JAREN 2022;8(3):166-176
doi:10.55646/jaren.2022.02360

Determination of Factors Affecting Endotracheal Tube Cuff Pressure in Adult Patients in Intensive Care Unit

Yoğun Bakım Ünitesinde Yatan Erişkin Hastalarda Endotrakeal Tüp Kaf Basıncını Etkileyen Faktörlerin Belirlenmesi

Ayda Kebapçı

ABSTRACT

***Aim**: This study aimed to determine factors that affect endotracheal tube cuff pressure (ETCP) in adult patients under mechanical ventilation support in intensive care unit.*
***Background**: Maintaining the ETCP within safe ranges, which ensures airway patency and provides positive pressure ventilation, is a complex circumstance due to many factors. Although there are recommendations for the prevention of excessive or insufficient ETCP, there is still no consensus based on affecting factors.*
***Design**: The study was designed as a cross sectional, descriptive, and correlational study. A total of 67 patients who met the criteria of the study were included in the study, and 264 ETCP measurements were performed during their hospitalization in the intensive care unit.*
***Results**: The mean age was 70.56.7% of participants were men, and 21.4% of them were admitted to the ICU after surgical intervention. The mean ETCP value was 28.5cmHg (5-127 cmHg). 55.7% of measurements were hyperinflation, 58.71% of patients had orotracheal tube, %84.4 of endotracheal tubes had standard circular cuff and mean tube size number was 8.0. Mean head of bed degree was 25 degree and 61.7% of patient was in supine position. In the regression analysis, the variables affecting the nursing image age, body mass index (kg/m2), type of tracheal tube, shape of cuff, size of tube and head of bed degree (p<0.05).*
***Conclusion**: The results of the study show that the ETCP values were mostly high and were affected by both patient-specific factors and endotracheal tube-related factors. It is recommended that standard protocols should be developed to manage ETCP and monitor ETCP by intensive care nurses with frequent intervals, considering patient-specific variables and endotracheal tube characteristics, since potentially undesirable elevations in the patient's ETCP values are common.*

***Keywords:** Endotracheal tube cuff pressure, mechanical ventilation, nursing, intensive care*

ÖZ

***Amaç**: Hava yolu açıklığını ve pozitif basınçlı ventilasyonun uygulanmasını sağlayan endotrakeal tüp kaf basıncının (ETKB) güvenli aralıklar içinde tutulması, birçok faktör nedeniyle karmaşık bir durumdur. Aşırı veya yetersiz ETKB'nin önlenmesine ilişkin öneriler bulunmakla birlikte, günümüzde hala ETKB düzeyini etkileyen faktörlere ilişkin bir görüş birliği bulunmamaktadır. Bu çalışmada, yoğun bakım ünitesinde erişkin hastalarda endotrakeal kaf basıncını etkileyen faktörlerin belirlenmesi amaçlanmıştır.*
***Yöntem**: Bu prospektif çalışma, kesitsel, tanımlayıcı ve ilişki araştırıcı tipte idi. Çalışmanın kriterlerine uygun 67 hasta araştırmaya dahil edildi ve bu hastaların yoğun bakım ünitesinde yatışları boyunca toplam 264 kez ETKB ölçümü gerçekleştirildi.*
***Bulgular**: Hastaların yaş ortalamasının 70, %56,7'sinin erkek, %21,4'ünün cerrahi müdahale sonrası yoğun bakım ünitesine kabul edildiği bulundu. Ortalama ETKB değeri 28,5 cmHg (5-127 cmHg) idi. Ölçümlerin %55,7'sinde hiperinflasyon belirlendi. Hastaların %58,71'inde orotrakeal tüp tercih edildiği, %84,4'ünde standart yuvarlak kaf olduğu ve ortalama tüp numarasının 8.0 olduğu bulundu. Hastaların ortalama yatak başı yükseklik derecesi 25 derece idi ve %61,7'si supine pozisyondaydı. Regresyon analizinde; ETKB değerini etkileyen değişkenlerin yaş, beden kitle indeksi (kg/m2), trakeal tüp cinsi, kaf şekli, tüp boyutu ve yatak başı yükseklik derecesi olduğu belirlendi (p<0.05).*
***Sonuç ve Öneriler**: Çalışmanın sonuçları, ETKB değerlerinin çoğunlukla yüksek olduğu ve hastaya özgü faktörlerden yanı sıra endotrakeal tüp ile ilgili faktörlerden etkilendiğini göstermektedir.*

Received/Geliş: 11.08.2022
Accepted/Kabul: 09.09.2022
Published Online: 16.12.2022

Cite as: Kebapçı A. Determination of factors affecting endotracheal tube cuff pressure in adult patients in intensive care unit. Jaren. 2022;8(3):166-176.

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Hastanın ETKB değerlerinde potansiyel olarak istenmeyen yükselmeler sık görüldüğünden, hastaya özgü değişkenler ile endotrakeal tüp özellikleri de dikkate alınarak yoğun bakım hemşireleri tarafından ETKB'nin sık izlenmesi gerektiğini ve basıncın standart yönetimine ilişkin protokollerin geliştirilmesine gereksinim olduğunu göstermektedir.

