laryngoscope through the oral route.

For the CTTs, cuff pressure manometer was used to guide the inflation of the cuff (15–20 cm H_2O).

If the ETT had an excessive air leak that prevented appropriate ventilation or if there was no air leak present at a 20 cm H_2O inflation pressure, it was determined that it was either too tiny or too large, and the patient was excluded.

At the end of surgery, the patient was extubated under muscle relaxant effect and lubricated LMA was reinserted. The transverse subglottic diameter was estimated. Flexible endoscope was introduced through the previously inserted LMA to detect recent airway injuries.

Muscle relaxant was reversed, the LMA was removed awake, and the patient was transferred to the PACU.

4. Measurements

Age, gender, and bodyweight (kg) of the patient; operation performed (type and duration); COPUR score of the patient's airway; and the subglottic

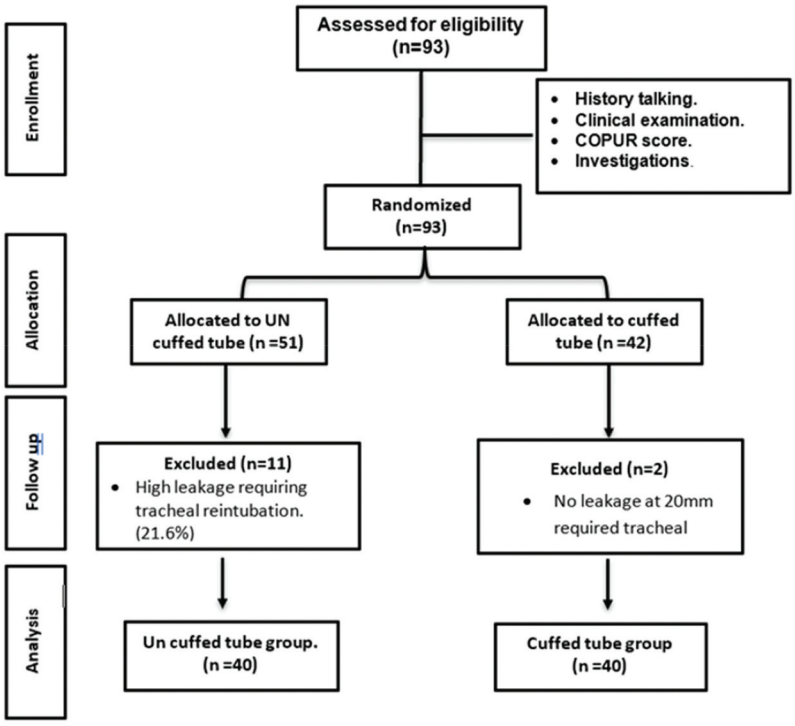


Figure 1.

diameter were determined after induction of general anaesthesia and just after extubation.

Airway injuries assessment was done through flexible endoscopy after extubation and was classified into four groups: no injury, mild injuries (hyperemia, edema less than 50% of subglottic diameter and epiglottic edema), moderate injuries (edema more than 50% of subglottic diameter, hemorrhage, mucosal lacerations, and ulcers), and severe injuries (cricoid splitting, tracheal tear, vocal cord tear and arytenoid cartilage dislocation).

Presence of laryngospasm, croup, or stridor up to 24 hours of extubation and the incidence of unplanned extubations were found.

5. Statistical analysis of the data

The IBM SPSS software package version 20.0 was used to analyze the data. Number and percentage were used to describe qualitative data, while the range (minimum and maximum), mean, standard deviation, and median were used to characterize quantitative data. The 5% level was used to determine the significance of the obtained data.

6. Results

There were 42 patients in group C. Two patients were excluded due to the very large tube size resulting in no leakage at 20 mm Hg (4.8%) inspiratory pressure so tracheal reintubation was done to place a proper size ETT, while in group U, there were 51 patients, 11 patients (21.6%) were excluded due to high leakage so tracheal reintubation was done by placing a proper size ETT (Figures 1,2).

Statistical analysis showed no significant differences between the two groups: age, gender, weight (Table 1), surgical intervention (Table 2) and its duration.

