

Comparison of the Effect of Open and Closed Endotracheal Suctioning Methods on Pain and Agitation in Medical ICU Patients: A Clinical Trial

Raziyeh Dastdadeh,¹ Abbas Ebadi,^{2,*} and Amir Vahedian-Azimi³

¹Student of Master Degree in Nursing, Tehran Medical Branch, Islamic Azad University, Tehran, Iran

²Behavioral Sciences Research Center, Nursing Faculty, Baqiyatallah University of Medical Sciences, Tehran, Iran

³Nursing Faculty, Baqiyatallah University of Medical Sciences, Tehran, Iran

*Corresponding author: Abbas Ebadi, Behavioral Sciences Research Center, Nursing Faculty, Baqiyatallah University of Medical Sciences, Tehran, Iran. Tel: +98-9122149019, Fax: +98-2126127237, E-mail: ebadi1347@yahoo.comebadi1347@bmsu.ac.ir

Received 2016 April 12; Revised 2016 June 05; Accepted 2016 June 23.

Abstract

Background: Endotracheal suctioning is a necessary procedure practiced by nurses in intensive care units to remove lung secretions. This procedure leads to higher oxygenation levels and reduced breathing difficulties. It also prevents atelectasis, pulmonary infections, and the accumulation of secretions.

Objectives: The present study aims to compare the effectiveness of open and closed endotracheal suction tube systems on pain and agitation in patients under mechanical ventilation.

Methods: A randomized controlled clinical trial was conducted in the general intensive care units of Khatam ol-Anbia hospital and Sina hospital, Tehran, Iran, in 2015. In total, 60 patients who were qualified to be included in the study were randomly assigned to either the intervention group or the control group. When necessary, suction was carried out for each patient using the standard technique. The patients' level of pain and agitation was measured in both groups at five stages (before, during, immediately after, 5 minutes after, and 15 minutes after the intervention) using the behavioral pain scale and the Richmond agitation sedation scale.

Results: Significant statistical differences in the pain and agitation at different times within each of the two groups were observed for both open and closed suction ($P > 0.001$). However, these changes at different times between the two groups was not significant ($P < 0.05$).

Conclusions: Although statistical differences were observed in the levels of pain and agitation in the two groups, the type of suction system did not have any effect on the level of pain and agitation of patients under mechanical ventilation. The researchers recommend that other studies with larger sample sizes should be carried out.

Keywords: Endotracheal Suctioning, Open Suctioning, Closed Suctioning, Pain, Agitation, Mechanical Ventilation

1. Background

Endotracheal suctioning is a common method frequently used by nurses in intensive care units (ICUs) to maintain gas exchange, adequate oxygenation, and alveolar ventilation in patients under mechanical ventilation (1). Tracheal tube suctioning is a stressful and uncomfortable procedure and may cause complications such as vagal stimulation, increased respiratory rate, atelectasis, hypoxia, increased intracranial pressure, damage to the lining of the trachea, cardiac dysrhythmia, bleeding, and an increased risk of hospital-acquired infections. These physiological complications can also affect the central nervous system, leading to manifestations such as agitation, pain, hallucinations, aggression, delusions, anxiety, and the severity of the disease (2-5). Thus, one important goal of caring for patients undergoing mechanical ventilation is to prevent the above-mentioned complications by keep-

ing the air passage open and providing the highest amount of gas exchange (6).

The two standard and well-known methods for suctioning lung secretions are the open suction system (OSS) and the closed suction system (CSS). The OSS works by disconnecting the ventilator circuit and inserting a catheter. In CSS, suction is done using a catheter in an enclosed sheath attached to the inside of the trachea without disconnecting the ventilator circuit (7-9).

Different studies have compared the two systems with regard to physiological disorders, oxygenation, and ventilation changes and have succeeded in demonstrating the advantages of one endotracheal suctioning method over the other. Open suction is reportedly associated with inadequate arterial saturation, inability to maintain a positive end expiratory pressure (PEEP), and increased heart rate, blood pressure, and cardiac arrhythmias. Furthermore,

OSS exposes the personnel to infectious discharge from patients. It also exposes patients' artificial air passages to microbial contamination. Furthermore, in some studies, CSS has demonstrated fewer physiological complications than has OSS (7, 10, 11).

