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Tracheal Cuff Pressure Changes and Associated Factors in Children who underwent Tonsillectomy at Shafa Polyclinic of Zanjan in the 1399-1400 period

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Abstract

Background: Endotracheal intubation is a common procedure during tonsillectomy in children, and tracheal tube cuff pressure is subjected to fluctuation during this surgery due to changes in the position of the head and neck. Unusual changes in the tracheal cuff pressure can cause damage to the airway mucosa, tracheal mucosa ischemia, tracheal stenosis, and pulmonary aspiration.

Objectives: The present study was conducted to investigate tracheal tube cuff pressure changes and associated factors during tonsillectomy surgery in children.

Methods: This cross-sectional study was conducted on 106 children, 3-8 years of age. In this study, the ideal tracheal tube cuff pressure was designated to be 18 cmH2O and measured at four stages phases: after tracheal intubation, after changing the position of the head and neck, 15 minutes after intubation, and before extubation. The data was analysed using SPSS statistics version 26. Frequency (percentage), and mean (standard deviation), as well as Wilcoxon, Friedman, linear regression, and Wald chi-square tests were used for data analysis.

Results: The means (standard deviations) of the cuff pressure following after intubation, after subsequent to changing the position of the head and neck, 15 minutes after intubation, and prior to before extubation were 26.69 (6.10), 29.07 (8.39), 29.91 (5.77), and 24.12 (4.72), respectively. The baseline cuff pressure had no statistically significant relationship with age, gender, tube size, BMI, and cuff pressure changes at the 15th minute ($P>0.05$). The two variables of, gender and tube size, but not age and BMI ($P>0.05$), were significantly correlated with cuff pressure change prior to extubation compared with baseline line cuff pressure ($P<0.05$), but eithr age or BMI werenot significantly related to the change in cuff pressure prior to extubation compared with baseline cuff pressure ($P>0.05$).

Conclusion: Tracheal tube cuff pressure during tonsillectomy in children can increase due to the change of head and neck position, making monitoring of these changes necessary in patients undergoing tonsillectomy.

Keywords: trachea, airway extubation, cuff pressure, tracheal tube, pediatrics, tonsillectomy

Introduction

Tracheal tubes are tools for airway management in anesthetized patients. In cuffed tracheal tubes, inflating the cuff within the normal range provides the tube with insulation and protection [1]. Tracheal tube cuff pressure management is an important step in airway management after intubation. The normal range of tracheal tube cuff pressure is between 20-30 cmH2O [2]. In neonates and young children, acceptable cuff pressure may fall even below this range because of the low perfusion pressure of tracheal mucosa in infants and young children [3].

Factors such as increased body temperature, ventilation with positive pressure, ventilation with N2O, and larynx spasm can increase tracheal tube cuff pressure, while relaxation and a decrease in muscle tone lower the cuff pressure [4]. Cuff pressure of less than 15-20 cmH2O causes air leakage, pulmonary aspiration, and subsequently. ventilator-dependent pneumonia in patients under anesthesia and mechanical ventilation at intensive care units [5]. High cuff pressure (more than 30 cmH2O) lowers blood supply, leading to tracheal ischemia, stenosis, and necrosis, as well as coughing, sore throat, and hoarseness [6].

There is no guideline for the frequency of monitoring of cuff pressure or a standard method for its measurement. Normally, the tracheal tube cuff pressure is not measured during surgery and anesthesia [7]. Changing the body position in intensive care units and operating rooms affects the tracheal tube cuff pressure, requiring measuring and adjusting the cuff pressure after each position change [6].

Adverse respiratory events during pediatric surgeries can lead to complications and even death during anesthesia. The most common threat in pediatric anesthesia is elevated high airway pressure [8]. Children’s airway is funnel-shaped, narrowing in the cricoid cartilage, so the likelihood of airway injuries in children is higher than in adults when using cuffed tracheal tubes [9].

