

Effect of Minimally Invasive Endotracheal Tube Suctioning on Suction-Related Pain, Airway Clearance and Airway Trauma in intubated Patients: A Randomized Controlled Trial

Mahdi Shamali,¹ Atye Babaii,^{2,*} Mohammad Abbasinia,² Mohsen Shahriari,³ Mohammad Akbari Kaji,⁴ and Kim Oren Gradel⁵

¹Nursing and Midwifery Care Research Centre, Faculty of Nursing and Midwifery, Isfahan University of Medical Sciences, Isfahan, IR Iran

²Department of Nursing, Faculty of Nursing and Midwifery, Qom University of Medical Sciences, Qom, IR Iran

³Nursing and Midwifery Care Research Centre, Department of Adult Health Nursing, Faculty of Nursing and Midwifery, Isfahan University of Medical Sciences, Isfahan, IR Iran

⁴Member of Young Researcher Group, Department of Nursing, Faculty of Nursing and Midwifery, Islamic Azad University Khoorasgan Branch, Isfahan, IR Iran

⁵Center for Clinical Epidemiology, Odense University Hospital, University of Southern Denmark, Odense, Denmark

*Corresponding author: Atye Babaii, Department of Nursing, Faculty of Nursing and Midwifery, Qom University of Medical Sciences, Qom, IR Iran. Tel: +98-2538850824, Fax: +98-2536122855, E-mail: atyebabaii@yahoo.com

Received 2015 December 30; Revised 2016 August 10; Accepted 2016 August 13.

Abstract

Background: Due to the frequency and risks associated with endotracheal suctioning, there is a need to examine clinical practice critically and identify clinical research to guide practice. Correct technique and preparation by the clinicians can assist to reduce the risks of adverse events and the level of discomfort for the patients.

Objectives: The current study aimed to investigate the effects of routine versus the minimally invasive endotracheal tube suctioning procedure on suction-related pain, airway clearance and airway trauma in patients who were intubated.

Methods: In this randomized clinical trial, 64 patients with intubation in the intensive care units (ICUs) of Alzahra Hospital, Isfahan, Iran, were randomly allocated to minimally invasive endotracheal tube suctioning (MIETS) and routine endotracheal tube suctioning (RETS) groups. Pain intensity was assessed immediately before, immediately after and 10 minutes after endotracheal tube suctioning (ETS). Airway clearance was defined by numbers of suctioning and airway trauma noted after suctioning. The Chi-square test, independent T-test, and repeated measures analysis of variance were performed to analyze the data.

Results: There was no significant difference in the number of suctionings needed to effectively clear airway between the two groups. No significant differences were observed in the pain score changes during the three-time measurements in the MIETS group. However, in the RETS group the increase of pain scores were statistically significant during the three-time measurements. In addition, the number of airway traumatization was significantly higher in the RETS group. The number of medications used as a pain relief during 10 minutes after the ETS was significantly higher in the RETS group.

Conclusions: The results of the study suggest that using MIETS instead of RETS caused a lower incidence of airway traumatization and lower suction-related pain intensity. In addition, MIETS was sufficiently effective, the same as RETS, to remove airway secretions. Hence, MIETS may be useful to reduce the complications of ETS as long as being effective to remove airway secretions.

Keywords: Suction, Pain, Nurses, Intensive Care Units

1. Background

Maintaining the patency of the airway is the primary goal of nursing care in patients with intubation (1). Endotracheal tube suctioning (ETS) is a procedure aimed to keep the airways patent by mechanically removing accumulated pulmonary secretions (2). ETS is one of the most frequent and important responsibilities of the nurses working in the intensive care units (3). Despite being a necessary procedure, it can lead to complications, such as mucus traumatization, pain, discomfort, infection, impairment of the physiological indices, bronchoconstriction, atelectasis and increase in intracranial pressure (2, 4).

ETS is a routine nursing procedure (5). But in some wards there is no evidence based manual for it to guide nurses' performance (6). Some suctioning practices are still performed regardless of evidence that clearly indicates no benefit (7). Invasive techniques such as manual ventilation with a bag-valve-mask (4) and instillation of normal saline (8) have no benefit to the patient when suctioning. However, this is routinely implemented in some intensive care units (ICUs) in Iran (7). Hyperinflation using a manual resuscitator bag or the ventilator is used as a method of both hyper oxygenation and lung recruitment maneuvers. Hyperinflation is not a benign procedure and is associated with adverse effects including barotrauma,

patient discomfort and significant increases in pulmonary airway pressure (4).

Instillation of normal saline via the endotracheal tube prior to suctioning is a common practice in some intensive care units (8). The theory behind this practice is that the saline loosens and thins secretions and stimulates the cough reflex thus facilitating removal of secretions (9). Most studies failed to support a routine use of normal saline solution during ETS and suggest that it may be harmful to the patient (2, 7, 9, 10).

A further consideration is the degree of negative pressure applied during the procedure. There is no evidence to suggest an exact maximum pressure to be applied, however recommendations for acceptable suction pressures given in the literature range from 80 to 170 mmHg (10). Based on clinical experience, it is recommended to use the lowest possible suction pressure during ETS, usually 80-120 mmHg (4).

Another consideration is the depth of catheter insertion during ETS. A number of papers recommended that the suction catheter should be inserted into the carina and retracted 1-2 cm before applying suction (4). While the deep suctioning maybe necessary in patients with large amount of secretions in lower airways (11), most studies recommended to use minimally invasive suction, in which the suction catheter is inserted to the length of endotracheal tube only, which is associated with fewer adverse effects (4, 10).

Due to the frequency and risks associated with the ETS, there is a need to examine clinical practice critically, and identify clinical research to guide practice. Correct technique and preparation can assist to reduce the risks of adverse events and the level of discomfort in the patient. The current study developed a minimally invasive endotracheal tube suctioning (MIETS) procedure, using the best current research evidence related to ETS which facilitates the removal of airway secretions, while preventing potential complications of the ETS for safer suctioning practices.

2. Objectives

The current study aimed to investigate the effects of routine endotracheal tube suctioning (RETS) versus MIETS procedure on suction-related pain, airway clearance and airway trauma in patients who were intubated.

3. Methods

3.1. Study Design and Participants

The study was a nonblinded randomized clinical trial conducted from February to June 2015. Participants were

recruited from patients admitted to the ICUs of Alzahra University Hospital, Isfahan, Iran. Patients who met the inclusion criteria were consecutively enrolled in the trial. Afterward, samples were randomly allocated into experimental (MIETS) and control (RETS) groups. To do this, the researcher prepared a list of numbers from 1 to 64, and then samples were allocated into two equal groups by a random number table.

The sample size was calculated based on a previous study in which Arroyo-Novoa et al. investigated pain related to tracheal suctioning in awake acutely and critically ill adults. According to the results of pain variables d and σ were 1.9 and 2.7, respectively (12).

$$n = \frac{2 \left(Z_{1-\frac{\alpha}{2}} + Z_{1-\frac{\beta}{2}} \right)^2 \sigma^2}{d^2} \quad (1)$$

Accordingly, with a type I error probability of 0.05 and a power of 0.80, the sample size was determined to be thirty two patients for each group. Figure 1 shows the consort flow diagram.

The inclusion criteria were age over 18 years, receiving intubation and mechanical ventilation for more than 24 hours and less than two weeks, open suction system, no chronic respiratory disease, agreement of the patient or their family members to participate in the study, no thrombocytopenia or other coagulation disorders, being oriented to time, place, and person, receiving no neuromuscular blocking or cardiovascular medications, no history of airway traumatization in previous suctionings, no cardiac arrhythmia and dysrhythmia and no history of disease or injuries that impaired sensory transmission from the procedure site. The exclusion criteria included patient's reluctance to remain in the study, the exit of endotracheal tube during the study and deterioration of the patient's condition (bradycardia: heart rate (HR) < 60 beats per minute, arrhythmia, cyanosis, extreme loss of arterial oxygen: SpO₂ < 86%).

3.2. Instruments

The instrument for data collection consisted of two parts. The first part included the demographic and clinical information such as age, gender, type of patient, duration of intubation, mode of mechanical ventilation and prescribed medication (opioids, sedatives, and/or non-steroidal anti-inflammatories) as a sedative 10 minutes before and 10 minutes after the ETS. The second part included questions about the airway traumatization after ETS (Yes, No), the number of required suction for effective airway cleaning and pain intensity score. This instrument was developed by relevant literature, and its content and face validity was confirmed by eight faculty members of Isfahan University of Medical Sciences.

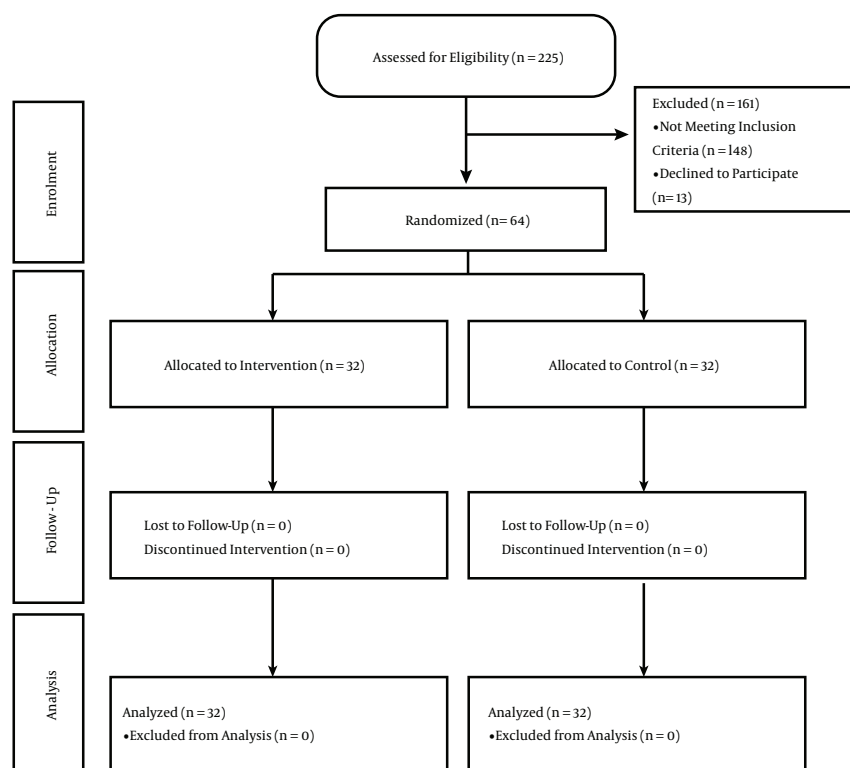


Figure 1. Consort Flow Diagram

Pain intensity was measured by 0-10 numeral rating scale (NRS). This self-report is the most accurate indicator of pain (12). Patients were asked to report their pain score from 0, which indicates no pain, to 10 worst pain score, by showing their finger or by eye confirm on showing the numbers by researcher. Concurrent and construct validities of the NRS are established (12-15). Test-retest reliability for the NRS is 0.94 (16). The pain intensity was assessed immediately before, immediately after and 10 minutes after the ETS.

The airway traumatization was defined as observation of blood in aspirated mucus and secretions during the ETS. The airway traumatization was assessed immediately after ETS.

3.3. Procedures

The researcher attended the ICUs of Alzahra Hospital every day and randomly allocated the patients who met the inclusion criteria, and had signed the informed consent form, to MIETS and RETS groups. Before suctioning, the researcher extracted all the demographic and clinical information from their hospital records and completed the first part of the instrument. Then, in the second part of

the instrument, data were recorded immediately before, immediately after and 10 minutes after the ETS. To do this, the patients' requirement to ETS was evaluated by physical assessment including auscultation and palpation of the chest, and review of the patient's secretion production over recent hours. In the experimental and control groups the ETS was performed using MIETS and RETS methods, respectively. The patients' pain intensity scores were measured and recorded only in the first time of suctioning. One researcher performed all endotracheal tube suctioning procedures and another researcher measured and recorded data needed in the instrument.

The diameter of the suction catheter used in both groups of patients was half of the internal diameter of the endotracheal tube (4, 10). Also, in both groups, after each suctioning of the endotracheal tube, the patients' airways were examined to ensure effective cleaning. If the airway secretions were not cleaned properly, ETS was performed again up to maximum of three times (10) (with interval of three minutes), each time 10 seconds (4).

In RETS, after disconnecting the patients from the ventilator, manual hyper oxygenation and hyperventilation was carried out for one minute (4). Then a suction catheter

with an effective length was introduced into the endotracheal tube until resistance was met (reached the carina), after that it was retracted a centimeter (10) and a negative pressure (100-200 mmHg) (4) was applied for a maximum duration of 10 seconds while removing the catheter. Manual hyperinflation was applied between the cycles of suctioning. Prior to each suctioning, 8 mL of normal saline was instilled (9, 10).

In MIETS, the patients were hyper oxygenated only by ventilator for one minute. Short suction catheter was made according to the different sizes of endotracheal tubes by marking on a catheter with sterile device. Hence, it was impossible to touch the trachea or bronchi with the suction catheter. Then, patients were removed from ventilator and a custom made short suction catheter with effective length was introduced only into the end of the endotracheal tube and a negative pressure (80-120 mmHg) (4) was applied for a maximum duration of 10 seconds while removing the catheter. Manual hyperinflation and installation of normal saline were not applied in this group.

3.4. Ethical Considerations

The ethics committee of Isfahan University of Medical Sciences approved the study (no: 294003). Also, permissions were obtained from the hospital and the wards authorities. The study participants were informed about the aim and the course of the study, free to participate in the study, free to withdraw from the study at any stage, confidentiality of patients' information and lack of adverse effects of each ETS method. Then, a written informed consent was obtained from them. The recorded code in the registration center of clinical trials is IRCT2015072423314N1.

3.5. Data Analysis

All analyses were performed using the SPSS software 13 (SPSS, Inc., Chicago, IL). Chi-square test and independent T-test were used to compare the demographic and clinical characteristics between the two groups. Chi-square test was used to compare airway traumatization and numbers of suctioning in the groups. Repeated measures analysis of variance (RMANOVA) was used to compare pain intensity scores and Chi-square test was used to compare medication used in the groups. A P-value less than 0.05 was considered statistically significant in all tests.

4. Results

During the study, none of the subjects was excluded based on the exclusion criteria. The mean ages of the MIETS and RETS groups were 47.12 ± 17.2 and 47 ± 18.08 years, respectively. Males comprised 68.8% of the MIETS group

and 75% of the RETS group. In the MIETS and RETS groups, majority of the subjects were patients with trauma 46.9% and 43.8% of the total, respectively. The mean hours of intubation were 57.43 ± 25.25 in the MIETS and 57.5 ± 24.87 in the RETS groups. In addition, the most frequent mode of ventilation of the MIETS group was synchronized intermittent mandatory ventilation (SIMV) 46.9% and for the RETS group were SIMV and continuous positive airway pressure (CPAP) 40.6%. Chi-square and independent T-tests showed no significant differences in demographic and clinical characteristics between the two groups ($P > 0.05$; Table 1).

Chi-square test showed no significant difference in the number of suctionings needed to effectively clear airway between the two groups ($P > 0.05$). Comparing the frequency of airway traumatization during the ETS, Chi-square test indicated that the number of traumatization was significantly higher in the RETS group ($P < 0.05$; Table 1).

The repeated-measures ANOVA (the Mauchly significance test for sphericity, $w = 0.700$, $P = 0.005$, $[U+1D4B] = 0.769$) showed (Greenhouse-Geisser corrections of F ratios were performed) a significant increase in the mean score of pain in the three-time measurements in the RETS group [$F(1.538, 47.680) = 89.918$, $P < 0.001$, $\eta^2 = 0.744$], but in the MIETS group (the Mauchly significance test for sphericity, $w = 0.532$, $P < 0.001$, $[U+1D4B] = 0.681$) showed (Greenhouse-Geisser corrections of F ratios were performed) no significant differences in the mean score of pain in the three-time measurements [$F(1.363, 42.238) = 0.492$, $P = 0.544$, $\eta^2 = 0.016$]. Furthermore, the interaction between the two groups and time (the Mauchly significance test for sphericity, $w = 0.894$, $P = 0.033$, $[U+1D4B] = 0.945$) was (Huynh-Feldt corrections of F ratios were performed) significant [$F(1.889, 117.126) = 67.850$, $P < 0.001$, $\eta^2 = 0.523$]. Similarly, there was a significant difference between the groups [$F(1, 293.146) = 7.050$, $P = 0.010$, $\eta^2 = 0.102$; Table 2].

The results of Chi-square test showed that the number of medications used as a pain relief during 10 minutes before the ETS, did not differ significantly between the two groups ($P = 0.545$). In contrast, the number of medications used during 10 minutes after the ETS were significantly higher in the RETS group ($P = 0.026$; Table 3).

5. Discussion

The analysis revealed several statistically significant differences in the evaluation of the RETS versus MIETS in terms of suction-related pain, airway traumatization and use of pain relief medications. In contrast, there was no significant difference in the number of suctionings needed to effectively clear airway between the two groups.

Table 1. Patients' Demographic Characteristics^a

Characteristics	MIETS	RETS	P Value
Gender			0.578 ^b
Male	22 (68.8)	24 (75)	
Female	10 (31.3)	8 (25)	
Age, y	47.12 ± 17.2	47 ± 18.08	0.977 ^c
Type of patients			0.860 ^b
Trauma	15 (46.9)	14 (43.8)	
Medical	8 (25)	7 (21.9)	
Surgical	9 (28.1)	11 (34.4)	
Duration of intubation, h	57.43 ± 25.25	57.5 ± 24.87	0.992 ^c
Modes of mechanical ventilation			0.958 ^b
SIMV	15 (46.9)	13 (40.6)	
CPAP	11 (34.4)	13 (40.6)	
AC	2 (6.3)	2 (6.3)	
Other	4 (12.5)	4 (12.5)	
Airway traumatization after ETS			0.03 ^b
Yes	1 (3.1)	8 (25)	
No	31 (96.9)	24 (75)	
Numbers of suctioning			0.281 ^b
One time	20 (62.5)	24 (75)	
Two times	12 (37.5)	8 (25)	

Abbreviations: CPAP, continuous positive airway pressure; MIETS, minimally invasive endotracheal tube suctioning; RETS, routine endotracheal tube suctioning; SIMV, synchronized intermittent mandatory ventilation.

^aData are presented as No. (%), or mean ± SD

^bThe results of chi-square test.

^cThe results of independent t-test.

The MIETS procedure evaluated in the current study in removing secretions was as effective as that of the RETS. Inconsistent with the current study results, a study showed that the number of suctionings needed for efficient airway cleaning in the shallow suctioning group was significantly higher compared to that of the deep suctioning group (5). The different results of prior studies compared with those of the current study may be related to the discrepancy in the subjects of these studies. The subjects in the current study were conscious and able to cough to assist the removal of airway secretions. Cough is the major mechanism of airway that assists removal of airway secretions (17, 18). However, in specific patients with large amounts of secretions in the lower airways a more rigorous conventional procedure may be required. The present study suggested that, in general, the MIETS procedure was sufficient to remove secretions.

With respect to the airway traumatization during the ETS, the findings of the present study reported signifi-

cantly higher incidence of clinically detected blood in aspirated mucus in the RETS group compared to that of the MIETS group. Deep suctioning in the lower airways along with higher negative pressure in the RETS may theoretically explain the differences in the incidence of blood in the aspirated mucus. In line with the current study, a study also showed higher incidence of clinically detected blood in aspirated mucus in the RETS group compared to that of the MIETS group (2).

Deep ETS, by inserting the suction catheter to the carina, could lead to trauma (19). In addition, it may cause a greater negative pressure applied to the lungs, due to occlusion of more than half of bronchial lumen (4). Since high negative pressure is more effective in removing secretions, it may produce significant damage to tracheal tissue (10, 20).

Furthermore, the results of the current study showed that the MIETS versus RETS is significantly associated with lower pain and use of pain relief medications during 10

Table 2. Mean of Pain Intensity Score Across the Three-Time Periods of ETS^a

Variable	MIETS	RETS	RMANOVA	
Before ETS	1.90 ± 1.37	2.00 ± 1.36	P ^b < 0.001, P ^c = 0.010	F = 67.850, F = 7.050
Immediately after ETS	1.90 ± 1.27	3.71 ± 1.22		
Ten min after ETS	1.84 ± 1.29	2.43 ± 1.26		
RMANOVA	P ^d = 0.614, F = 0.492	P ^d < 0.001, F = 89.918		

Abbreviations: ETS, endotracheal tube suctioning; MIETS, minimally invasive endotracheal tube suctioning; RETS: routine endotracheal tube suctioning; RMANOVA, repeated measures analysis of variance.

^aData are presented as mean ± SD.

^bInteraction between groups and time.

^cPain score changes between two groups.

^dPain score changes within groups.

Table 3. Pain Relief Medications Across the Three-Time Periods of ETS^a

Variable	MIETS	RETS	P Value ^b
Ten minutes before ETS			0.545
Yes	8 (25)	6 (18.8)	
No	24 (75)	26 (81.3)	
Ten minutes after ETS			0.026
Yes	27 (84.4)	19 (59.4)	
No	5 (15.6)	13 (40.6)	

Abbreviations: ETS, endotracheal tube suctioning; MIETS, minimally invasive endotracheal tube suctioning; RETS, routine endotracheal tube suctioning.

^aData are presented as No. (%).

^bChi-square test.

minutes after the ETS. