Comparison between Endotracheal Tube Cuff Pressure Measurements Before and After nursing Interventions among Mechanically Ventilated Patients

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Abstract

Background: *Endotracheal intubation and mechanical ventilation are essential lifesaving procedures for many critically ill patients. Tracheal intubation with a cuffed tube is considered definitive airway management in adults. The tube cuff is designed to provide a seal against aspiration and to prevent leaks during positive pressure ventilation. A cuff pressure between 20 and 30 cmH_2O has been proposed guideline published by the Royal College of Anaesthetists to prevent the complications of over/under inflation of the cuff.* ***Objective:*** *To compare the endotracheal tube cuff pressure measurements before and after nursing interventions among mechanically ventilated patients.* ***Settings:*** *The study was carried out in the general ICU at Damanhour Medical National Institute that consist of three main halls with fifteen beds; hall I (4 beds), hall II (4 beds), and hall III (8 beds). .* ***Subjects:*** *A convenient sample of 70 adult patients who were mechanically-ventilated via an endotracheal tube with high-volume low-pressure cuff and a diameter ranging from 7 – 8.5 mm were included in the study.* ***Tools:*** *one tool was developed by the researcher used for data collection namely "Endotracheal tube cuff pressure measurement record". It was used to record the endotracheal tube cuff pressure measurements before and after the selected nursing interventions. It consists of three parts. Cuff pressure was assessed before nursing interventions and after nursing interventions.* ***Results:*** *The majority of the studied sample was male with age 51-60 years. Results of the study showed that there was a significant decrease in the mean values of endotracheal cuff pressure starting before till 30 minutes after the complete bed bath, oral hygiene, and right and left lateral positioning procedures. Conversely in the endotracheal suctioning, the mean value of ETT cuff pressure before showed an increase immediately after, followed by a decrease after 15 minutes, then an increase after 30 minutes.* ***Conclusion:*** *The study concluded that the cuff pressure measurements were significantly changed after performing the selected nursing interventions at different timing.* ***Recommendations:*** *Conducting educational program for the ICU nurses to indicate the importance of the endotracheal tube cuff pressure measurement after performing each of selected nursing interventions.*

Keywords: Endotracheal tube, Cuff pressure, Nursing interventions, Mechanical ventilation

Introduction

The endotracheal tube (ETT) is the most commonly used artificial airway for providing short-term respiratory support when the patient's respiratory problem cannot be resolved by other noninvasive procedures. ETT cuff pressure management is an essential part of airway management in intubated and mechanically ventilated patients in order to minimize possible complications. However, the pressure exerted on the trachea must be maintained within a therapeutic range (25 - 30 cmH_2O or 18 - 22 mmHg) that is high enough to ensure delivery of MV and prevention of marked aspiration, but low enough to ensure perfusion to the tracheal capillaries without causing injury (Rittayamai et al., 2015; Gupta & Rosen, 2016).

Measuring the pressure in the pilot balloon of the ETT cuff can be a good criterion for the pressure that the cuff imposes on the tracheal mucosa. Over-inflation of the ETT cuff (pressure >30 cm H_2O) for 15 min is enough to provide evidence of tissue histology of the mucosal lesions that may be the first stage in causing mucosal damage or complications such as tracheal tears. In contrast, under-inflation (pressure <20 cm H_2O) of the ETT cuff associated with air leakage, aspiration of secretions, ventilator-associated pneumonia, inadequate delivery of prescribed tidal volume, and accidental extubation White, Makara & Martinez-Taboada, 2020; Kumar, Seet & Zundert, 2021).

Maintaining the ETT cuff pressure within an optimal range is challenging for critical care nurses for the reason that many factors influence this pressure. These factors include: the patient-related factors as variation in head and neck position; changes in a patient's body position; changes in body temperature, environmental circumstances, and therapeutic interventions. In addition, there is evidence that tracheal tube cuff pressure could be changed over time. While, other studies recognized that variation in cuff pressure is transient and ETT cuff pressure return to normal within 15 minutes after patients' position changes (Khalil, Morsy, Salama & Sayed, 2018; Ahtiala et al., 2018).