In group C, the COPUR score ranged from 5 to 11 with a mean value of 7.70 ± 1.44; meanwhile, in group U, the duration of the operations performed ranged

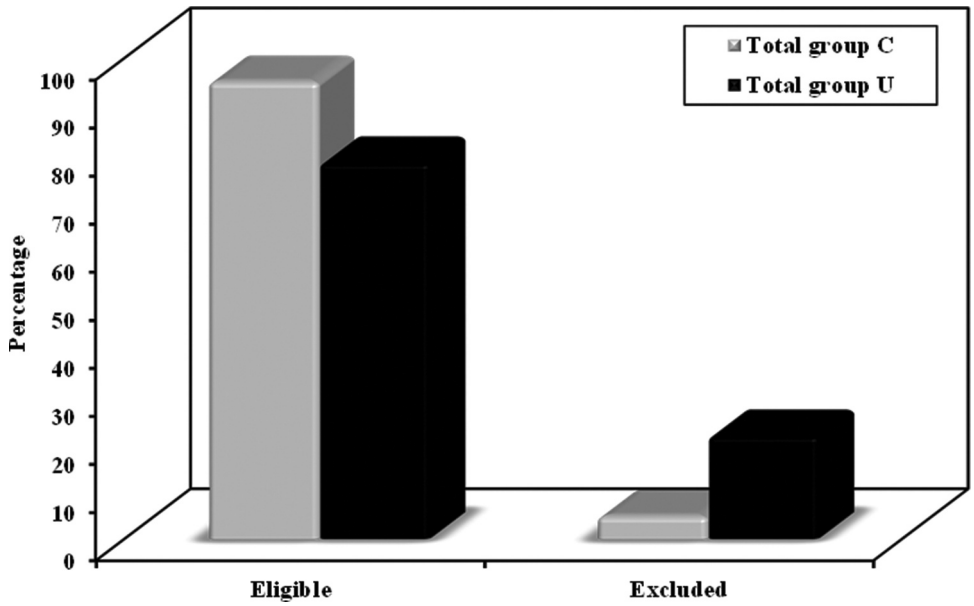


Figure 2.

Table 1. Relation between change in the subglottic diameter with the incidence of stridor and airway injuries in each group.

			Change in the subglottic diameter			
		No.	Mean ± SD.	Median (Min. – Max.)	U	p
Airway injuries	**Cuffed**					
	No	**37**	0.02 ± 0.10	0.0 (−0.10–0.30)	10.50*	0.014*
	Yes (Mild)	**3**	0.20 ± 0.10	0.20 (0.10–0.30)		
	Un Cuffed					
	No	**36**	0.03 ± 0.06	0.0 (0.0–0.20)	24.00*	0.028*
	Yes (Mild)	**4**	0.28 ± 0.30	0.20 (0.0–0.70)		
Stridor	**Cuffed**					
	No	**39**	0.03 ± 0.10	0.0 (−0.10–0.30)	–	–
	Yes	**1**		0.30		
	Un Cuffed					
	No	**37**	0.04 ± 0.07	0.0 (0.0–0.20)	29.5	0.192
	Yes	**3**	0.27 ± 0.38	0.10 (0.0–0.70)		

SD: Standard deviation; U: Mann Whitney test.
p: *p* value for comparing between the different categories. *: Statistically significant at p ≤ 0.05.

Table 2. Inner and outer diameters of the used endotracheal tubes, cooperative analysis.

Tube size	Cuffed ($n = 40$)	Un cuffed ($n = 40$)	t	p
Outer diameter				
Mean ± SD.	5.42 ± 0.47	6.45 ± 0.51	9.331*	<0.001*
Median (Min. – Max.)	5.60 (5.0–6.30)	6.20 (5.50–7.60)		
Inner diameter				
Mean ± SD.	3.84 ± 0.36	4.68 ± 0.37	10.224*	<0.001*
Median (Min. – Max.)	4.0 (3.50–4.50)	4.50 (4.0–5.50)		

SD: Standard deviation; t: Student t-test.
p: *p* value for comparing between the two studied groups.
Statistically significant at $p \leq 0.05$.

from 5 to 11 with a mean value of 7.58 ± 1.53. The results showed no significant difference as regard to the the COPUR score (*p* value = 0.708).