Anahtar kelimeler: *Endotrakeal tüp kaf basıncı, mekanik ventilasyon, hemşirelik, yoğun bakım*

INTRODUCTION

Endotracheal intubation is an effective way to provide rapid and safe airway patency and respiratory support in the intensive care unit (ICU) [1]. Endotracheal intubation allows effective isolation of the trachea by inflating the balloon (cuff) of the endotracheal tube (ETT) just below the vocal cords. The inflatable cuff is an important part of endotracheal tube management, which ensures airway patency and positive pressure ventilation. The endotracheal tube cuff pressure (ETCP) should be between 20-30 cmH_2O to safely close the airway [2].

It has been reported that excessive inflation of the endotracheal cuff (>30 cmH_2O) causes hoarseness, sore throat, inadequate swallowing of secretions, tracheal stenosis, tracheal wall damage and ischemia due to decreased mucosal capillary blood flow. It has been shown that these effects can occur even in a very short time under high pressure [3]. In contrast, inadequate inflation of the endotracheal cuff (below 20 cmH_2O) causes ventilatory associated pneumonia (VAP) due to ineffective ventilation and microaspiration of gastric secretions and leakage of oropharyngeal and subglottic secretions into the lungs [7].

Keeping ETCP within safe ranges is a complex situation due to many factors [8,9]. These factors are mainly; patient movements, different neck and head positions, sedation, type of surgical intervention, presence of nasogastric tube, intubation time and intubation tube position [8,10, 11].

In the literature, it is stated that subjective methods such as estimating whether the pressure is sufficient by palpation or there is a noise from the cuff (the cuff may be insufficiently inflated) [12-16], or objective methods by using manual cuff pressure gauges or automatic cuff pressure regulating devices [17,18]. It is emphasized that the cuff pressure should be measured objectively at certain intervals to prevent excessive or insufficient ETCP level and related complications [19,20]. However, although there is no standard method regarding the measurement frequency, there are intensive care units that measure every four hours, every eight hours or twice a day [21]. The American Association of Critical-Care Nurses (AACN) states that to achieve an appropriate pressure and prevent mucosal damage, the amount of pressure and air volume required the dimensions, shape of the tube, mechanical ventilator mode, and the patient's blood pressure should be taken into account [22]. This indicates that a single mean cuff pressure value within the safe range will not be valid to all patients. In ICUs, ETCP monitoring is carried out by intensive care nurses frequently. However, there is no consensus or protocol in the literature based on scientific results or recommendations regarding the standard management of excessive or insufficient ETCP with considering the variables specific to patients and clinical characteristics [21-23]. Therefore, excessive, or insufficient ETCP is frequently encountered in intensive care patients.

Research Questions

- What is the endotracheal cuff pressure level in patients in the intensive care unit?
- What are the factors affecting the endotracheal cuff pressure in patients in the intensive care unit?

METHOD

Aim

The aim of this study is to determine the endotracheal tube cuff pressure and the affecting factors among intensive care patients.

Type of Study

This prospective study was designed as a cross-sectional, descriptive, and correlational study using the STROBE (The Strengthening the Reporting of Observational Studies in Epidemiology) statement (Appendix-1).

Population and Sample

The population of the study consisted of approximately 600 intubated adult patients admitted in the surgical and internal medicine

intensive care unit of a private foundation university hospital between November 2019 and November 2020. Sample of the study consisted of 67 patients who were over 18 years of age, admitted to the ICU after surgery or due to internal diseases, stayed in the ICU for at least 12 hours, were intubated with an endotracheal tube or had tracheostomy, and received mechanical ventilation support. Patients with tracheostomy in were not included in the study for the first 15 days after tracheostomy insertion since edema and inflammation in the procedure area may affect the measurements. Patients who were difficulty intubated, who had undergone laryngotracheal and neck surgery, who had position restriction and who had anatomical anomalies were not included in the study.

The sample size was calculated with the G-Power 3.1 package program by power analysis. Using the linear regression model and considering the six predictors that were correlated with the dependent variable (ETCP), the power obtained for the sample size was 95% for the 95% confidence interval and 5% standard error [24]. All variables were added to the linear regression model using the backward method. Only variables found to be significant at the 0.05 level were included in the model table, and the nonsignificant variables were removed from the model and the final model was decided.

Data Collection

In the study, data collection was carried out in the surgical and internal medicine adult ICU of Koç University Hospital between November 2019 and March 2020. Data were collected using the data collection form developed by the researcher considering the studies in the literature. Data collection form included the demographic and clinical characteristics of the patients. Data on demographic characteristics were obtained from electronic patient records and some of the clinical data were obtained from electronic patient records and some were obtained directly from the patient at the bedside.

Data on demographic characteristics consisted of age, gender, body mass index (BMI) and comorbid diseases of the patients. In clinical characteristics of the patient included the primary diagnosis for admission to the ICU and cuff pressure value were obtained. In addition, the following datas were also obtained during each ETCP measurement simultaneously: the position of the patient (right/left supine, lateral, etc.), the degree of the patient's head of bed, the presence of a nasogastric tube, the day after intubation, the type and number of the tube, the shape of the cuff, tidal volume (Vt), mean airway pressure (Pmean), positive end-expiratory pressure (PEEP), airway peak pressure (Ppeak), tidal volume value, inspiration/expiration (I:E) ratio, systolic and diastolic blood pressure values (mmHg). Furthermore, Richmond Agitation and Sedation Scale (RASS) scores of the patients were obtained by the investigator before each ETCP measurement in each patient. ETCP measurements were performed at the patient's bedside with a manual cuff manometer (Cuff Pressure Gauge "Universal", VBM, Mainline Medical, Inc. Georgia, USA) by the researcher and the obtained data were recorded.