In this regard, with the increasing demand for global intensive care, and the essential role of nurses in ICUs for monitoring; regulating, and maintaining cuff pressure, it is necessary to assess cuff pressure changes due to various nursing interventions like complete-in-bed bath, oral hygiene, endotracheal suctioning, right & left lateral position with HOB 30˚. These interventions were selected **because they are the core of the daily ICU routine** (Hassan & Baraka, 2021)**.**

To the best of our knowledge, there are no studies that have specifically investigated the effect of these interventions on cuff pressure. In addition, the previously mentioned studies were limited by the frequency of the ETT cuff pressure measurements; they measured the ETT cuff pressure once after nursing interventions. In the current study the researcher measured the ETT cuff pressure at three times immediately after, after 15 minutes, and after 30 minutes.

Aims of the Study

This study aims to compare endotracheal tube cuff pressure measurements before and after nursing interventions among mechanically ventilated patients.

Research Questions

- Is there a change in endotracheal tube cuff pressure measurements before and

after nursing interventions among mechanically ventilated patients?

Materials and Method

Materials

Design: The descriptive comparative design was adopted to carry out this study. ***Settings:*** This study was conducted in Damanhur Medical National Institute general ICU that consists of three main halls with fifteen beds; hall I that contains 4 beds, hall II contains 4 beds, and hall III contains 8 beds. It receives approximately 30 patients / month.

Subjects: A convenient sample of 70 adult patients who were mechanically-ventilated via an endotracheal tube with high-volume low-pressure cuff and a diameter ranging from 7 – 8.5 mm were included in the study. The sample size was calculated using power analysis (Epi-info7) program based on the following parameters: Small population size is 85 over three months, acceptable error 10%, confidence coefficient 95% and expected frequency 50%.

Exclusion criteria:

- Agitation and irritability.
- Unstable spinal cord injury.
- Laryngeal oedema/stenosis.
- Tracheal bleeding or tracheal fistula.
- Hemodynamic and respiratory instabilities.
- Body temperature abnormalities.
- Inadequate integrity of the pilot balloon favoring a false positive result.

Tools: One tool was used to collect data of the study:

This tool was developed by the researcher after reviewing related literature (Asfour., 2016; Beccaria et al., 2017; Das& Kumar.,2015; Sultan et al.,2011). This tool was used to record ETT cuff pressure measurements before and after the selected nursing interventions in mechanically ventilated patients. It consists of three parts:

First part: patient's socio-demographic and admission data: This part includes socio-demographic data of age and gender. It also includes clinical data as current diagnosis, past medical history, date of ICU admission, length of intubation, site of intubation, size of ETT, type of ETT, date & time of patients' intubation, and duration of mechanical ventilation.

Second part: Tracheal cuff pressure measurements: This part includes monitoring the ETT cuff pressure measurements at different timing as the following:

- The first reading of the patient's ETT cuff pressure. These values were classified and scored as follows: ETT cuff pressure measurements less than 20 cmH_2O were considered as an under-inflation measurement and scored 0, ETT cuff pressure measurements ranging from 20 to 30 cmH_2O were considered as a normal inflation measurement and scored 1, and ETT cuff pressure measurements more than 30 cmH_2O were considered as an over-inflation measurement and scored 2.
- The patient's normal ETT cuff pressure as measured by the researcher.
- The ETT cuff pressure measurements at different timing immediately before and after (immediately, 15 minutes, 30 minutes) the selected nursing interventions (complete bed bath, oral hygiene, ETT suction, and **right lateral and left lateral positions with the head of the bed 30˚).**

Third part: Variables affecting the ETT cuff pressure measurements:

This part included: hemodynamic parameters (Temperature, Heart rate, Respiratory rate, Systolic blood pressure, Diastolic blood pressure, peripheral oxygen saturation), ventilator parameters (mode of mechanical ventilation, positive end expiratory pressure, peak inspiratory pressure), and ETT fixation point.

Method

- Approval of the ethics committee of the faculty of nursing was obtained. An official approval to conduct this study was obtained after providing explanation of the aim of the study. An informed consent was obtained from the patients' legal guardians. The study tool was tested for content validity by 5 experts in the field of the study. The necessary modifications were done accordingly. Reliability of the tool was tested using Cronbach's Alpha test. The reliability coefficient was 0.952 which is accepted. A pilot study was carried out on 10% of the study sample in order to test the clarity and applicability of the research tool. Data was collected by the researchers during the period from January 2021 to June 2021.