In group C, the change in the subglottic diameter ranged from −0.1 to 0.3 with a mean value of 0.03 ± 0.11 mm, while in group U the change in the subglottic diameter ranged from 0.0 to 0.7 with a mean value of 0.05 ± 0.12 mm. No statistical significant difference can be detected between the two groups as regard to the change in the subglottic diameter (*p* value = 0.442). (Figure 3)

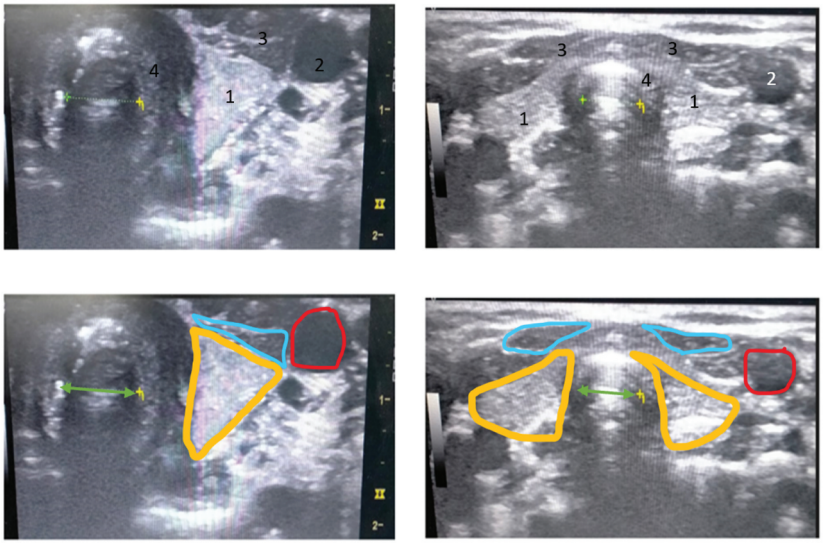
In group C, one (2.5%) patient was complicated by stridor, while in group U three (7.5%) patients were complicated by stridor (p-value = (0.615). In group C, three (7.5%) patients were complicated by mild airway injuries, while in group U, four (10.0%) patients were complicated by mild airway injuries. No significant difference can be detected between the two groups regarding the incidence of neither stridor nor airway injuries. In both groups no patient showed unplanned extubation. (Figure 4)

There was a positive correlation between the change in the subglottic diameter and the occurrence of airway injuries in the cuffed and uncuffed groups (*P* = 0.014), while there was no relation between the change in the subglottic diameter and the occurrence of stridor in both groups. Also, no relation detected between the duration of endotracheal intubation with the incidence of neither stridor nor airway injuries in both groups (Table 1).

In group C, the range of the inner diameter of the endotracheal tube ranged from 3.5 to 4.5 with a mean value of 3.84 ± 0.36 mm, while in group U, the range of the inner diameter of the endotracheal tube ranged from 4 to 5.5 with a mean value of 4.68 ± 0.37 mm. (*P* = 0.001) (Table 2).

7. Discussion

As regarded to the number of excluded patients due to tube exchange to overcome the excessive air leakage or very large tube size resulting in no leakage at 20 cm H2O, there was significant lower rate of tube exchange in group C (2 patients) than in group U (11 patients). It can be explained by the presence of the cuff which can be easily modified to establish a good seal at 20 cmH2O without the need to exchange the TT.



1. Thyroid gland.
2. Carotid artery.
3. Strap muscles.
4. Subglottic diameter.

- Orang……Thyroid gland.
- Red…….... Carotid artery.
- Blue……Strap muscles.
- Green……. Subglottic diameter.

Figure 3.

