Original Article
2022, 12(1): 14-22
DOI: 10.22038/EBCJ.2021.60071.2560

Received: 14/09/2021
Accept & ePublished: 26/12/2021

Evidence Based Care Journal
http://ebcj.mums.ac.ir
Online ISSN: 2008-370X

Effect of Body Position Change and Vital Signals on Endotracheal Tube Cuff Pressure Variations

Mahmood Hosseinzadeh Maleki[1], Mohamad Amin Younessi Heravi[2], Reza Ghasemi[3], Rasool Gharaee[4], Mohsen Yaghubi[5*]

Abstract

Background: The body position change, as a common intervention in the intensive care unit (ICU), may affect endotracheal tube cuff pressure changes.

Aim: This study investigated the effect of body position change and vital signals on endotracheal tube cuff pressure in children after bidirectional Glenn shunt surgery.

Method: This randomized controlled trial was conducted on 29 children with an oral endotracheal tube hospitalized in the ICU after Glenn shunt surgery. The endotracheal tube cuff pressure was measured at the patient's bed placed at a 30-degree angle. Other positions included right and left lateral in bed at a 30° upward angle as well as right and left lateral in bed angle at a 45° angle, respectively. The measurements were repeated every 10 min three times in different positions. Vital signals were measured in each group. The data were analyzed using SPSS 20.

Results: The results showed a significant relationship (P<0.001) between the body position change and level of cuff pressure after positioning patient's body on their right side at an angle of 30˚, left side at an angle of 30° (P=0.004), and right side at an angle of 45° (P=0.010). The results showed no significant correlation between vital signals and endotracheal tube cuff pressure, except in mean arterial pressure.

Implications for Practice: It is recommended that endotracheal tube cuff pressure in patients should be checked and corrected (if necessary), after changing the patient's body position.

Keywords: Cuff pressure, Endotracheal intubation, Vital signs

1. Associated Professor, Department of Cardiac Surgery, Imam Reza Hospital, Mashhad University of Medical Sciences, Mashhad, Iran
2. Assistant Professor, Department of Medical Physics and Radiology, School of Medicine, North Khorasan University of Medical Sciences, Bojnurd, Iran.
3. Assistant Professor, Department of Cardiology, 9-Day Hospital, Torbat Heydariyeh University of Medical Sciences, Torbat Heydariyeh, Iran
4. MSc in Emergency Nursing, Department of Emergency Medicine, Imam Reza Hospital, Mashhad University of Medical Sciences, Mashhad, Iran
5. MSc in Extra-Corporeal Technology (Perfusion), Department of Extra-Corporeal Circulation, Razavi Hospital, Imam Reza International University, Mashhad, Iran

* Corresponding author, Email: n.m.yaghubi@gmail.com

Introduction

The number of patients who needed endotracheal intubation for various causes has increased due to the increasing rate of survival in patients with critical conditions. The aim is to maintain an open airway and ensure adequate patient ventilation (1-2). It is estimated that this method has been used 13-20 million times in America (3). Although endotracheal intubation and other treatments have many benefits for patients, severe and sometimes irreversible complications may occur in case these complications are ignored. Application of the endotracheal tube has revealed its complications (2-3). The most critical complications include tracheal mucosa damage caused by excessive dilation of the tracheal tube cuff (more than 30 cmH_2O) that causes ischemia and such complications as hypoglossal and recurrent laryngeal nerve damage, erosion, cartilage softening, tracheal dilation, bleeding, infection and narrowing of the trachea (4). Among the challenges of caring for patients in intensive care units (ICU), one can refer to setting the endotracheal tube cuff pressure and the side effects of the lack of adequate cuff pressure (5). Nseir et al. showed that only 18% of patients in ICU had a standard range of endotracheal tube cuff pressure, and others had high or low cuff pressure, despite the manual control of cuff pressure (6). Moreover, a linear correlation exists between cuff volume and pressure after increasing cuff volume for insulation. On the other hand, inadequate dilation of the endotracheal tube cuff (less than 18 cmH_2O) contributes to aspiration of upper respiratory tract secretions. Therefore, it is essential that endotracheal tube cuff pressure be set in appropriate intervals with a standard range of cuff pressure (2, 4).

