

Original Article



The Effect of Different Body Positions on Endotracheal Tube Cuff Pressure in Patients under Mechanical Ventilation

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iums.ac.ir**Abstract****Introduction:** Maintaining endotracheal tube intracuff pressure (ETTICP) within an optimal range is crucial for effective ventilation and prevention of aspiration. This study aimed to determine the effect of changing body position on ETTICP in patients under mechanical ventilation.**Methods:** In the current single-group study, each patient was taken as his/her own control. Thirty patients who met the inclusion criteria were selected as the study sample. First, the patients were placed in a supine (flat) position, head of the bed was raised to 30 degrees, and ETTICP was set at 25 cmH₂O as the baseline. Then, the ETTICP changes in the three positions (left lateral, right lateral, and semi-fowler) were compared with the baseline. Interventions were made on a random basis among the patients. Data were analyzed by repeated-measures ANOVA using SPSS version 13.**Results:** There was a significant difference among ETTICP means in three different body positions, so that ETTICP was higher in the left lateral position compared to other positions. Moreover, there was a significant difference among ETTICP means 0, 15, 45, and 90 minutes after changing the body position. ETTICP means after 0 and 15 minutes were significantly higher than other times compared to the baseline.**Conclusion:** ETTICP changes were affected by different body positions and the passage of time. Thus, regular monitoring and adjusting of ETTICP after any body positioning is essential, especially immediately and 15 minutes after repositioning.**Introduction**

Endotracheal intubation is a standard and safe method to maintain an open airway and provide effective ventilation.¹⁻³ The cuff must be sufficiently filled^{4,5} and kept within the normal range of 20-30 cmH₂O for adequate mechanical ventilation.^{6,7} Pressure variation outside this range causes some complications for patients.⁸⁻¹⁰

The pressures of more than 30 cmH₂O cause damage to the trachea,^{6,11} sore throat and dysphonia,¹² abrasion of the carotid artery,¹¹ and the trachea softening;¹² in addition, the injury rate increases over time.¹³ Nonetheless, the insufficient endotracheal tube intracuff pressure (ETTICP) results in the micro-aspiration of the contents of the mouth, larynx, and stomach,^{10,14} especially during inhalation,^{10,15} which is a significant contributor to pneumonia caused by the ventilator.^{10,14} The risk of this complication increases by up to four times due to the pressure of less than 20 cmH₂O.¹⁶ Moreover, the inadequate ETTICP leads to insufficient delivery of the determined vital capacity to the patient.¹¹

Maintaining the ETTICP in the safe range is seen as a care challenge. Numerous and various factors are effective in the changes in the pressure of the tracheal tube cuff,

including individual and environmental conditions and features and therapeutic interventions.¹⁷⁻¹⁹ These factors include changes in the patient's body condition,^{18,19} anesthetic agents,²⁰ changes in the tracheal muscle tone,²¹ decreasing and increasing of body temperature,²² the release of anesthetic gases into the cuff,¹⁶ changing the position of the tracheal tube placement,¹⁶ changing the head position and the position of the endotracheal tube in the mouth,¹⁷ oxygenation,²² and mechanical ventilation.²⁰

Changing the patient's position from supine to prone position also causes the displacement of the tracheal tube and changes ETTICP.^{19,23} Changing the positions of the head causes the displacement of the tracheal tube.^{17,19} Lifting the head affects the ETTICP by influencing the position of the neck.¹⁶ It has been shown that changing the patient's position toward the ventilator or contrary to the ventilator direction is also effective in changing the ETTICP. In addition, the patient's rotation opposite the ventilator direction increases the ETTICP.²¹

Changing the patient's position is considered as the main care measures, especially in the intensive care unit (ICU), which is done routinely at regular intervals (usually every two hours). A close relationship has been found between

environmental factors, health care, and therapeutic interventions, particularly patient's repositioning with changes in the pressure of the tracheal tube cuff. Thus, the need to maintain the ETTICP in the safe range and prevent abnormal changes and subsequent resulting consequences for the patient has been emphasized. Accordingly, this study aimed to investigate the effect of different body positions on the ETTICP, and also the impact of time passage on these changes.

Materials and Methods

This was a single-group study with repeated-measures ANOVA, in which each person was considered his/her own control. The study population included all patients under mechanical ventilation admitted to Ayatollah Mousavi teaching hospital affiliated to Zanjan University of Medical Sciences, Iran from 15 October to 30 February 2016.

