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Original Article

Comparison of Various Cuff Inflation Techniques for Microcuff Tubes in Pediatric Patients Undergoing Surgery under General Anesthesia

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Abstract

Background: In pediatric airway management, the primary goal of endotracheal cuff inflation techniques is to create an adequate tracheal seal allowing positive pressure ventilation and decreasing the risk of gastric aspiration without exerting excessive pressure on the tracheal wall. In this study, we assessed the safety and reliability of the sealing pressure of the microcuff pediatric tracheal tube's cuff in the prevention of the post-extubation airway complications compared with the other inflation techniques.

Materials and Methods: 90 pediatric patients of either sex, aged 3–8 years of American Society of Anaesthesiologists physical Status I-II, scheduled for surgeries of <2 h duration, were randomly allocated to Group C (n = 30) in which the patient's tracheal tube cuff was aspirated to the maximum and then inflated with air to attain a cuff pressure of 20 cm of water, Group S (n = 30) in which the patient's tracheal tube cuff was completely aspirated and then inflated with air during the inspiratory phase of mechanical ventilation of the patients to prevent air leak when the peak airway pressure was 20 cm of water and Group F (n = 30) in which the patient's tracheal tube cuff was aspirated completely and then inflated to an adequate pressure using finger estimation. The incidence and severity of post-operative pharyngo-laryngeal morbidity was assessed postoperatively.

Results: Mean cuff pressures and the volume of air needed to fill the cuff were significantly lower in Group S as compared to Group C and Group F. Total incidence of sore throat in the study was 31.11%. Highest incidence was observed in the 4th h. Statistically significant difference was seen when Group C and Group S were compared with Group F (P < 0.05). On comparing Group S and Group F, the incidence of post-operative sore throat was reduced in Group S and was statistically significant at 2, 4, 8, 12, and 24 h postoperatively (P < 0.05). Cough, dysphagia, post-extubation stridor, and hoarseness were also reduced in Group S. Seven out of 30 patients in the control group developed tracheal leak.

Conclusion: We concluded that sealing cuff pressure technique is safer than the other two techniques in preventing post-extubation complications.

Key words: Finger estimation, Microcuff pediatric tracheal tube, Sealing cuff pressure

INTRODUCTION

Before 1940, endotracheal intubations in pediatric population were considered as potentially dangerous and traumatic invasive procedures.[1] In 1960, polyvinyl chloride incorporated uncuffed endotracheal tubes were introduced which have been the standard for tracheal intubation in infants and children ever since. At present, endotracheal intubation is regularly done for critical care management in children for maintenance of oxygenation, for airway protection, pulmonary toileting, and ease of positive pressure ventilation as well as in the conduct of anesthesia.[2]

Pediatric airway management is critical in routine anesthesia practice. One of the more recent changes that have taken place in the clinical practice of pediatric anesthesia has been the transition from the routine use

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of uncuffed to cuffed endotracheal tubes but the general use of cuffed tubes in children aged below 8–10 years has been considered inappropriate largely due to the differences in the airway anatomy of adult and pediatric population.[3] The major concern regarding the use of an inflatable cuff in the pediatric population today is the potential risk of tracheal mucosal ischemia due to cuff hyperinflation[4] which can lead to sore throat, loss of cilia in tracheal rings, tracheal mucosa pressure necrosis, scarring, and subglottic stenosis,[5,6] which is the most common cause of post-extubation upper airway obstruction. This resulted in the introduction of microcuff (high-volume and low-pressure cuff) endotracheal tubes in the pediatric population. Cuff pressure monitoring devices have been proven to reliably measure cuff pressures and to prevent hyperinflation in cuffed endotracheal tubes.[7] Microcuff endotracheal tubes vary from the normal cuffed ones in that the cuffs are made of thinner material, fixed closer to the tip of the endotracheal tube and are cylindrical in shape which leads to sealing of the pediatric upper airway at the lower pressures compared with traditional cuffs, thus reducing the risk of ischemic mucosal damage.[8]

In our study, we used three different ways of cuff inflation, that is, endotracheal tube cuff of the patient's in the control group was aspirated as much as possible and then inflated with air to achieve a cuff pressure of 20 cm of water, in the sealing group patient's endotracheal tube cuff was fully aspirated and then inflated with air to prevent air leaks during the inspiratory phase of mechanical ventilation of the patients when the peak airway pressure was 20 cm of water and in the finger group patient's endotracheal tube cuff was aspirated as much as possible and then inflated to a suitable pressure using finger estimation. Hence, in this study, we assessed the safety and reliability of the sealing pressure of the Microcuff pediatric tracheal tube's cuff in the prevention of post-operative pharyngolaryngeal morbidity (post-extubation cough, stridor, sore throat, dysphagia, and hoarseness) compared with the other inflation techniques.