The changes in muscle tracheal tone, hypothermia, hyperthermia, endotracheal tube repositioning, and intubation duration can affect endotracheal tube cuff pressure. Furthermore, prolonged intubation and mechanical ventilation, wrong endotracheal tube size, wrong placement of endotracheal tubes, and hypotension can cause tracheal damages. Among the various factors mentioned, it is believed that inappropriate cuff pressure is the most critical factor in tracheal damage (7).

It should be noted that different nursing interventions can affect the endotracheal tube cuff pressure in patients (6, 8). Frequent change of the patient's positions is the most prevalent nursing action in ICU to prevent pressure ulcers and assist ventilation, according to the disease nature (9). Head and neck movement exercises (rotating, extension, and flexion) in the supine position can displace the endotracheal tube in patients. The extension and flexion of the head and neck cause the endotracheal tube to move forward and toward the rear, respectively, while the impact of head and neck rotation is unpredictable (10-14).

Overall, the literature review on endotracheal tube cuff pressure indicated that less attention has been paid to complications from pressure changes and the factors influencing it, including body position change, as a common intervention in ICU. Moreover, evidence indicated the effect of body position change on endotracheal tube cuff pressure in infants after Glenn shunt surgery due to elevated head of the bed and changes in body position. This study aimed to investigate the effect of body position change and vital signals on endotracheal tube cuff pressure variations in children after Glenn shunt surgery.

Methods

This randomized clinical trial study was conducted from November 2017 to March 2020, in Imam Reza hospital, Mashhad, Iran. The study sample included all the children hospitalized in the ICU after Glenn shunt surgery. The participants were selected through the block randomization method using a computerized randomization planner, considering the inclusion and exclusion criteria. The informed written consent was obtained from the patients' legal guardians. The sample size was determined at 26 considering means space and study hypothesis (14), and mean deviations S_1=0.59, S_2=1.86, and means μ_1=2.11 and μ_2=3.21. Considering the attrition rate, 28 patients were finally selected, and each block included 7 participants. The CONSORT diagram of the study is illustrated in Figure 1.

The inclusion criteria included patients with an oral endotracheal tube (SUPA, Tehran, Iran) connected to the mechanical ventilator (Drager, Germany), following the bidirectional Glenn shunt surgery, using the off-pump technique. All the patients were intubated with a cone-shaped cuff and had an appropriate sedation level (from -2 to 0 degree), according to Richmond Agitation-Sedation

