International Journal of Chemical and Biochemical Sciences
(ISSN 2226-9614)

Journal Home page: www.iscientific.org/Journal.html

The Relationship Between Endotracheal Tube Different Cuff Pressure Measurements and The Incidence of Ventilator-Associated Pneumonia

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Abstract

Endotracheal tube cuff pressure measurement is an essential practice for management of mechanically ventilated patients. Based on guidelines, it's recommended to maintain the endotracheal tube cuff pressure within a range between 20-30cm H2O. When the endotracheal tube cuff pressure is lower than the normal range, it increases the risk of micro-aspirations and the passage of contaminated secretions of the oral cavity into the trachea; this potentially causing aspiration pneumonitis and ends with ventilator associated pneumonia. This study aimed to assess the relationship between endotracheal tube different cuff pressure measurements and the incidence of ventilator associated pneumonia. A non-randomized descriptive correlational research design was utilized to achieve the aim of this study. ***Setting:*** The study was conducted at two medical intensive care units at Ain Shams University hospital, which are affiliated with Ain Shams University, Cairo-Egypt. A purposive sample of 192 patients were included in the study from the previously mentioned settings. Three tools were used in this study, Patient assessment sheet. It consisted of three parts: demographic data of the patients, clinical data of the patients and mechanical ventilation data. Endotracheal tube cuff pressure measurements tool. Modified clinical pulmonary infection score.This study findings revealed that 46.9% of the studied patients had pressure measurements of less than 20 cmH2O on the 1st day. While, 62% and 55.2% of them had pressure measurements of 20-30 cmH2O on the 2nd and 3rd days respectively. Furthermore, 46.4% of the studied patients developed VAP on the 1st day increased to 50% and 52.6% of them on the 2nd and 3rd days respectively. The current study concluded that there was a statistically significant correlation between endotracheal tube cuff pressure measurements and incidence of ventilator associated pneumonia.Providing education and training sessions to health care providers on the importance of cuff pressure measurement and the potential complications associated with incorrect cuff pressure.

Keywords: Endotracheal tube, Cuff pressure and Ventilator associated pneumonia

Full-length article **Corresponding Author*, e-mail: ptrservices2022@gmail.com

1. Introduction

Critical illness refers to a severe medical condition that poses a threat to a patient's life and requires intensive medical interventions and monitoring. Critically ill patients often present with organ dysfunction, compromised physiological stability and a high risk of morbidity and mortality. The management of these patients requires a multidisciplinary approach, involving critical care physicians, nurses, respiratory therapists and other health care professionals [16]. The severity and complexity of critical illness necessitate comprehensive monitoring and interventions. One of the most crucial supportive therapies for critically ill patients is mechanical ventilation. Mechanical ventilation is used to support or replace a patient's breathing function when their respiratory system is compromised. It plays a vital role in the management of acute respiratory failure, severe lung injury, severe pneumonia, chronic obstructive pulmonary disease (COPD) or neurological conditions affecting breathing and various other conditions [19].

Patient's monitoring is crucial during mechanical ventilation. It involves continuous assessment of vital signs, oxygen saturation, continuous measuring of endotracheal tube cuff pressure and other parameters. This helps health care professionals evaluate the effectiveness of ventilation, make necessary adjustments and prevent complications of mechanical ventilation. One of the most important interventions for mechanically ventilated patients is monitoring the endotracheal tube cuff pressure [7]. The endotracheal tube (ETT) is a medical device used in critical care to establish an artificial airway and facilitate mechanical ventilation. ETT is secured with the patient's trachea by injecting amount of pressure inside the cuff in order to create a seal to prevent the entry of pharyngeal contents into the

trachea during ventilation. Maintaining appropriate ETT cuff pressure is important during mechanical ventilation to prevent complications such as aspiration, air leakage and injury to the tracheal mucosa [2]. Periodic monitoring of endotracheal tube cuff pressure is vital to confirm it remains within the recommended range. ETT cuff pressure can be monitored by using a digital manometer or a cuff pressure monitoring system. It should be measured at regular intervals, typically every 6 to 8 hours, and adjust as needed. The optimal cuff pressure range varies among guidelines and studies. However, a commonly cited range is 20-30 cmH2O. This range aims to maintain appropriate seal, while, minimizing the possibility of complications. It's important to prevent lower ETT cuff pressure than 20 cmH2O, which may cause ventilator associated pneumonia as well as avoid excessive cuff pressure more than 30 cmH2O to prevent tracheal mucosal damage **(Grivans et al., 2019)**.

Ventilator-associated pneumonia (VAP) is a serious and common complication that can occur for mechanically ventilated patients. It's associated with high rates of mortality, morbidity as well as a high burden of health care. VAP refers to lung infection that occurs for mechanically ventilated patients for 48 hours after intubation. It's characterized by a new or worsening radiographic infiltrates, fever, purulent tracheal secretions, signs of respiratory distress and presence of pathogenic bacteria in respiratory samples **(Ommid et al., 2021)**. There are several factors that leads to development of VAP, including prolonged mechanical ventilation, advanced age, underlying comorbidities, impaired immune function, sedation, aspiration, decrease the cuff pressure of the ETT less than 20 cmH2O and the presence of a nasogastric tube. The rate of VAP can be minimised by preventive measures and implementing ventilator bundle practices. These measures include strict hand hygiene, raising the head of bed 45 degree, mouth care by using chlorhexidine, daily interruption of sedation and assess the patient's ability for weaning from mechanical ventilation, prophylaxis to prevent deep vein thrombosis and peptic ulcer diseases, as well as, regular monitoring and adjustment of endotracheal tube cuff pressure. By measuring the ETT cuff pressure regularly, health care providers can optimize patient's outcomes, minimize complications and contribute to the overall safety and effectiveness of mechanical ventilation.