MATERIALS AND METHODS

After approval from Institutional Ethics Committee of Government Medical College Amritsar, a prospective controlled, randomized, double-blinded, comparative study was conducted in a total of 90 children undergoing surgery under general anesthesia of either sex male/female in the age group of 3–8 years of American Society of Anaesthesiologists Grades I or II who needed oro-tracheal intubation for planned controlled ventilation during the elective surgical procedures of up to 2 h. Children having oropharyngeal pathology, suspected difficult intubation or airway anomalies, planned post-operative ventilation in the ICU, a recent attack (within 6 weeks) of the upper respiratory tract infection, and history of bronchial asthma were excluded from the study. Informed consent from parents/guardians of each and every patient enrolled in the study was taken.

Study Design

This was a prospective double-blinded randomized clinical study which included a total of 90 children between the age group of 3–8 years. Sample size was selected after consulting the statistician and taking into account the parameters such as incidence of sore throat, tracheal leak, post-extubation cough, stridor, hoarseness, dysphagia, and also data based on the previous studies to get the power of study >85%. Each group included 30 patients undergoing surgery under general anesthesia using Microcuff pediatric tracheal tubes.

Randomization was done by computer generated randomization number list. The Microcuff was inflated using different techniques by the anesthesiologist who was not a part of the study and post-extubation morbidity was studied by different anesthesiologist; thereby ensuring double blinding.

Technique

GROUP C: Control group (n = 30):

In this group, the patient's tracheal tube cuff was aspirated to the maximum and then inflated with air to attain a cuff pressure of 20 cm of water.

GROUP S: Sealing group (n = 30):

In this group, the patient's tracheal tube cuff was completely aspirated and then inflated with air during the inspiratory phase of mechanical ventilation of the patients to prevent air leaks when the peak airway pressure was 20 cm of water.

GROUP F: Finger group (n = 30):

In this group, the patient's tracheal tube cuff was aspirated completely and then inflated to an adequate pressure using finger estimation [Figure 1].

All the patients received pre-medication with injection (inj.) Glycopyrrolate 0.01 mg/kg intravenously (IV) and inj. fentanyl 2 mg/kg IV before induction of anesthesia and were pre-oxygenated for 3 min (min). Then, the patient was induced with inj. propofol 2.5 mg/kg IV and endotracheal intubation was done by senior anesthesiologist having experience of 3 years after aiding with inj.