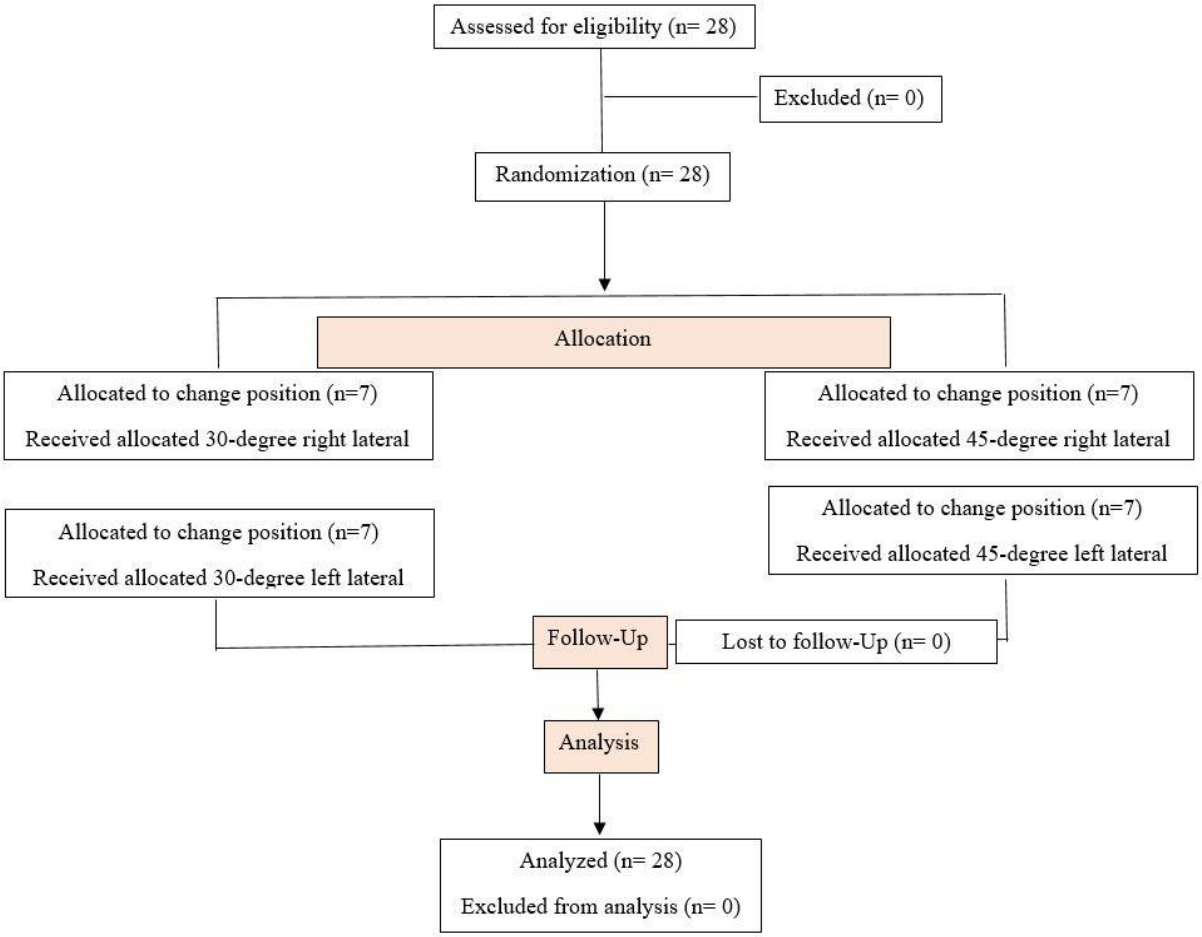

Figure 1. CONSORT diagram presenting the flow of participants in each stage of the randomized trial

Scale. An endotracheal tube was inserted in all patients by a specific cardiac anesthesiologist. The endotracheal tube size was measured through the following formula:

(Age/4+4) -0.5=endotracheal tube size (15).

The children enrolled in the study had no subglottic stenosis which makes it difficult to insert the endotracheal tube. The exclusion criteria included reluctance to continue the study (by the patient's guardian), reduced blood oxygen saturation of less than 75%, and increased endotracheal tube cuff pressure of higher than 50 cmH2O lasting for half an hour post-intervention. Other inclusion criteria included systolic blood pressure higher than 70 mmHg, central temperature between 36-37.8 °C, and age range of 4-24 months. The VBM manometer (made in Germany), based on water temperature, was used to determine patients' endotracheal tube cuff pressure. The range of the precision manometer was 0-120 cm of water. Such variables as age, gender, and endotracheal tube size were investigated in participants. Data were collected using a demographic checklist, endotracheal tube cuff pressure record, and Richmond Agitation-Sedation Scale. The validity and reliability of Richmond- Agitation Scale (RASS) have been evaluated in a similar study (16). The reliability of the endotracheal tube cuff manometer, compared to a mercury manometer, was approved several times. In the waiting room and perfect condition, the researchers introduced themselves and described the study design, objectives, and possible side effects to the patient's guardian. Subsequently, written informed consent (approved by the Ethics Committee) was taken from them.

The patients' central temperature was measured using a Timpani Thermometer (Ontario L4Z. V4, Canada). The reliability of the Timpani Thermometer, compared to that of a standard thermal skin

sensor, was approved several times. Blood pressure was checked and recorded using an arterial line in the right or left radial artery. The reliability of the arterial pressure transducer, compared to a standard automatic blood pressure monitoring, was approved several times. The placement of the endotracheal tube was verified by bilateral lung auscultation, and a portable chest X-ray was performed to accurately set the endotracheal tube placement after entering ICU. The endotracheal cuff pressure was then measured and revised if necessary. For all the patients, the base pressure of endotracheal tube cuff pressure was adjusted to 25 cmH_2O. However, the air leakage around the endotracheal tube cuff was set between 20-30 cmH_2O, as measured by the ventilator.

Patient endotracheal tube bandage was closed and fixed on 12 to 13 cm mentioned on the endotracheal tube to prevent the endotracheal tube from entering or leaving (body position change to the left and right) (17-19). The interval between the last suction and the next cuff pressure measurement was set at about half an hour due to the endotracheal tube cuff pressure removal and suction effect and considering the short-term influence on cuff pressure. The patients were placed in the base position (Cuff pressure of 25 cmH_2O, patient's bed angle of 30˚, and head placed in a neutral position) and the patient's cuff pressure was measured. Afterward, endotracheal tube cuff pressure was measured and recorded three times every 10 min. In the first position, the patient was rotated to the right, and the patient's endotracheal tube cuff pressure was measured at the end of exhalation (3). Other positions included left lateral in bed at an upward angle of 30° and right lateral with the patient's bed at an angle of 45º.