1.1. Significance of the study

One of the critical types of hospital acquired infection is ventilator associated pneumonia. It develops in critically patients who receive mechanical ventilation and it leads to prolonged hospital stay, as well as, increased mortality rates. VAP is a global issue and is one of the top three infection concerns of clinicians. It accounts for up to 60% of all deaths from health care-associated infections. Approximately 8–28% of critical care patients develop VAP [8].. Globally, the VAP is occurred for 10–28% in the United States. At the national level, the prevalence of VAP in Egypt about 9.94% at intensive care units, while, the death rate among ventilated patients was high about 68.2% and only 31.8% of patients recovered [3,9].

Moreover, a study conducted at the ICUs of Ain Shams University Hospital showed that among the ventilated patients who developed VAP, 41% was early onset VAP and late onset was 59% [14]. Additionally, there was a study conducted in Egypt at Asuit university hospital regarding the relation between the ETT cuff pressure and the incidence of VAP, which revealed that the rate of VAP was from 11.2% to 22.0% due to decrease the ETT cuff pressure less than 20 cmH2O [20].. According to [4] an observational study about inappropriate endotracheal tube cuff pressure and its association with incidence of VAP reported that were exposed to inappropriate ETT cuff pressure. Additionally, a descriptive cross sectional study conducted at Ain Shams University Hospital found that 55.1% of studied patients aged from 18-75 years were developed ventilator associated pneumonia [10]. Throughout the last several decades, many studies have focused on the endotracheal tube role in the pathogenesis of VAP due the complications that occur from the tracheal intubation, such as inhibition of the cough reflex, mucociliary clearance impairment and damage the epithelial surface of trachea. Additionally, easy access for bacteria from upper respiratory tract to the lower tract which allows the biofilm formation of the surface of the endotracheal tube [26].

1.2. Aim of the study

The aim of this study was to assess the relationship between endotracheal tube different cuff pressure measurements and the incidence of ventilator associated pneumonia through the following objectives:

1- Measure the endotracheal tube cuff pressure for mechanical ventilated patients admitted to intensive care unit.
2- Assess the incidence of ventilator associated pneumonia among mechanically ventilated patients.
3- Determine the relationship between endotracheal tube different cuff pressure measurements and the incidence of ventilator-associated pneumonia among mechanically ventilated patients.

1.3. Research question

The aim of this study was achieved through answering the following question:

- What is the relationship between endotracheal tube different cuff pressure measurements and the incidence of ventilator associated pneumonia?

2. Subject and Methods

2.1. Technical Design

2.1.1. Research Design

Non-randomized descriptive correlational research design was utilized to achieve the aim of this study.

2.1.2. Research Setting

This study was conducted at two medical intensive care units at Ain Shams University hospital, which are affiliated with Ain Shams University, Cairo-Egypt.

2.2. Subjects (Sampling)

2.2.1. Sample Type

A purposive sample of mechanically ventilated patients were included in the study from the previously mentioned settings.

2.2.2. Sample size

Total of 192 patients were included in the study through a period of six months based on the inclusion and exclusion criteria.

2.3. Inclusion criteria

- Adult patients from both gender >20 years old, orally intubated and receiving mechanical ventilation for more than 48 hours.
- Patient intubated with cuffed endotracheal tube.

2.4. Exclusion criteria

- Patient diagnosed with pneumonia at the time of admission.
- History of exposure to aspiration of stomach contents before or during admission.
- History of cardiopulmonary resuscitation.

2.5. Tools of data collection

Three tools were used for data collection in the present study.

2.5.1. ***Tool (1): Patient assessment sheet:*** which was developed by the researcher based on related literature review, it included three parts:

Part I: Demographic data of the patients which entailed: the patient's age, gender, occupation and residence.

Part II: Clinical data of the patients which entailed: current medical history and past medical history.

- **Current medical history** includes patient's diagnosis, reasons for admission, level of consciousness, current prescribed medications, invasive devices, length of stay at ICU and duration of mechanical ventilation.
- **Past medical history** includes history of lung diseases, history of gastro-esophageal reflux disease and history of smoking.

Part III: Mechanical ventilation data: This part was utilized to assess parameters of mechanical ventilation such as mode of mechanical ventilation, fraction of inspired oxygen (FIO2), tidal volume (Vt), respiratory rate, minute ventilation, positive end expiratory pressure (PEEP) and pressure support ventilation (PSV).

2.5.2. Tool (2): Endotracheal tube cuff pressure measurements tool

This tool was adopted from [20]. It contained two items (ETT size and ETT cuff pressure measurements) to assess endotracheal tube cuff pressure measurements of patients whether high, low or within the normal range.

2.5.3. Tool (3): Modified clinical pulmonary infection score (MCPIS)

This scale was adopted from [5]. It was utilized to assess the incidence of VAP through five criteria. These criteria including (body temperature, pulmonary secretion, WBC, PO2–FiO2 ratio based on mmHg and chest X-ray).

