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Effect of patient position on endotracheal cuff pressure in mechanically ventilated critically ill patients

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ABSTRACT

Background: Endotracheal tube cuff pressure must be maintained within 20–30 mH_2O to prevent complications. There is limited literature reporting the impact of nursing care on endotracheal cuff pressure. However, few studies have reported the effect of nursing care on endotracheal cuff pressure.
Objectives: This study was performed to investigate the effects of body position on endotracheal cuff pressure.
Methods: Twenty-five patients receiving mechanical ventilatory therapy were placed in a baseline position (semirecumbent position with the head of the bed elevated at 30° and head in a neutral position) with endotracheal tube cuff was adjusted to 25 cmH_2O. The patients were moved into 16 different positions: anteflexion of the head; hyperextension of the head; left lateral flexion of the head; right lateral flexion of the head; rotation of the head to the left; rotation of the head to the right; semirecumbent position with 45° elevation of the head of the bed; recumbent position with 10° elevation of the head of the bed; supine position; trendelenburg position 10°; left lateral position at 30°, 45°, and 90°; and right lateral position at 30°, 45°, and 90°. The endotracheal tube cuff pressure was measured and recorded after each position change.
Results: Among the 400 endotracheal tube cuff pressure measurements (25 patients × 16 positions) 10 (2.5%) were lower than 20 cmH_2O; 201 (50.3%) were between 20–30 cmH_2O and 189 (47.3%) were higher than 30 cmH_2O. Mean endotracheal tube cuff pressure increased from 25 to 32.59 ± 4.08 cmH_2O after changing the patients' position. Friedman test indicated a statistically significant deviation in the ETCP across the 16 positions (X2: 122.019, p: 0.0001).
Conclusions: Body positioning during daily nursing care effected the endotracheal tube cuff pressure, suggesting that endotracheal tube cuff pressure should be measured after changing a patient's position and adjusted within the recommended range.

1. Background

Although mechanical ventilation is a supportive therapy for diseases leading to respiratory failure, it can cause serious complications.[1–3] The management of endotracheal cuff pressure (ETCP) is one of the most crucial factors associated with complications of mechanical ventilation.[1–3] The management of ETCP involves cuff pressure management, with the purpose of maintaining the airway and tracheal perfusion, ensuring ventilation and preventing aspiration.[3–5]

In the literature it has been recommended that ETCP should be maintained within the range of 20–30 cmH_2O, which is sufficiently

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high for preventing aspiration but sufficiently low for ensuring tracheal capillary perfusion.[5,6] There are various techniques for maintaining ETCP include minimal occlusive volume, minimal leak technique, cuff pressure measurement and palpation. In critical care areas, the ETCP measurement method is commonly used and standard of care for cuff pressure management.[7,8] However, maintaining ETCP within the recommended range is challenging because patient-related, environmental and therapeutic factors may contribute to deviations in ETCP.[4,5,9]

1.1. Over-inflation of the ETCP

Over-inflation of the endotracheal cuff occurs when the endotracheal cuff pressure exceeds the capillary perfusion pressure of tracheal mucosa.[6] Many factors, including positive pressure ventilation, nitrous oxide, high altitude, laryngeal spasm, bronchoconstriction and edema are associated with the over-inflation of an endotracheal cuff.[4,9,10] Excess ETCP is transmitted onto the trachea, leading to hypoperfusion, which is associated with tracheal ischemia, stenosis, necrosis, inflammation, ulceration, nerve damage or fistula.[6] Excessive ETCP can also lead to respiratory complications, such as cough, sore throat, hoarseness and blood-streaked expectoration.[6,10] Even in a short period an endotracheal cuff pressure higher than 30 cmH_2O can cause tracheal lesions leading to complications.[6]

1.2. Sub-inflation of the ETCP is also associated with complications

If ETCP is too low, secretions can be microaspirated, leading to ventilator-associated pneumonia.[4,5,9] Accidental extubation and inadequate ventilation are the other concerns associated with low ETCP. Sedative and neuromuscular blocking medications, low core temperature, and time can lead to a sub-inflated endotracheal cuff.[4,9,10]

Of the many factors associated with deviations in ETCP, body positioning is another factor that should be considered.[8] Some studies have shown that a patient's position during surgery, particularly the supine and prone positions, results in deviations in ETCP.[11–13] Alterations in the head and neck position can also cause a significant rise in ETCP.[13–15] Lizy et al. determined that simple and frequent body positioning of patients receiving mechanical ventilatory therapy has a significant effect on the ETCP.[10] Almost all of these studies were performed in operating rooms which involved prolonged positioning.[11–13] As different from surgical patients, periodically changing critically ill patients' positions is one of the most important nursing practices for preventing complications of immobility.[16] Many different positions are used while caring for critically ill patients receiving mechanical ventilator therapy.[16] The potential advantages of the positioning of critically ill patients are promoting comfort and relaxation, preventing deformities or injuries, stimulating circulation, improving gastrointestinal functions, promoting respiratory function. Besides changing positions allows for visibility and accessibility during treatments or diagnostic tests.[17] Nevertheless, information on the effects of various and frequent body positioning on ETCP is lacking. Thus, the present study was performed to determine the effects of patient positioning on ETCP.