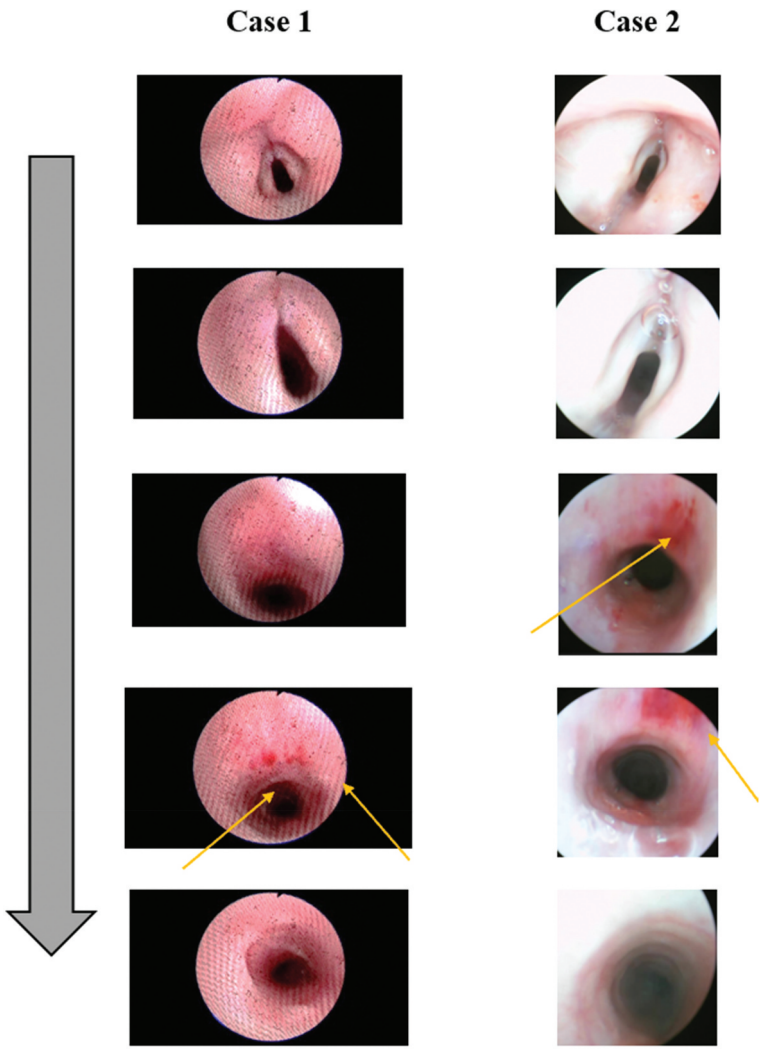


Figure 4.

These results coincide with De Orange et al. [12] in systematic review included three trials (2804 children), where endotracheal tube exchange rate was statistically significantly lower in the cuffed group.

Comparable outcomes were reported by Khine et al. [13], in a study on the paediatric age group up to 8 years of age (total number = 488) requiring general anaesthesia and tracheal intubation. In the uncuffed tube group, there were significantly more patients who needed tracheal reintubation in order to insert an appropriate-sized tube (54 of 237 patients) than in the cuffed tube group (3 of 251 patients).

In contrast, Thomas et al. [14] conducted a single-center cohort study. The rate of changing the endotracheal tubes to the proper size did not differ significantly. However, the selected population (infants <3 kg) and the subsequent very small internal tracheal diameter can explain that result.

In concern to the change in the subglottic diameter and the occurrence of stridor, croup or laryngeal spasm, no statistically significant difference between the two groups could be found.

Many results in agreement with these results could be found in the former literature review, for example, Dreakers et al. [15], in a study over 282 sequential endotracheal intubations in the PICU. There was no statistical difference found between the two groups [13,16–21].

In contrast, Veder et al. [21], in a study over 150 infants. Although there was no cuff pressure monitoring, the usage of cuffed ETT was linked to a statistically higher risk of airway injuries and subsequently high incidence of stridor.

In the terms of airway injuries, the current study showed only mild airway injuries after extubation (8.75%) in both groups with no significant difference in between, despite the significant statistical difference found regarding the outer diameter of the ETT. It can be justified by good monitoring of cuff pressure (below 20 cmH_2O) and unified anaesthetist performing the endotracheal intubation.

In agreement with that Brodsky et al. [22], in a systematic review, concluded that grade I injuries were the most common occurring airway complication

found with a prevalence ranging (9– 84%) across 9 (45%) studies.

On the other side, many studies [23–25] counter these results. Schweiger et al. [26] in a study over infants where flexible laryngoscopy was done after extubation. The prevalence of subglottic stenosis was 11.38% and was associated with history of severe airway injuries during extubation.

However, most of the former studies [23–26] were performed within the intensive care units, where many factors can influence the prevalence of airway injuries, for example, the prolonged time of intubation (more than 24 hours) compared to (2 to 4 hours) the current study, usually no proper cuff pressure monitoring is used and no proper monitoring of the sedation level or the degree of muscle relaxation is used and that most of endotracheal intubation done in emergency situations increasing the risk of iatrogenic airway trauma.

In the present research, an obvious difference between the two groups as regard the inner diameter of the TT is demonstrated. Consecutively and according to Hagen – Poiseuille equation for laminar flow, it is expected that the work of breathing is higher in the CTT group than the UTT group. However, in the setting of general anaesthesia, the patient is already on a controlled mechanical ventilation which in turn alleviates the work of breathing resulting from the small inner diameter of the endotracheal tube [27].

Also, there was a positive correlation between the change in the subglottic diameter before and after the intubation process and the incidence of airway injuries discovered through the endoscopic examination indicating that ultrasonographic measured subglottic diameter is a sensitive non-invasive objective tool for early detection of airway injuries after endotracheal intubation.