The research environment in this study consisted of two ICU departments with 20 beds. Because a deviation of 5 cmH₂O from baseline would be needed to reach the maximum cuff pressure limits, the power analysis was based on an anticipated difference of 5 or more cmH₂O, with a standard deviation of 5 cmH₂O. For this difference to be significant ($\beta=0.20$; $\alpha=0.05$), a minimum sample of 18 patients was needed. So, 30 eligible patients were selected through convenience sampling. The inclusion criteria included patients aged over 18 years, under mechanical ventilation with orotracheal intubation, and with stable hemodynamic status who underwent intubation in the first 72 hours. Patients with complicated intubation, restricted changing position, prone position, a history of neck stiffness or moving restrictions, a peripheral body temperature of less than 35°C or more than 38°C, having chest tube, and with body mass index (BMI) more than 35 were excluded from the study.

The order of intervention was randomly determined by the dice-throwing method. After approval of the study at the Research Ethics Committee (ZUMS.REC.1393.172), an informed consent was obtained from the patients' guardians.

Initially, the patient was placed by two experienced nurses in a supine position with the head of the bed raised to 30 degrees (base position), so that the head and neck were in line with the body. Then, the pressure of the ETTICP was measured at minutes 0 and 15 using the calibrated manometer (Mallinckrodt Medical, Athlone). The pressure was set at 25 cmH₂O in the event of being higher or lower than the normal range (20-30 cmH₂O). The ETTICP of 25 cmH₂O was considered as the baseline or control, by which the changes in the pressure of the ETTICP at other three positions (intervention) were controlled and compared. To begin, two experienced nurses put the patient at the left lateral position. Then, the ETTICP was measured and recorded immediately after changing the position (minute 0) and 15, 45, and

90 minutes after that. The same two nurses changed the patient's position to the base position after 90 minutes. The researcher measured the ETTICPs at minutes 0, 15, 45, and 90. This process was also repeated for the right lateral and semi-Fowler's positions randomly. Hence, 12 measurements (4 measurements for each position) were made for each patient (without considering the measurements of baseline status). Each intervention consisted of three independent steps. Each step took 105 minutes (15 minutes for control phase and 90 minutes for intervention phase). In total, there was only one intervention for each patient, which lasted 315 minutes. The entire intervention was completed in one shift. Head and neck were placed in line with the body in all conditions. Pillows and medical rolls were used to change the position and maintain the patient's comfort correctly. All the measurements were made by the researcher herself and simultaneously with the end of the patient expiration. Distribution of the data was investigated and confirmed by quantile-quantile (Q-Q) plot method. Descriptive statistics, independent *t* test and repeated-measures ANOVA using SPSS version 13 were used to analyze the data. The significance level was considered to be less than 0.05.

Results

Among 30 participants included in the study, 22 (73.3%) were male and 8 (26.7%) were female; and the age range of the subjects was 22-88 years, with mean (SD) 57.93 (19.69) years. Moreover, 15 (50%) of patients had been hospitalized due to medical problems, 14 (46.7%) due to multiple trauma, and 1 (3.3%) due to surgical reasons. In addition, 10 (33.3%) of the patients had a consciousness level of 3-6 in terms of the Glasgow Coma Scale (GCS), 14 (46.7%) with GCS of 6-9, and 6 (20%) GCS of 9-12.

The independent *t*-test results showed no significant difference between the ETTICP means in the three positions at 5 times in patients with a ventilator on their right side and the patients with the ventilator on their left side ($P > 0.05$).

The results of repeated-measures ANOVA showed that all of the ETTICP means at five times and three positions were significantly different from each other. Thus, the Greenhouse-Geisser paired test provided significant results for the differences among the ETTICP means at three positions ($P=0.001$), for the differences among the ETTICP means at different times ($P < 0.001$), and for the interaction effects of the measurement times and three positions ($P=0.007$) (Table 1).

According to the Bonferroni's post hoc test, in a paired comparison of the ETTICP means at three positions, only the ETTICP mean in the left lateral position had a significant difference with the ETTICP mean in the semi-Fowler's position ($P=0.005$) (Table 2).

Furthermore, the Bonferroni's post hoc test results for the paired comparison of the pressure means at five

Table 1. The mean and standard deviation of intracuff pressure (cm H₂O) in five measurement times

Positions	Mean (SD)					P value ^a
	Baseline	After change of position	15th min	45th min	90th min	
Left lateral	25(0)	35.13(11.50)	27.03(2.53)	26.97(2.94)	27.20(3.55)	0.001*
Right lateral	25(0)	33.20(7.35)	25.87(3.13)	25.73(2.29)	25.27(3.03)	
Semi-fowler	25(0)	28.87(6.67)	26.30(3.41)	25.10(2.86)	25.73(3.33)	

^a Repeated-measures ANOVA; *Statistically significant.