Several studies have been conducted on cuff pressure changes in adults, children, and even infants undergoing various surgeries, as well as in patients under mechanical ventilation in special care units. Moreover, multiple studies have been dedicated to investigating the effects of changing body, head, and neck positions on cuff pressure [1,10,11]. The results of these studies; however, have been contradictory in some cases. For example, Kim et al. (2021), who investigated the effects of head and neck position on the nasal tracheal tube cuff pressure, declared that the tracheal cuff pressure did not alter after head and neck extension [12]. In a study, Asiraman et al. (2015) reported that tracheal tube cuff pressure decreased progressively when lying on the back or on the side [13]. Meanwhile, Alkan et al. (2017) investigated the effect of body position on tracheal tube cuff pressure in patients under mechanical ventilation and described an increase in the cuff pressure following head and neck extension [6].

The fact that children’s airways are narrower and more prone to swelling and inflammation than adults, necessitates perioperative airway management, and difficult airway during pediatric surgeries should be anticipated, considering that it is may be a complicacy in pediatric ENT surgerical procedures. which should be considered to foresee difficult airway during surgeries, including nasopharyngeal surgery in which a difficult airway is more probable in children [14]. Few studies have been conducted on tracheal tube cuff pressure changes in children undergoing adenotonsillectomy [15]. In our literature review, we found no study on cuff pressure changes during tonsillectomy in children aged 3-8 years. Therefore, this study was conducted to investigate tracheal tube cuff pressure changes during tonsillectomy in children 3-8 years of age.aged. The results of this study can help reduce hospital-related complications and injuries, as well as the workload of nurses and medical staff, the costs imposed on hospitalized patients, the length of hospitalization, etc. Our findings can also provide information about tracheal tube cuff pressure changes during tonsillectomy surgery and illuminate its risk factors in 3-8 -year-old children, helping in preventing complications during and after the surgery (e.g., sore throat, hoarseness, tracheal stenosis, and tracheal mucosal ischemia). In addition, due to the fact that the tracheal tube cuff pressure is not routinely monitored during surgeries and in special care units, The results of this study can highlight the importance of measuring and adjusting the tracheal tube cuff pressure as standard medical care for all patients undergoing various surgeries, especially adenotonsillectomy and throat surgeries, and the patients in the intensive care units.

Methods

This cross-sectional study was conducted in the operating room of Shafa Polyclinic of Zanjan city from December 2020 to October 2021. Our study population included 3-8-year-old children undergoing adenotonsillectomy at Shafa Polyclinic.

Using the formula n= $\frac{(2\,(Z1-a/2+Z1-\beta))^2\times\delta^2}{d^2}$, the sample size was estimated at n=106 considering a type 1 error of 0.05, a type 2 error of 0.2, d=3, and ð=7.8. Regarding the sample size of similar studies by Kamata (2017), Olsen (2016), and Krishna (2017), ranging from 84 to 100 [15-17], 106 children in the age range of 3-8 years old were enrolled in this study. Sampling was performed using the available simple sampling method, recruiting childen undergoing adenotonsillectomy in the operating room of the Shafa Polyclinic of Zanhan city from December 2020 to October 2021. No subject was excluded from the study.

The participants in the present study included children in the age range of 3-8 years old, ASA class I and III (i.e., classification by the American Society of Anesthesiologists based on the physical condition), and a BMI less than 25. Children with a history of difficult intubation, restriction of neck movements, cervical spinal instability, anatomical airway disorder, and upper airway infections were not included in the study. Exclusion criteria in this study were as follows: surgery length exceeding 30 minutes for any reason, having to readminister muscle relaxants during the procedure, the occurrence of any complication during the surgery, and more than one attempt for intubation.

After anesthesia and nasal endotracheal intubation, vital signs, including Spo2, pulse rate per minute, and armpit temperature, were recorded for all patients. A simple High-Volume Low-Pressure (HVLP) cuffed tracheal tube made of Poly Vinyl Chloride (PVC) was used in this study. N_2O gas was not used due to its confounding and boosting effect on the cuff pressure. The Davis-gag retractor is a metal device used to open the patient's mouth so that the surgeon can have a better grip on tonsils when removing them.

The tracheal tube cuff pressure was measured using a standard, calibrated aneroid Android manual manometer manufactured by the German Kovidin Co, with an accuracy of 0-120 cmH2O. In the present study, the cuff pressure was designated as 18 cmH2O.

Demographic and clinical information gathered included age, gender, height, weight, BMI, and tracheal tube size, which were recorded in a checklist. Tracheal tube cuff pressure was measured at four occasions: after tracheal intubation (initial), after changing the position of the head and neck (baseline), at the 15th minute. The 15-minute time point, and prior to extubation. After each measurement, the cuff pressure was readjusted to 18 cmH2O. The data were collected, using observation method, by the researcher and a research assistant, who were constantly present during the surgery, in the operating room of Shafa Polyclinic, surgery, by observation.

Then the data were analysed using SPSS software version 26. The non-parametric test of one-sample Kolmogorov-Smirnov was used to determine if the data were normally distributed. Because the distributions of age and BMI were not normal, median and interquartile ranges were used to present these variables. Percentage (frequency) was used to describe qualitative variables, and quantitative variables were described using mean (standard deviation), median, and interquartile range. The distribution of the cuff pressure difference between the baseline and at the 15th minute and before extubation was assessed by the one-sample Kolmogorov-Smirnov test, showing that both had non-normal distributions, so the Wilcoxon Signed Rank test was used to compare the baseline cuff pressure with cuff pressures at these two time points. The Friedman test was also used to compare tracheal tube cuff pressure measured at three time points, excluding the one after tracheal intubation. The relationship between independent and dependent variables was assessed using linear regression, standard beta regression coefficient, and standard error. Standard error was used to boost the validity of the results.

This research was reviewed and approved by the ethics committee of Zanjan University of Medical Sciences under the ethics code of IR.ZUMS.REC.1399.304. In order to comply with ethical standards, after obtaining ethical approval and required permissions, the researcher paid a visit to the Shafa Polyclinic of Zanjan to submit the introduction letter to the manager and obtain permission to conduct the research. Then the researcher got acquainted with the research environment. The study's objectives and protocol were explained to the children's parents before the surgery, and they were assured of the safety of cuff pressure measurement before obtaining their verbal consent. The researcher was committed to keeping the patients' information confidential and observing all ethical principles when using research sources and tools.

Results

Out of a total of 106 children in the age range of 3 to 8 years who underwent tonsillectomy at the Shafa Polyclinic of Zanjan, 57 were female (53.8%), and 49 were male (46.2%). The mean (standard deviation) of age was 6.88 (1.41) years.

The mean of tracheal tube cuff pressure at the baseline after changing the position of the head and neck (i.e., head and neck extension) and using the Davis-gag retractor and shoulder roll was obtained as 29.07 (8.39) cmH2O, which was 11.07 cmH2O higher compared with ideal targeted cuff pressure (i.e., 18 cmH2O). Table 1 shows the tracheal tube cuff pressure measured at four time points.

The mean difference between the baseline and the 15th minute cuff pressures was 0.84 cmH2O, while this was -4.95 cmH2O comparing the baseline and pre-extubation cuff pressures. The mean cuff pressure at the 15th minute was slightly higher compared with the baseline cuff pressure, and 3.22 cmH2O was higher compared with to the initial mean cuff pressure. The mean of pre-extubation cuff pressure was 4.95 and 2.57 cmH2O lower compared with the mean of baseline and initial values, respectively (Table 1).

Table 1: Cuff Pressure Measurement at Four Time points; Following Intubation (initial), After Changing the Head and Beck Position (Baseline), After the 15th Minute, and Before Extubation

Time point	N	Mean (SD)	Median	Min	Max	Ideal cuff pressure	Baseline cuff pressure	Difference between relative mean and baseline pressure
Initial	106	26.69 (6.10)	27.5	12	38	8.69	-2.38	-13.22
Baseline	106	29.07 (8.39)	30	12	42	11.07	-	-
15-minute	106	29.91 (5.77)	30	8	40	11.91	0.84	4.66
Pre-extubation	106	24.12 (4.72)	25	10	34	6.12	-4.95	-27.46

According to the findings of this research, nine (8.49%), seven (6.60%), 43 (40.56%), 42 (39.62%), and five (4.71%) participants had baseline cuff pressures of <18, around 18, 18-30, 30-40, and >40 cmH2O, respectively. Table 2 describes the frequencies and percentages of normal and out-of-the-ideal range cuff pressures at four measurement times.

Table 2: Frequency Distribution and Cuff Pressure Percentage Within the Ideal Range and Out-of-Ideal Range in the Four Time points Measured

		Frequency	%
Initial	<18 cmH2o	11	10.30
	18 cmH2o	8	7.50
	18-30 cmH2o	55	51.88
	30-40 cmH2o	32	30.10
	40 cmH2o >	-	-
Baseline	18 cmH2o <	9	8.49
	18 cmH2o	7	6.60
	18-30 cmH2o	43	40.60
	30-40 cmH2o	42	39.60
	>40 cmH2o	5	4.70
the 15th minute	18 cmH2o <	4	3.77
	18 cmH2o	2	1.88
	18-30 cmH2o	46	43.39
	30-40 cmH2o	54	50.94
	>40 cmH2o	-	-
Pre-extubation	<18 cmH2o	12	11.32
	18 cmH2o	-	-
	18-30 cmH2o	85	80.18
	30-40 cmH2o	9	8.49
	>40 cmH2o	-	-

According to the Wilcoxon signed-rank test, no statistically significant difference was observed between the the 15th minute and baseline cuff pressures (P=0.241); however, a statistically significant difference was observed comparing the baseline and pre-extubation cuff pressures (P=0.032). In addition, the Friedman test revealed a statistically significant difference comparing the cuff pressures measured at the baseline, the 15th minute, and before extubation (P=0.041, f2=60.09).

According to Table 3, age, sex, BMI, and tube size were not significantly associated with the difference between the 15th minute and baseline cuff pressures as shown by the Wald test (P>0.05).

Table 3: A Marginal Longitudinal Model for Determining the Relationship Between Independent Variables (Age, Sex, BMI, Tube size) and the Cuff Pressure Difference Between the 15th minute and Baseline

Source	Wald Chi-square	df	P
Constant value	225.01	1	<0.001
Gender	0.46	1	0.494
Dependent variables	0.72	1	0.395
Age	1.97	1	0.160
BMI	0.06	1	0.794
Tube size	0.16	1	0.681

***the Wald test**
****cuff pressure difference between the 15th minute time point and baseline**

As shown in Table 4, neither age nor BMI was significantly associated with cuff pressure change from the baseline to pre-extubation, as evidenced by the regression model (P>0.05). However, gender and endotracheal tube size were significantly associated with cuff pressure change from the baseline to pre-extubation using the regression model and the Wald test (P<0.05).

Table 4: A Marginal Longitudinal Model for Determining the Relationship Between Independent Variables (Age, Sex, BMI, Tube size) and the Cuff Pressure Difference Between the Baseline and Pre-extubation

Source	Wald Chi-square	df	P
Constant value	32.48	1	<0.001
Gender	13.39	5	0.020
Dependent variables	4.50	2	0.105
Age	4.57	3	0.205
BMI	0.06	1	0.003
Tube size	32.48	1	<0.001

***P value based on the Wald test**
****dependent variable: cuff pressure difference**

According to a linear regression model, as shown in Table 5, none of the variables of age, gender, BMI, and tube size significantly affected the cuff pressure difference between the 15th minute and the baseline (P>0.05).

Table 5: Linear Regression Model with 95% Confidence Interval of the Wald Test, Beta Standard Regression Coefficient, Standard Error, Wald Chi-square, Degree of Freedom, and Significance Level Based on the Effect of Independent Variables on the Dependent Variable of the Cuff Pressure Difference Between the 15th minute Time point and Baseline

	B coefficient	Standard error	Min	Max	Wald chi-square	df	P
Constant value	3.23	0.21	2.81	3.65	227.03	1	<0.001
Sex 1	-0.02	0.03	-0.08	0.04	0.46	1	0.494
Sex 2	0^a	-	-	-	-	-	-
No. 1	-0.03	0.03	-0.10	0.04	0.72	1	0.395
No. 1 or 2	0^a	-	-	-	-	-	-
Age	0.04	0.03	-0.01	0.10	1.97	1	0.160
BMI	0.001	0.005	-0.009	0.01	0.06	1	0.794
Tube size	-0.03	0.07	-0.18	0.11	0.16	1	0.681
Degree	0.05	-	-	-	-	-	-

Sex 1: male, sex 2: female, Sh: Index, a=0
***linear regression model**

Based on our findings and the linear regression model, only tracheal tube size had a significant effect on the cuff pressure difference between the baseline and pre-extubation phase (Table 6, P=0.035). On average, the chance of a reduction in the tracheal tube cuff pressure compared to the baseline, increased by 110% with the increase of the tube size (i.e., the chance of a reduction in the tracheal tube cuff pressure was greater when using larger tubes).

Table 6: Linear Regression Model with 95% Confidence Interval of the Wald Test, Beta Standard Regression Coefficient, Standard Error, Wald Chi-square, Degree of Freedom, and Significance Level Based on the Effects of Independent Variables on the Dependent Variable of the Cuff Pressure Difference Between the Baseline and Pre-extubation

	coefficient B	Standard error	Min	Max	Wald chi-square	df	P
Constant value	38.31	5.96	26.62	49.99	41.30	1	<0.001
Sex 1, Dv., I 1 or 2	4.55	6.67	-8.53	17.64	0.46	1	0.495
Sex 2	3.07	3.20	-3.20	9.35	0.92	1	0.337
No. 1	2.80	5.63	-8.23	13.85	0.24	1	0.618
No. 1 or 2	0^a	-	-	-	-	-	-
Age	-0.36	0.22	0.79	0.07	2.61	1	0.106
BMI	-0.28	0.14	-0.57	0.008	3.62	1	0.057
Tube size	-3.10	1.81	-6.66	0.45	2.91	1	0.088
Degree	-4.08	1.93	-7.87	-.29	4.47	1	0.035

Dv. Dependent variable, I: index,

Discussion

In the present study, the mean of tracheal tube baseline cuff pressure increased with the extension of the head and neck and the use of the Davis-gag retractor and shoulder roll compared to the ideal cuff pressure in question. Kim et al. (2021) in their study assessed the effects of the head and neck position on nasal tube cuff pressure and showed that the average cuff pressure after changing the head and neck extensional position was comparable with the ideal cuff pressure, which was inconsistent with our results. One reason for this discrepancy may be the fact that different types of tracheal tubes were used in these studies. While the tracheal tube used in the present study was made of PVC (Poly Vinyl Chloride), and it was of the HVLP (High Volume Low Pressure) type, the PVC tracheal tube used by Kim et al. was of the Portex type. Also, another reason for the difference observed in cuff pressure changes following head extension may be due to the fact that Kim et al. did not use the Davis-gag retractor. Cuff pressure changes following the alteration of the head and neck position occur due to the movement and deformation of anatomical structures. Therefore, the movements of the tube through the nasal passage along the airway, as well as the change of the force applied on the cuff by the surrounding structures, can be responsible for changes in the tracheal tube cuff pressure following the alteration of the head and neck position [12]. Soleimani et al. (2018), quoting Farre et al., stated that the type of tracheal tube can influence the elevation of the tracheal tube cuff pressure independent of changes in the patient's condition [4]. The tracheal tube used in the present study was made of PVC, and was of HVLP type.

In the study by Kumasava et al. (2015), cuff pressure changes were more pronounced in high-volume low-pressure than in taper-cuffed tracheal tubes. In this study, the mean of tracheal tube cuff pressure increased following the change of head and neck extension respective to the desired pressure [18], which was in line with the present study. The type and material of the tracheal tubes used in these studies were the same.