Variables of the Study

The independent variables were age, gender, BMI, comorbid diseases of the patients, presence of nasogastric tube (present/absent), tube type (endotracheal tube / tracheostomy tube), tube size, cuff shape (cubic / standard-circular), the position of the patient (right/left supine, lateral, etc.), the degree of the patient's head of bed, tidal volume (Vt), PEEP, mean airway pressure (Pmean), airway peak pressure (Ppeak), inspiration/expiration (I:E) ratio, day of intubation, systolic and diastolic blood pressure value (mmHg), RASS score. The dependent variable was the ETCP value (cmHg).

Procedures

Orotracheal intubation of the patients was performed by anesthesiologists in the operating room in the patients who were transferred to the ICU after the surgical intervention, and the patients who directly were admitted to the ICU by the intensive care specialists in ICU. Endotracheal tube sizes of patients who were orotracheal intubated or had tracheostomy were determined by anesthesiologists and intensive care specialists.

After orotracheal intubation, the endotracheal tube was fixed with elastic fixation bands on the right or left side of the lip of patients. During the study, the tube positions of the patients were not changed. The endotracheal tubes used in the patients were made of polyvinyl chloride (PVC) and had a circular cuff. However, endotracheal tubes with a subglottic

aspiration port and a tapered (conic) cuff were preferred in some patients who were predicted to have a long stay in the ICU by the intensive care specialist. Tracheostomy tubes of patients were made of PVC material, with circular cuffs, and neck straps were used for fixation.

Before starting the study, the tube cuff pressure of the patients to be included in the study was adjusted to the level of 25 cmHg with a manual cuff manometer and measurements within the scope of the study were started 12 hours after this adjustment. ETCP measurements were repeated twice a day (every 12 hours) by the investigator. After each measurement, if the cuff pressure value is higher or lower than the normal range, the cuff pressure was adjusted to the normal level (25 cmHg).

During the ETCP pressure measurement, the clinical data of the patients were determined and recorded simultaneously. Before the ETCP measurement, it was ensured that no nursing intervention (changing the patient's position, endotracheal aspiration, oral care, etc.) was applied or any mechanical ventilation mode or setting changes were made 30 minutes before the measurement to prevent changes that may occur in ETCP values. ETCP measurements were made at the patient's bedside with a manual cuff pressure manometer (Cuff Pressure Gauge "Universal", Mainline Medical, Inc. Georgia, USA) and the obtained data were recorded. It was continued until the patients were extubated or discharged from the ICU. A total of 264 ETCP measurements were performed in 67 patients, included in the study.

Ethics approval and consent

The study was approved by the Koç University Institutional Review Board (2018.323.IRB2.049). Written and verbal informed consent of participation in and for publication of the study was obtained from patients who were conscious. However, if the patient was under sedation, their first-degree relatives were informed according to the Declaration of Helsinki, and their verbal and written consents were obtained.

Statistical analysis

The data were analyzed using the Statistical Package for the Social Sciences (SPSS) software, version 26.0 for Windows. Numbers, percentages, means, medians, and standard deviation were used as the descriptive statistical methods. It was determined that the continuous data on the demographic and clinical characteristics of the patient did not show a normal distribution. To estimate the dependent variable with the independent variables, a linear regression model was established, and linear regression analysis was performed. The significance was evaluated at levels of $p < 0.05$.

RESULTS

A total number of 67 patients were prospectively enrolled. Most patients were male (56,7%) and were admitted to ICU after surgical intervention (58,2%) with hypertension (52%). The mean age of patients was 70 (20-100). Most patients had comorbid disease (74,6%) and the majority were found to have hypertension (47,8%). Details regarding the baseline sociodemographic of patients and relatives are reported in Table 1.

Clinical characteristics of the patients are reported in Table 2. The mean ETCP was 28,5 cmHg (5-127 cmHg). During 264 ETCP measurements of patients, it was found that 55.7% had hyperinflation (ETCP> 30 cmHg), and 4.2% had hypoinflation (<20 cmHg) (Table 2). The mean RASS score was -2, the mean degree of head of bed of patients was 25 degrees (0-90), the mean tidal volume was 450 ml (166-1085), the mean PEEP was 6.9 cmH_2O (1.2- 28), and the mean airway peak pressure was on average 20.0 cmH_2O (5.50-36.6) was found. The mean tube size

Table 1. Demographic and Clinical Characteristics of the Patients (n=67)

	Median	**Min**	**Max**
Age	70	20	one hundred
BMI (kg/m^2)	25.2	16.5	53.3
		n=67	**%**
Gender	Male	38	56.7
	Woman	29	43.3
Diagnosis	Medical	28	41.8
	Surgical	39	58.2
Comorbid Disease	No	17	25.4
	Yes	50	74.6
Presence of Hypertension	No	35	52.2
	Yes	32	47.8

was 8.0 (6-9.5). Majority of patients (58.71%) had an orotracheal tube inserted, 84.4% of patients had a circular cuffed ET, 83.3% of the patients had NGT. It was determined that they were mostly (61.7%) in the supine position (Table 2).