Table 2. Comparison of the intracuff pressure means at three positions (Bonferroni's post hoc test)

Variables	Mean differences (SE)	95% CI for difference		P value
		Lower limit	Upper limit	
Left lateral				
Right lateral	1.25 (0.51)	- 0.05	2.55	0.06
Semi-fowler	2.07 (0.59)	0.57	3.57	0.005*
Right lateral				
Left lateral	- 1.25 (0.51)	- 0.55	- 2.55	0.06
Semi-fowler	0.81 (0.44)	- 0.31	1.94	0.23
Semi-fowler				
Left lateral	- 2.07 (0.59)	- 3.57	- 0.57	0.005*
Right lateral	- 0.81 (0.44)	- 1.94	0.31	0.23

*Statistically significant.

measurement times revealed that the differences between the baseline pressure means and the pressure means immediately after the position change ($P < 0.001$) and 15 minutes later ($P = 0.01$) were significant. The results of the paired comparison of the ETTICP means immediately after repositioning with all the times of the baseline, 15, 45, and 90 minutes were significant ($P < 0.001$) (Table 3).

Discussion

Current study results showed that not only the ETTICP means were different in the three positions, but they also varied at different times of the measurements. ETTICP changes were affected by different body positions, and the passage of time. Despite the fact that the means of all pressures at five measurement times in all three positions were normal, the ETTICP means in the left lateral position showed the highest value.

The results suggest that the ETTICP means were significantly high immediately after repositioning. The remarkable thing to note was the quick decrease in the ETTICP up to minute 15, which returned the normal range (20-30 cmH₂O). In other words, the changes in the ETTICP were not significant at minutes 45 and 90 after changing the position. However, these changes in the left lateral position were still higher than the other two positions.

Sole et al, stated that the changes in the pressure of the tracheal tube after repositioning are often transient and become normal within 15 minutes.¹⁶ Athiraman et al, reported that the ETTICP decreased over time by the neck muscle relaxation.²⁰ In the study by Kim et al, the ETTICP mean increased to 31.5 with a standard deviation of 5.9

Table 3. Comparison of the intracuff pressure means at five measurement times (Bonferroni's post hoc test)

Variables	Mean differences (SE)	95% CI for difference		P value
		Lower limit	Upper limit	
Baseline				
Minute 0	7.40(1.21)	-11.07	-3.74	< 0.001*
Minute 15	-1.40(0.41)	-2.64	-0.16	0.02*
Minute 45	-0.93(0.38)	-2.09	0.23	0.21
Minute 90	-1.07(0.46)	-2.45	0.32	0.27
Minute 0				
Baseline	7.40(1.21)	3.74	11.07	< 0.001*
Minute 15	6(1.08)	2.70	9.30	< 0.001*
Minute 45	6.47(1.09)	3.16	9.77	< 0.001*
Minute 90	6.33(1.06)	3.12	9.56	< 0.001*
Minute 15				
Baseline	1.40(0.41)	0.16	2.64	0.02*
Minute 0	-6(1.08)	-9.30	-2.70	< 0.001*
Minute 45	0.47(0.26)	-0.32	1.25	0.82
Minute 90	0.33(0.27)	-0.49	1.15	1
Minute 45				
Baseline	0.93(0.38)	-0.23	2.09	0.21
Minute 0	-6.46(1.09)	-9.77	-3.16	< 0.001*
Minute 15	-0.47(0.26)	-1.25	0.32	0.82
Minute 90	-0.13(0.23)	-0.83	0.56	1
Minute 90				
Baseline	1.07(0.46)	-0.32	2.45	0.27
Minute 0	-6.33(1.06)	-9.55	-3.12	< 0.001*
Minute 15	-0.33(0.27)	-1.15	0.49	1
Minute 45	0.13(0.23)	-0.56	0.83	1

*Statistically significant.

cmH₂O by changing the body position from supine to the prone position without any changes in the head and neck alignment,²³ which is consistent with our study. In the study by Minonishi et al,¹⁹ the ETTICP was evaluated after changing position from supine to the prone by turning the head to the right, but in the study by Kim et al,²³ no change was made in the angle of the head, which can be the reason for the difference between these studies. According to Savitha et al, with head and neck extension, a drop in the ETTICP can occur,²⁴ which is in conformity with the study by Kim et al,²³ regarding the lack of significant increase in the pressure in the head and neck extension in the supine position. We did not examine the extension and flexion of the head and neck in our study. However, our results are

in agreement with the mentioned studies in terms of the ETTICP changes with the changes in the body position.