2.6. Scoring system of modified clinical pulmonary infection score scale

Each criterion in MCPIS scale scored from 0 to 2 except oxygenation, which zero indicates existence of acute respiratory distress (ARDS) signs and 2 indicates absence of ARDS signs. The total score is varied from 0 to10. Scores over 5 in this scale reveals involvement in VAP, while, the score ≤ 5 indicate absence of VAP.

2.7. Tools validity and reliability

The study tools were tested for validity (face and content validity) by a jury of 5 experts, two assistant professors and three lecturers of medical surgical nursing at faculty of nursing, Helwan university. The experts reviewed the tools for clarity, relevance, accuracy, comprehensiveness, simplicity, applicability and necessary modifications were done. Cronbach's Alpha was used to determine the internal reliability of the adapted tools. Reliability score for ventilator- associated pneumonia assessment tool was 0.765 and 0.87 for the other tools.

2.8. Ethical Consideration

An official permission to conduct the proposed study was obtained from the Scientific Research Ethics Committee at Faculty of Nursing, Helwan University. Participation in the study was voluntary and subjects' relatives were given complete full information about the study. The ethical considerations included explaining the purpose and nature of the study, confidentiality of the information where it wasn't be accessed by any other party without taking permission of the participants. Ethics, values, culture and beliefs were respected.

2.9. Operational design

2.9.1. Preparatory phase

It included reviewing of past, current, national and international related literature and theoretical knowledge of various aspects of the study using books, articles, internet, periodicals and magazines to develop tools for data collection.

2.9.2. Pilot study

The pilot study was done on 10% of the sample (20 patients) to test the applicability, feasibility and clarity of questions and time needed to complete the study tools by the researcher and each subject. Based on the results of the pilot study, modifications were done and the subjects included in the pilot study were excluded from the study.

2.9.3. Field work

After official permission obtained from previously mentioned settings. The study was conducted over six months started from the beginning of January 2023 to June 2023. The researcher visited the settings three days per week (Tuesday, Wednesday, and Thursday) at the morning shifts (8:00 am to 2:00 pm). The study's tools were completed and filled in by the researcher within an average time of 30-50 minutes as following:

For patient assessment sheet which included patient's personal and clinical data took about 5-10 minutes which collected on the first day of the visits. Mechanical ventilator data took about 5-10 minutes, endotracheal tube cuff pressure measurements took about 5-10 minutes and modified clinical pulmonary infection score scale took about 15-20 minutes which were collected on the 3 days.

2.9.4. For endotracheal tube cuff pressure measurements

The endotracheal tube cuff pressure was measured by using a digital manometer by connecting it with the inflation valve of pilot balloon of the endotracheal tube. Therefore, the cuff pressure was shown on the screen and then the manometer was disconnected from the inflation valve of

the pilot balloon. The readings of the endotracheal tube cuff pressure were measured for all patients through the 3 days of data collection. Cuff pressure was recorded in centimeter of water. The ETT cuff pressure of 20–30 cm H2O was considered as standard. No correction was made to cuff pressure even high or low.

2.9.5. For assessing the incidence of VAP

The researcher used MCPIS scale on a daily basis for the incidence of VAP. Axillary body temperature measured for all patients by using a mercury thermometer for at least five minutes and then 0.5 °C was added to the reading and repeated every day for three days. Pulmonary secretions were observed and assessed during endotracheal suctioning with a sterile catheter (whether secretion was absent, non-purulent or purulent) and some studied patients had done sputum culture. Result of WBC recorded for all patients every day for 3 days. PO2/ FiO2 ratio was calculated through the following:

PO2 represents arterial pressure of oxygen from the arterial blood gases result. FiO2 represents the fraction (percent) of inspired oxygen that the patient was receiving from mechanical ventilation and it expressed as a decimal (40% oxygen = FIO2 of 0.40). PO2 divided by FiO2 = P/F ratio. Chest X-ray was done for all patients to observe the presence of infiltration. After collection of the MCPIS items, the investigator calculated the total score for each patient to determine the incidence of VAP.

2.10. Administrative design

After explanation of the study's aim and objectives, an official permission was obtained from the dean of Faculty of Nursing, Helwan University and the general manager of Ain Shams University hospital asking for cooperation and permission to conduct the study.

2.11. Statistical design

Upon completion of data collection, collected data were organized, tabulated and analyzed using Statistical Package for Social Science (SPSS), version 24 for analysis. For quantitative data, numbers, percentage, mean, and standard deviation (SD) were used to describe results. For qualitative data which describe a categorical set of data, the frequency and percentage of each category were calculated. Appropriate significance was adopted at $P < 0.05$ for interpretation of results [23]. The observed associated differences were considered as not significant if $p>0.05$ and significant if $p<0.05$. Appropriate inferential statistics such as chi square, "t" test and ANOVA test were used as well.

3. Results and Discussion

Table (1): highlights the demographic characteristics of the studied patients. It shows that the same percentage of the studied patients (38.5%) were in the age group 40 to less than 50 years or 50 to less than 65 years and 59.4% of them were male. Regarding occupation, 40.1% of the studied patients had manual work. 62.5% of them were living in urban areas.

Table (2): reveals the studied patients' current medical history, it presents that 29.7% and 27.6% of the studied patients were diagnosed with trauma and stroke respectively. Concerning reasons for admission, disturbed conscious level was the most common reason for admission among 58.3% of the studied patients, followed by hypoxia was the reason for admission among 20.8% of them. Furthermore, it reveals that 38.5% of the studied patients had stayed at intensive care unit for 5- < 10 days with a mean length of stay 11.625 + 4.426, while, 43.2% of them were connected to mechanical ventilation for 10 - < 15 days with a mean duration of 10.671 + 3.772.