Table 2. Clinical characteristics of patients obtained during ETCP measurements

	median	min	Max
ETCP value (mmHg)	28.5	5	127
RASS Score	-2.0	-6.0	1.0
Head of bed degree (°)	25.0	0	90
Which day after intubation	5.0	1	48
Tidal volume (Vt) (ml)	450.0	166	1085
PEEP (cmH_2O)	6.9	1.20	28.0
Mean Airway pressure (Pmean) (cmH_2O)	10.27	9.70	13.40
Peak Pressure (Ppeak) (cmH_2O)	20.0	5.50	36.60
Inspiration (I)	1	1	1
Expiration (E)	2	1	2,5
Systolic blood pressure (SBP) (mmHg)	111.0	30	189
Diastolic blood pressure (DBP) (mmHg)	60.0	10	95
Tube size	8.0	6.0	9.5

		n=264*	Percent (%)
Hyperinflation (ETCP> 30 cmHg)	No	147	55.7
	Yes	117	44.3
Hypoinflation (ETCP< 20 cmHg)	No	253	95.8
	Yes	11	4.2
Tube type	Tracheostomy	109	41.29
	Orotracheal	155	58.71
Cuff shape	Circular	223	84.47
	Conical	41	15.53
Presence of Nasogastric tube (NGT)	No	44	16.67
	Yes	220	83.33
Position	Supine	163	61.74
	Right Lateral	45	17.05
	Left Lateral	56	21.21

ETCP: Endotracheal cuff pressure, PEEP: Positive end expiration pressure
**A total number of ETCP measurements made during the patient's stay in ICU. It includes data on clinical characteristics of patients at the time of all each measurement.*

The findings of the linear regression model regarding the factors affecting the ETCP of the patients are given in Table 3. The R2 value of the model was found at the level of 21.4%, and the ETCP value was explained at the level of 21.4% by the independent variables. According to the F test result of the model, the F statistical value was 11,171, and the model was found significant since the p value was <0.05. Age, BMI, tube type, shape of tube cuff, tube size, and the degree of head of bed were found to be the most affecting variables on the ETCP values of the patients (p<0.05, Table 3). According to these results, age affects ETCP in the opposite direction and ETCP level decreases as age increases. It was found that BMI affected ETCP and as BMI increased ETCP level increased, respectively (p<0.05). ETCP was higher when the tube type was orotracheal tube. It was found that in case of tapered (conical) cuff, ETCP was lower. The tube size affected ETCP in the right direction, and ETCP increased as tube number increased, and ETCP level increased as the patient's degree of the head of bed increased (p<0.05) (Table 3).

Limitations

There are some limitations in this study. In the study, ETCP values were measured every 12 hours and changes in pressure levels could not be observed during this period. In addition, this study was conducted in ICU of a single center therefore, the results cannot be generalized.

DISCUSSION

In this study, it was determined that the changes in the ETCP values of the patients occurred and were related to the independent variables. High levels of ETCP, if not adjusted into the normal range and not corrected, may lead to impaired perfusion of the tracheal mucosa. The fact that 44.3% of the patients had hyperinflation shows that, in parallel with other studies, hyperinflation is very common in clinical practice. In the study, it was determined that the change in the measured ETCP values of the patients in the linear regression model was directly related to age, BMI, tube type, tube size, cuff shape and degree of head of bed of the patient.

In the study, it was found that the ETCP value of the patients decreased as the age increased (p<0.05). Elderly patients are prone to structural and functional changes surrounding the airway, such as atrophy of the glottic muscles and reduction in neck ROM,

Table 3. Factors Affecting Endotracheal Tube Cuff Pressure (n=264)

Variables	B	SE	t *	p **	95% Confidence Interval	
					Lower	Upper
Constant term	-17,844	14,917	-1,196	0.233	-47,225	11,537
Age	-0.148	0.077	-2,333	0.020	-0.332	-0.028
BMI	0.202	0.167	3,080	0.002	0.186	0.846
Tube type	0.345	2,288	5,304	<0.001	7,628	16,640
Cuff shape	-0.212	2,993	-3,340	0.001	-15,892	-4,100
Tube size	0.176	1,716	3,056	0.002	1,864	8,622
Head of bed degree (°)	0.120	0.134	2,074	0.039	0.014	0.544

R^2: 21.4% F: 11,171; d: 1,988
**t: t-test*
*** p<0.05*

compared to younger individuals [27]. Although there is no study examining the relationship between ETCP and age, this study suggests that the decrease in ETCP as age increases, resulting in a decrease in the ETCP value obtained from the inflated cuff due to the development of atrophy in the glottic muscles with increasing age.

In this study, it was found that BMI affects ETCP and as BMI increases, ETCP also increases. Contrary to what was obtained in this study, studies did not find a significant difference between ETCP and BMI [25,28,29]. D'anza et al. (2013) found that as BMI increased, the tracheal width of the patients decreased [30]. Similarly, considering the results obtained in this study, it is thought that as the BMI increases, due to narrowed tracheal diameter of the patients the ETCP may have increased.

It was found that the ETCP level was lower in ET with tapered (cubic) cuff compared to tubes with circular cuffs (Table 3). It is stated that it is not known exactly how the cuff shape and accompanying changes in body position affect the cuff pressure [9]. However, similar to this study, Mahmoodpoor et al. (2017) found that the pressure value in tubes with conical cuffs was significantly lower when compared to tubes with cylindrical cuffs, and the VAP rate was also lower [31].