2. Method

2.1. Study aim

This prospective, observational study was performed to investigate the effects of body positioning on ETCP.

2.2. Study design and settings

Data were collected between February 19 and June 6, 2016 at the Ege University Hospital Anesthesiology intensive care unit (ICU), which is a 27-bed tertiary adult ICU that cares for approximately 450 patients annually. The ETCP is monitored and adjusted every 4 h by ICU nurses. All patients were intubated with the same high volume low pressure cuffed oral endotracheal tube (Chilecom Cuffed Endotracheal Tubes; Chilecom Medical Devices Co., Ltd., Huizhou, China) of appropriate size.

Data were collected using a form designed for this study. The form included 26 questions regarding patient's age, sex, body height and weight, diagnosis, comorbidities, endotracheal tube size, endotracheal tube fixation area, positive end-expiratory pressure, Ramsay Sedation Scale score, and ETCP measured after each position change. Demographic data were collected from the patient's medical record and via direct observation.

The Ramsay Sedation Scale is a scale used to assess the rousability with respect to patient's ability to respond. It defines the conscious state at six levels from level 1 (patient is anxious) to level 6 (the patient is completely unresponsive).[18]

All patients were placed in the baseline position: which was a semirecumbent position with the head of the bed elevated at 30° and the head in a neutral position. The endotracheal tube was then connected to a cuff pressure manometer (VBM Medizintechnik GmbH, Sulz am Neckar, Germany) using a connecting tube, and ETCP was adjusted to 25 cmH_2O. The lines were equipped with male and female luer-lock adapters were used to prevent disconnections and leaks. All patients were moved into one of 16 selected positions in the same sequence from the baseline position. Sixteen body positions often used during daily nursing care were selected. The 16 positions were; anteflexion of the head, hyperextension of the head, left lateral flexion of the head, right lateral flexion of the head, rotation of the head to the left, rotation of the head to the right, semirecumbent position with a 45° elevation of the head of the bed, recumbent position with a 10° elevation of the head of the bed, supine position, 10° trendelenburg position, left lateral position at 30°, 45°, and 90°; and right lateral position at 30°, 45°, and 90°. All patients were placed in Hill-Rom AvantGuard® patient beds (Hill-Rom, Chicago, IL, USA). All beds had angle indicators located on the head side rails, indicating the exact angle of the head when the head of the bed was elevated. The head of bed elevation angle was measured using these angle indicators.

The ETCP was measured and recorded after each position change. To avoid any potential effect on ETCP; the researchers did not interfere with the process by inflating/deflating of the cuffs. A registered nurse from the research team and a trained auxiliary staff moved the patients into the predetermined positions. Another registered nurse from the research team was responsible for ETCP measurements and recordings. Total intervention time for each patient was 40–45 min.

2.3. Sample selection

The sample size was determined statistically using a power analysis. The Type II error was set to 0.20, Type I error was set to 0.05, and the anticipated difference in ETCP was ≥ 6 cmH_2O (because a deviation of 5 cmH_2O was required to exceed the recommended ETCP limits); thus, 13 patients were required for the study. All patients older than 18 years of age, who were orotracheally intubated and were receiving invasive mechanical ventilatory therapy were included in the study (Fig. 1).

Patients who had received a tracheostomy, were not intubated, had a contraindication of head of bed elevation, had a disability in neck mobility, were hemodynamically unstable, were not able

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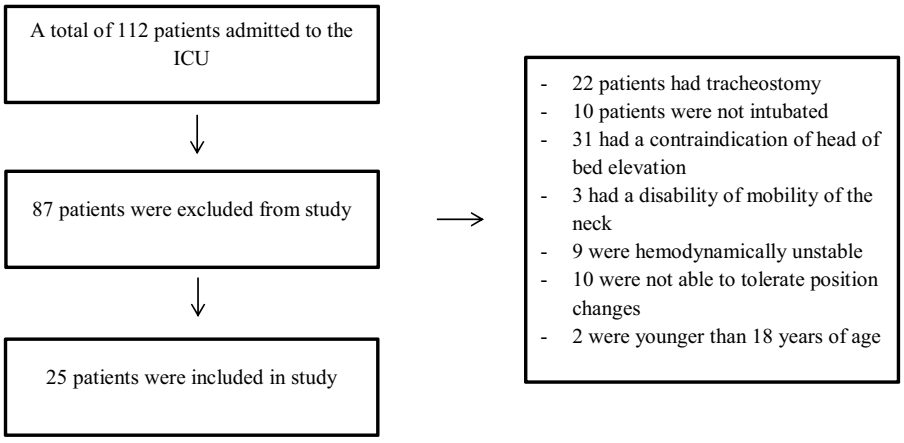

Fig. 1. Study sample flow.

to tolerate position changes or were younger than 18 years of age were excluded from the study (Fig. 1).

2.4. Ethical issues

This study was approved by the Ethics Committee of the Ege University Nursing Faculty. Written permission to perform the study was obtained from the institution where the research was conducted. The ethics committee and the institution required informed consent from all patients/relatives. Verbal consent was obtained from the relatives of the patients because all patients were sedated or unconscious. The relatives of the patients were informed about the details and purpose of the study, and verbal consent from all of the volunteer relatives of the patients was obtained prior to enrollment.

2.5. Statistical analyses

The data were analyzed using the Statistical Package for the Social Sciences (SPSS) for Windows 21.0 (IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.). The patient's descriptive data are expressed as numbers, percentages, and mean values. The Wilcoxon signed-rank, Spearman's Correlation, Friedman and Kruskal–Wallis tests were performed for variables that were not normally distributed. A p-value of <0.05 was considered statistically significant.

Table 1
Medical conditions of the patients.

Medical conditions	Number	Percentage
Diagnosis[a]		
Respiratory failure	25	100
Postoperative complication	8	32
Cardiovascular disease	6	24
Neurological disease	6	24
Respiratory disease	4	16
Gastrointestinal disease	3	12
Trauma	3	12.0
Malignancy	3	12
Acute kidney failure	1	4
Intoxication	1	4
Comorbidities		
Yes	11	44
No	14	56
Endotracheal tube size		
7.5	17	68
8.0	5	20
8.5	3	12
Endotracheal tube fixation area		
Right corner of the mouth	21	84
Left corner of the mouth	4	16
Positive end-expiratory pressure	6.04 ± 2.17 (min: 3 max: 12)	
Ramsay sedation score	4.24 ± 1.3 (min: 2 max: 6)	

[a] Patients have multiple diagnosis.

3. Results

A total of 112 patients were admitted to the ICU during the study period and 25 patients who met the research inclusion criteria were selected. Of the 25 patients, 14 (56%) were male and 11 (44%) were female. The mean age of the patients was 60 ± 19.4 (range, 20–91) years. The mean body mass index was 27.5 ± 4.4 (range, 18.4–36.7) kg/m^2. The medical conditions of the patients are given in Table 1. It was found that the potential confounding variables such as comorbidities, age, gender, body mass index, endotracheal tube size, endotracheal tube fixation area, positive end-expiratory pressure and Ramsay Sedation Scale score did not effect the ETCP.

Table 2 reflects the intermittently measured ETCP values. In total, 400 (25 patients × 16 positions) ETCP measurements were performed. Among them, 10 (2.5%) were lower than 20 cmH_2O; 201 (50.3%) were between 20–30 cmH_2O and 189 (47.3%) were higher than 30 cmH_2O (Table 2).

A statistically significant difference in ETCP was detected between the baseline and all other positions. As seen from Table 2 the ETCP increased the most after the patients' head hyperextended (43.7 ± 19.5; range, 20–108 cmH_2O) and rotated to the right (38.3 ± 11.5; range, 25–78 cmH_2O) position (Table 2). It could be said that hyperextension of the head and rotation of the head to the right are the positions causing the most deviation in ETCP.

Table 3 shows a comparison between the ETCP values for patients in the left and right lateral positions. ETCP values were significantly higher when the patients were in the left lateral position at 45° than when they were in the right lateral position at 45°.

The main result of the study was that the ETCP increased from 25 to 32.6 ± 4.1 cmH_2O after changing the patients' position. Friedman test indicated a statistically significant deviation in the ETCP across the 16 positions (X^2: 122, p: 0.0001) (Table 2).

