Original Article

Endotracheal tube cuff pressure contiuous monitoring in intensive care units patients

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Abstract

Context: Endotracheal tube (ETT) cuff pressure should be kept within an optimal range to ensure positive ventilation and prevent the aspiration of oral and gastric contents while maintaining tracheal perfusion.

Aims: The aims of the study are to assess the ETT cuff pressure using continuous monitoring.

Settings and Design: This cross-sectional descriptive study was conducted on 61 orally intubated patients receiving mechanical ventilation admitted to the intensive care unit's educational therapeutic hospitals in Rasht in the summer of 2013.

Material and Methods: The measurements were carried out using a monitor-connected transducer for 6 h for each unit of study during in two shifts of morning and evening. Variables such as age, sex, diagnosis type, body mass index, and days intubated were investigated. Due to the noninterventional nature of the study, according to the Ethics Committee with registration number 9053, it was not necessary to obtain consent from the patients or their legal guardianship.

Statistical Analysis Used: All data obtained was analyzed using descriptive statistics (mean and standard deviation) and inferential statistics (*t*-test, analysis of variance, and Pearson).

Results: This study showed that cuff pressure in 90.2% of cases was in normal range (20–30 H_2O) and only one person (1.6%) had a pressure of <20 and in 5 (8.2%) higher cuff pressures from 30 cm H_2O. The correlation between days intubated ($P = 0.01$) and body mass index ($P = 0.01$) with cuff pressure was statistically significant.

Conclusions: During the 6-h continuous monitoring, the cuff pressure was 9.8% of normal range and this could be a reminder that to prevent complications due to increased or decreased cuff pressure, it may be necessary to have fewer intervals to control the cuff pressure.

Keywords: Intensive care units, Intubation, Monitoring, Pressure

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Received: 15 July 2018; **Accepted:** 22 September 2018; **Published:** 29 November 2018.

INTRODUCTION

Patients admitted to the intensive care unit (ICU) often undergo mechanical ventilation as part of their treatment, and for this, they require intubation with an endotracheal tube (ETT) to provide an artificial airway. The tube has a high-volume low-pressure cuff at the distal end that is

Access this article online	
Quick Response Code:	Website: www.jnmsjournal.org
	DOI: 10.4103/JNMS.JNMS_18_18

How to cite this article: Taslimi L, Mohamadi Khaleghdoost T, Khanghah Ghanbari A, Leili Kazemnezhad E. Endotracheal tube cuff pressure contiuous monitoring in intensive care units patients. J Nurs Midwifery Sci 2018;5:63-7.