Suctioning is accompanied by pain, fear, and sensations of suffocation commonly associated with patients' loss of breath (3, 12). According to published research, most adult patients in ICUs experience pain and agitation resulting in physical and psychological complications that may last many years after discharge from the hospital (13). These patients' discomfort is often accompanied by signs and symptoms of agitation in the form of behavioral, physical, and psychological changes (14, 15). Mechanically ventilated patients are unable to express their feelings orally, and these communication difficulties lead to chaotic and disturbing situations for patients hospitalized in ICUs such as desperation and fear of being excluded from treatment decisions (16, 17).

The abundance of noise, light, and other stimuli in ICU environments may also lead to more discomfort and agitation in patients. Agitation is an observable sign that may occur alone or together with severe anxiety, delusions, and impaired brain function (18, 19).

Recent guidelines on the management of pain, agitation, and delirium in adult patients recommend a systemic and rigorous evaluation of pain in critically ill patients, particularly because pain is consistently undertreated in adult patients. The goals of control and management of patients' pain, agitation, and delirium should constantly be focused on patients' comfort and safety to mitigate short-term and long-term problems associated with excessive or inadequate treatment (2, 20-22).

Considering the high level of mental-emotional turmoil experienced by mechanically ventilated patients and the importance of such patients' comfort in achieving the desired treatment outcomes, assessing their psychological status and meeting their mental-emotional needs is of great significance. The nurse, as the person with the most important role in suctioning the patient, should be able to manage the suctioning process so that the patient's pain and agitation is minimized. Pain and agitation should not be ignored or treated with indifference (2, 15, 23).

2. Objectives

This study was conducted with the aim of comparing the effect of open and closed endotracheal suctioning on mechanically ventilated patients' levels of pain and agitation.

3. Patients and Methods

3.1. Study Design

The study was a single-blind randomized controlled clinical trial conducted in Iran.

3.2. Samples and Setting

The study was conducted in the general intensive care unit (GICU) of Khatam-ol-Anbia hospital and Sina hospital in Tehran, Iran from, spring 2015 to autumn 2015. The criteria for entering the study included the following: obtaining written informed consent from the patient's family; over 18 years of age; under mechanical ventilation and requiring endotracheal suctioning; consciousness level with a Glasgow coma score of 7 or higher; vital signs within normal limits; no high-dose sedatives or tranquilizers (deep sedation) during the previous six hours; no severe facial trauma; normal hearing and speaking ability (according to medical records and statements of the patient's family); no neurological damage affecting breathing (such as quadriplegia); no record of mental illness or severe neurological problems; and no neuromuscular diseases.

Exclusion criteria consisted of the following: tracheal extubation; need for repeated suctioning or suctioning at intervals shorter than 20 minutes; reduced level of consciousness during suctioning; dysrhythmia; reduced SpO₂ level by more than 10% during suctioning; and need for tranquilizers and painkillers in excess of the common treatment protocol.

For sampling, we used the random allocation block method. All patients who met the inclusion criteria were recruited. The sample size was calculated using Altman's nomogram. By considering a confidence interval of 95% and a power of 80%, a sample size of 30 patients was determined for each group.

3.3. Ethical Considerations

The present study was registered on irct.ir with identifying code IRCT201508268650N6 and was registered at the Islamic Azad University ethics committee medical sciences branch of Tehran, Iran (ethical code: IR.IAU.TMU.REC.1394.23). The ethical considerations were related to confidentiality and anonymity during the study period and in publication of the study. The purpose of the study was explained to all patients' families, and informed consent was obtained from the family of each patient who agreed to be included in the study.

3.4. Intervention

Demographic questionnaires were filled out by the researcher based on the patient's file and statements from the patient's family. If the criteria necessitating suctioning were present, the suctioning was done for the patient using the standard technique and the sterile method. The sizes of the open and the closed suction catheters were standardized (the suction catheter has an external diameter less than 50% of the size of the endotracheal tube inner diameter). Vital signs were recorded by a monitor. All patients received 100% oxygen for 1 min before suctioning. Immediately after that, endotracheal suctioning by ICU nurses was conducted on a rotating basis for 10 to 15 s with a maximum pressure of 120 mmHg. Following that, the patient was again hyper-oxygenated with 100% oxygen for 1 min, and hemodynamic variables were recorded at five temporal stages (before, during, and immediately after, 5 minutes after, and 15 minutes after the suctioning) for both groups with the monitoring device. The pain and agitation of the two groups were measured using the Richmond agitation sedation scale at the five temporal stages.