In another study, it was found that ET with a conical cuff caused significantly less gastric secretion leakage compared to cylindrical cuffed tubes and was more effective in preventing the development of VAP [32,33]. In a study conducted in patients undergoing cervical surgery, it was found that the ETCP value measured in the conical cuff changed much less frequently during surgery and the cuff pressure was lower than in cylindrical cuffed endotracheal tubes [34].

In a meta-analysis study, it was found that there was no significant difference between conical and cylindrical cuffed tracheal tubes in terms of VAP development incidence and mortality [35]. Therefore, it is thought that the preference of conical cuffed endotracheal tubes, especially in patients who will undergo surgical intervention, will prevent mucosal perfusion disorder and tracheal damage, reduce the need for adjustment to keep the cuff pressure within normal ranges, and prevent increased cuff pressure and related complications.

In this study, it was found that although the patient's position did not affect the degree of the patient's head of bed, it was a factor affecting the ETCP and the cuff pressure increased as the degree of head of bed increased ($p<0.05$). In a study, it was found that simple and frequent changes in body position in mechanically ventilated patients could have a significant effect on MENR, and 40.6% of the measurements exceeded the upper target limit of 30 cmH_2O [9].

Komosawa et al. (2015) found that neck flexion and extension cause intracuff pressure to exceed 30 cmH_2O with high incidences such as 90% (flexion) and 50% (extension) [36]. In other studies, it was found that the orotracheal tube shifted unpredictably with head position changes [37,38]. It was also determined that changing the head position at different degrees

of head of bed in mechanically ventilated patients leads to continuous changes in endotracheal cuff pressure [39]. Nazari et al. (2020) found that ETCP increased (often above 30 cmH_2O) in all six head positions, and the highest-pressure differences were observed in anterior flexion and left rotation positions [40]. It was determined that an increase in intracuff pressure occurs mostly with head and neck flexion, and changes in the head position of the patients lead to an increase in the cuff pressure in 68.1% of the patients [41]. Choi et al. (2017) found that the ETCP value was higher after the patients were placed in the lateral position after the straight supine position [42].

Kim et al. (2021) also emphasizes that the ETCP value exceeds more than 30 cmH_2O in 12% of the patients, therefore, the cuff pressure should be adjusted after tracheal intubation and each position change [8]. In studies, it was stated that ETCP values that are higher than the recommended level is very common in patients despite the known risks [17,43]. However, in a prospective study, the estimated incidence of tracheal stenosis was 4% in patients intubated for 5 to 10 days, and 12% in patients intubated for 11 to 24 days [9]. These results suggest that the degree of head of bed and position changes often lead to an increase in pressure due to the change in the position of the tubes within the trachea. For this reason, it is suggested that intensive care nurses avoid unnecessary head and neck movements of patients and re-evaluate and adjust the cuff pressure after each change in the degree of head of bed and position, resulting in fewer complications in patients.

In this study, it was found that placement an orotracheal tube caused a high level of ETCP. This result shows that the ETCB value is lower in patients with tracheostomy. There is no study in the literature regarding the ETCB value according to the type of the tracheal tube among adults. Kim et al. (2021) showed in their study that changing the position of the head causes the displacement of the tube. This result obtained from this study suggests that the tracheal tubes placed by tracheostomy move less in the trachea, while the orotracheal tubes cause higher cuff pressures due to the greater displacement or movement of the orotracheal tubes during the head and neck positions [8].

In this study, it was found that the size of tracheal tubes affected ETCP and as the tube size increased, ETCP increased ($p<0.05$). There has been no study of the effect of different sized tracheal tubes on the ETCP value in adult patients. However, Krishna et al. (2017) in their study among pediatric patients, it was observed that the mean ETCP value was significantly higher in small sized endotracheal tubes [44]. In the same study, it was stated that even though the endotracheal tube size is very small, the cuff can still be closed by inflating the cuff with additional air, but this will undesirably transform a cuff into a higher volume and high pressure [44]. In this respect, it was emphasized that if it is not possible to close the trachea with the least amount of air by using a small-size tube, it may be more advantageous to prefer a larger-numbered tracheal tube instead of inflating the cuff with more air. The result obtained from this study, on the other hand, suggests that the choice of tube size may not be sufficient by considering only gender for adults, tracheal diameter with age in adults should be considered. Although in the literature, the choice of tube size in patients is often decided by gender and using some formulas in pediatric patients, these approaches are predictive approaches in clinical practice and there is variability in the diameter of the trachea. In their study Liu et al. (2021) showed that the transverse diameter of the cricoid cartilage could be accurately measured by ultrasonography and showed that the tracheal tube size of the patients could be best estimated by ultrasonography measurement of the cricoid diameter [45]. It is stated that measuring the diameter of the subglottic airway by ultrasonography will facilitate the selection of appropriately size of ET in pediatric patients. Therefore, this method can provide a better determination of the ET cuff diameter suitable for the optimal tracheal diameter compared to standard age and height-based formulas [46].