inflated to seal the trachea to deliver mechanical ventilation. ETT cuff pressure must be kept within a therapeutic range to prevent complications. It is recommended that the cuff pressure is kept between 20 and 30 cm H_2O to prevent complications while sealing the trachea.[1] Thoracic and Infectious Diseases Society of America recommend a cuff of 25 cm H_2O.[2] In the study of Nikbakhsh *et al*., it was shown that preserving the pressure of the cuff of the ETT at 20–30 cm H_2O prevents tracheal intubation complications.[3] Although improvements in the production of tubes with high-volume low-pressure cuffs have reduced the risk of injury to the trachea, the effects of cuff pressure have not been completely eliminated, and these cuffs can also cause a high pressure that changes the trachea and causes partial obstruction to complete mucosal blood flow and causes complications such as stridor, sore throat, coughing, and dyspnea,[4] inflammation, tracheomalacia, and tracheoesophageal fistula,[5] and tracheal stenosis.[6] Overinflation 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.[7] On the other hand, underinflation of the ETT cuff associated with air leakage, aspiration of secretions, ventilator-associated pneumonia, inadequate delivery of prescribed tidal volume, and accidental extubation.[8] These complications will lead to morbidity, mortality, and hospital costs. However, during patient stay in ICU and the use of an ETT with or without ventilator cuff pressure may increase or decrease both of which can be harmful to the patient. No standards exist for frequency and method of monitoring cuff pressure. The most common measurement frequency is each 8–12 h.[9,10] The cuff pressure is measured when warnings such as an audible air leakage or alarms related to reducing the exhaled tidal volume indicate a decrease in cuff pressure.[11] Often, the ETT cuff pressure is estimated by palpating the pilot balloon. However, estimation techniques can be inaccurate,[12-15] with less than one-third of the pressures within a desired therapeutic range.[13,16] These studies consider the direct measurement of cuff pressure by a manometer. The frequency of cuff pressure measurements by manometer in the United States is estimated to be 13–20 million times a year.[17] However, Morris *et al*. reported that the use of a manometer to control cuff pressure did not reduce the prevalence of high cuff pressure and recommended the use of a more sensitive monitoring method.[18] However, due to the factors affecting cuff pressure such as the patient's position, certain anesthetic agents and the type of the ETT,[19] its size,[20] sedation, and the duration of intubation,[11] it is difficult to detect cuff pressures in the interval between measurements and does not reflect the many factors that influence cuff pressure. Intermittent monitoring of cuff pressure may give a false sense of security that the pressure is within a therapeutic normal range. Meanwhile, cuff pressure decreases by 2 cm H_2O when attaching a cufflator to the pilot balloon,[21] so frequent measurement of cuff pressure may have its own inherent risks. It is difficult to maintain cuff pressures within the therapeutic range unless continuous monitoring or an automatic regulating device is attached. Sole *et al*. reported the possibility of continuous monitoring of cuff pressure compared to intermittent control by a manometer, but in this study, no significant differences were observed in cuff pressure changes over time.[11] While another study by Memela, continuous monitoring of cuff pressure showed that ETT cuff pressure was widely distributed during mechanical ventilation in poor patients. Therefore, cuff pressure changes may be detected early using continuous monitoring.[22] In the study of Nseir *et al*., continuous control of cuff pressure was performed to identify the effective factors, and lack of sedation and duration of intubation were introduced as cuff pressure reducing factors.[23] Physician and nurses in the ICU are responsible for the treatment, care, and improving the quality of care. It is necessary that the care should be such that it causes less complications in the patient and that care should always seek out care with minimal complications and risks. As noted, the purpose of inflation the cuff is to provide and deliver a positive pressure ventilation without losing tidal volume and prevent aspiration of oral and gastric secretions. To do this, the cuff should push into the tracheal wall and this pressure should be adjusted so that does in addition to the above the trachea will not be injured. Therefore, care is necessary, and its precise control along with effective factors is of great importance. Despite the importance of controlling cuff pressure to prevent its complications, the best way to measure and maintain the cuff pressure, as well as the proper times to measure it, is unknown. Therefore, the purpose of this study was to assess the ETT cuff pressure using continuous monitoring.

MATERIAL AND METHODS

This research is a cross-sectional descriptive study, which was conducted on patients admitted to the ICUs educational therapeutic hospitals in Rasht in the summer of 2013. The sample size required for the based on the results of the study Sole and *et al*. (2009); with confidence interval 95% and accuracy of 0.25 cm H_2O (standard deviation, 0.1), 61 were determined. Inclusion criteria were age over 18 years, admitted to the ICU for at least 24 h, orally intubated, receiving mechanical ventilation,

and angle of 30–45° head. Removing mechanical ventilation or changing its settings, performing a suction for half an hour before sampling, extubation, and also manipulating the cuff were exclusion criteria. Due to the noninterventional nature of the study, according to the Ethics Committee with registration number 9053, it was not necessary to obtain consent from the patients or their legal guardianship. Each of the patients who had the criteria for entering the study was studied by nonprobabolity gradual sampling. Data were collected during two shifts of morning and evening. All samples were intubated with a SUPA tube. The measurements were carried out using a monitor-connected transducer for 6 h for each unit of research, and variables such as age, sex, diagnosis type, BMI, and days intubated were investigated. Demographic data were collected from the patient's medical record. Continuous ETT cuff pressure was recorded by connecting the pilot balloon of the ETT to a 3-way stopcock with a 15-cm (6-inch) extension tube and transducer. The transducer was connected to an monitor (Saadat-Co) with a cable. The transducer was zeroed, and the mean pressure was recorded in cm H_2O. The initial ETT cuff pressure was measured with the cufflator manometer (Mallinckrodt) connected to the three way. The cuff pressure was adjusted by entering or exiting the air by cufflator manometer to the base pressure of 25 cm H_2O. After zeroing, the path was closed to the cufflator manometer and opened toward the transducer. The cuff pressure was monitored for 6 h. Because of the impossibility of accessing all cuff pressure data recorded in the monitors in <1 s, the cuff pressure is monitored in the trend curve every hour, and the mean cuff pressure is calculated by selecting ten points during the period and at the end mean of the cuff pressure was calculated over a continuous period of 6 h. After 6 h, the cuff pressure was adjusted again, if necessary and was placed in the normal range. Sixty-nine patients were enrolled. During the study period, three patients for computed tomography scan and one patient for X-ray were transferred for radiography. Furthermore, in two samples, the cuff pressure was manipulated by the personnel. One patient was extubated, and in two patients, the mechanical ventilation setting was changed to physician's order, with a total of eight samples excluded. Finally, data were analyzed for 61 patients. Continuous cuff pressure monitoring was done in each sample for 360 min. Data were entered into the computer and were analyzed using descriptive statistics (mean, standard deviation, and distribution) and inferential statistics (*t*-test, Pearson, and analysis of variance [ANOVA]) using SPSS version 21 (SPSS Inc., Chicago, IL, USA). A significant level was defined with $P < 0.05$. The normal pressure range of 20–30 cm H_2O was considered as a normal range.[1]

RESULTS

This study was carried out on 61 samples with a minimum of 18 and a maximum age of 92 years with internal diagnosis, surgery, and trauma, and other cases (cardiovascular, suicide, etc.) were admitted to ICUs educational therapeutic hospitals in Rasht [Table 1]. During the continuous monitoring, the cuff pressure in 55 persons (90.2%) of the cases was in normal range, and only one person (1.6%) had a pressure of <20 and in 5 (8.2%), a cuff pressure of more than cm H_2O water has been. The results showed that during the continuous monitoring period, the mean cuff pressure per hour was in the range of 20–30 cm or near to it. The repeated measurement of ANOVA was used to investigating the cuff pressure changes over time. The results indicated that the trend of changes during the study period had some various fluctuations, but based on the results of the Gizier test, these differences were not statistically significant (Manchly, s W, $P > 0.0001$) [Table 2 and Figure 1].

Pearson test was used to determine the relationship between cuff pressure with quantitative variables (age, body mass index, and days intubated). The results indicated that there was a significant relationship between days intubated and BMI with cuff pressure. While there was no significant relationship between age with cuff pressure. Independent

Table 1: Baseline characteristics of sample

Characteristic	Value
Age, mean (SD), years	42 (20)
Sex, *n* (%) of patients	
Male	34 (55.7)
Female	27 (44.3)
BMI, mean (SD)	25.26 (4.33)
Diagnosis type, *n* (%) of patients	
Medical	12 (19.7)
Surgical	19 (31.1)
Trauma	23 (37.7)
Other	7 (11.5)
Days intubated, mean (SD)	3 (1)

SD: Standard deviation, BMI: Body mass index

Table 2: The mean and standard deviation of the tube pressure cuff pressure in the continuous method separated by time

Time (h)	Cuff pressure			
	Mean (SD)	95% CI		Type and test result
		Lower bound	Upper bound	
1st	26.32 (3.83)	25.34	27.30	Green house-Gessier *P*=0.051
2nd	27.35 (3.72)	26.39	28.30	
3rd	26.25 (3.25)	25.42	27.09	
4th	26.94 (3.98)	25.91	27.96	
5th	26.31 (4.85)	25.07	27.55	
6th	25.41 (5.77)	23.93	26.88	
Total	26.42 (3.10)	25.63	27.22	

SD: Standard deviation, CI: Confidence interval

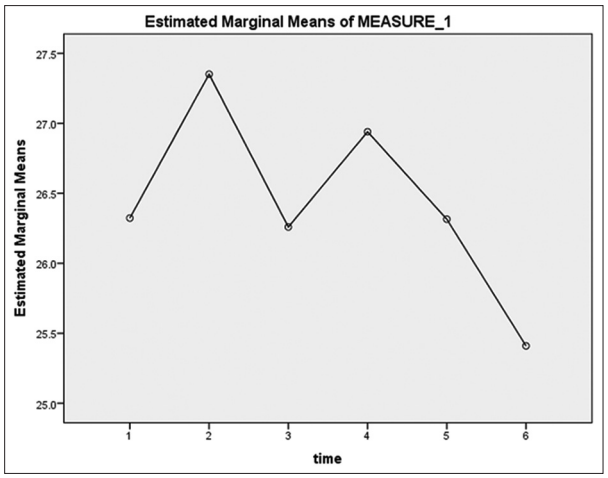

Figure 1: Changes in the tube pressure cuff during 6 h

t-test also did not show any significant correlation between cuff pressure and sex variable. There was no significant relationship between diagnosis type with cuff pressure (ANOVA test) [Table 3].