Table (3): presents the distribution of the studied patients according to endotracheal tube size and cuff pressure measurements, which reveals that 55.7% of the studied patients were intubated with 7 mmID endotracheal tube on the 1st and 2nd days and 55.2% of them were intubated with the same size of endotracheal tube on the 3rd day. Concerning endotracheal tube cuff pressure measurements, 46.9% of the studied patients had pressure measurements of less than 20 cmH2O on the 1st day. While, 62% and 55.2% of them had pressure measurements of 20- 30 cmH2O on the 2nd and 3rd days respectively.

Figure (1): shows the distribution of the studied patients according to incidence of ventilator associated pneumonia, which displayed that 53.6% of the studied patients didn't develop ventilator associated pneumonia on the 1st day compared to 50% and 47.4% of them on the 2nd and 3rd days respectively. While, 46.4% of the studied patients developed VAP on the 1st day increased to 50% and 52.6% of them on the 2nd and 3rd days respectively. Table (4): presents the comparison between studied patients with VAP and patients without VAP according to parameters of ventilator associated pneumonia, which reveals that there were statistically significant differences between patients with VAP and patients without VAP according to parameters of ventilator associated pneumonia. There was a high statistically significant difference regarding temperature and pulmonary secretions with (p value 0.000) and there was statistically significant difference regarding WBC (p value 0.065) and chest x-ray with (p value 0.058). There were no statistically significant differences between patients with VAP and patients without VAP according to PO2/FIO2 ratio. Table (5): shows relations between incidence of ventilator associated pneumonia among the studied patients and endotracheal tube size and cuff pressure measurements and revealed that there was no statistically significant relation between incidence of ventilator associated pneumonia among the studied patients and endotracheal tube size. While, there was a high statistically significant relation between incidences of ventilator associated pneumonia and endotracheal tube cuff pressure measurements with (p value= 0.000).

Mechanical ventilation and endotracheal intubation are essential life saving treatments for patients with critical illnesses. However, after 24 hours of intubation, endotracheal tube can decrease mechanisms that naturally protect the patient's airway such as mucosal and coughing reflexes. Additionally, micro-aspiration of secretions to the lower respiratory tract and colonization of pathogens are the predisposing factors for incidence of VAP. Hence, monitoring cuff pressure of the endotracheal tube is a golden practice in management of ETT and minimizes the incidence of VAP. Endotracheal tube cuff pressure should be maintained within the normal range between 20-30 cmH2O to prevent the risk of damage to tracheal mucosa and the risk of ventilator-associated pneumonia [1]. Regarding the patients' age, the current study findings showed that more

than one third of the studied patients were in the age group of 40 to less than 50 years and more than one third of them were in the age group of 50 to less than 65 years. From investigator point of view, this age group had the highest incidence of VAP due to history of chronic diseases, having poor gage and cough reflexes, deficiency in immunity and recurrent serious comorbidities.

This finding is similar to a study conducted in Asian and North Indian ICUs which titled "An observational prospective study on incidence of ventilator associated pneumonia in patients with continuous endotracheal-tube cuff-pressure control system" and showed that more than half of the total studied patients were between the age of 31-60 years old. In relation to gender, more than half of the studied patients were males in relation to females. This finding could be due to more than two thirds of the male patients were smokers and had history of lung diseases. All these factors are predisposing factors for ICU admission as well as acquiring serious types of infection such as VAP. This finding agrees with an observational study carried out in French by [11], which titled "epidemiology, risk factors and prognosis of ventilator-associated pneumonia during severe COVID-19: multicenter observational study across 149 European intensive care units" and illustrated the majority of the studied patients were males. Additionally, the same results were supported by a multicenter, observational and retrospective study conducted in Italy by [12] about "incidence and prognosis of ventilator-associated pneumonia in critically ill patients with COVID-19: a multicenter study" and mentioned that the majority of the studied patients were male. Concerning the patients' medical diagnosis, the present study revealed that less than one third of the studied patients were diagnosed with trauma and stroke respectively. From the investigator point of view is that the first cause of ICU admission at the study setting was trauma because it's an emergency ICUs which received the critical traumatic patients. Moreover, traumatic injury is one of the risk factors for the incidence of VAP due to alterations that occur in the patients' immunity and aspiration that may result from brain injury and lung contusion.

This study finding was supported by a cross sectional study carried out at the Addis Ababa Burn, Emergency, and Trauma hospital by [18] titled "patterns of admission and outcome of patients admitted to the intensive care unit" and found that more than half of the studied patients admitted to ICU with trauma followed by medical about less than one third of them, non-traumatic neurosurgical conditions, and burn. Furthermore, the findings of the current study are allied with a narrative review conducted by [21] titled "ventilator-associated pneumonia in adults: a narrative review " and reported a high percentage of the studied patients were traumatic patients. On the other hand, this result is contrariwise to a study done by [12] who stated that the most frequent comorbid conditions were hypertension among about two thirds of the studied patients and diabetes mellitus among less than one quarter of them.