Ethical considerations:

- Written informed consent will be obtained from patient family member after explaining the aim of the study and the right to refuse to participate in the study and/ or withdraw at any time. Patient's privacy will be respected. Data confidentiality will be assured during implementation of the study.

Statistical Analysis

The collected data were organized, tabulated and statically analyzed using the statistical package for social studies (SPSS) Version 25.0. Qualitative data were described using number and percent. Quantitative data were described mean ± standard deviation. Finally, analysis and interpretation of data were conducted. P-values of 0.05 or less were considered statistically significant.

Results

Table (1) illustrates the characteristics of the **Table I** shows the distribution of the studied patients according to their demographic and clinical characteristics. Most of the studied patients (54.3%) were males; aged between 51 and 60 years old and neurological disorders were the main diagnosis among them, more than half of the studied patients had a history of diabetes and other endocrine and gastrointestinal disorders. The high frequency (52.9%) of studied patients was intubated for 4 days and more. The mean sizes of the ETT were between 7 to 8 mm for all the studied patients. Sixty percent of the studied patients were on SIMV mode, while 40% of them were on assist control ventilation mode ACV mode. The mean of PEEP was about 5 cm H_2o and the mean of the PIP was about 23.49 ± 3.86 cm H_2O.

Table II presents the distribution of studied patients according to first endotracheal cuff pressure measurements. It was noted that the high percentage (65.7%) of studied patients recorded a cuff pressure above 30 cmH_2o, while 17.1% of them recorded a cuff pressure below 20 cmH_2O.

Table III presents the comparison of tracheal cuff pressure measurement at different timing among different nursing interventions.

As regards the timing of nursing intervention, it can be noted that there was

a descending trend in the mean values of ETT cuff pressure starting before till 30 minutes after for complete bed bath, oral hygiene, and right and left lateral positioning except in the endotracheal suction. In complete bed bath this table shows that there is a statistically significant decrease of tracheal cuff pressure starting before till after 30 minutes {(24.4±1.3), (22.9±1.4), (22.8±1.4) and (22.1±1.5)}, (F=157.2, p=.0001), that significant was detected by using Bonferroni test between {before Vs (immediately, 15minutes and 30minutes)}, {immediately Vs (15 minutes &30 minutes)}. As well in oral hygiene, there is a statistically significant decrease of cuff pressure starting before till after 30 minutes {(24.4±1.3), (22.9±1.4), (22.8±1.4) and (22.1±1.5)}, (F=118.4, p=.0001). Post hoc show significant difference among all times of nursing interventions except between (immediately Vs 15 minutes) as p-value=001. There is statistically significant difference in cuff pressure using endotracheal suction procedures among times of nursing interventions as (F=3.7, p=.012). Post hoc show significant difference among all times of nursing interventions except between {immediately Vs (15 minutes &30 minutes)} as p value (.725, .361) respectively. Additionally in the right and left lateral 30 positioning, a statistically significant difference in cuff pressure using both procedures among times of nursing interventions as {(F=295.7, P=.0001), (F=198.7, p=.0001) respectively}.

As regards the different nursing interventions, this table shows that there is no statistically significant difference in the mean values of the endotracheal cuff pressure between the five procedures before and immediately after nursing interventions as (p=0.447 and 0.16 respectively). While after 15 and 30 minutes there were highly significant differences in the mean values of endotracheal cuff pressure between the five procedures with p=0.0001 for both times.

Discussion

Maintaining the endotracheal cuff pressure within a therapeutic range is the biggest challenge facing the ICU nurses. Unfortunately, several studies have reported that ETT cuff pressure is influenced by several factors. These factors include therapeutic interventions, mainly nursing interventions. Incorporation of integrative nursing practices in the management of the ETT cuff pressure may potentially prevent complications associated with over inflation and under inflation of the cuff. Frequent monitoring of the cuff pressure is the main cause behind the prevention of such complications (Letvin et al., 2018; Zhang, Chen, Ni, Zhang & Fan, 2017).

In the present study, it was observed that the first readings of the ETT cuff pressure for most of studied patients were out of normal range. This observation may be related to limited resources in the selected settings and absence of the cuff pressure manometer. Most of CCNs rely only on palpation of the pilot balloon as an indicator for the ETT intra-cuff pressure, injecting extra amount of air for ETT cuff inflation. Numerous studies have shown that palpation of the pilot-balloon has no correlation with the actual pressure in the cuff and the sensitivity is around 50% in most studies (Nesir et al., 2011; Sole et al., 2011).