In concordance with that Kundra et al [28], performed research about perioperative use of ultrasound in anaesthesia especially in the field of airway assessment. It was concluded that ultrasonographic examination of the airway has become the first noninvasive and simple airway assessment tool with comparable sensitivity to computed tomography and magnetic resonance scanning.

The current study cannot demonstrate any relation between the duration of endotracheal intubation with neither the incidence of airway injuries nor the incidence of stridor. It might be justified by the selected short-term endotracheal intubation period (surgeries lasting from 2 to 4 hours) and the adopted proper cuff monitoring.

In concordance with that, Veder et al [21] in a study to detect the relation between prolonged intubation and post-extubation stridor. Statistical analysis of the derived data did not demonstrate any significant relation between the duration of endotracheal intubation and post-extubation stridor despite that the data collected showed a trend towards significance in developing stridor after intubation for more than a week ($P = 0.05$).

However, Brodsky et al. [22] in a systematic review including 21 studies and 6140 patients demonstrated that the duration of endotracheal intubation was a main risk factor in developing laryngeal injury especially if the duration of endotracheal intubations exceeds 2 hours.

8. Conclusion

(1) No difference is found between the usage of cuffed or uncuffed tracheal tubes in the paediatric age group in terms of early airway changes. However, the rate of tube exchange is significantly lower when using cuffed endotracheal tubes.
(2) There is a positive correlation between the endoscopic and ultrasound findings in the detection of post-intubation sequelae in paediatrics.
(3) Short-term endotracheal intubation (2 to 4 hours) neither affects the incidence nor the severity of paediatric airway injuries.
(4) Cuffed endotracheal tubes cause high work of breathing due to the smaller inner diameter compared to the uncuffed endotracheal tubes that can be compensated by using automatic tube compensation.
(5) Using the external diameter of the endotracheal tube instead of the inner diameter is crucial for proper sizing especially in the paediatrics.

Disclosure statement

The authors report that there are no competing interests to declare.

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References

[1] Rabbitts JA, Groenewald CB, Cravero J. Epidemiology of pediatric surgery in the United States. Paediatr Anaesth. 2020;30(10):1083–1090. doi: 10.1111/pan.13993
[2] Orliaguet GA, Renaud E, Lejay M, et al. Postal survey of cuffed or uncuffed tracheal tubes used for paediatric tracheal intubation. Paediatr Anaesth. 2001;11(3):277–281. doi: 10.1046/j.1460-9592.2001.00689.x