As regards to reasons for patients' admission, the current study showed that more than half of the studied patients had disturbance in conscious level, which was the most common cause for admission, followed by hypoxia that accounts for less than one quarter of the studied patients. From the investigator point of view, These findings may be due to the majority of the patients were admitted with traumatic injury which cause alteration in conscious level. Consequently, patients with disturbance in conscious level may be exposed to other symptoms, such as hypoxemia, metabolic disturbances, electrolytes imbalances, respiratory distress, disturbance in glucose level and others. The current study is congruent with a retrospective study in Swedish done by [27] about "emergency department admissions to the intensive care unit – a national retrospective study" and found that decreased level of consciousness and seizures were the most common cause of ICU admission, followed by respiratory and cardiovascular dysfunction.

By evaluating the patients' length of ICU stay and duration of mechanical ventilation, the present study revealed that more than one third of the studied patients had stayed at intensive care unit for 5- < 10 days with a mean length of stay 11.625 + 4.426 and they were connected to mechanical ventilation for 10 - < 15 days with a mean duration of 10.671 + 3.772. These study findings can be explained by the longest duration of mechanical ventilation, the longest length of ICU stay because they are interrelated. Furthermore, the most studied patients had life-threatening conditions which increase either the duration of mechanical ventilation or ICU length duration. This study finding agrees with a cohort study done by [24] in France, which titled "increased incidence of ventilator-acquired pneumonia in coronavirus disease 2019 patients: a multicentric cohort study" and demonstrated that the majority of patients had a longer duration of mechanical ventilation which ranged from 5–20 days and longer length of ICU stay which ranged from 5–18 days. Regarding distribution of the studied patients according to endotracheal tube size, the current study displayed that more than half of the studied patients were intubated with 7 mmID endotracheal tube on the 1st , 2nd and 3rd days. From the investigator point of view, the most common sizes of endotracheal tube for adult patients is ranged from 7mmID to 8mmID and the size is based on the patients' gender, age and patient's neck height. The current study result is dissimilar to a cross sectional, descriptive, and correlational study which conducted by [15] about "determination of factors affecting endotracheal tube cuff pressure in adult patients in intensive care unit" and showed that the mean tube size was 8.0 (6-9.5).

Concerning endotracheal tube cuff pressure measurements, about half of the studied patients had pressure measurements of less than 20 cmH_2O on the 1st day. While, about two thirds and more than half of them had pressure measurements of 20-30 cmH_2O on the 2nd 3rd days respectively. These study results may be interpreted by the ETT cuff pressure measurements were changed throughout the assessment days because of some related factors, such as patients' positions, position of the patients' head, ETT cuff position, volume of air inside the ETT cuff and duration of ETT placement.

The present study is harmonized with the results of randomized study conducted by [17] about "measuring endotracheal tube intracuff pressure: no room for complacency" and stated that about half of the studied patients had fewer ETT cuff pressure measurements < 20 cmH_2O and half of them were within the recommended range of 20–30 cmH_2O.

Table 1: Frequency and percentage distribution of the studied patients according to their demographic characteristics (N=192)

Patients' characteristics		No	%
Age (in years)	20 < 30	5	2.6
	30 < 40	39	20.3
	40 < 50	74	**38.5**
	50 ≤ 65	74	**38.5**
Mean ± SD	46.541 ± 8.343		
Gender	Male	114	**59.4**
	Female	78	40.6
Occupation	Official work	12	6.3
	Manual work	77	**40.1**
	Retired	29	15.1
	Housewife	72	37.5
	Student	2	1.0
Residence	Rural	72	37.5
	Urban	120	**62.5**

Table 2. Studied Patients Current Medical History-Frequency and percentage distribution of the studied patients according to their current history (N=192)

Patients' characteristics		No	%
Patient's diagnosis	Trauma	57	**29.7**
	Stroke	53	**27.6**
	Respiratory failure	34	17.7
	Pericardial effusion	8	4.2
	Kidney failure	6	3.1
	Systemic lupus erthromatosis	11	5.7
	Sigmo-rectal cancer	9	4.7
	Lung cancer	10	5.2
	Others (Cardiac tamponade Cardiomyopathy, Crohn's disease)	4	2
Reasons for admission	Disturbed conscious level	112	**58.3**
	Hypoxia	40	**20.8**
	Hypovolemia	10	5.2
	Dyspnea	8	4.2
	Tachypnea	10	5.2
	Hypoglycemia	10	5.2
	Apnea	2	1.0

ARDS Acute Respiratory Distress Syndrome

- Frequency and percentage distribution of the studied patients according to their length of stay and duration of mechanical ventilation (N=192)

Patients' characteristics		No	%
Length of stay at intensive care unit	5- < 10 days	74	**38.5**
	10 - < 15 days	61	31.8
	≥ 15 days	57	29.7
Mean ± SD	11.625 ± 4.426		
Duration of mechanical ventilation	5- < 10 days	70	36.5
	10 - < 15 days	83	**43.2**
	≥ 15 days	39	20.3
Mean ± SD	10.671 ± 3.772		

Table 3. Frequency and percentage distribution of the studied patients according to endotracheal tube size and cuff pressure measurements (N=192)

Items	1st day		2nd day		3rd day	
	No	%	No	%	No	%
Endotracheal tube size:						
7 mmID	107	**55.7**	107	**55.7**	106	**55.2**
7.5 mmID	59	30.7	59	30.7	61	31.8
8 mmID	26	13.5	26	13.5	25	13.0
Endotracheal tube cuff pressure measurements:						
▪ < 20 cmH2O	90	**46.9**	53	27.6	75	39.1
▪ 20- 30 cmH2O	90	46.9	119	**62.0**	106	**55.2**
▪ > 30 cmH2O	12	6.3	20	10.4	11	5.7

mmID: millimeter Internal Diameter

Table 4. Comparison between studied patients with VAP and patients without VAP according to parameters of ventilator associated pneumonia on the 3rd day of the study (N=192)

