Original Article

Endotracheal Tube Cuff Pressure in Patients Admitted to Intensive Care Units After Cardiac Surgery

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ABSTRACT

Background: The endotracheal tube (ETT) cuff pressure must be kept within the range of 20 to 30 cmH_2O in order to prevent tube displacement and air leakage, maintain the circulation of the tracheal capillaries, and prevent the aspiration of oral and gastric contents to the lower parts of the respiratory tract. This study aimed to determine the ETT cuff pressure and appropriate intervals for measuring it in patients admitted to intensive care units (ICUs).

Methods: This descriptive cross-sectional study was conducted on 100 patients after cardiac surgery with general anesthesia admitted to ICUs between May and November 2017. For each research unit, the ETT cuff pressure was measured twice at a 6-hour interval using a cuff pressure manometer. Descriptive (ie, mean, standard deviation, and frequency distribution) and inferential (ie, *t*-test, Pearson, and ANOVA) statistics were used to describe the data. All the ETT cuff pressure measurements were performed with a calibrated manometer. The data were analyzed using the SPSS software, version 22.0.

Results: The mean ETT cuff pressure was 38.3 ± 24.9 cmH_2O. In the first measurement, the ETT cuff pressure was normal in only 17% of the subjects, while this figure increased to 78% after the 6-hour control period and cuff-pressure correction. There was a significant relationship between the number of days of intubation and the ETT cuff pressure in both first ($P = 0.003$) and second ($P = 0.01$) measurements.

Conclusions: The ETT cuff pressure often exceeds the recommended normal range, which can serve as a reminder that it may be necessary to control it at shorter intervals to avoid complications caused by increases or decreases in the cuff pressure. ***(Iranian Heart Journal 2020; 21(3): 33-39)***

KEYWORDS: Endotracheal tube, Cuff pressure, Intensive care units, Cardiac surgery

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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 eliminated by other noninvasive procedures. [1, 2] An important aspect of airway management in a patient with the ETT is monitoring the cuff in order to minimize possible complications as most of the ETTs used for adults have a cuff at their ends. [3,4] The cuff is inflated in order to allow breathing with positive pressure without a loss of the tidal volume and prevent tube displacement and the aspiration of oral and gastric contents. Therefore, managing the ETT cuff pressure is one of the most important factors to be considered in patients undergoing mechanical ventilation. [5] An excessive increase in the ETT cuff pressure can cause damage to the tracheal wall, nerve damage, tracheal stenosis, tracheal fistulae, and hoarseness so that an increase in the pressure of the ETT cuff to more than 65 cmH_2O can result in ischemia and tracheal injury within 15 minutes. [6] The most common complications in patients after extubation are sore throat and hoarseness, which have been reported in 15% to 80% of cases. [7] Complications such as airway obstruction and laryngeal edema after extubation due to high cuff pressures in patients in the intensive care unit (ICU) are estimated to be present in 2% to 16% of cases. [7,8] The main pathophysiology in postoperative tracheal stenosis is high ETT cuff pressure, chronic inflammation, and fibrosis, which occur in 19% of intubations. [9] On the other hand, a low ETT cuff pressure causes a 50- to 100-mL decrease in the tidal volume, tube displacement, and self-extubation in patients under mechanical ventilation. [3,7] The ETT is one of the main risk factors for developing ventilator-associated pneumonia, whose mortality rate is estimated to range between 2% and 70% and can be caused by low cuff pressures and subsequent aspiration. [10-12] 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. [13] The cuff pressure for pressure-induced complications to occur is also estimated to be about 30 to 50 cmH_2O. [3] What is considered in most studies to be the target cuff pressure is 20 to 30 cmH_2O. [6,7,14,15] The American Society of Thoracic and Infectious Diseases recommends a cuff pressure of 25 cmH_2O, which ensures mechanical ventilation and the prevention of aspiration and blood flow to the tracheal capillaries. [16] In different sources, the appropriate interval for measuring the cuff pressure with a manometer varies from every 4 hours to 12 hours. [17] The cuff pressure is controlled at least at each shift using a manometer. The studies in this area have shown that controlling the cuff pressure every 6 hours and maintaining it in the range of 20 to 30 cmH_2O prevents tracheal intubation complications. [4] It is recommended that if the cuff pressure is intermittently monitored, measuring intervals should be less than every 8 hours. [18] Therefore, cuff pressure in mechanically ventilated patients may increase or decrease, both of which can be harmful. What usually ensues is prolonged mechanical ventilation and ICU and hospital lengths of stay as well as additional invasive procedures such as surgery, all of which increase the cost of hospitalization. [19,20] Therefore, the purpose of this study was to determine the ETT cuff pressure in intubated patients and appropriate intervals for its measurement.