3.5. Data Collection

The data collection tool consisted of four parts: the demographic information form, quantitative demographic variables (age and remaining at ICU), qualitative demographic variables (gender, marital status, type of suction, history of intubation), and physiological parameters (heart rate, systolic blood pressure, diastolic blood pressure, mean arterial pressure, and arterial blood oxygen saturation). They were measured using a monitoring device with the trademark "SAADAT". The devices were assessed and calibrated by servicing companies according to the manufacturers' manuals.

Patients' level of pain was recorded and measured using the pain behavior scale designed by Payen et al. (24), which focuses mainly on behavioral indicators of pain (20, 24). The level of agitation was recorded and measured by the Richmond agitation sedation scale designed by Sessler et al. (25) at the five previously mentioned temporal intervals.

3.6. Data Analysis

The data were analyzed using the software SPSS, version 22, and the chi-squared test, t-test, Mann-Whitney test, and analysis of variation (ANOVA) with repeated measures statistical tests. The P value significance level was set at less than 0.05.

4. Results

In this study, 60 patients under mechanical ventilation were evaluated. According to the results of the independent t-test and chi-squared test, there were no significant differences between the intervention group and the control group in terms of demographic characteristics (Table 1).

Table 1. Summary Statistics and the Results of the Tests for Comparing Groups for Qualitative Variables

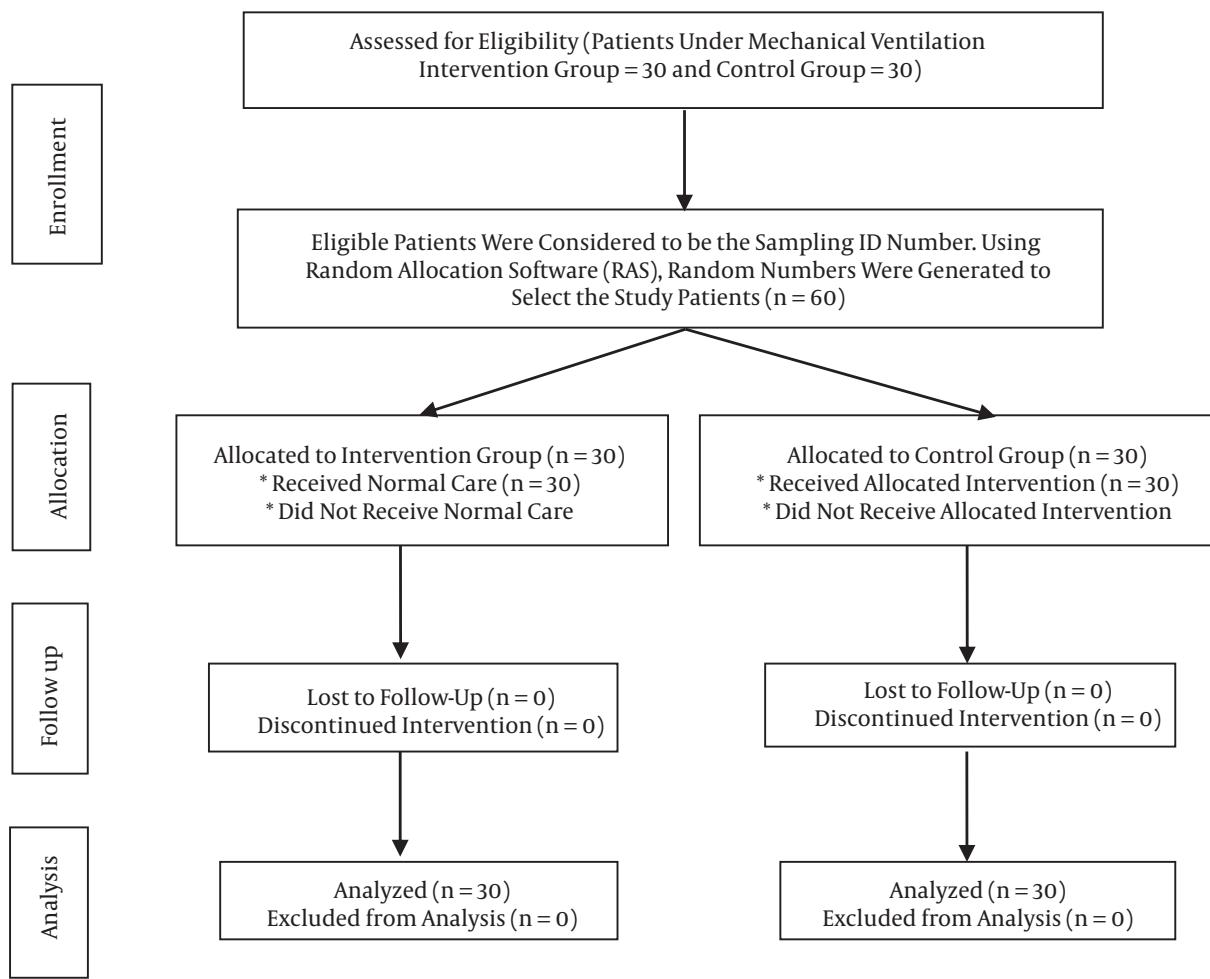
Characteristic	OSS	CSS	P Value
Age, y	18 (65)	20 (66)	0.756 ^a
Sex (male)	19 (64)	16 (54)	-
History of ventilation	8 (26)	8 (26)	0.999 ^a
Length of ICU stay	9 (10)	15 (19)	
Smoking	9 (30)	11 (36.3)	