4. Discussion

Critically ill patients are often immobilized because of multiple factors related to their illness and therapeutic interventions. Body positioning is one of the most important nursing practices for these patients to prevent complications that can occur due to immobility.[16,17] However, body positioning is a therapeutic inter-

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Table 2
ETCP values after position change.

Patient position ETCP range	ETCP range number (percentage)	Mean values of ETCP	p Value from baseline position[a]	p Value[b]
Anteflexion of the head				X^2: 122.019
<20	2 (8)	29.96 ± 7.19	Z: −2.998	p: 0.0001
20–30	10 (40)	min: 12 max: 44	p: 0.003	
>30	13 (52)			
Hyperextension of the head				
<20	–	43.68 ± 19.45	Z: −4.065	
20–30	7 (28)	min: 20 max: 108	p: 0.0001	
>30	18 (72)			
Left lateral flexion of the head				
<20	–	34.48 ± 8.57	Z: −4.173	
20–30	11 (44)	min: 20 max: 56	p: 0.0001	
>30	14 (56)			
Right lateral flexion of the head				
<20	1 (4)	32.28 ± 7.33	Z: −3.781	
20–30	10 (40)	min: 16 max: 48	p: 0.001	
>30	14 (56)			
Rotation of the head to the left				
<20	1 (4)	35.52 ± 10.17	Z: −3.838	
20–30	8 (32)	min: 14 max: 60	p: 0.001	
>30	16 (64)			
Rotation of the head to the right				
<20	–	38.28 ± 11.53	Z: −4.290	
20–30	8 (32)	min: 25 max: 78	p: 0.001	
>30	17 (68)			
Semirecumbent position with 45° elevation of the head of the bed				
<20	1 (4)	28.6 ± 6.63	Z: −2.608	
20–30	18 (72)	min: 18 max: 50	p: 0.009	
>30	6 (24)			
Recumbent position with 10° elevation of the head of the bed				
<20	–	27.08 ± 4.42	Z: −1.999	
20–30	21 (84)	min: 20 max: 36	p: 0.046	
>30	4 (16)			
Supine position				
<20	–	28.16 ± 5.46	Z: −2.538	
20–30	20 (80)	min: 20 max: 40	p: 0.011	
>30	5 (20)			
Trendelenburg position 10°				
<20	–	29.36 ± 4.80	Z: −3.612	
20–30	17 (68)	min: 22 max: 42	p: 0.001	
>30	8 (32)			
Left lateral position at 30°				
<20	–	32.48 ± 7.00	Z: 4.019	
20–30	12 (48)	min: 22 max: 55	p: 0.001	
>30	13 (52)			
Left lateral position at 45°				
<20	–	33.52 ± 8.27	Z: −4.206	
20–30	12 (48)	min: 25 max: 65	p: 0.001	
>30	13 (52)			
Left lateral position at 90°				
<20	–	37.00 ± 11.25	Z: −4.249	
20–30	8	min: 24 max: 72	p: 0.001	
>30	17 (68)			
Right lateral position at 30°				
<20	2 (8)	30.16 ± 7.08	Z: −2.942	
20–30	11 (44)	min: 12 max: 42	p: 0.003	
>30	12 (48)			
Right lateral position at 45°				
<20	2 (8)	29.12 ± 6.21	Z: −2.839	
20–30	15 (60)	min: 16 max: 46	p: 0.005	
>30	8 (32)			
Right lateral position at 90°				
<20	1 (4)	31.72 ± 7.14	Z: −3.539	
20–30	13 (52)	min: 16 max: 44	p: 0.001	
>30	11 (44)			

[a] ETCP in the baseline position (25 cmH_2O) was compared with ETCP in defined position.
[b] The ETCP was evaluated across all positions.

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Table 3
Comparison between the ETCP values for patients in left and right positions.

Patient position	p Value
Left lateral flexion of the head Right lateral flexion of the head	Z: −0.863 p: 0.388
Rotation of the head to the left Rotation of the head to the right	Z: −0.356 p: 0.722
Left lateral position at 30° Right lateral position at 30°	Z: −0.475 p: 0.635
Left lateral position at 45° Right lateral position at 45°	Z: −2.206 p: 0.027
Left lateral position at 90° Right lateral position at 90°	Z: −1.831 p: 0.067

vention, and position changes, particularly those causing head or neck movements, can cause changes in ETCP. The changes in ETCP have been explained using the anatomic structure of the neck and increase in intrathoracic pressure caused by the gravitational effect of the position change.[11–13] Changes in ETCP are associated with several complications such as ventilator-associated pneumonia, tracheal stenosis, necrosis, hoarseness, nerve damage or fistula.[4,5,9]