METHODS

This descriptive cross-sectional study was conducted on 100 patients after cardiac surgery with general anesthesia admitted to ICUs in Rajaie Cardiovascular Medical and Research Center between May and November 2017. The sample size was determined as 73 patients based on the study of Sole et al [13] with a mean cuff pressure of 0.25 ± 1 cmH_2O with a 95% confidence interval (CI). For higher validity, the sample size was increased to 100. The inclusion criteria were age above 18 years and an ICU stay of at least 24 hours, In the event of weaning from mechanical ventilation or any change in its settings compared with those at the beginning of the study, performing a suction half an hour before the sampling, removing the ETT and, manipulating the cuff during the study, the subjects were excluded from the study. The participants for the study were selected through convenience sampling. For each research unit, the ETT cuff pressure was measured twice at a 6-hour interval using a cuff pressure manometer and variables such as age, sex, the body mass index (BMI), and the number of days of intubation were recorded. Demographic data were collected through medical records of the patients. The cuff pressure was measured using a calibrated manometer (Posey Co, Arcadia, California), which measures the pressure from 0 to 120 cmH_2O with a precision of 2 cmH_2O. [14] In the first measurement, the manometer pressure was read and recorded in cmH_2O at the inspiration phase. Then, with the inhalation or exhalation, the cuff pressure was adjusted to 25 cmH_2O; and after 6 hours, the cuff pressure was again measured and, if necessary, adjusted to the normal range. Descriptive (ie, mean, standard deviation, and frequency distribution) and inferential (ie, *t*-test, Pearson, and ANOVA) statistics were used to describe the data. All significance levels were defined as a *P* value of less than 0.05. The normal range of the cuff pressure was considered to be 20 to 30 cmH_2O. Repeated-measures analysis of variance (ANOVA) was applied to investigate the extent of changes in the measurements. Through the use of the SPSS software, version 22.0, the Pearson test was employed to investigate the relationship between the quantitative variables and the ETT cuff pressure, the independent *t*-test for the binary qualitative variable (sex), and ANOVA for the detection of variables with than 2 states.

RESULTS

The current research was conducted on 100 patients at a mean age of 45 ± 20 years, with the lowest age of 18 years and the highest age of 86 years. The patients were 47% female (n = 47) and 53% male (n = 53). The type of surgery on the patients is listed in Table 1. The mean BMI of the patients was 25.26 ± 4.33, with a minimum of 17.77 and a maximum of 31.50. The average number of days on mechanical ventilation was 3 ± 1 days, with a minimum of 2 days and a maximum of 12 days.

Table 1: Distribution of the patients hospitalized in the ICU based on the type of surgery

Type of Surgery	Frequency
	Number(%)
CABG + valve surgery	38(38%)
Only CABG surgery	47(47%)
Only valve surgery	15(15%)
Total	100(100%)

ICU, Intensive care unit: CABG, Coronary artery bypass grafting surgery

The cuff pressure in the first measurement was below 20 cmH_2O in 34 (34%) patients, normal (20–30 cmH_2O) in 17 (17%), and above 30 cmH_2O in 49 (49%), while the cuff pressure in the second measurement was below 20 cmH_2O in 9 (9%) patients, normal in 78 (78%), and above 30 cmH_2O in 13 (13%).
The mean ± standard deviation of the cuff pressure was 38.3 ± 2 4.9 cmH_2O (CI = 95%, upper limit = 42.41, and lower limit = 30.63) in the first measurement and 23.4 ± 7 cmH_2O (CI = 95%, upper limit = 27.66, and lower limit = 24.34) in the second measurement. In the first measurement, the lowest and the highest cuff pressures were 11 and 125 cmH_2O, respectively, while they were 18 and

62 cmH_2O in the second measurement. The cuff pressure was within the normal range in 17% of the first measurement, whereas it rose to 78% in the second measurement. The ANOVA test indicated that this difference was significant ($P < 0.005$).

The Pearson test was used to investigate the relationship between the cuff pressure and the quantitative variables (ie, age, the BMI, and the number of days of intubation); the results showed a significant relationship between the number of days of intubation and the cuff pressure in both first (P = 0.003) and second (P = 0.01) measurements. Additionally, the relationship between the BMI and the cuff pressure was significant in both first (P = 0.006) and second (P = 0.02) measurements. Nonetheless, there was no significant relationship between age and the cuff pressure in both first (P = 0.06) and second (P = 0.94) measurements.