Table 3: Relationship of cuff pressure with variable

Variable	Type and test result
Age	Pearson test *P*=0.151
BMI	Pearson test *P*=0.010
Days intubated	Pearson test *P*=0.010
Sex	*t*-test *P*=0.684
Diagnosis type	ANOVA *P*=0.813

ANOVA: Analysis of variance, BMI: Body mass index

DISCUSSION

The results of this study indicate that in continuous monitoring period, cuff pressure was normal in 90.2% of cases, and in only one person (1.6%), pressure was <20 and in 5 (8.2%) pressure. The cuff has been above cm H_2O. These results indicate that cuff pressure control is effective in maintaining it in the normal range. This information is also consistent with the results of the Memela study that during a 8-h continuous monitoring period, the cuff pressure for all units studied was 13% of the cuff pressure in the lower range (<20 cm H_2O) and 23% at high pressures (>30 cm H_2O), and an average of 64% of the time was within normal pressure range (20–30 cm H_2O).[22] However, in this study, the trend of changes in the pressure of the cuff during 6 h of continuous monitoring was not significant but near to the level of significance. In the study of Sole *et al*. (2009), to investigate the accuracy and the possibility of continuous monitoring of cuff pressure and assess cuff pressure changes over time, there was no significant change in cuff pressures during 12 h of continuous monitoring. While in another study conducted by Sole *et al*. (2011), with the aim of evaluating the effectiveness of an intervention to maintain a cuff pressure in the range of 20–30 cm H_2O, the results showed that the cuff pressure was decreased during the 12-h period of continuous monitoring. As the results show, the mean cuff pressure was the most at the 2nd h and at the 6th h, it was the lowest. Laying the mean cuff pressure in the 2nd and 4th h may be attributed to factors such as endotracheal suction, coughing, or patient fight with the mechanical ventilation as shown in the study of Sole *et al*. (2011), cuff pressure during suctioning, coughing, position change, and patient fight with the mechanical ventilation increases for a short period, most of which are transient and take up to 5 min or less. It may be necessary to control the pressure of the cuff at lower intervals, as in the study of Mousavi *et al*. (2009), despite 6-h control of the cuff, in 18% of cases, the cuff pressure was in abnormal range.[5] In this study, the mean cuff pressure per hour was 20–30 cm H_2O or near it, and at the sixth time, it was the least. Because what ultimately leads to lower cuff pressure over time, as stated in the study of Nseir (2009), is the nonsedation of the intubate patients, the coughing and the patient fight with the ventilator, which, despite the transient increase in cuff pressure, increases the pressure airway, which causes the cuff to be empty and reduce its pressure over time.[23] As in Hoffman *et al*.'s study, there was no significant relationship between cuff pressure and age and sex;[4] in this study, the relationship between cuff pressure and these two variables was not found. However, as in the study Khoshsirat *et al*., the most common cause of intubation was due to trauma,[24] like previous studies, men were more likely to participate in the study than women.[21,24] In the study of BMI, it was also observed that the relationship of this variable with the mean cuff pressure was significant. However, this relationship was not statistically significant in Hoffman *et al*., which investigated the relationship between cuff pressure and height of patients.[4] Perhaps this issue, as described in the Hamilton study, is due to the anatomical and physiological differences in patients that may require different amounts of air to achieve the target pressure of the cuff of the ETT.[25] The correlation of days intubated with mean cuff pressure was also significant which also confirms the results of Sole and Nseir studies.[1,23] In the study of Nseir, the correlation between the days intubated and the lowering of the pressure of the ETT cuff is explained by the fact that high-volume low-pressure cuffs after several days of use are porous. Furthermore, nonsedation of intubate patients, coughing, and patient

fight with ventilator cause an increase in airway pressure, which causes the cuff air to drain and reduce its pressure over time.[23] The study also investigated the relationship between cuff pressures and diagnosis type, which was not statistically significant which also confirms the study results of Nseir *et al*.[23] Perhaps the reason for this is the same routine care for patients in the ICU. In this study, only cuff pressure was studied, and other aspects such as complications due to cuff pressure were not investigated.

CONCLUSION

These results emphasize the regular monitoring of cuff pressures and variables that can affect it. Furthermore, despite the ease of measuring the pressure of the cuff, the devices needed to measure is not widely available. Finally, due to the very diverse and different outcomes in the measurement methods and factors affecting the pressure of the cuff of the tracheal tube, the findings of this study could lead to more extensive studies regarding changes in the pressure of the cuff of the ETT, the factors affecting it, and comparing the research, to achieve a suitable method for measuring and controlling the pressure of the cuff.

Conflicts of interest

There are no conflicts of interest.

Author contribution

All authors contributed to this research.

Financial support and sponsorship

This study was financially supported by Research Deputy of Gilan University of Medical Sciences and Health Services.

Acknowledgment

This article is based on a research project approved by Guilan University of Medical Sciences with registration number 9053. Thanks for your gratitude to assistant professor of Research and Technology of Guilan University of Medical Sciences and Health Services, Social Health Effects Research Center, Nursing and Midwifery Faculty, and staff members of ICUs educational centers Pursina and Razi and thanks for the patients and their families, who helped us briskly in this study.

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