^aBased on chi-squared test.

The results demonstrated that the measurement at different temporal stages of the heart rate, systolic blood pressure and diastolic blood pressure variables had a significant difference between the two groups of open suctioning and closed suctioning over time. However, these variables did not show a significant difference between the two groups at all stages, and the pulse rate variable demonstrated a significant difference inside the closed suction group. Also, the time required for heart rate and mean arterial pressure to return to their baseline (initial state) was shorter for CSS. Physiological stability was also better in the CSS group (Table 2).

Table 3 shows the pain behavior scale in the three areas of facial expression, upper limbs and compatibility with the ventilator for the open and closed suctioning groups. The Mann-Whitney U test did not demonstrate any statistically significant difference between facial expression, upper limbs, and compatibility with the ventilator at the three times after the suctioning in the two groups ($P > 0.05$). The ANOVA test with repeated measures showed a significant difference inside both groups in the three areas of facial expression, upper limbs, and compatibility with the ventilator ($P < 0.001$). However, this test did not demonstrate any significant difference between the open and closed suctioning groups in the three areas of facial expression, upper limbs, and compatibility with the ventilator ($P > 0.05$) (Table 3).

After comparing the scores obtained using the Richmond agitation sedation scale, it became evident that the mean agitation of patients during suctioning is lower in the intervention group compared to that in the control

**Figure 1.** Flow Chart of Sampling Process**Table 2.** Mean Values of Heart Rate, Arterial Blood Pressure, MAP, and SpO₂ in the Patients Who Underwent Endotracheal Suction with the Open and Closed Suction Systems (n = 60)^a

Variable	OSS					CSS					P
	Before	During the Suction	Immediately After Suctioning	Post-Suctioning 5th Minute	Post-Suctioning 15th Minute	Before	During the Suction	Immediately After Suctioning	Post-Suctioning 5th Minute	Post-Suctioning 15th Minute	
HR (min)	83.07 (21.00)	90.00 (19.00)	93.00 (17.00)	87.03 (19.04)	88.00 (18.00)	80.00 (21.00)	92.00 (16.00)	94.00 (17.00)	85.07 (17.00)	85.00 (17.00)	P = 0.829; F = 0.047
BP systolic (mmHg)	133.00 (22.0)	-	144.07 (27.0)	134.00 (25.0)	127.00 (22.0)	124.00 (20.0)	-	131.00 (25.0)	127.00 (19.00)	123.00 (20.00)	P < 0.630; F = 0.235
BP diastolic (mmHg)	75.00 (13.0)	-	81.07 (20.0)	76.00 (18.0)	75.03 (17.0)	72.00 (17.0)	-	74.00 (18.0)	71.00 (14.0)	70.00 (14.0)	P = 0.739; F = 0.112
MAP (mmHg)	94.00 (15.0)	-	102.00 (21.0)	95.00 (19.0)	92.00 (17.0)	89.00 (17.0)	-	93.00 (20.07)	90.00 (15.0)	87.00 (15.0)	P = 0.635; F = 0.228
SpO ₂ (%)	97.00 (5.0)	96.00 (3.0)	96.00 (4.0)	97.00 (2.0)	97.00 (3.0)	98.00 (1.0)	97.03 (2.0)	96.00 (3.0)	97.00 (2.0)	97.00 (2.0)	P = 0.619; F = 0.250

^aData are presented as mean (SD).