Items		Developed VAP (101)		Not developed VAP (91)		P value
		No	%	No	%	
Temperature	36-38.4	7	6.9	60	66	0.000 **
	38.5-39.8	59	58.4	23	25.2	
	Less than 36 and average 39	35	34.7	8	8.8	
White blood cells	4000-11.000	13	12.9	30	32.9	0.065 *
	Over 11.000	75	71.3	25	27.5	
	Less than 4000	13	12.9	36	39.6	
Pulmonary secretions	Absence of pulmonary secretions	6	5.9	38	41.8	0.000 **
	Existence of non-infectious pulmonary secretions	15	14.9	51	56	
	Existence of infectious pulmonary secretions	80	79.2	2	2.2	
Oxygenation: PO2/FIO2 ratio (mmHg)	Over 240 or existence of ARDS signs	53	52.5	56	61.5	0.658
	Less or equal to 240 and absence of ARDS signs	48	47.5	35	38.5	
Chest X-ray	No infiltration	26	25.8	14	15.4	0.058 *
	Patchy or diffuse infiltration	55	54.4	38	41.7	
	Localized infiltration	20	19.8	39	42.9	

ARDS Acute Respiratory Distress Syndrome
* Significant (S) p > 0.05 * * Highly significant (S) p > 0.001

Table 5. Relations between incidence of ventilator associated pneumonia among the studied patients and endotracheal tube size and cuff pressure measurements (N=192)

Patients' characteristics		Incidence of VAP				Chi square	P value
		Developed VAP (101)		Not developed VAP (91)			
		No	%	No	%		
Endotracheal tube size	7mmID	57	56.4	49	53.8	0.855	0.652
	7.5 mmID	33	32.7	28	30.7		
	8 mmID	11	10.9	14	15.5		
Endotracheal tube cuff pressure measurements	< 20 cmH2O	53	52.5	22	24.2	33.49	0.000 **
	20-30 cmH2O	39	38.6	67	73.6		
	> 30 cmH2O	9	8.9	2	2.2		

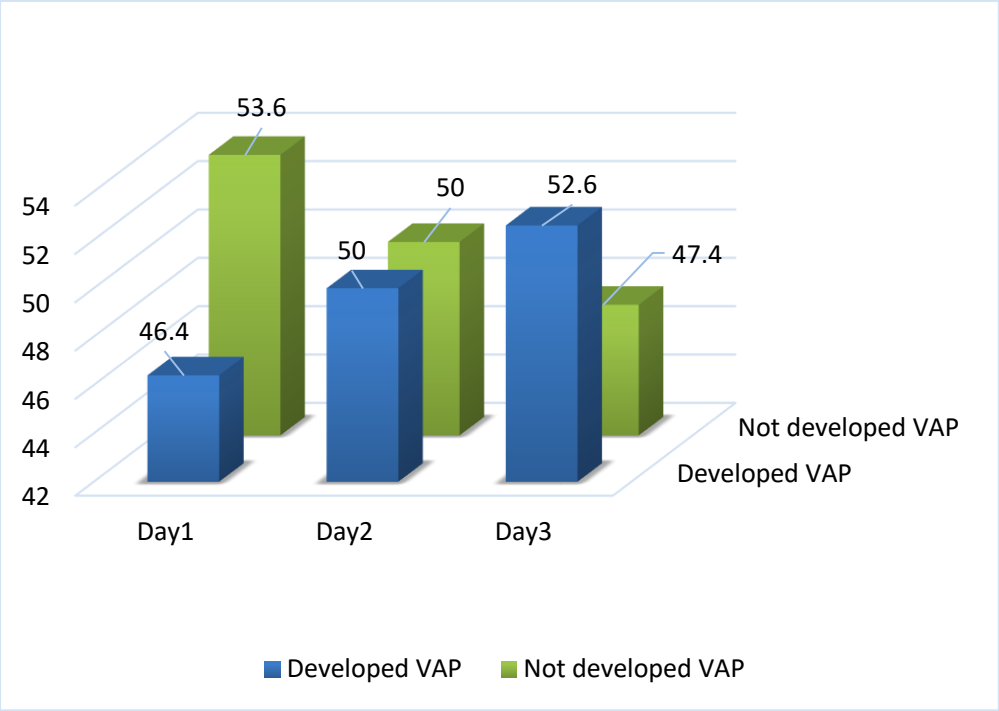

Figure 1. Percentage distribution of the studied patients according to incidence of ventilator associated pneumonia (N=192)

The current study findings mismatch with a cross-sectional study carried out by [25] which titled "Under or overpressure: an audit of endotracheal cuff pressure monitoring at the tertiary care center" and showed that most of the cuff pressure values were high among more than one third of the patients. While, optimal cuff and sub-optimal cuff pressures were found in about one third of patients, respectively. By evaluating the distribution of the studied patients according to incidence of ventilator associated pneumonia, the finding of the current study illustrated that more than half of the studied patients didn't develop ventilator associated pneumonia and about half of them developed VAP on the 1st day of the assessment. On 3rd day about half of the studied patients didn't develop VAP, while , more than half of them had VAP. These findings may be due to malpractice of some items of VAP bundle, such as airway care including cuff pressure adjustment, suctioning the subglottic secretions and keeping the head of the bed at an angle of 45° which can significantly reduce the mean MCPIS scores among mechanically ventilated patients. As well, there was more than half of the studied patients had low ETT cuff pressure on the 1st day which predisposed them to develop VAP. Additionally, presence of invasive devices, such as nasogastric tubes which may cause reflux and vomiting and leads to colonization of bacteria in the mouth and reflux of gastric contents into the lungs and results in VAP.