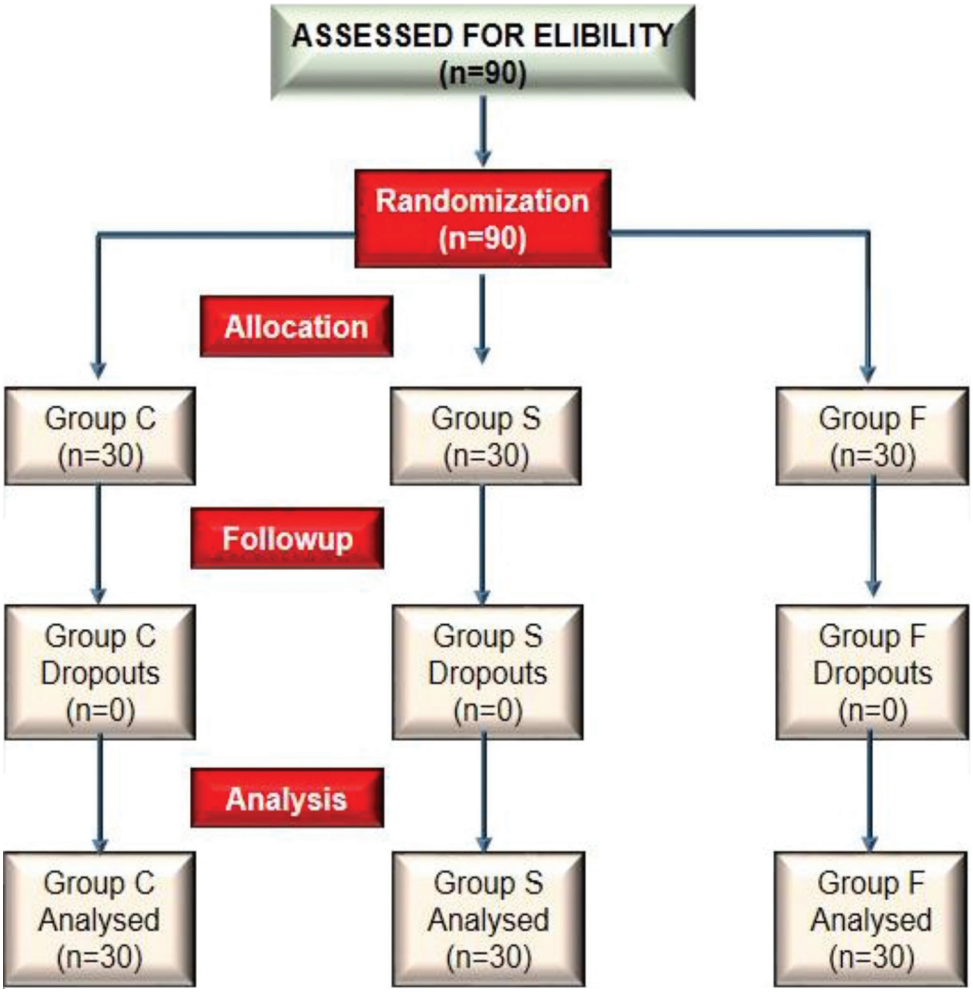


Figure 1: Consort diagram

vecuronium bromide 0.08 mg/kg IV, using oral Microcuff pediatric tracheal tube. The size of the tubes which were used was calculated according to the Khine's *et al*. formula (ID = age/4+3).

The volume of air which was used to fill the cuff as depicted by the cuff pressure was recorded using the hand held cuff pressure gauge in each group. The tracheal leakage was noted both by observing the difference between inspiratory and expiratory tidal volume and by audible technique. Controlled mechanical ventilation was adapted to maintain end-tidal carbon dioxide at 30–35 mm Hg. Maintenance of anesthesia was done with sevoflurane (2% end-tidal), 30% oxygen in the air and with inj. vecuronium bromide 0.01 mg/kg IV. Additional boluses of inj. fentanyl (2 mg/kg/body weight) IV were administered to maintain surgical anesthesia. The patient was ventilated with 100% oxygen after discontinuation of sevoflurane and the pharynx was suctioned gently on completion of surgery. Inj. neostigmine 0.05 mg/kg IV and inj. glycopyrrolate 0.01 mg/kg IV were used to reverse the residual muscle paralysis. The trachea of the patient was extubated after fulfilling the following criteria: (1) Efficient spontaneous respiration and (2) fully awake patient. The duration of laryngoscopy, duration of surgery, and post-extubation stridor (new high pitched inspiratory sound within 1 h of extubation) was recorded. Post-extubation coughing was recorded and graded based on the modified four point scale as follows:

Grade 0 = No cough.
Grade 1 = (Mild) single bout of cough.
Grade 2 = (Moderate) more than one episode of unsustained (≤5 s) coughing.
Grade 3 = (Severe) sustained (>5 s) hours of coughing.

Post-operative sore throat (POST) was graded on a four-point scale (0–3).

0 = No sore throat.
1 = Mild sore throat (complained of sore throat only on asking).
2 = Moderate sore throat (complained of sore throat on his/her own).

3 = Severe sore throat (change of voice or hoarseness, associated with throat pain).

Inj. fentanyl (2 mg/kg/body weight) was used for rescue analgesia when visual analogue scale (VAS) >4 in all the groups. The same blinded anesthesiologist recorded coughing, sore throat, and hoarseness using VAS (VAS: 0–10 cm) at various intervals up to 24 h after tracheal extubation.