group. This was not a meaningful finding. Also, after conducting a part-by-part control of different measurement

times between the two groups, it became evident that the most agitation occurs during the suctioning, while the pa-

Table 3. Behavioral Pain Scale (BPS)^a

Item	Measurement Time	Group Opened suctioning				Group Closed Suctioning				Mann-Whitney U Test	ANOVA with Repeated Sizes		
		Calm	Scowl	Eyes Closed	Grimace	Calm	Scowl	Eyes Closed	Grimace		Group Open	Group Closed	Intergroup
Facial expression	Before	25 (83)	5 (16)	-	-	26 (86)	4 (13)	-	-	0.720	P < 0.001; F = 104.530	P < 0.001; F = 78.812	P = 0.252; F = 1.326
	During the suction	-	18 (60)	12 (40)	-	-	14 (46)	16 (53)	-	0.305			
	Immediately after suctioning	15 (50)	15 (50)	-	-	12 (40)	17 (56)	1 (3)	-	0.372			
	Post-suctioning 5th minute	29 (96)	1 (3)	-	-	28 (93)	1 (3)	1 (3)	-	0.544			
	Post-suctioning 15th minute	30 (100)	-	-	-	28 (93)	1 (3)	1 (3)	-	0.154			
Upper limb movements	Description	No moving	Bent limbs	Gathered fingers	Contraction	No moving	Bent limbs	Gathered fingers	Contraction		P < 0.001; F = 37.395	P < 0.001; F = 54.233	P = 0.107; F = 2.688
	Before	15 (50)	14 (46)	1 (3)	-	11 (36)	18 (60)	1 (3)	-	0.328			
	During the suction	1 (3)	18 (60)	10 (33)	1 (3)	1 (3)	12 (40)	13 (43)	4 (13)	1.000			
	Immediately after suctioning	12 (40)	17 (56)	1 (3)	-	8 (26)	19 (63)	3 (10)	-	0.194			
	Post-suctioning 5th minute	17 (56)	13 (43)	-	-	12 (40)	17 (56)	1 (3)	-	0.168			
	Post-suctioning 15th minute	19 (63)	11 (36)	-	-	14 (46)	15 (50)	1 (3)	-	0.170			
Compatible with ventilator	Description	Tolerate	Cough	Fighting	In-tolerance	Tolerate	Cough	Fighting	In tolerance		P < 0.001; F = 57.225	P < 0.001; F = 44.157	P = 0.606; F = 0.268
	Before	29 (96)	1 (3)	-	-	28 (93)	1 (3)	1 (3)	-	0.542			
	During the suction	7 (23)	16 (53)	7 (23)	-	7 (23)	15 (50)	8 (26)	-	0.852			
	Immediately after suctioning	30 (100)	-	-	-	100 (30)	-	-	-	1.000			
	Post-suctioning 5th minute	30 (100)	-	-	-	100 (30)	-	-	-	1.000			
	Post-suctioning 15th minute	30 (100)	-	-	-	100 (30)	-	-	-	1.000			

^aData are presented as No. (%).

tient becomes calm again in the period after the intervention ([Table 4](#)).

5. Discussion

The findings of this study show that both open and closed endotracheal suctioning lead to an increase in pain and agitation levels in mechanically ventilated patients. Both systems are equal in terms of the severity of pain and agitation. CSS may offer benefits for mechanically ventilated patients based on its innovative characteristics, such as being suctioned by a single nurse (with regard to

sterility conditions), reducing the length of the suctioning procedure, reducing the function of the remaining capacity in patients who need end-expiratory positive airway pressure, reducing hemodynamic compromise during suction, reducing leakage of particulate matter, preventing leaking of mucus into space, and reducing the risk of transmission to other patients and nurses. Furthermore, the patient is not detached from the ventilator and ventilation continues during the suctioning. The patient is also calmer and more willing to cooperate ([8](#)). CSS has been suggested for use in patients suffering from acute lung injuries or acute respiratory distress syndrome because such