Athiraman et al, evaluated the patients undergoing neurosurgery and reported a significant difference between the ETTICP in the supine position at the beginning, during, and at the end of surgery before extubating the endotracheal tube. The results were also similar in the surgeries in the prone position.²⁰ Nevertheless, it has been stated in these studies, like our study, that the ETTICP is different with changes in the head and body position.

In our study, the location of the ventilator did not affect the ETTICP and its variations due to changes in the patient's position. In the study by de Godoy et al, changing the patients' position to the opposite side of the ventilator location shifted the ETTICP higher than to the same ventilator location.²¹

Moreover, the results of this study were in line with the study by Lizy et al, in terms of high ETTICP after changing the position.¹⁷ The ETTICP in our study was greater in the left lateral position. However, in the study by Lizy et al, the left lateral and right lateral positions were examined at angles of 30, 45, and 90 degrees, while in our study, their triple positions were evaluated only at 45 degree. The main difference between our study and the study by Lizy et al, was that they measured the ETTICP only once for each patient.¹⁷ In contrast, in the current study, the ETTICP was measured at minutes 0 (immediately), 30, 45, and 90 after changing the position.

In the study by de Godoy et al, moving the patient under mechanical ventilation also caused a change in the ETTICP, which is in line with our study from this perspective. However, it should be noted that the study by Godoy et al, did not indicate the change in either right or left positions, and merely altering the position from the semi-Fowler's position with a head angle of 35 degree to the sides or toward the opposite direction of the ventilator was examined.²¹ However, in our study, the position change from the baseline to the left lateral position resulted in a significant change in the ETTICP.

The endotracheal tube cuff's principal function is to implement proper tracheal sealing at a pressure high enough to prevent both gas leak and fluid aspiration, and low enough to maintain tracheal perfusion.²⁵ Endotracheal cuff pressure may be affected by various factors and interventions that will significantly impact the pressure reading.²⁵⁻²⁸ Thus, Proper monitoring of ETTICP is critical in mechanically ventilated patients and continuous regulation of ETTICP should be routine practice.²⁸⁻³⁰

The distinctive feature of current study from other similar studies is that current study assessed changes in ETTICP at five points after changing the patients' positions, which in other studies has not been studied over time. Another strength of current study was that each patient acted as their own control, and this controlled the effects of the confounding variables. The first limitation

of this study was the lack of an appropriate control group. The study measurements were performed only at five-time intervals due to the impossibility of continuous monitoring of the ETTICP. Hence, it is recommended that future studies measure the ETTICP continuously to provide accurate information.

Conclusion

The ETTICP in patients under mechanical ventilation in ICU was influenced by two important factors, including body position and the passage of time. The ETTICP increased as the position changed, and these changes were varied in different positions. Pressure changes had increasing feature in all cases. Moreover, the changes were a function of time, that is, the ETTICP was high at minute 0 (immediately after changing the position) and declined until the minute 15, and in most cases, it comes close to the safe range. Then, the changes, though declining until 90 minutes, rarely leave the safe range.

Regular monitoring of the ETTICP and its regular recording and setting are essential as other vital signs in every shift. Controlling and adjusting the ETTICP is important when changing the patient's position, particularly immediately after repositioning and 15 minutes later. Based on the results of this study and other studies confirming these results, it is recommended to use a properly calibrated manometer to control the ETTICP and avoid using conventional methods, like touch controls, which are not reliable. It is also recommended to control the ETTICP immediately after repositioning and 15 minutes later. The ETTICP should also be set and maintained in the safe range (20-30 cmH₂O) for effective ventilation and the prevention of aspiration.

Research Highlights

What is the current knowledge?

The need to maintain the endotracheal tube intracuff pressure (ETTICP) in the safe range and prevent abnormal changes and subsequent resulting consequences for the patient has been emphasized.

What is new here?

The ETTICP in patients under mechanical ventilation in ICU was influenced by two important factors, including body position and the passage of time. The ETTICP increased as the position changed, and these changes were varied in different positions. Pressure changes had increasing feature in all cases. Moreover, the changes were a function of time, that is, the ETTICP was high at minute 0 (immediately after changing the position) and declined until the minute 15, and in most cases, it comes close to the safe range. Then, the changes, though declining until 90 minutes, rarely leave the safe range.

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Authors' Contributions

MD, ZM: Conceptualization, investigation, data curation; MD: Methodology, supervision, project administration; MD, AJ: Data analysis, writing-review and editing; MD, AJ, ZM: Writing-original draft. All authors have read and agreed to the published version of the manuscript.

Ethical Issues

This study was approved by the Research Ethics Committee of Zanjan University of Medical Sciences (ZUMS.REC.1393.172).

Conflicts of Interest

The authors declare no conflict of interest in this study.

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