During changing positions, the location of the endotracheal tube was marked since it was not possible to stretch the endotracheal tube. If displaced, the tracheal tube was returned to the original site. The patient's endotracheal tube cuff pressure after changing position and proceeding was recorded, as mentioned previously. The bed's angle was measured according to the procedure described in the study conducted by Younessi et al. (20). The vital signals (systolic blood pressure, diastolic blood pressure, mean arterial pressure, temperature, heart rate, and SPO_2) in each position and at different times were measured and recorded as well.

The manometer was connected to the manometer endotracheal balloon to prevent and reduce the likelihood of massive air leakage from the balloon endotracheal tube cuff and reduce the cuff pressure attached to the manometer. To avoid bias, the individuals responsible for performing the intervention, controlling individual pressure cuff, and exchanging information about the illness were not among them. The researcher was responsible for changing patients' positions, and the research fellow conducted endotracheal tube cuff pressure measurements.

All appropriate patient consent forms were prepared, through which the patients' family have given their consent for the publication of patients' images and other clinical information. The patients' legal guardians were ensured about the confidentiality of the patients' names and initials; however, anonymity could not be guaranteed.

Data description was presented as frequency distribution tables, graphs, and mean±SD. Data were analyzed using repeated-measures ANOVA, Games-Howell post-hoc test, Pearson's correlation coefficient, and independent T-test. A p-value less than 0.05 ($P<0.05$) was considered statistically significant. All statistical analyses were performed using SPSS (Version 20.0, SPSS Inc., Chicago, IL, USA).

Results

The study was conducted on 28 children in the age range of 12-24 months and the mean age of 16.54±3.21 months, from whom 21 (75.0%) and 7 (25.0%) children were male and female, respectively. The endotracheal tube size was between 4 and 5.5 mm, and the internal diameter of most (51.7%) tracheal tubes used in this experiment was 5 mm. No significant relationship was observed between demographic variables, such as age ($P=0.084$) and gender ($P=0.070$), and endotracheal tube cuff pressure changes.

The results showed a significant relationship ($P<0.001$) between the body position change and level of cuff pressure after positioning the body to the right side at an angle of 30°. The level of endotracheal tube cuff pressure increased after changing the patient's position. Moreover, a significant relationship was observed between the level of endotracheal tube cuff pressure and the body position change to the left side at an angle of 30° ($P=0.004$) and to the right side at an angle of 45° ($P=0.001$)

Table 1. Impact of position changes on the patient's endotracheal tube cuff pressure

Body position		Mean±SD (difference between post-intervention and basic position)	P-value
Basic position	Intervention 1	5.97±0.522	0.001
	Intervention 2	7.48±0.925	0.004
	Intervention 3	7.59±0.827	0.012
	Intervention 4	8.59±0.790	0.075

Intervention 1: 30-degree bed angle and body position shift to the right; Intervention 2: 30-degree bed angle and body position shift to the left; Intervention 3: 45-degree bed angle and body position shift to the right; Intervention 4: 45-degree bed angle and body position shift to the left.

since the level of endotracheal tube cuff pressure increased by changing positions in these states. Variations of the endotracheal tube cuff pressure level after patients' position changes are summarized in Table 1.

No relationship was observed between endotracheal tube cuff pressure in time trend and position changes. Results showed that the endotracheal tube cuff pressure did not significantly change after changes in the patient's position (Figure 2).

This study showed no significant correlation between vital signals and endotracheal tube cuff pressure, except in a few cases. The negative correlation between endotracheal tube cuff pressure and mean arterial pressure (MAP) was observed only 10 min after changing the patient's position to left lateral with a 45° bed angle (P=0.027, r=-0.32). The endotracheal tube cuff pressure was decreased following the enhancement of the MAP in this position. Moreover, the endotracheal tube cuff pressure was elevated in parallel with MAP (P=0.041, r=0.32) 10 min after repositioning to the left lateral with a bed angle of 30°.