We used Aldrete score of nine out of ten for discharge of the patient from recovery room. Aldrete's score also known as post anesthetic discharge scoring system is a medical scoring system that measures the recovery after anesthesia which includes consciousness, respiration, activity, oxygen saturation, and blood circulation (blood pressure) which were observed for 24 h postoperatively.

Statistical Analysis

Raw data were recorded in a Microsoft Excel spread sheet and analyzed using Statistical Package for the Social Sciences (SPSS version 24.00 Armonk, NY: IBM Corp.). The continuous data were presented as mean with standard deviation (mean ± SD). Number of patients and/or percentage of cases expressed as discrete categorical data. Categorical variables were analyzed using Chi-square test. Normally distributed continuous variables were analyzed using independent sample *t*-test. The *P* value was determined finally to evaluate the levels of significance. $P > 0.05$ was considered non-significant, $P = 0.01–0.05$ was considered significant, and $P < 0.001$ was considered highly significant. The results were then analyzed and compared to the previous studies.

RESULTS

Ninety patients were enrolled in the present study in three different groups. No patients were lost in follow-up and excluded from analysis. All the three groups were comparable in terms of demographic parameters.

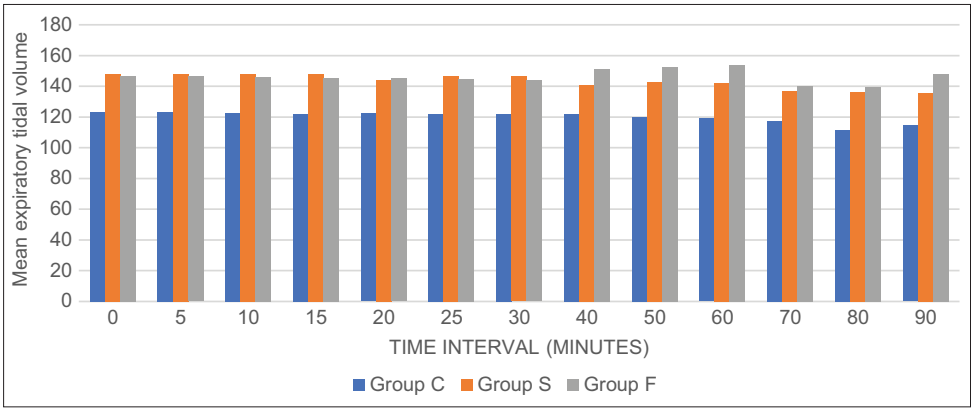
The mean expiratory tidal volume was measured intraoperatively at 0, 5, 10, 15, 20, 25, and 30 min and then at an interval of every 10 min till the end of the surgery. Seven out of 30 patients in the control group developed tracheal leak, that is, incidence of 23.33%. There was zero incidence of tracheal leak in the sealing and the finger group. The difference between mean expiratory tidal volume at all the measured intervals was statistically significant ($P < 0.05$) between Groups C and S, and Groups C and F but was non-significant ($P > 0.05$) between Groups S and F [Graph 1].

The mean cuff pressure that also depicted the volume of air required to fill the cuff was measured intraoperatively at 0, 5, 10, 15, 20, 25, and 30 min and then at an interval of every 10 min till the end of the surgery. The mean cuff pressure and the volume of air to fill the cuff were significantly lower in the Group S as compared to the Group C ($P < 0.05$), whereas their values were significantly high ($P < 0.05$) in the Group F when compared to both the Group C and Group S [Graph 2].