CONCLUSION

The results obtained from this study showed that ETCB levels were often high. It was also found that the patient's age, BMI, tracheal tube type, size and cuff shape, and the degree of head of bed of patient caused deviations in ETCP levels. Higher levels of ETCP in the measurements made in this study are a very significant finding as they impair the mucosal capillary perfusion and cause tracheal damage. The results obtained are clinically important in the prevention of high or low level ETCP values and associated complications, especially in patients who were hospitalized in the ICU for a long time and had tracheal intubation. Since potentially undesirable increases in the patient's ETCP values are common, it

shows that intensive care nurses should monitor ETCP at frequent intervals, considering patient-specific variables and endotracheal tube characteristics, and that standard protocols should be developed to keep ETCP in the normal range. In addition, intensive care specialists should decide on the tube type and size, considering the characteristics of the tubes and the age-related changes in the patient's trachea.

Author contribution
Study conception and design: AK; data collection: AK; analysis and interpretation of results: AK; draft manuscript preparation: AK. The author reviewed the results and approved the final version of the manuscript.

Ethical approval
The study was approved by the Koç University Biomedical Research Ethics Committee (Protocol no. 2018.323.IRB2.049/28.11.2018).

Funding
The authors declare that the study received no funding.

Conflict of interest
The authors declare that there is no conflict of interest.

Yazar katkısı
Araştırma fikri ve tasarımı: AK; veri toplama: AK; sonuçların analizi ve yorumlanması: AK; araştırma metnini hazırlama: AK. Yazar araştırma sonuçlarını gözden geçirdi ve araştırmanın son halini onayladı.

Etik kurul onayı
Bu araştırma için Koç Üniversitesi Biyomedikal Araştırmalar Etik Kurulu Üniversitesi Etik Kurulundan onay alınmıştır (Karar no: 2018.323. IRB2.049/28.11.2018).

Finansal destek
Yazarlar araştırma için finansal bir destek almadıklarını beyan etmiştir.

Çıkar çatışması
Yazarlar herhangi bir çıkar çatışması olmadığını beyan etmiştir.

REFERENCES

1. Totonchi Z, Jalili F, Hashemian SM, Jabardarjani HR. Tracheal Stenosis and Cuff Pressure: Comparison of Minimal Occlusive Volume and Palpation Techniques. Tanaffos 2015; 14(4): 252.
2. Carhart E, Stuck LH, & Salzman JG. Achieving a Safe Endotracheal Tube Cuff Pressure in the Prehospital Setting: Was It Time to Revise the Standard Kaf Inflation Practice? Prehospital Emergency Care 2016;20(2):273-277. **[Crossref]**
3. Sultan P, Carvalho B, Rose BO, Cregg R. Endotracheal tube Cuff pressure monitoring: a review of the evidence. J Perioper Pract 2011;21(11):379-87. **[Crossref]**
4. Chenelle CT, Oto J, Sulemanji D, Fisher DF, & Kacmarek RM. Evaluation of an automated endotracheal tube Cuff controller during simulated mechanical ventilation. Respiratory care 2015;60(2):183-190. **[Crossref]**
5. Hockey C, Van Zundert A, Paratz J. Does objective measurement of tracheal tube Cuff pressures minimise adverse effects and maintain accurate kaf pressures? A systematic review and meta-analysis. Anaesthesia & Intensive Care 2016;44(5):560-70. **[Crossref]**
6. Lorente L, Blot S, Rello J. New issues and controversies in the prevention of ventilator-associated pneumonia. Am. J. Respir. Crit. Care Med 2010;182(7):870-876. **[Crossref]**
7. Nseir S, Zerimech F, Fournier C, Lubret R, Ramon P, Durocher, Balduyck M. Continuous control of tracheal Cuff pressure and microaspiration of gastric contents in critically ill patients. Am J Respir Crit Care Med 2011; 184:1041-1047. **[Crossref]**
8. Kim HJ, Jang J, Kim SY, Park WK, Kim HJ. Effects of Head and Neck Position on Nasotracheal Tube Intracuff Pressure: A Prospective Observational Study. J Clin Med 2021 30;10(17):3910. **[Crossref]**
9. Lizy C, Swinnen W, Labeau S, Poelaert J, Vogelaers D, Vandewoude K, Blot,S. Cuff pressure of endotracheal tubes after changes in body position in critically ill patients treated with mechanical ventilation. American Journal of Critical Care 2014; 23(1), e1-e8. **[Crossref]**
10. Athiraman, U., Gupta, R., & Singh, G. Endotracheal cuff pressure changes with change in position in neurosurgical patients. International Journal of Critical Illness and Injury Science, 2015; 5(4), 237. **[Crossref]**
11. Talekar CR, Udy AA, Boots RJ, Lipman J, Cook D. Tracheal Cuff pressure monitoring in the ICU: a literature review and survey of current practice in Queensland. Anaesth Intensive Care 2014; 42:761-770. **[Crossref]**
12. Hoffman RJ, Parwani V, Hahn IH. Experienced emergency medicine physicians cannot safely inflate or estimate endotracheal tube cuff pressure using standard techniques. Am J Emerg Med. 2006;24(2):139-143. **[Crossref]**