In the study of Olsen et al. (2016), the mean of tracheal tube cuff pressure in children (1-17 years old) increased during adenotonsillectomy and after changing the head and neck position [14], which was in agreement with the present study. The tracheal tube used in Olsen et al.'s study was of the microcuff type (in comparison with the HVLP type applied in the present study), justifying the greater increase in the mean tracheal tube cuff pressure after head and neck extension in our study. Both studies reported an increase in the cuff pressure following changing the head and neck position (i.e., extension). In addition, different types of retractors used in these two studies may explain the greater increase in the mean cuff pressure in the present study compared to Olsen et al.'s study.

In the present study, cuff pressure changes showed an ascending trend during tonsillectomy and then a descending trend toward the end of the surgery and before extubation, which was in line with the findings of Asiraman et al. (2015), who investigated tracheal tube cuff pressure changes following position changing in patients undergoing neurosurgery [18]. The declining trend of the cuff pressure prior to extubation can be due to the removal of the Davis-gag retractor from the patient's mouth, relieving the pressure imposed on the tracheal tube by the retractor, returning the head extension to its neutral position, and the removal of the shoulder roll.

A statistically significant difference was observed comparing the tracheal tube cuff pressure between the three time points studied (i.e., the baseline, the 15th minute and prior to extubation), which was in parallel with the results of Mahori et al. (2019), who reported statistically significant alterations in the baseline tracheal tube cuff pressure following changing the position to the palmar and then to the one-sided position. In the recent study, a statistically significant difference was also observed between the baseline and postoperative cuff pressures [1].

In the study of Dinmohammadi et al. (2015), a significant difference was observed between the mean cuff pressure in different positions and also between different times after changing the body position, which was consistent with the results of the present study. Moreover, in the recent study, the highest mean cuff pressure was recorded at the 15th minute time point, which agreed with our observation in the present study [19].

In the present study, neither age nor BMI was significantly associated with tracheal tube cuff pressure changes following the alteration of the head and neck position in children undergoing adenotonsillectomy. There was also no significant relationship between gender and cuff pressure change from the baseline to the 15th minute time point following the changing of the head and neck position during adenotonsillectomy. However, gender seemed to influence cuff pressure alterations from the baseline to the pre-extubation phase. In the study of Darkova et al. (2015), who evaluated the air volume needed to achieve an acceptable cuff pressure in adults, age showed an indirect relationship with the tracheal tube cuff pressure [20], which contradicted our observation in the present study. In another study by Wettstein et al. (2020), who assessed tracheal tube cuff pressure in the PICU, age and gender were found to have no association with tracheal tube cuff pressure [21], which was in agreement with the results of the present study.

Due to the Covid-19 pandemic and a reduction in performing elective surgeries and adenotonsillectomy, we had to change the research environment from the Valiasr Hospital (Aj) to the Shafa Polyclinic in Zanjan city, where it was scheduled to perform adenotonsillectomy on only two days a week. Even on these two days, only a single day was actively dedicated to operations. Therefore, a sharp decline in the number of pediatric adenotonsillectomy surgeries caused some difficulties in designing the study. As it is not routine to record systolic and diastolic blood pressure, as well as mean arterial pressure in children, and due to the unavailability of the necessary equipment for this purpose, these parameters were not gathered in this study.

Conclusion

During adenotonsillectomy in children, changing the position of the head and neck and using the Davis-gag retractor and a shoulder roll can increase the tracheal tube cuff pressure. Factors such as age, gender, BMI, and the tracheal tube size can influence tracheal tube cuff pressure alterations. In this study, gender and the size of the tracheal tube significantly affected tracheal tube cuff pressure changes. Considering that both the increase and decrease of the tracheal tube cuff pressure during surgery can be life-threatening for patients under anesthesia, it seems necessary to monitor this parameter during various surgeries, especially adenotonsillectomy. Regarding the significant relationship observed between age and cuff pressure changes, it is suggested to conduct more studies with larger sample sizes to investigate the link between cuff pressure changes and age-related and other demographic parameters such as BMI.

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Conflict of interest

There is no conflict of interest to declare.

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