There are no relationships between the patients' SPO2 (P=0.086) and body temperature (P=0.088) with variations in endotracheal tube cuff pressure following position changes. Furthermore, there was no correlation between endotracheal tube cuff pressure changes and systolic/ diastolic pressure in the time trend presented in Figure 3.

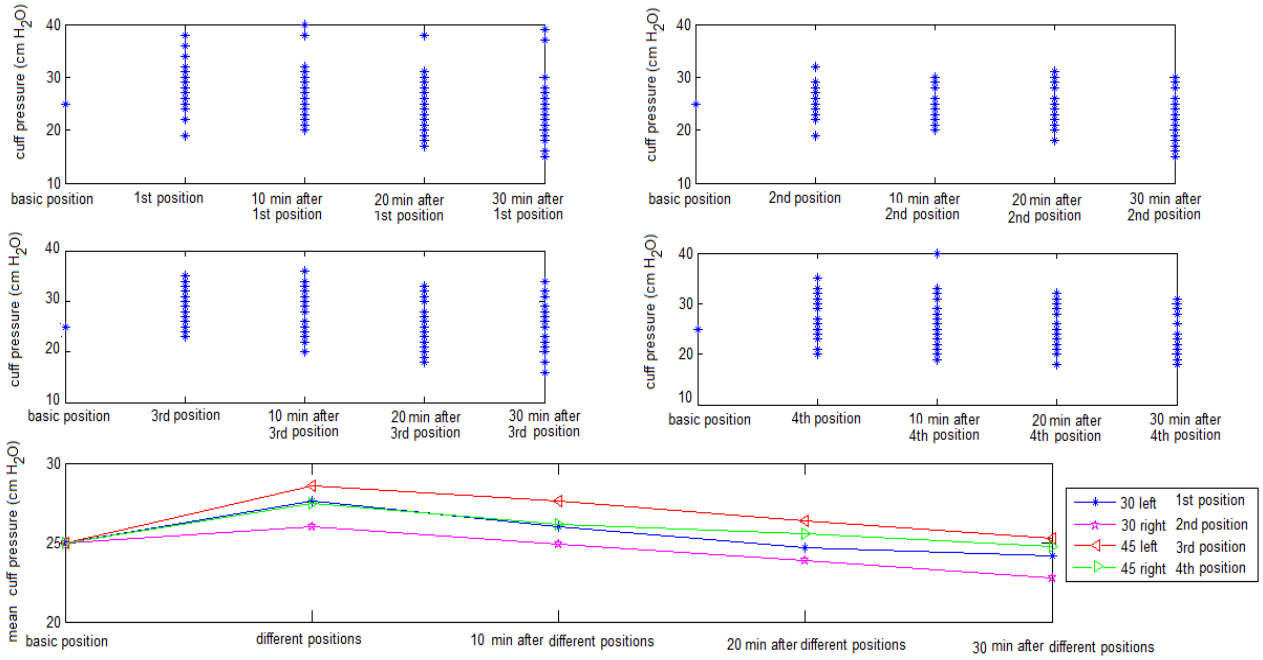

Figure 2. Relationship between endotracheal tube cuff pressure in time trend and following position changes. (1st position: 30-degree bed angle and body position shift to the right, top right; 2nd position: 30-degree bed angle and body position shift to the left, downright; 3rd position: 45-degree bed angle and body position shift to the right, down left; 4th position: 45-degree bed angle and body position shift to the left, top left)