Table 4. Richmond Agitation Sedation Scale (RASS)^a

Group	Term	Before	During the Suction	Immediately After Suctioning	Post-Suctioning 5th Minute	Post-Suctioning 15th Minute
Group open suctioning	Combative	-	-	-	-	-
	Very agitated	-	-	-	-	-
	Agitated	-	-	-	-	-
	Restless	2 (6)	12 (40)	2 (6)	2 (6)	2 (6)
	Alert and calm	13 (43)	3 (10)	13 (43)	13 (43)	13 (43)
	Drowsy	8 (26)	10 (33)	8 (26)	8 (26)	8 (26)
	Light sedation	3 (10)	1 (3)	3 (10)	3 (10)	3 (10)
	Moderate sedation	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)
	Deep sedation	3 (10)	3 (10)	3 (10)	3 (10)	3 (10)
	Unarousable	-	-	-	-	-
Group closed suctioning	Combative	-	-	-	-	-
	Very agitated	-	1 (3)	-	-	-
	Agitated	-	2 (6)	1 (3)	-	-
	Restless	3 (10)	15 (50)	6 (20)	5 (16)	4 (13)
	Alert and calm	14 (46)	2 (6)	10 (33)	12 (40)	13 (43)
	Drowsy	8 (26)	6 (20)	8 (26)	8 (26)	8 (26)
	Light sedation	4 (13)	4 (13)	4 (13)	4 (13)	4 (13)
	Moderate sedation	1 (3)	-	1 (3)	1 (3)	1 (3)
	Deep sedation	-	-	-	-	-
	Unarousable	-	-	-	-	-
Mann-Whitney U test		0.419	0.082	0.204	0.302	0.357
Group open				P < 0.001; F = 19.333		
Group closed				P < 0.001; F = 22.255		
Intergroup				P < 0.126; F = 2.415		

^aData are presented as No. (%).

patients' alveoli are more vulnerable (26).

The results reported by Mohammadpour et al. showed no significant difference in the amount pain between the open and closed suction methods (27).

In a study by Acikgoz et al. (28), the pain score obtained in infants with an N-PASS scale during OS was slightly higher compared to that obtained during CS.

Jongerden et al. demonstrated in their study that the mean arterial blood pressure, heart rate, and blood oxygen saturation changed immediately after tracheal suctioning and reached baseline 5 minutes post-suctioning. Changes in heart beat and mean arterial blood pressure were significant after CS and OS, whereas for SpO₂, better amounts were observed in the third and fifth minutes after open suctioning (29).

On the other hand, numerous studies report that, re-

duced costs, and improved care and quality of care. It is well documented that the most important advantage of CSS is the eradication of any weak point due to the detachment of the mechanical ventilation device from the patient. Still, there is little information about the effect of CSS on hemodynamic parameters (30). The results of a study by Evans et al. demonstrated that CS is done more often during the day and that nurses spend less time carrying out CS compared to OS. The CS procedure requires less time and fewer nurses than OS. It also causes fewer physiological complications in patients (7). The results of another study by Corley et al. showed that end-expiratory lung volume improved more slowly with CS compared to OS at all time points. Although CS reduced the lung volume lost during suction, there is less recovery of volume after the suctioning. Thus, the use of CS cannot be advised to protect lung

volumes after suctioning (26).

5.1. Conclusion

Overall, according to the findings of this study, changes in the level of pain and agitation were observed over time in the two groups receiving open and closed suctioning, but the type of suctioning system used had no effect on the level of pain and agitation in mechanically ventilated patients. No difference was observed between the two suctioning methods in terms of the level of pain and agitation in the present study. Nonetheless, with regard to studies on the control of these two methods with other clinical variables such as physiological disorders, oxygenation, and ventilation changes, and considering the advantages of CS, the researchers suggest that other studies should be done with larger sample sizes.

Acknowledgments

This paper was extracted from the author's MSc thesis at the nursing faculty of the Islamic Azad University, Tehran Medical Branch, Iran. We are also grateful to all participants in the study and Khatam ol-Anbia hospital and Sina hospital for their support.

Footnotes

Authors' Contribution: Conception and design: Raziye Dastdadeh and Abbas Ebadi; analysis and interpretation of the data: Amir Vahedian-Azimi and Abbas Ebadi; data collection: Raziye Dastdadeh; writing the article: Raziye Dastdadeh and Abbas Ebadi; critical revision of the article and final approval of the article: All authors worked equally on the manuscript.

Financial Disclosure: There is no conflict of interest.

Funding Support: There is no support for the present study.