13. Jiang N, Del Signore AG, Iloreta AM, Malkin BD. Evaluation of a teaching tool to increase the accuracy of pilot balloon palpation for measuring tracheostomy tube cuff pressure. Laryngoscope 2013; 123:1884-1888. [Crossref]
14. Maboudi A, Abtahi H, Hosseini M, Tamadon A, Safavi E. Accuracy of endotracheal tube cuff pressure adjustment by fingertip palpation after training of intensive care unit nurses. Iran Red Crescent Med J 2013; 15:381-384. [Crossref]
15. Parwani V, Hoffman RJ, Russell A, Bhwerel C, Preblick C, Hahn IH. Practicing paramedics cannot generate or estimate safe endotracheal tube cuff pressure using standard techniques. Prehosp Emerg Care 2007; 11:307-311. [Crossref]
16. Velasco Sanz TR, Ronda Delgado de la Fuente M, Sanchez de la Ventana AB, Reyes Merino Martinez M. Cuff pressure control at the intensive care unit: influence of nursing professionals' training. Enferm Intensiva 2015; 26:40-45. [Crossref]
17. Galinski M, Tréoux V, Garrigue B, Lapostolle F, Borron SW, Adnet F. Intracuff pressures of endotracheal tubes in the management of airway emergencies: the need for pressure monitoring. Ann Emerg Med 2006;47(6):545-547. [Crossref]
18. Stewart SL, Secrest JA, Norwood BR, Zachary R. A comparison of endotracheal tube cuff pressures using estimation techniques and direct intrakaf measurement. AANA J 2003; 71(6):443-447.
19. Alvwerez Lerma F, Sanchez Garcia M, Lorente L, Gordo F, Anon JM, Alvwerez J, et al. Guidelines for the prevention of ventilator associated pneumonia and their implementation. The Spanwash 'Zero-VAP' bundle. Med Intensiva 2014; 38:226-236. [Crossref]
20. Palmer LB. Ventilator-associated tracheobronchitis. Curr Respir Med Rev 2010; 6:58-64. [Crossref]
21. Kebapci, A., & Ozkaynak, M. Endotracheal Tube Cuff Pressure Management: An Observational Study Guided by the SEIPS Model. Dimensions of Critical Care Nursing 2022; 41(2):64-75. [Crossref]
22. Johnston R. Tracheostomy Kaf and Tube Care, (In) Procedure Manual for High Acuity, Progressive and Critical Care, (Ed.) Debra L. Wiegand, Elseiver, Seveth Edition, 2017; St. Louis Missouri.
23. Sole ML, Su X, Talbert S, Penoyer DA, Kalita S, Jimenez E, et al. Evaluation of an intervention to maintain endotracheal tube cuff pressure within therapeutic range. Am J Crit Care 2011;20(2):109-18. 5. [Crossref]
24. Polit, D.F. and Beck, C.T. (2004) Nursing Research: Principles and Methods. 7th Edition, Lippincott Williams & Wilkins, Philadelphia.
25. Rokamp KZ, Secher NH, Møller AM, Nielsen HB. Tracheal tube and laryngeal mask cuff pressure during anaesthesia - manda-tory monitoring is in need. BMC Anesthesiol 2010; 10:20. [Crossref]
26. Rosero, E. B., Ozayar, E., Eslava-Schmalbach, J., Minhajuddin, A., & Joshi, G. P. (2018). Effects of increasing airway pressures on the pressure of the endotracheal tube cuff during pelvic laparoscopic surgery. Anesthesia & Analgesia, 127(1), 120-125. [Crossref]
27. Johnson KN, Botros DB, Groban L, Bryan YF. Anatomic and physiopathologic changes affecting the airway of the elderly patient: implications for geriatric-focused airway management. Clinical interventions in aging 2015; 10: 1925. [Crossref]
28. Wu CY, Yeh YC, Wang MC, Lai CH, Fan SZ. Changes in endotracheal tube cuff pressure during laparoscopic surgery in head-up or head-down position. BMC Anesthesiol 2014; 14:75. [Crossref]
29. Kwon, Y, Jang JS, Hwang S.M, Lee JJ, Hong SJ, Hong SJ, Lee HS. The change of endotracheal tube cuff pressure during laparoscopic surgery. Open Medicine 2019; 14(1): 431-436. [Crossref]
30. D'Anza B, Knight J, Greene JS. (2013). Do obese patients need larger endotracheal tubes? Otolaryngology Head and Neck Surgery 2013; 149 (2_suppl): 47-48. [Crossref]
31. Mahmoodpoor A, Hamishehkar H, Hamidi M, Shadvar K, Sanaie S, Golzari SE, Nader N.D. A prospective randomized trial of tapered- cuff endotracheal tubes with intermittent subglottic suctioning in preventing ventilator-associated pneumonia in critically ill patients. Journal of Critical Care 2017; 38:152-156. [Crossref]
32. Shiotsuka J, Lefor AT, Sanui M, Nagata O, Horiguchi A, Sasabuchi Y. A quantitative evaluation of fluid leakage around a polyvinyl chloride tapered endotracheal tube cuff using an in-vitro model. HSR Proceedings in Intensive Care & Cardiovascular Anesthesia 2012; 4(3): 169.
33. Khashaba SA, Chaari A, Uddin F, Hamamah D, Ismail M, Tierney E, Casey W.F. Tapered-cuff versus cylindrical-kaf tracheal tube in preventing fluid leak: An in-vitro experimental study. Trends in Anaesthesia and Critical Care 2019; 25: 41-45. [Crossref]
34. Li YS, Tan EC, Tsai YJ, Mandell MS, Huang SS, Chiang TY, Huang WC, Chang WK, Chu YC. A Tapered Kaf Tracheal Tube Decreases the Need for Cuff Pressure Adjustment After Surgical Retraction During Anterior Cervical Spine Surgery: A Randomized Controlled, Double-Blind Trial. Front Med (Lausanne) 2022; 29(9):920726. [Crossref]
35. Huang WM, Huang XA, Du YP, Li LX, Wu FF, Hong SQ, Tang FX, Ye ZQ. Tapered cuff versus Conventional Kaf for Ventilator-Associated Pneumonia in Ventilated Patients: A Meta-Analysis of Randomized Controlled Trials. Can Respir J 2019; 22: 7876417. [Crossref]
36. Komasawa N, Mihara R, Imagawa K, Hattori K, Minami T. Comparison of Pressure Changes by Head and Neck Position between High-Volume Low-Pressure and Taper-Shaped Cufs: A Randomized Controlled Trial. BioMed Res. Int 2015; 2015:386080. [Crossref]

37. Inoue S, Takauchi Y, Kuro M, Ninaga H. [Effects of changes in head and neck position on a tracheal tube cuff]. Masui 1998;47(9):1069-72.
38. Tailleur R, Bathory I, Dolci M. Frascarolo P, Kern C, Schoettker P. Endotracheal tube displacement during head and neck movements. Observational clinical trial. J. Clin. Anesth 2016; 32:54-58. **[Crossref]**
39. Okgun Alcan A, Yavuz van Giersbergen M, Dincarslan G, Hepcivici Z, Kaya E, Uyar M. Effect of patient position on endotracheal cuff pressure in mechanically ventilated critically ill patients. Aust Crit Care 2017;30(5):267-272. **[Crossref]**
40. Nazari R, Salehpour Omran M, Sharif Nia H, Yaghoobzadeh A. Effect of Head Position Change on Endotracheal Cuff Pressure in Mechanically Ventilated Patients: A Quasi-Experimental Study. Tanaffos 2020;19(2):129-134.
41. Kako H, Krishna SG, Ramesh AS, Merz MN, Elmaraghy C, Grischkan J, Jatana KR, Ruda J, Tobias JD. The relationship between head and neck position and endotracheal tube intracuff pressure in the pediatric population. Paediatr Anaesth 2014 Mar;24(3):316-21. **[Crossref]**
42. Choi E, Park Y, Jeon Y. Comparison of the kaf pressure of a TaperGuard endotracheal tube and a cylindrical endotracheal tube after lateral rotation of head during middle ear surgery: A single-blind, randomized clinical consort study. Medicine (Baltimore) 2017 Mar;96(10): e6257. **[Crossref]**
43. Chopra M, Jones L, Boulanger C. Prospective observational measurement of tracheal tube cuff pressures in the emergency department. Emerg Med J 2010;27(4):270-271. **[Crossref]**
44. Krishna SG, Hakim M, Sebastian R, Dellinger HL, Tumin D, Tobias JD. Cuffed endotracheal tubes in children: the effect of the size of the Cuffed endotracheal tube on intrakaf pressure. Paediatr Anaesth 2017;27(5):494-500. **[Crossref]**
45. Liu S, Zhou J, Qi W, Cheng L, Dong Y. Prediction of double-lumen tube size by ultrasonography for Asian women: A prospective observational study. Journal of Cardiothoracic and Vascular Anesthesia 2021; 35(5): 1410-1415. **[Crossref]**
46. Shibasaki M, Nakajima Y, Shime N, Sawa T, Sessler D. I. Prediction of optimal endotracheal tube cuff volume from tracheal diameter and from patient height and age: a prospective cohort trial. Journal of anesthesia 2012; 26(4): 536-540. **[Crossref]**

APPENDIX

Appendix 1. STROBE Statement-checklist of items that should be included in reports of observational studies

	Item No.	Recommendation	Page No.
Title and abstract	1	*(a)* Indicate the study's design with a commonly used term in the title or the abstract	1
		(b) Provide in the abstract an informative and balanced summary of what was done and what was found	1
		Introduction	
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	13-4
		Methods	
Study design	4	Present key elements of study design early in the paper	4
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	*(a) Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	5
		(b) Cohort study—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment meth-ods if there is more than one group	6
Bias	9	Describe any efforts to address potential sources of bias	-
Study size	10	Explain how the study size was arrived at	5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6

**Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.*

Continued on next page.

Appendix 1. Continued

	Item No.	Recommendation	Page No.
Statistical methods	12	*(a)* Describe all statistical methods, including those used to control for confounding	7
		(b) Describe any methods used to examine subgroups and interactions	
		(c) Explain how missing data were addressed	
		(d) Cohort study—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	
		(e) Describe any sensitivity analyses	
		Results	
Participants	13*	*(a)* Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	7
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	*(a)* Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Cohort study—Summarise follow-up time (eg, average and total amount)	7
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	7
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	
Main results	16	*(a)* Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8
		(b) Report category boundaries when continuous variables were categorized	
		(c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
		Discussion	
Key results	18	Summarise key results with reference to study objectives	8-9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	8
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	
Generalisability	21	Discuss the generalisability (external validity) of the study results	8
		Other information	
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	

**Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.*

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.