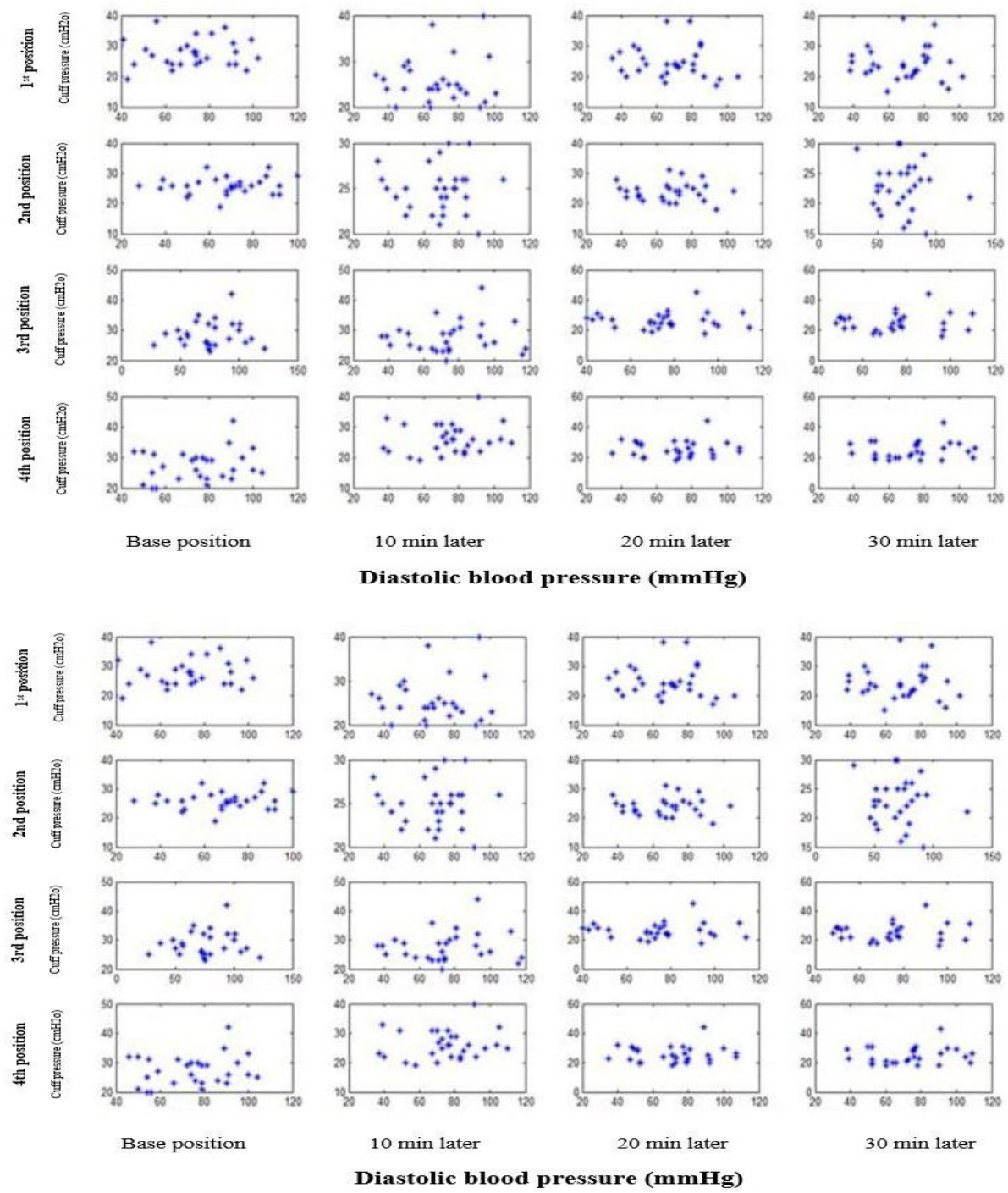

Figure 3. Relationship between endotracheal tube cuff pressure and systolic/ diastolic blood pressure in patients' time trends

Discussion

In this study, the nursing procedure's impact and change in the body position were assessed by endotracheal tube cuff pressure. The results of this study confirmed the hypothesis that changes in body position could result in a significant increase in the patient's endotracheal tube cuff pressure. Accordingly, it was observed that changing body positions resulted in extensive variations in endotracheal tube cuff pressure (21).

The most important finding of this study was the fact that changes in body position could have a significant impact on endotracheal tube cuff pressure. This finding was consistent with the results of other studies (7, 8, 11, 14). The results of another study (11) showed a statistically significant increase

in the endotracheal tube cuff pressure due to changes in the patient's position, particularly in a head-down position. The discrepancies between the results obtained in this study with those obtained in the previously mentioned studies can be due to increased airway pressure following increased intra-abdominal pressure caused by body repositioning (22-23).

Unique features of this study include keeping the patient's head aligned with the body's natural axis during position changes and measuring the endotracheal tube cuff pressure. Failure to keep the head in line with the body's axis and anatomical differences can cause changes in the endotracheal tube cuff pressure, attributed to increased cervical muscle strain (24). The continuous measurement of endotracheal tube cuff pressure during body repositioning was another unique novelty in the present study, compared to similar studies. Previous studies have reported significant changes in endotracheal tube cuff pressure in ICU patients (7, 25). However, in those studies, endotracheal tube cuff pressure was assessed manually and periodically, which resulted in decreased endotracheal tube cuff pressure (22). In this study, fixing the endotracheal tube in the middle of the patient's mouth and checking its position after each change in body position neutralized the impact of tube displacement on the cuff pressure. In their study, Valencia et al. (25) reported the impact of head and body position and angle on endotracheal tube cuff pressure. Therefore, taking this variable into account, the patient s' head was kept aligned with their body in the present study. Although pressure control provides essential and valuable information about cuff pressure, low or high cuff pressure may not be measured accurately (16).

The absolute novelty of this study was the evaluation of the impact of vital signals in different positions on the endotracheal tube cuff pressure variations. In the study performed by Godoy et al. (7), such thermal conditions as hypothermia and hyperthermia, and hypertensive states resulted in changes in the endotracheal tube cuff pressure. Therefore, this study was the first comprehensive report of the impact of some vital signals on the endotracheal tube cuff pressure.

The application of a novel approach in this study revealed the effect of vital signal changes on the endotracheal tube cuff pressure in critically ill babies with an endotracheal tube after Glenn shunt surgery. Although the findings of the study hypothesis were not expected, they showed that the safety of sufficient ventilation (without mechanical ventilation complications) was associated with unstable hemodynamic conditions (e.g., hypertensive or febrile conditions) in patients under mechanical ventilation.

Among the limitations of this study, one can refer to the ignorance of idiosyncratic differences in the patients regarding the anatomical status of the neck (tracheal) and the tone of muscles around the tracheal. Due to the application of an analog manometer, errors might have occurred in reading the numbers, which could affect the results. Continuous measurement of endotracheal tube cuff pressure is a detailed feasible practice that has been previously performed under the researchers' supervision in a completely safe manner. The endotracheal tube cuff pressure is very different in different patients. More research is needed to identify factors, activities, and personal characteristics that can affect endotracheal tube cuff pressure.

Implications for Practice

Based on the obtained results in this study, it is recommended that endotracheal tube cuff pressure in children should be checked and corrected (if necessary) after cardiac surgeries. This is true especially in patients whose positions need to be changed or maintained in upward angles of the bed, including those undergoing Glenn shunt surgery.

Acknowledgments

The authors would like to express their gratitude to all the patients' families for their cooperation in this study. The study protocol was approved by the Ethics Committee of Sabzevar University of Medical Sciences, Sabzevar, Iran (IR.MEDSAB.REC.1394.37). This study was registered on the Iranian Registry of Clinical Trials website (IRCT2014051817735N1).

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of the present study.

References

1. Ghanei Motlagh F, Ghasemi R, Nazari S, Yaghubi M. Successful outcome of pregnancy in a 31 years old woman with uncorrected Tetralogy of Fallot; A case report. J North Khorasan Univ med sci. 2017;8(3):541-7.
2. Saleh Moghaddam AR, Malekzade J, Mesbahi Z, Esmaeli H. Relationship between temperature and cuff pressure in mechanically ventilated patients with endotracheal tube. Horizon Med Sci. 2013;19(2):105-9.
3. Soltani G, Abbasi Tashnizi M, Moeinipour AA, Ganjifard M, Esfahanizadeh J, Sepehri Shamloo A, et al. Comparing the effect of preoperative administration of methylprednisolone and its administration before and during surgery on the clinical outcome in pediatric open heart surgeries. Iran Red Crescent Med J. 2013;15(6):483-7.
4. Alipour N, Toulabi T, Manouchehrian N, Anbari K, Rahimi Bashar F. A Comparison of the effect of open and closed endotracheal suctioning on hemodynamic status of patients in the ICU. Evidence Based Care, 2014; 3(4): 65-74.
5. Sabermoghaddam M, Zoka A. Effect of Positioning on the Pressure of Endotracheal Tube Cuff Filled with Air versus Saline: A Double-blind Randomized Clinical Trial. Evid Based Care J. 2020;9(4):7-14.
6. Nseir S, Duguet A, Copin M-C, De Jonckheere J, Zhang M, Similowski T, et al. Continuous control of endotracheal cuff pressure and tracheal wall damage: a randomized controlled animal study. Crit Care. 2007;11(5):1-8.
7. Godoy ACFd, Vieira RJ, Capitani EMD. Endotracheal tube cuff pressure alteration after changes in position in patients under mechanical ventilation. Endotracheal tube cuff pressure alteration after changes in position in patients under mechanical ventilation. J Bras Pneumol. 2008;34(5):294-7.
8. 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(2):133-43.
9. Younessi Heravi MA, Gazerani A, Amini Z, Salimi P, Falahi Z, Yaghubi M. Pain estimation after coronary angiography based on vital signs by using artificial neural networks. Anaesth. Pain Intensive Care. 2021;25(1): 29-34.
10. Minonishi T, Kinoshita H, Hirayama M, Kawahito S, Azma T, Hatakeyama N, et al. The supine-to-prone position change induces modification of endotracheal tube cuff pressure accompanied by tube displacement. J Clin Anesth. 2013;25(1):28-31.
11. Wu C-Y, Yeh Y-C, Wang M-C, Lai C-H, Fan S-Z. Changes in endotracheal tube cuff pressure during laparoscopic surgery in head-up or head-down position. BMC Anesthesiol. 2014;14(1):1-6.
12. Kim D, Jeon B, Son J-S, Lee J-R, Ko S, Lim H, et al. The changes of endotracheal tube cuff pressure by the position changes from supine to prone and the flexion and extension of head. Korean J Anesthesiol. 2015;68(1):27-31.
13. Safavi M. Influence of head flexion after endotracheal intubation on intraocular pressure and cardio-respiratory response in patients undergoing cataract surgery. Ghana Med J. 2008;42(3):105-9.
14. Lizy C, Swinnen W, Labeau S, Poelaert J, Vogelaers D, Vandewoude K, et al. Cuff pressure of endotracheal tubes after changes in body position in critically ill patients treated with mechanical ventilation. Am J Crit Care. 2014;23(1):e1-e8.
15. Park S, Ahn J, Yoon SU, Choo KS, Kim HJ, Chung M, Kim HY, et al. Prediction of endotracheal tube size using a printed three-dimensional airway model in pediatric patients with congenital heart disease: a prospective, single-center, single-group study. Korean J Anesthesiol. 2021;74(4):333-341.
16. Nseir S, Brisson H, Marquette C-H, 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;26(3):229-34.
17. Estaji Z, Rad M, Rakhshani M, miri M. The effect of body position changes on the endotracheal tube cuff pressure of patients hospitalized in intensive care unit. J Sabzevar Univ Med Sci. 2018; 25(5):723-729.
18. Tadrisi S, Madani S, Farmand F, Ebadi A, Karimi Zarchi AA, Saghafinia M, et al. Richmond agitation-sedation scale validity and reliability in intensive care unit adult patients; Persian version.

2009;2(1): 15-21.
19. Sanaie S, Rahmani F, Chokhachian S, Mahmoodpoor A, Rahimi Panahi J, Mehdizadeh Esfanjani R, et al. Comparison of tracheal tube cuff pressure with two technique: fixed volume , minimal leak test techniques. J Cardiovasc Thorac Res. 2019;11(1):48-52.
20. Heravi MAY, Yaghubi M, Joharinia S. Effect of change in patient's bed angles on pain after coronary angiography according to vital signals. Res Med Sci. 2015;20(10):937-43.
21. Hoffman RJ, Parwani V, Hahn I-H. Experienced emergency medicine physicians cannot safely inflate or estimate endotracheal tube cuff pressure using standard techniques. Am J Emerg Med. 2006;24(2):139-43.
22. Komasawa N, Mihara R, Imagawa K, Hattori K, Minami T. Comparison of Pressure Changes by Head and Neck Position between High-Volume Low-Pressure and Taper-Shaped Cuffs: A Randomized Controlled Trial. BioMed Res Int. 2015;2015:1-6.
23. Asai S, Motoyama A, Matsumoto Y, Konami H, Imanaka H, Nishimura M, et al. Decrease in cuff pressure during the measurement procedure: an experimental study. J Intensive Care. 2014;2(1):1-5.
24. Hamilton VA, Grap MJ. The role of the endotracheal tube cuff in microaspiration. Heart Lung. 2012;41(2):167-72.
25. Valencia M, Ferrer M, Farre R, Navajas D, Badia JR, Nicolas JM, et al. Automatic control of tracheal tube cuff pressure in ventilated patients in semirecumbent position: a randomized trial. Crit Care Med. 2007;35(6):1543-9.