References

1. Oh J, Sohn JH, Shin CS, Na SH, Yoon HJ, Kim JJ, et al. Mutual relationship between anxiety and pain in the intensive care unit and its effect on medications. *J Crit Care.* 2015;30(5):1043-8. doi: 10.1016/j.jcrc.2015.05.025. [PubMed: 26116140].
2. Barr J, Kishman CPJ, Jaeschke R. The methodological approach used to develop the 2013 Pain, Agitation, and Delirium Clinical Practice Guidelines for adult ICU patients. *Crit Care Med.* 2013;41(9 Suppl 1):1-15. doi: 10.1097/CCM.0b013e3182a167d7. [PubMed: 23989088].
3. Pedersen CM, Rosendahl-Nielsen M, Hjermind J, Egerod I. Endotracheal suctioning of the adult intubated patient-what is the evidence?. *Intensive Crit Care Nurs.* 2009;25(1):21-30. doi: 10.1016/j.iccn.2008.05.004. [PubMed: 18632271].
4. Sole ML, Bennett M, Ashworth S. Clinical Indicators for Endotracheal Suctioning in Adult Patients Receiving Mechanical Ventilation. *Am J Crit Care.* 2015;24(4):318-24. doi: 10.4037/ajcc2015794. [PubMed: 26134331] quiz 325.
5. Yazdannik AR, Haghagh S, Saghaei M, Eghbali M. Comparing two levels of closed system suction pressure in ICU patients: Evaluating the relative safety of higher values of suction pressure. *Iran J Nurs Midwifery Res.* 2013;18(2):117-22. [PubMed: 23983740].
6. Sole ML, Bennett M. Comparison of airway management practices between registered nurses and respiratory care practitioners. *Am J Crit Care.* 2014;23(3):191-9. doi: 10.4037/ajcc2014424. [PubMed: 24786807] quiz 200.
7. Evans J, Syddall S, Butt W, Kinney S. Comparison of open and closed suction on safety, efficacy and nursing time in a paediatric intensive care unit. *Aust Crit Care.* 2014;27(2):70-4. doi: 10.1016/j.auc.2014.01.003. [PubMed: 24636425] quiz 75-6.
8. Kuriyama A, Umakoshi N, Fujinaga J, Takada T. Impact of closed versus open tracheal suctioning systems for mechanically ventilated adults: a systematic review and meta-analysis. *Intensive Care Med.* 2015;41(3):402-11. doi: 10.1007/s00134-014-3565-4. [PubMed: 25425442].
9. Haghagh S, Yazdannik A. The practice of intensive care nurses using the closed suctioning system: An observational study. *Iran J Nurs Midwifery Res.* 2015;20(5):619-25. doi: 10.4103/1735-9066.164509. [PubMed: 26457102].
10. Ricard JD, Eveillard M, Martin Y, Barnaud G, Branger C, Dreyfuss D. Influence of tracheal suctioning systems on health care workers' gloves and equipment contamination: a comparison of closed and open systems. *Am J Infect Control.* 2011;39(7):605-7. doi: 10.1016/j.ajic.2010.10.031. [PubMed: 21514008].
11. Subirana M, Sola I, Benito S. Closed tracheal suction systems versus open tracheal suction systems for mechanically ventilated adult patients. *Cochrane Database Syst Rev.* 2007(4):CD004581. doi: 10.1002/14651858.CD004581.pub2. [PubMed: 17943823].
12. Yaman Aktas Y, Karabulut N. The effects of music therapy in endotracheal suctioning of mechanically ventilated patients. *Nurs Crit Care.* 2016;21(1):44-52. doi: 10.1111/nicc.12159. [PubMed: 25721305].
13. Rose L, Smith O, Gelinas C, Haslam L, Dale C, Luk E, et al. Critical care nurses' pain assessment and management practices: a survey in Canada. *Am J Crit Care.* 2012;21(4):251-9. doi: 10.4037/ajcc2012611. [PubMed: 22751367].
14. Tate JA, Devito Dabbs A, Hoffman LA, Milbrandt E, Happ MB. Anxiety and agitation in mechanically ventilated patients. *Qual Health Res.* 2012;22(2):157-73. doi: 10.1177/1049732311421616. [PubMed: 21908706].
15. Samuelson KA. Adult intensive care patients' perception of endotracheal tube-related discomforts: a prospective evaluation. *Heart Lung.* 2011;40(1):49-55. doi: 10.1016/j.hrtlng.2009.12.009. [PubMed: 20561863].
16. Heiderscheit A, Chlan L, Donley K. Instituting a music listening intervention for critically ill patients receiving mechanical ventilation: Exemplars from two patient cases. *Music Med.* 2011;3(4):239-46. doi: 10.1177/1943862111410981. [PubMed: 22081788].
17. Happ MB, Sereika SM, Houze MP, Seaman JB, Tate JA, Nilsen ML, et al. Quality of care and resource use among mechanically ventilated patients before and after an intervention to assist nurse-nonvocal patient communication. *Heart Lung.* 2015;44(5):408-15. doi: 10.1016/j.hrtlng.2015.07.001. [PubMed: 26354859].
18. Darbyshire JL, Young JD. An investigation of sound levels on intensive care units with reference to the WHO guidelines. *Crit Care.* 2013;17(5):187. doi: 10.1186/cc12870. [PubMed: 24005004].
19. Park M, Vos P, Vlaskamp BN, Kohlrausch A, Oldenbeuving AW. The influence of APACHE II score on the average noise level in an intensive care unit: an observational study. *BMC Anesthesiol.* 2015;15:42. doi: 10.1186/s12871-015-0019-7. [PubMed: 25861240].