First, the Kolmogorov–Smirnov test was used to investigate the normal distribution of the differences. The distribution of the differences based on this test was normal (P = 0.25). The independent *t*-test also showed no significant relationship between the cuff pressure and sex. An investigation of the relationship between the cuff pressure and the type of surgery via the ANOVA test revealed no significant relationship between these 2 variables (Table 2).

Table 2: Comparisons of the condition of the endotracheal tube at the 2 intervals

Level of Endotracheal Cuff Pressure (cmH_2O)	First Measurement Before Correcting the Cuff Pressure	Second Measurement After Correcting the Cuff Pressure
<20	34(34%)	9(9%)
20-30	17(17%)	78(78%)
>30	49(49%)	13(13%)
Total	100	100
Mean±SD	38/25±54/88	23/4±7
Test*	P<0.005	

* Repeated measure ANOVA

The Wilcoxon statistical test showed a significant difference between the mean pressure of the ETT cuff before and after the correction of the cuff pressure (P = 0.001) (Table 4).

DISCUSSION

As a principle, maintaining the airway is the first step of treatment in all patients who are in a critical life-threatening condition and experience a loss of consciousness or respiratory problem. [6] Intubation is the method employed in emergencies. Due to the fact that the ETT cuff is a major source of complications related to artificial airways, it is essential to monitor and control it accurately and at appropriate intervals. In the present research, the ETT cuff pressure in the first measurement was normal in only 17% of the patients, and this figure increased to 78% after the 6-hour control period and cuff-pressure correction. Further, our statistical test indicated that this difference was significant. Although the mean cuff pressure was 25 cmH_2O in the second measurement, the pressure was still below 20 in 9 patients and above 30 in 13 patients. This finding, also reported in a study by Rose et al, [18] could indicate that a non-regular measurement of the ETT cuff pressure should be a routine. It can also indicate that the control of the cuff pressure, despite the availability of facilities for monitoring with a manometer, is often carried out and estimated by touching the pilot balloon, whose precision is questioned according to the results of studies by Nasiri et al, [21] Stwart et al, [22] Zand et al, [23] Hoffman et al, [24] and Liu et al. [25] Moreover, when an estimated cuff-pressure control was used in these studies, it was above 30 cmH_2O. In this study, despite the 6-hour control period, the cuff pressure was still 22% out of the normal range, which could be a reminder that the prevention of complications caused by increases or decreases in the cuff pressure may require the control of cuffs at shorter intervals. As was demonstrated in a study by Mousavi et al, [6] despite a 6-hour cuff-pressure control period, the cuff pressure was not within the normal range in 18% of the cases assessed.

Table 3: Relationship between the cuff pressure and the quantitative and qualitative variables

Variable		First Measurement	Second Measurement
Sex	Male Female	36.37±20.81 33.08±23.41	23.87±6.81 24.06±3.19
P*		0.43	0.85
Type of Surgery	CABG + valve surgery CABG surgery Valve surgery	42.83±28. 08 37.65±25.96 28.71±22. 93	24.83±3.40 26.04±9.58 25.86±5.41
P**		0.47	0.78

* *t*-test
** ANOVA
CABG, Coronary artery bypass graft surgery

Table 4: Comparisons of the mean of the endotracheal tube cuff pressure and the core body temperature before and after the correction of the cuff pressure in the patients hospitalized in the intensive care unit

Variable	Before Correcting Correcting the Cuff Pressure	After Correcting the Cuff Pressure	*P* value*
	Mean±SD	Mean±SD	
Endotracheal tube cuff pressure	45.43(6.58)	27.78(3.73)	0.001
Core body temperature	37.5(0.5)	37.4(0.5)	0.001

* Wilcoxon test

The relationship between the cuff pressure and the number of days of intubation showed that a significant relationship between these 2 variables, which is compatible with the results of the studies by Sole et al [13] and Nseir et al. [14] In the study by Nseir and colleagues, [14] the relationship between the number of days of intubation and a decreased ETT cuff pressure was explained by the fact that low-volume and high-pressure cuffs became porous after a few days. Additionally, the authors concluded that the non-administration of sedatives to patients undergoing mechanical ventilation, coughing, and patient-ventilator asynchrony increased the airway pressure, leading to cuff deflation and decreased cuff pressure over time. The relationship between the BMI and the cuff pressure was statistically significant in our study. Still, this relationship was not statistically significant in a study by Hoffman et al, [24] who investigated the relationship between the cuff pressure and the height of patients. Perhaps this issue, as was stated in a study by Hamilton and Grap, [26] is due to the anatomical and physiological differences in patients, necessitating different amounts of air to achieve the target pressure of the ETT cuff. Chiming in with the results reported by Hoffman et al, [24] we also found no significant relationship between the cuff pressure and age and sex. Furthermore, in line with some previous studies, [3,6,11] our male patients outnumbered their female counterparts. Although the purpose of this study was not to determine the effect of patient movements and nursing care on the ETT cuff pressure, it can be noted that as was described in a study by Sole et al, [13] factors such as suctioning and patient movements can cause a temporary increase in the cuff pressure. In addition, such factors as the patient's body temperature, [18] the position of the head, [7] and the size of the ETT and its position, [12] which we did not evaluate in the present study, may explain the abnormalities in the cuff pressure despite its 6-hour control period. These results emphasize the significance of the regular monitoring of the cuff pressure and the variables that can influence it.

CONCLUSIONS

In most cases in the present investigation, the ETT cuff pressure exceeded the recommended normal range because it was often adjusted based on clinical judgments. This can be a reminder that the prevention of complications caused by rises or falls in the cuff pressure may necessitate pressure control at shorter intervals or continuously.

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REFERENCES

1. Aeppli N, Lindauer B, Steurer MP, Weiss M, Dullenkopf A. Endotracheal tube cuff pressure changes during manual cuff pressure control manoeuvres: An in-vitro assessment. Acta Anaesthesiologica Scandinavica. 2019 Jan; 63(1):55-60.

2. Golaghaie F, Momeni R, Jafarimanesh H, Golestanieraghi M, Golitaleb M, Rafiei F. Impact of Stylet Bend Angle on the Performance of Orotracheal Intubation by Emergency Response Nurses: A Randomized Simulation Study. Eurasian Journal of Emergency Medicine. 2018 Jun 1; 17(2):45-9.

3. Hu J, Yu L, Jiang L, Yuan W, Bian W, Yang Y, Ruan H. Developing a Guideline for Endotracheal Suctioning of Adults With Artificial Airways in the Perianesthesia Setting in China. Journal of PeriAnesthesia Nursing. 2019 Feb 1;34(1):160-8.

4. Dadure C, Sabourdin N, Veyckemans F, Babre F, Bourdaud N, Dahmani S, De Queiroz M, Devys JM, Dubois MC, Kern D, Laffargue A. Management of the child's airway under anaesthesia: The French guidelines. Anaesthesia Critical Care & Pain Medicine. 2019 Feb 23.

5. Wen Z, Wei L, Chen J, Xie A, Li M, Bian L. Is continuous better than intermittent control of tracheal cuff pressure? A meta-analysis. Nursing in critical care. 2019 Mar; 24(2):76-82.

6. mousavi S A J, niakan lahiji M, akhovatian F, moradi moghadam O, valizade hassanlouei M A. An Investigation of endotracheal Tube cuff Pressure. Daneshvar Medicine. 2009; 17 (83) :43-48 URL: http://daneshvarmed.shahed.ac.ir/article-1-39-fa.html

7. Mishra R, Singh M, Mahobia M. Maintaining optimal endotracheal tube cuff pressure with pressure gauge reduces the frequency of postoperative airway complications during endoscopic cervical spine surgery. Anaesthesia, Pain & Intensive Care. 2019 Jan 19:442-6.

8. Mishra R, Singh M, Mahobia M. Maintaining optimal endotracheal tube cuff pressure with pressure gauge reduces the frequency of postoperative airway complications during endoscopic cervical spine surgery. Anaesthesia, Pain & Intensive Care. 2019 Jan 19:442-6.

9. Chang E, Wu L, Masters J, Lu J, Zhou S, Zhao W, Sun M, Meng F, Soo CP, Zhang J, Ma D. Iatrogenic subglottic tracheal stenosis after tracheostomy and endotracheal intubation: A cohort observational study of more severity in keloid phenotype. Acta Anaesthesiologica Scandinavica. 2019 Apr 14.

10. Sousa AS, Ferrito C, Paiva JA. Application of a ventilator associated pneumonia prevention guideline and outcomes: A quasi-experimental study. Intensive and Critical Care Nursing. 2019 Apr 1;51:50-6.

11. Sole ML, Poalillo FE, Byeres JF, Ludy JE. Bacterial Growth in Secretions and on Suctioning Equipment of Orally Intubated

Patients: A Pilot Study. Am J Crit Care. 2002; 11:141-149.

12. Blot S, Rello J, Vogelaers D. What is new in the prevention of ventilator associated pneumonia? Curr Opin Pulm Med 2011;17(May (3)):155–9, http://dx.doi.org/10.1097/mcp.0b013e328344db65.

13. Sengupta P, Sessler DI, Maglinger P, Wells S, Vogt A, Durrani J, et al. Endotracheal Tube Cuff Pressure in Three Hospitals, and the Volume Required to Produce an Appropriate Cuff Pressure. BMC Anesthesiology.2004;4:8.

14. Sole ML, Penoyer DA, Su X, Jimenez E, Kalita SJ, Poalillo E, et al. Assessment of Endotracheal Cuff Pressure by Continuous Monitoring: A Pilot Study. Am J Crit Care.2009; 18: 133-143.

15. Nseir S, Brisson H, Marquette CH, Chaud P, Di Pompeo C, Diarra M, et al. Variations in Endotracheal Cuff Pressure in Intubated Critically Ill Patients: Prevalence and Risk Factors. Eur J Anaesthesiol. 2009 Mar;26(3):229-34.

16. American Thoracic Society, Infectious Diseases Society of America. Guidelines for The Management of Adults with Hospital Acquired, Ventilator-Associated, And Healthcare- Associated Pneumonia. Am J Respire Crit Care Med. 2005; 171(4):388-416.

17. Corda DM, Robards CB, Rice MJ, Morey TE, Gravenstein N, Vasilopoulos T, Brull SJ. Clinical application of limiting laryngeal mask airway cuff pressures utilizing inflating syringe intrinsic recoil. Rom J Anaesth Intensive Care. 2018 Apr;25(1):11.

18. Lizy C, Swinnen W, Labeau S, Poelaert J, Vogelaers D, Vandewoude K, Dulhunty J, Blot S. Cuff pressure of endotracheal tubes after changes in body position in critically ill patients treated with mechanical ventilation. Am J Crit Car. 2014 Jan 1;23(1): e1-8.

19. Golitaleb M, Kargar F, Aghai FG, Harorani M, Jadidi A, Abkenar HB, Haghazali M. Hyperbilirubinemia after open cardiac surgery. Iranian Heart Journal. 2017;18(2):30-5.

20. Golitaleb M, Golaghaie F, mousavi MS, Harorani M, Abkenar HB, Haghazali M, Mashayekh A. Gastrointestinal Complications After Cardiac Surgery.Iranian Heart Journal. 2019;20(2):56-61.

21. Rose L, Redl L. Survey of Cuff Management Practices in Intensive Care Units in Australia and New Zealand. Am J Crit Care. 2008; 17(5):428-435.

22. Stwart S, Secrest JA, Norwood BR, Zachary R. A Comparation of Endotracheal Tube Cuff Pressure Using Estimation Techniques and Direct Intracuff Measurement. AANA J. 2003; 71(6): 443-447.

23. Zand F, Nekooeian A, Rohani M. Endotracheal Tube Cuff Pressure Monitoring in Intensive Care Unit Iran Red Crescent Med J e.2008; 10(3):223-227.

24. Hoffman RJ, Parwani V, Hahm I. Experienced Emergency Medicine Physicians Cannot Safety Inflate or Estimate Endotracheal Tube Cuff Pressure Using Standard Technique. Am J Emerg Med.2006; 24(2): 139-143.

25. Liu J, Zhang X, Gong W, Li S, Wang F, Fu S, et al. Correlations Between Controlled Endotracheal Tube Cuff Pressure and Post Procedural Complications: A Multicenter Study. Anesth Analg. 2010 Nov;111(5): 1133-7. doi:10.1213/ANE.0b013e3181f2ecc7. Epub 2010 Aug 24.

26. Hamilton VA, Grap MJ. The Role of the Endotracheal Thbe Cuff in Micro aspiration. Heart & Lung. 2011; 41:167-172.

27. Sadeghi F, Golitaleb M, Totonchi Z, Harorani M, Azarfarin R, BakhshandeAbkenar H. Factors Influencing a Prolonged ICU Stay After Coronary Artery Bypass Graft Surgery: A Cross-sectional Study. Iranian Heart Journal.;20(4):85-91