Regarding complete bed bath results of the current study depicts that the mean values of tracheal cuff pressure decreased significantly below the baseline measurements at different timing immediately, 15 minutes, and 30 minutes after the procedure. It was noted that the lowest mean scores for the cuff pressure measurements were after 30 minutes. These

findings may be attributed to the random changes either in position of the body or position of the head and neck, resulting in displacement of the ETT (Lizy et al., 2014). Similar findings were documented by Beccaria et al., (2017). They reported that after nursing care, the in-bed bathing presented a significant decrease in the endotracheal cuff pressure below the baseline measurement.

Concerning oral hygiene, the present study found that the mean values of the ETT cuff pressure also significantly decreased below the baseline measurements immediately, 15 minutes, and 30 minutes after the intervention. It was noted that the lowest mean values of tracheal cuff pressure were after 30 minutes. These findings may be due to positional change of ETT during oral hygiene procedure, leading to displacement of the ETT and change of cuff pressure measurements before and after. In this study, the data that could prove whether there is a change in the cuff pressure associated with oral hygiene was not clear (Kim et al., 2015; Beccaria et al., 2017)

As regards endotracheal suctioning, it was noted that the mean values of the endotracheal cuff pressure were increased above the baseline measurement only immediately after. While, the ETT cuff pressure significantly decreased below the baseline measurements after 15 minutes and 30 minutes. This result congruent with the results of the study done by Nazari et al., (2021). They showed that cuff pressure changes were transient and occurred over 5 minutes. The cause of this pressure increase during suctioning is unknown and requires further study. However, the stimulation caused during suctioning may lead the patient to react and induce airway spasm and thereby increase the cuff pressure. They also suggested manual checking and adjustment of the cuff pressure after each episode of suctioning. In addition, a study done by Khalil, Morsy, Salama & Sayed, (2018) reported a decrease in ETT cuff pressure 15 minutes after suctioning.

Findings of the current study revealed that the ETT cuff pressure measurements significantly decreased below the baseline measurements at the different timing immediately, 15 minute, and 30 minutes after the right lateral 30 position. This variation in the ETT cuff pressure may be attributed to displacement of the ETT over the cuff caused by changes in the position of the mechanical ventilator circuit. These results were consistent with the results reported by Pavlisa et al. (2016). They stated that the ETT cuff pressure measurement decreased after changing patients' body position to the right lateral position. On the other hand, Godoy et al. (2008) who found alteration in the ETT cuff pressure after changing patients' position.

Regarding the left lateral 30˚ position, it was noted that the mean values of the ETT cuff pressure were also significantly decreased below the baseline measurement at the different timing immediately, 15 minute, and 30 minutes after the intervention. This may be attributed to the same justification of moving the ETT from its place during patients position change. According to Lizy et al., (2014) changes in a patient’s body position resulted in significant deviations in the cuff pressure of endotracheal tubes.

In a similar study done by Beccaria et al., (2017) revealed that statistically significant decrease in the cuff pressure regarding the change of body positioning. Also, Khalil et al. (2018) found reduction in the ETT cuff pressure after changing patients' body position either to the left or right lateral position. These results are consistent with Sole et al. (2011) who found

that ETT cuff pressure decreased and some patients required intervention within the first hour after the pressure was adjusted to 22 cm H_2O. Moreover, these findings are consistent with Khalil et al. (2018) who found reduction in ETT cuff pressure after changing patients' body position to the lateral position.

Another study compatible with this study done by Nazari, Omran, Nia & Yaghoobzadeh,(2020) reported that changing the head position in mechanically ventilated patients increases endotracheal cuff pressure. Therefore, it is suggested that the cuff pressure should be re-examined and adjusted after each head position change while avoiding unnecessary movements of the head and neck of the intubated patients. From another point of view, Kim et al., (2015) noted that after the change from the supine to the lateral flank position, the ETT cuff pressure was significantly higher in the Taper Guard ETT than in the conventional ETT.

Results of the current study revealed that performing the selected nursing interventions resulted in potentially decreased ETT cuff pressure that could be harmful for the critically ill patients. The researchers suggest a need for a strict monitoring of the pressure, and for this reason it is mandatory for the critical care nurse to check and recheck the cuff pressure via the ETT cuff manometer after any nursing intervention done for the intubated patients. The ETT cuff pressure should be kept within the prescribed limits of 20-30 cm H_2o, to avoid the occurrence of complications resulting from over or under inflation of ETT cuff.