20. Rijkenberg S, Stilma W, Endeman H, Bosman RJ, Oudemans-van Straaten HM. Pain measurement in mechanically ventilated critically ill patients: Behavioral Pain Scale versus Critical-Care Pain Observation Tool. *J Crit Care*. 2015;30(1):167-72. doi: 10.1016/j.jcrc.2014.09.007. [PubMed: 25446372].
21. Aghaie B, Rejeh N, Heravi-Karimooi M, Ebadi A, Moradian ST, Vaismoradi M, et al. Effect of nature-based sound therapy on agitation and anxiety in coronary artery bypass graft patients during the weaning of mechanical ventilation: A randomised clinical trial. *Int J Nurs Stud.* 2014;51(4):526-38. doi: 10.1016/j.ijnurstu.2013.08.003. [PubMed: 24035670].
22. Khalaila R, Zbidat W, Anwar K, Bayya A, Linton DM, Sviri S. Communication difficulties and psychoemotional distress in patients receiving mechanical ventilation. *Am J Crit Care*. 2011;20(6):470-9. doi: 10.4037/ajcc2011989. [PubMed: 22045144].
23. Chlan L, Savik K. Patterns of anxiety in critically ill patients receiving mechanical ventilatory support. *Nurs Res.* 2011;60(3 Suppl):S50-7. doi: 10.1097/NNR.0b013e318216009c. [PubMed: 21543962].
24. Payen JF, Bru O, Bosson JL, Lagrasta A, Novel E, Deschaux I, et al. Assessing pain in critically ill sedated patients by using a behavioral pain scale. *Crit Care Med.* 2001;29(12):2258-63. [PubMed: 11801819].
25. Sessler CN, Gosnell MS, Grap MJ, Brophy GM, O'Neal PV, Keane KA, et al. The Richmond Agitation-Sedation Scale: validity and reliability in adult intensive care unit patients. *Am J Respir Crit Care Med.* 2002;166(10):1338-44. doi: 10.1164/rccm.2107138. [PubMed: 12421743].
26. Corley A, Spooner AJ, Barnett AG, Caruana LR, Hammond NE, Fraser JF. End-expiratory lung volume recovers more slowly after closed endotracheal suctioning than after open suctioning: a randomized crossover study. *J Crit Care*. 2012;27(6):742 e1-7. doi: 10.1016/j.jcrc.2012.08.019. [PubMed: 23102530].
27. Mohammadpour A, Amini S, Shakeri MT, Mirzaei S. Comparing the effect of open and closed endotracheal suctioning on pain and oxygenation in post CABG patients under mechanical ventilation. *Iran J Nurs Midwifery Res.* 2015;20(2):195.
28. Acikgoz A, Yildiz S. Effects of Open and Closed Suctioning Systems on Pain in Newborns Treated with Mechanical Ventilation. *Pain Manag Nurs.* 2015;16(5):653-63. doi: 10.1016/j.pmn.2015.01.002. [PubMed: 26163740].
29. Jongerden IP, Kesecioglu J, Speelberg B, Buiting AG, Leverstein-van Hall MA, Bonten MJ. Changes in heart rate, mean arterial pressure, and oxygen saturation after open and closed endotracheal suctioning: a prospective observational study. *J Crit Care*. 2012;27(6):647-54. doi: 10.1016/j.jcrc.2012.02.016. [PubMed: 22520496].
30. Ozden D, Gorgulu RS. Effects of open and closed suction systems on the haemodynamic parameters in cardiac surgery patients. *Nurs Crit Care*. 2015;20(3):118-25. doi: 10.1111/nicc.12094. [PubMed: 24991700].