The results of this study indicate that approximately 50% of the ETCP measurements were not within the recommended range. Among these measurements, 2.5% were lower and 47.3% were higher than the recommended range. Mean ETCP were increased from 25 to 32.6 ± 4.1 cmH_2O after the position changes. These findings indicate that patient positioning effects ETCP. These results demonstrate that frequent position changes cause statistically significant deviations in ETCP. There are some reports which support our findings.[10,11,19]

Athiraman et al. observed the effect of different positions on the ETCP in patients undergoing neurosurgery and found a significant decrease in ETCP when patients were maintained in the supine and prone positions.[19] In our study, most of the ETCP values were within the recommended range but significantly increased compared with the baseline ETCP values in the supine position. These results are conflicting with our results. It is thought that this difference was a result of time period leading reduction of ETCP.

Minonishi et al. demonstrated a small correlation between position change from supine to prone and ETCP in patients undergoing spine surgery.[12] Similarly, Kim et al. reported that changing a patient's position from supine to prone increases ETCP.[11] They also stated that ETCP increases when patients are in a supine and prone position with the head flexed.[11] Kako et al. assessed the changes in intracuff pressure with changes in the head and neck position in children and reported a significant increase in ETCP when the head and neck position was changed.[14] Wu et al. determined that the ETCP is increased when patients were moved to the head-down position during laparoscopic surgery.[13] Similarly, Inoue et al. stated that changes in the head and neck position causing endotracheal movement effects ETCP.[15] Yildirim et al. stated that CO_2 insufflation during laparoscopic surgery effects intrathoracic pressure by moving the diaphragm upward, which increases inspiratory pressure and ETCP. They also stated that changing the head and neck position moves the endotracheal tube, which effects ETCP.[20] Our results also indicated a significant increase in all positions leading head and neck movements. These findings have demonstrated that head and neck movements leading displacement of the endotracheal tube can contribute in ETCP deviations.

Lizy et al. found that simple and frequent body positioning of unarousable patients receiving mechanical ventilatory therapy has a significant effect on the ETCP.[10] Similarly, in our study changing body position caused a significant increase (25 to 32.6 ± 4.1 cmH_2O) in ETCP. A previous study conducted by Lizy et al. utilized specifically unarousable mechanically ventilated patients, while this study excluded only non-sedated and minimally sedated patients.[10] Both moderate and deep sedated patients were included in the study due to comparing the effects of positioning patients from different sedation level on ETCP. We found that Ramsay Sedation Scale score did not differ in ETCP. The ETCP values of patients from all levels of sedation included in the study were increased by body positioning.

Current studies have confirmed that changing the position of patients who are receiving mechanical ventilatory therapy is associated with significant deviations in ETCP.[10–12] Our findings showed a similarity to those studies.

Nevertheless, time also contributes to a loss of ETCP.[6] Sole et al. compared changes in ETCP over 4, 8 and 12 h and reported a loss of ETCP volume over time.[21] Our findings differed from those of Sole et al. as our results indicate that the time elapsed, the anatomic structure of the neck and intra-thoracic pressure caused by a position change play roles in these ETCP variations.[21]

The results of this and other current studies demonstrated that maintaining of ETCP within the recommended range is challenging.[10–12] ETCP may not be within the target range between intermittent measurements.[22] Devices that automatically adjust ETCP within the recommended range have been developed.[21] Current studies have indicated that these devices more effectively maintain ETCP than adjusting ETCP intermittently.[23,24]

Several patient-related, environmental and therapeutic factors, such as the size of the endotracheal tube, sedation, age, positive pressure ventilation are known to contribute to deviations in ETPC.[4,5,9] We found that comorbidities, age, gender, body mass index, endotracheal tube size, endotracheal tube fixation area and positive end-expiratory pressure did not contribute to the ETCP, probably because of the small sample size.

This study has some limitations which have to be mentioned. ETCP was measured only after a position change and was not monitored for a period of time during which it may have changed. ETCP was measured with a manual manometer which provides only a snapshot and by unblinded observers. The positions were not changed in random order. However, we did use the same brand of the endotracheal tube (Chilecom Cuffed Endotracheal Tubes; Chilecom Medical Devices Co., Ltd., Huizhou, China) during the study.

5. Conclusion

Changing the body position of mechanically ventilated patients altered ETCP, suggesting that ETCP should be measured after a position change and adjusted within the recommended range. Further studies should be undertaken to investigate the effects of different techniques (continuous ETCP monitoring systems, long term outcome measures) and patients on ETCP.

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