[3] Tobias JD, Morton N. 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. doi: 10.1111/pan.12528
[4] Holzki J, Laschat M, Puder C. Stridor is not a scientifically valid outcome measure for assessing airway injury. Pediatric Anesthesia query. 2009;19 (1):180–197. doi: 10.1111/j.1460-9592.2009.03004.x
[5] Benjamin B, Holinger LD. Laryngeal complications of endotracheal intubation. Ann Otol Rhinol Laryngol. 2008;117(9):2–20. doi: 10.1177/000348940811705901
[6] Benjamin B. Prolonged intubation injuries of the larynx: endoscopic diagnosis, classification, and treatment. Ann Otol Rhinol Laryngol Suppl. 1993;102 (4_suppl):1–15. doi: https://doi.org/10.1177/00034894931020s401
[7] Sadoughi B, Fried MP, Sulica L, et al. Hoarseness evaluation: a transatlantic survey of laryngeal experts. Laryngoscope. 2014;124(1):221–226. doi: 10.1002/lary.24178
[8] Lam AS, Bindschadler MD, Evans KN, et al. Accuracy and reliability of 4D-CT and flexible laryngoscopy in upper airway evaluation in robin sequence. Otolaryngol Head Neck Surg. 2022;166(4):760–767. doi: 10.1177/01945998211027353
[9] Sutagatti JG, Raja R, Kurdi MS. Ultrasonographic estimation of endotracheal tube size in paediatric patients and its comparison with physical indices based formulae: a prospective study. J Clin Diagn Res. 2017;11(5): Uc05–uc08. doi: 10.7860/jcdr/2017/25905.9838
[10] Rafiq M, Wani TM, Moore-Clingenpeel M, et al. Endotracheal tubes and the cricoid: is there a good fit? Int J Pediatr Otorhinolaryngol. 2016;85:8–11. DOI:10.1016/j.ijporl.2016.03.016
[11] Altun D, Orhan-Sungur M, Ali A, et al. The role of ultrasound in appropriate endotracheal tube size selection in pediatric patients. Paediatr Anaesth. 2017;27(10):1015–1020. doi: 10.1111/pan.13220
[12] De Orange FA, Andrade RG, Lemos A, et al. Cuffed versus uncuffed endotracheal tubes for general anaesthesia in children aged eight years and under. Cochrane Database Syst Rev. 2017;11(11):Cd011954. doi: 10.1002/14651858.CD011954.pub2
[13] Khine HH, Corddry DH, Kettrick RG, et al. Comparison of cuffed and uncuffed endotracheal tubes in young children during general anesthesia. Anesthesiology. 1997;86 (3):627–631. doi: 10.1097/00000542-199703000-00015
[14] Thomas RE, Rao SC, Minutillo C, et al. Cuffed endotracheal tubes in infants less than 3 kg: a retrospective cohort study. Paediatr Anaesth. 2018;28(3):204–209. doi: 10.1111/pan.13311
[15] Deakers TW, Reynolds G, Stretton M, et al. Cuffed endotracheal tubes in pediatric intensive care. J Pediatr. 1994;125(1):57–62. doi: 10.1016/s0022-3476(94)70121-0
[16] Newth CJ, Rachman B, Patel N, et al. The use of cuffed versus uncuffed endotracheal tubes in pediatric intensive care. J Pediatr. 2004;144(3):333–337. doi: 10.1016/j.jpeds.2003.12.018
[17] Chen L, Zhang J, Pan G, et al. Cuffed versus uncuffed endotracheal tubes in pediatrics: a meta-analysis. Open Med (Wars). 2018;13:366–373. doi: 10.1515/med-2018-0055
[18] Weiss M, Dullenkopf A. Cuffed tracheal tubes in children: past, present and future. Expert Rev Med Devices. 2007;4(1):73–82. doi: 10.1586/17434440.4.1.73
[19] Bibl K, Pracher L, Küng E, et al. Incidence of post-extubation stridor in infants with cuffed vs. Uncuffed endotracheal tube: a retrospective cohort analysis. Front Pediatr. 2022;10:864766. DOI:10.3389/fped.2022.864766
[20] de Wit M, Peelen LM, van Wolfswinkel L, et al. The incidence of postoperative respiratory complications: a retrospective analysis of cuffed vs uncuffed tracheal tubes in children 0-7 years of age. Paediatr Anaesth. 2018;28(3):210–217. doi: 10.1111/pan.13340
[21] Veder LL, Joosten KFM, Schlink K, et al. Post-extubation stridor after prolonged intubation in the pediatric intensive care unit (PICU): a prospective observational cohort study. Eur Arch Otorhinolaryngol. 2020;277 (6):1725–1731. doi: 10.1007/s00405-020-05877-0
[22] Brodsky MB, Levy MJ, Jedlanek E, et al. Laryngeal injury and upper airway symptoms after oral endotracheal intubation with mechanical ventilation during critical care: a systematic review. Crit Care Med. 2018;46 (12):2010–2017. doi: 10.1097/ccm.0000000000003368
[23] Dillier CM, Trachsel D, Baulig W, et al. Laryngeal damage due to an unexpectedly large and inappropriately designed cuffed pediatric tracheal tube in a 13-month-old child. Can J Anaesth. 2004;51(1):72–75. doi: 10.1007/bf03018551
[24] Shinn JR, Kimura KS, Campbell BR, et al. Incidence and outcomes of acute laryngeal injury after prolonged mechanical ventilation. Crit Care Med. 2019;47 (12):1699–1706. doi: 10.1097/ccm.0000000000004015
[25] Manica D, Schweiger C, Maróstica PJ, et al. Association between length of intubation and subglottic stenosis in children. Laryngoscope. 2013;123(4):1049–1054. doi: 10.1002/lary.23771
[26] Schweiger C, Marostica PJ, Smith MM, et al. Incidence of post-intubation subglottic stenosis in children: prospective study. J Laryngol Otol. 2013;127(4):399–403. doi: 10.1017/s002221511300025x
[27] Longnecker D, Mackey S, Newman M, et al., Anesthesiology. 3rd New York: McGraw-Hill Education. 2018.
[28] Kundra P, Mishra SK, Ramesh A. Ultrasound of the airway. Indian J Anaesth. 2011;55(5):456–462. doi: 10.4103/0019-5049.89868