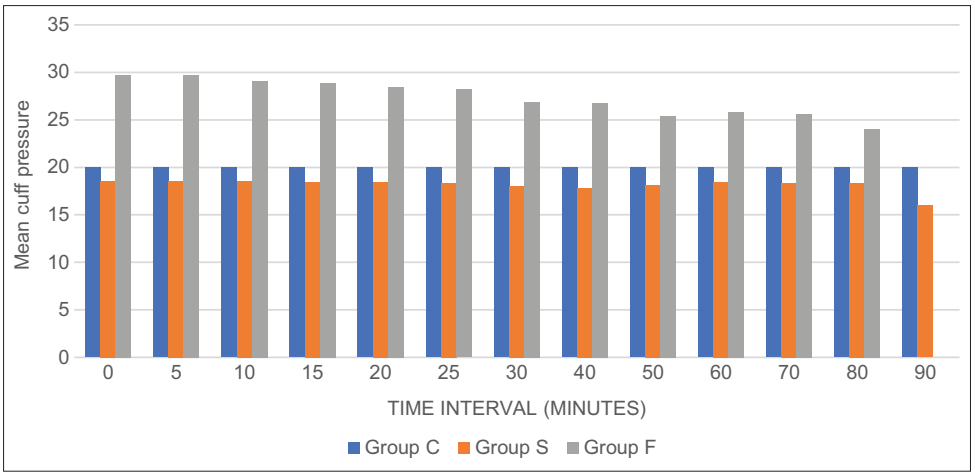
The overall incidence of sore throat was 31.11% (28/90) [Table 1]. The overall incidence of POST was higher in F group than in other groups. In Group F, the incidence of POST was observed to be 46.67% (14/30). In Group C, the incidence of POST was observed to be 23.34% (7/30). In Group S, the incidence of POST was observed to be 16.67% (5/30).

Maximum incidence of POST was observed at 4 h postoperatively in each group. Number of patients with sore throat was significantly higher in F group ($P < 0.05$) as compared to Group C and Group S. The incidence of sore throat in Group C and Group S after extubation was reduced when compared to the F group which was statistically significant ($P < 0.05$).

The intensity of sore throat was evaluated in three groups using VAS. VAS was measured postoperatively for sore



Graph 1: Mean expiratory tidal volume at different time intervals



Graph 2: Mean cuff pressure at different time interval

Table 1: Incidence of POST at different time interval

POST at	Group C		Group S		Group F		Total		*P*-value		
	No.	%	No.	%	No.	%	No.	%	C/S	S/F	C/F
2 h											
0 (Nil)	24	80.00	25	83.33	16	53.33	65	72.22	0.739	0.017	0.027
1 (Mild)	6	20.00	5	16.67	9	30.00	20	22.22			
2 (Moderate)	0	0.00	0	0.00	5	16.67	5	5.56			
3 (Severe)	0	0.00	0	0.00	0	0.00	0	0.00			
4 h											
0 (Nil)	23	76.67	25	83.33	14	46.67	62	68.89	0.768	0.009	0.047
1 (Mild)	5	16.67	4	13.33	9	30.00	18	20.00			
2 (Moderate)	2	6.67	1	3.33	7	23.33	10	11.11			
3 (Severe)	0	0.00	0	0.00	0	0.00	0	0.00			
8 h											
0 (Nil)	25	83.33	26	86.67	16	53.33	67	74.44	0.601	0.010	0.038
1 (Mild)	4	13.33	4	13.33	9	30.00	17	18.89			
2 (Moderate)	1	3.33	0	0.00	5	16.67	6	6.67			
3 (Severe)	0	0.00	0	0.00	0	0.00	0	0.00			
12 h											
0 (Nil)	26	86.67	27	90.00	16	53.33	69	76.67	0.601	0.005	0.019
1 (Mild)	3	10.00	3	10.00	10	33.33	16	17.78			
2 (Moderate)	1	3.33	0	0.00	4	13.33	5	5.56			
3 (Severe)	0	0.00	0	0.00	0	0.00	0	0.00			
24 h											
0 (Nil)	27	90.00	29	96.67	17	56.67	73	81.11	0.301	0.001	0.012
1 (Mild)	3	10.00	1	3.33	11	36.67	15	16.67			
2 (Moderate)	0	0.00	0	0.00	2	6.67	2	2.22			
3 (Severe)	0	0.00	0	0.00	0	0.00	0	0.00			
P value					C/S				NS		
					S/F				S		
					C/F				S		

POST: Post-operative sore throat, S: Significant ($P<0.05$), NS: Non-significant ($P>0.05$), HS: Highly significant ($P<0.001$)

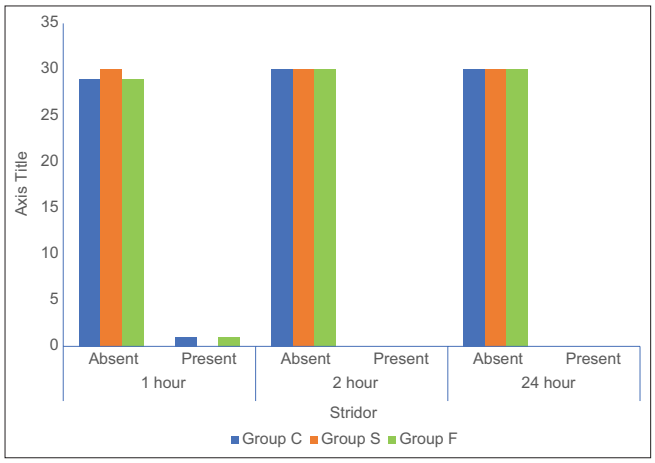
throat at 2, 4, 8, 12, and 24 h [Table 2]. Maximum mean VAS scores were observed at an interval of 4 h postoperatively in all the three groups but being maximum in the finger group. Mean VAS scores were significantly ($P < 0.05$) higher in the F group as compared to the C and S group. On comparing Group S with Group C, VAS score was reduced in Group S and it was statistically non-significant throughout all the time intervals. Inj. Fentanyl (2 mcg/kg) was given as rescue analgesia in all the patients when the VAS >4.

The overall incidence of stridor in the present study was 2.2% (2/90) [Graph 3]. 1 patient each in Group C and Group F developed stridor at 0 h postoperatively, that is, immediately after extubation. There was no patient in the Group S who developed stridor at the same time interval. At 2 and 24 h postoperatively, no stridor was seen in any group. Number of patients with stridor was higher in F and C group as compared to Group S but statistically non-significant ($P > 0.05$).

Table 2: Mean visual analog scale score at different time intervals

Duration	Group C		Group S		Group F		*t*-value			*P*-value		
	Mean	SD (+)	Mean	SD (+)	Mean	SD (+)	C/S	S/F	C/F	C/S	S/F	C/F
2 h	2.00	0.58	1.60	0.55	3.00	1.18	1.04	−3.53	−3.06	0.13	0.01	0.02
4 h	4.00	0.93	3.40	0.55	5.17	1.62	1.37	−4.74	−3.95	0.11	0.01	0.04
8 h	2.20	0.84	2.00	0.82	3.07	0.92	0.51	−3.72	−3.64	0.36	0.03	0.04
12 h	2.00	1.41	2.33	0.58	3.71	1.20	0.18	− 4.18	−4.14	0.36	0.04	0.01
24 h	1.75	1.26	2.00	0.00	2.07	1.14	1.26	−4.07	−3.23	0.32	0.00	0.00
P value					C/S					NS		
					S/F					S		
					C/F					S		

SD: Standard deviation, S: Significant (*P*<0.05), NS: Non-significant (*P*>0.05), HS: Highly significant (*P*<0.001)



Graph 3: Incidence of stridor postoperatively

The incidence of dysphagia for the groups at 2, 4, 8, 12, and 24 h after surgery was maximum at the interval of 4 h postoperatively, being maximum in the F group as compared to Groups C and S but statistically non-significant ($P > 0.05$).

There was a definitive decrease in the incidence of cough in Groups C and S at 2, 4, and 8 h as compared to the Group F. The incidence of cough was maximum at 4 h interval postoperatively in all the three groups. Number of patients with cough was non-significantly higher in F group as compared to Groups C and S. The incidence of cough in Group C and Group S after extubation was reduced when compared to the F group which was statistically non-significant ($P > 0.05$).

There was a definitive decrease in the incidence of hoarseness in Groups C and S at 2, 4, and 8 h as compared to the Group F. Maximum hoarseness was observed at 2 h interval postoperatively in all the three groups. Number of patients with hoarseness was non-significantly higher in F group as compared to Groups C and S. The incidence of hoarseness in Group C and Group S after extubation was reduced when compared to the F group which was statistically non-significant ($P > 0.05$).

DISCUSSION

Endotracheal intubation is an integral part of pediatric anesthetic techniques and pediatric critical care units for airway isolation, protection, and ventilation. The use of cuffed tracheal tubes in children below 8–10 years lead to decreased gas leak around the tracheal tube, improved effectiveness of ventilation, decreased atmospheric pollution, more definitive end-tidal carbon dioxide monitoring, lung function and oxygen consumption testing, decreased risk of aspiration, decreased need to change ill-fitting tracheal tubes, and low flow anesthesia.[9] Nonetheless, there is increased risk of complications such as post-extubation stridor or subglottic stenosis caused by injury to the tracheal mucosa (ulcerations, edema, and circular necrosis of the subglottic region) due to cuff hyperinflation.

All the groups were compared with respect to intraoperative and post-operative hemodynamic parameters, duration and number of attempts of laryngoscopy and these were observed to be statistically non-significant ($P > 0.05$).

In our study, tube exchange rate was zero in all the three groups as the selected tube sizes were adequate in tracheal sealing. Similar results were shown by the Chand *et al.*[10] in 2018, Kutemate *et al.*[11] in 2019, and Wakana *et al.*[12] in 2019 in their study when they used uncuffed and Microcuff endotracheal tubes during surgeries and noticed decreased tube exchange rates with Microcuff endotracheal tubes than uncuffed endotracheal tubes.

The mean inspiratory and expiratory tidal volume was measured in all the three groups at different time till the end of the surgery. Seven patients out of 30 (23.3%) developed tracheal leak around endotracheal tube cuff in the control group as compared to zero patients in the Group S and Group F. This could be explained by the variations in the size and length of the trachea in the pediatric population based on age. This was consistent with the observation by Al-Metwalli and Sadek.[4]

We observed that mean cuff pressures that also represented the volume of air needed to fill the cuff was significantly lower ($P < 0.05$) in the sealing group as compared to the control and finger group. This result has been in accordance with the studies conducted by Al-Metwalli and Sadek[4] and Al-Metwalli *et al*.[13]

Our study shows that low mean cuff pressures are required for effective tracheal sealing with an ultrathin high-volume, low-pressure cuff membrane in Microcuff pediatric tracheal tubes. This is also supported by the studies of Ramachandran *et al*.,[14] Weiss *et al*.,[15] Mhamane *et al*.,[16] and Inada *et al*.[17] who all reported lower mean sealing cuff pressures to achieve the adequate tracheal seal using Microcuff pediatric endotracheal tube.

Sore throat was observed and measured on the scale from 0 to 3 in all the three groups at 2, 4, 8, 12, and 24 h postoperatively. The overall incidence of sore throat in the present study was 31.11% (28/90) and the maximum incidence was reported at 4 h postoperatively as the patients were fully awake at this time interval in all the groups. All the groups exhibited decreased incidence of POST at 8 h, 12 h, and 24 h. Number of patients with sore throat was significantly higher in F group ($P < 0.05$) as compared to Group C and Group S. The reduction in the incidence of sore throat in Group C and Group S after extubation as compared to the F group was statistically significant. This is supported by the studies conducted by Al-Metwalli and Sadek, Al-Metwalli,[4,13] Inada *et al*.[17] and Ramachandran *et al*.[14]

The incidence of hoarseness, cough, dysphagia, and post-extubation stridor was non-significantly higher in the finger group ($P > 0.05$) as compared to the other groups as these symptoms principally correlate with the tracheal intubation and airway management. This finding is in concordance with the studies conducted by Al-Metwalli and Sadek, Al-Metwalli *et al*.,[4,13] Weiss *et al*.,[15] Chand *et al*.,[10] Ramachnadran *et al*.,[14] and Kutemate *et al*.[11]

Strengths of Study

In our study, all the intubations were done by the senior anesthesiologist. We continuously measured the intracuff pressure of endotracheal tube post-operatively, which is considered to be a major risk factor for POST. No patient was excluded from the study which also adds to the plus point of our study.

Limitations of Study

First, children under 3 years of age were not included in our study. Second, Microcuff tubes are more advantageous in children undergoing prolonged surgeries for example cardiac surgeries which were not conducted in our institute. Third, this was a single center study with a small number of patients and thus, the evidence level may be low to allow generalization. To address these issues, a well-structured, prospective randomized study is needed in the future.

CONCLUSION

From our study, we concluded that sealing cuff pressure technique is a safe, reliable, and most effective technique in providing an adequate tracheal seal at much lower cuff pressures as compared to other techniques available and decreasing the incidence and severity of post-extubation cough, stridor, sore throat, dysphagia, and hoarseness in pediatric patients undergoing surgeries under GA with tracheal intubation.

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