This study result is in the same line with an observational study conducted by [11] and mentioned that VAP occurred in about half of the studied patients. Additionally, this study finding is similar with a pretest-posttest study done by [22] and clarified that the incidence of VAP was about two thirds of the studied patients. By comparing the studied patients with VAP and patients without VAP according to parameters of ventilator associated pneumonia on the 3rd day of the study, there was a high statistically significant difference regarding temperature and pulmonary secretions and there was statistically significant difference regarding WBC and chest x-ray. There were no statistically significant differences between patients according to PO2/FiO2 ratio. This study is contradicted with a prospective observational study done by [6] and mentioned that PaO2/FiO2 was lower in patients with VAP than patients without VAP. Concerning the relations between incidence of ventilator associated pneumonia among the studied patients and endotracheal tube size and cuff pressure measurements, the study findings displayed that there was no statistically significant relation between incidence of ventilator associated pneumonia and endotracheal tube size. While there was a high statistically significant relation between incidences of ventilator associated pneumonia and endotracheal tube cuff pressure measurements.

These findings are interpreted by either under-inflation or over-inflation of the endotracheal tube cuff pressure expose the mechanically ventilated patients to serious complications. Under-inflation causes aspiration of subglottic secretion into lower respiratory tract and contributes to incidence of VAP. Hence, maintaining the ETT cuff pressure within the normal range helps in preventing the ETT complications as well as decrease the incidence of VAP.

The present study results are in the same line with an observational study conducted by [4] which titled "inappropriate endotracheal tube cuff pressure and its relation to ventilator associated pneumonia in intensive care unit" and clarified that during the observational periods, one third of the patients were exposed to inappropriate ETT cuff pressure. One of the previously mentioned study that conducted by [20] is consistent with the current study as it revealed that two thirds of patients had low endotracheal tube cuff pressure and there was

statistically significant relationship between endotracheal tube cuff pressure and incidence of ventilator associated pneumonia.

4. Conclusion

Regarding the present study results, it can be concluded that more than half of the studied patients had ventilator associated pneumonia, and more than half of the infected patients had low endotracheal tube cuff pressure less than 20 cm H2O. There were no statistically significant relations between incidence of ventilator associated pneumonia among the studied patients and endotracheal tube size. While, there was a high statistically significant relation between incidences of ventilator associated pneumonia and endotracheal tube cuff pressure measurements.

5. Recommendations

According to the study's findings, the following were recommended

1) Provide education and training sessions to health care providers on the importance of cuff pressure measurement and the potential complications associated with incorrect cuff pressure.
2) Establish a standardized method for measuring endotracheal tube cuff pressure to ensure consistency among health care providers.
3) Use a cuff manometer which is the gold standard for measuring endotracheal tube cuff pressure and provides an accurate and objective measurement of the pressure inside the cuff.
4) Continuous endotracheal tube cuff pressure control system and other VAP prevention bundle components should be set as essential part of care provided to all critically ill patients.

6. Further studies are also recommended

- Replication of the study on a larger sample acquired from different geographical areas in Egypt for generalization of the finding
- Comparative study of endotracheal tube cuff pressure monitoring methods, such as manual palpation, cuff pressure gauges and automatic cuff pressure control devices. Evaluate the accuracy, reliability and the ease of use of each method.

References

[1] N. Aeppli, B. Lindauer, M.P. Steurer, M. Weiss, A. Dullenkopf. (2019). Endotracheal tube cuff pressure changes during manual cuff pressure control manoeuvres: An in-vitro assessment. Acta anaesthesiologica Scandinavica. 63(1): 55–60.

[2] R.A. Ahmed, T.J. Boyer. (2023). Endotracheal Tube. In StatPearls. StatPearls Publishing.

[3] Z.H. Ali, T.S.A. Mawla, S.R. Ahmed. (2020). Assessment the Incidence of Ventilator-associated Pneumonia for Critically Ill Patients in the Intensive Care Unit. Egyptian Journal of Health Care. 11(4): 32-39.

[4] A. AlQahtani. (2020). Inappropriate Endotracheal Tube (ETT) cuff pressure and its relation to ventilator-associated pneumonia (VAP) in Intensive care unit (ICU).

[5] S. Bakhtiari, A. Yazdannik, S. Abbasi, N. Bahrami. (2015). The effect of an upper respiratory care program on incidence of ventilator-associated pneumonia in mechanically ventilated patients hospitalized in intensive care units. Iranian Journal of Nursing and Midwifery Research. 20(3): 354.

[6] D. Battaglini, L. Parodi, R. Cinotti, K. Asehnoune, F.S. Taccone, G. Orengo, C. Robba. (2023). Ventilator-associated pneumonia in neurocritically ill patients: insights from the ENIO international prospective observational study. Respiratory Research. 24(1): 146.

[7] A. Combes, D. Hajage, G. Capellier, A. Demoule, S. Lavoué, C. Guervilly, A. Mercat. (2018). Extracorporeal membrane oxygenation for severe acute respiratory distress syndrome. New England Journal of Medicine: 378(21): 1965-1975.