Limitation of the study:

The study was not based on random allocation and findings, which were based on a single clinical setting which compromises data extrapolation.

Conclusion

Based upon the findings of the current study, it could be concluded that the cuff pressure measurements were significantly changed after performing the selected nursing interventions at different timing. The highest ETT cuff pressure value was found to be in the right lateral position at the different timing after performing selected nursing interventions. There was a statistically significant relationship between ETT cuff pressure measurements and the patients' characteristics at different timing after performing selected nursing interventions.

Recommendations

In line with the findings of the study, the following recommendations are made:

1. Conduct in-service educational programs and workshops to raise CCNs awareness regarding the importance of tracheal cuff pressure monitoring.
2. Study the barriers facing the nurses to maintain endotracheal cuff pressure.
3. Provide the ETT cuff pressure manometers to the ICUs to facilitate measuring the ETT cuff pressure.
4. Further studies are required to explore the relationship between cuff pressure (exerted by different ET tubes) and long-term outcome measures of commonly occurring morbidity.
5. Replicate the study on a large probability sample is recommended for generalization of the findings.

Table (I): Distribution of the studied patients according to demographic and clinical characteristics (N=70)

Patient's clinical characteristics	No.	%
Age (in years)		
20–30	6	8.6
31–40	2	2.9
41–50	16	22.8
51–60	46	65.7
Gender		
Male	38	54.3
Female	32	45.7
Diagnosis		
Neurological disorders	38	54.2
Respiratory disorders	20	28.6
Cardiovascular disorders	6	8.6
Gastrointestinal disorder	6	8.6
Past medical history		
Diabetes & others	38	54.2
Cardiovascular disorder	26	37.1
Renal disorder	4	5.7
Liver disorder	2	2.9
Length of intubation		
< 4 days	33	47.1
≥ 4 days	37	52.9
Mean±SD	3.69±1.46	
Median (Min – Max)	(1 – 7)	
Size of ETT Mean ± SD	7.49 ± 0.23	
Mode of mechanical ventilation		
ACV	11	40.0
SIMV	59	60.0
PEEP (cmH_2O) Mean ± SD	5.48 ± 0.50	
PIP(cmH_2O) Mean ± SD	23.49 ± 3.86	

ETT: Endotracheal tube, **ACV:** assist control ventilation, **SIMV:** synchronized intermittent mandatory ventilation**, PEEP:** positive end expiratory pressure**, PIP:** peak inspiratory pressure

Table (II): Distribution of the studied patients according to first endotracheal cuff pressure measurements (N=70)

ETT cuff pressure	Frequency No. of the Patients	Percent (%)
< 20 cmH_2O	12	17.1
20-30 cmH_2O	12	17.1
>30 cmH_2O	53	65.7

Table (III): Comparison of endotracheal cuff pressure at different timing among different nursing interventions

Different timing	Cuff pressure of selected nursing intervention Mean±SD					Test of significance (p)
	Bed bath	Oral hygiene	Tracheal suction	Right lateral	Left lateral	
Before	24.95±1.79	24.4±1.3	24.8±1.8	24.8±1.8	24.7±1.8	(F_1=0.93, p_1=0.447)
Immediately	21.1±3.1	22.9±1.4	25.3±2.8	22.2±2.2	21.6±1.7	(F_1=1.6, p_1=0.16)
15 minutes	20.2±2.3	22.8±1.4	20.8±.1.8	20.6±.1.7	20.7±.1.9	(F_1=21.3, p_1=0.0001*)
30 minutes	19.98±2	22.1±1.5	22.1±2.2	20.3±1.7	19.7±1.7	(F_1=19.1, p_1=0.0001*)
Test of significance	(F_2=157.2, p_2=.0001*)	(F_2=118.4, p_2=.0001*)	(F_2=3.7, p_2=.012*)	(F_2=295.7, p_2=.0001*)	(F_2=198.7, p_2=.0001*)	

Pairwise comparison was done using Bonferroni test
F_1: One-Way independent ANOVA
F_2: One-Way Repeated Measure ANOVA
***:** Statistically significant at $p \leq 0.05$
p_1: p value for comparison between five nursing interventions
p_2: p value for comparison between different times

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