[8] R. Deshmukh, A. Mhaske, P.D. Guide, M.G.M. Director. Improving the outcome; bundle care approach for ventilator associated pneumonia (VAP). Journal of Clinical Otorhinolaryngology, Head, and Neck Surgery. 27(2): 1348-1353.

[9] R.M. Elkolaly, H.M. Bahr, B.I. El-Shafey, A.S. Basuoni, E.H. Elber. (2019). Incidence of ventilator-associated pneumonia: Egyptian study. Egyptian Journal of Bronchology. 13: 258-266.

[10] A. Fathy, R. Abdelhafeez, E.G. Abdel-Hady, S.A. Abd Elhafez. (2013). Analysis of ventilator associated pneumonia (VAP) studies in Egyptian University Hospitals. Egyptian Journal of Chest Diseases and Tuberculosis: 62(1): 17-25.

[11] M. Garnier, J.M. Constantin, N. Heming, L. Camous, A. Ferré, K. Razazi, and COVID-ICU Investigators. (2023). Epidemiology, Risk Factors and Prognosis of Ventilator-Associated Pneumonia During Severe COVID-19: Multicenter Observational Study Across 149 European Intensive Care Units. Anaesthesia Critical Care & Pain Medicine. 42(1): 101184.

[12] D.R. Giacobbe, D. Battaglini, E.M. Enrile, C. Dentone, A. Vena, C. Robba, M. Bassetti. (2021). Incidence and Prognosis of Ventilator-Associated Pneumonia in Critically Ill Patients with COVID-19: A Multicenter Study. Journal of Clinical Medicine. 10(4): 555.

[13] J.J. Vos, S.F. Ellermann, T.W.L. Scheeren. (2019). Journal of Clinical Monitoring and Computing 2017/2018 End of Year Summary: Monitoring—and Provocation—of the Microcirculation and Tissue Oxygenation. Journal of Clinical Monitoring and Computing. 33: 201-209.

[14] R.S. Hussein, S.A.Hakim, G. Wassef, A.M. AboulFoutoh, S.I. Damaty. (2017). Epidemiology of Ventilator-Associated Pneumonia in Hospital Surgery Intensive Care Units of Ain Shams University Hospital. Egyptian Journal of Community Medicine. 35(4).

[15] A. Kebapçı. (2022). Determination of Factors Affecting Endotracheal Tube Cuff Pressure in Adult Patients in Intensive Care Unit. Journal of Academic Research in Nursing (JAREN). 8(3).

[16] M.H. Kollef. (2021). Critical Care Medicine: The First 50 Years 1969-2019. Critical Care Medicine. 49(1): 86-94.

[17] C.M. Kumar, E. Seet, T.C. Van Zundert. (2021). Measuring Endotracheal Tube Intracuff Pressure: No Room for Complacency. Journal of Clinical Monitoring and Computing. 35: 3-10.

[18] D. Mamo, E. Aklog, Y. Gebremedhin. (2023). Patterns of Admission and Outcome of Patients Admitted to the Intensive Care Unit of Addis Ababa Burn Emergency and Trauma Hospital. Scientific Reports. 13(1): 6364.

[19] P.E. Marik. (2010). Hemodynamic Parameters to Guide Fluid Therapy. Transfusion Alternatives in Transfusion Medicine. 11(3): 102-112.

[20] S.H. Mohammed, O.A.E.G. Shawer, M.A. Mohamed, O.A. Mohammed. (2021). Relation Between Endotracheal Tube Cuff Pressure Measurements and The Incidence of Ventilator Associated Pneumonia. Assiut Scientific Nursing Journal. 9(26): 140-148.

[21] L. Papazian, M. Klompas, C.E. Luyt. (2020). Ventilator-Associated Pneumonia in Adults: A Narrative Review. Intensive Care Medicine. 46(5): 888-906.

[22] A. Safavi, S. Molavynejad, M. Rashidi, M. Asadizaker, E. Maraghi. (2023). The Effect of an Infection Control Guideline on the Incidence of Ventilator-Associated Pneumonia in Patients Admitted to the Intensive Care Units. BMC Infectious Diseases. 23(1): 1-7.

[23] P.A. Siregar. (2021). Manajemen Data SPSS (Statistical Package For The Social Sciences).

[24] C.H. Vacheron, A. Lepape, A. Savey, A. Machut, J.F. Timsit, P. Vanhems, and REA-REZO Study Group (2022). Increased Incidence of Ventilator-Acquired Pneumonia in Coronavirus Disease 2019 Patients: A Multicentric Cohort Study. Critical Care Medicine. 50(3): 449-459.

[25] B. Viswambharan, M.J. Kumari, G. Krishnan, L. Ramamoorthy. (2021). Under or Overpressure: An Audit of Endotracheal Cuff Pressure Monitoring at the Tertiary Care Center. Acute and Critical Care. 36(4): 374-379.

[26] N.L. Werner, A. Cralley, R. Lawless, K.B. Platnick, M.J. Cohen, J.J. Coleman, C.C. Burlew. (2022). Time to Look for Another Infectious Source? White Blood Cell Trends During Ventilator-Associated Pneumonia. Surgical Infections. 23(7): 656-660.

[27] S.B. Wilhelms, D.B. Wilhelms. (2021). Emergency Department Admissions to the Intensive Care Unit– A National Retrospective Study. BMC Emergency Medicine. 21: 1-9.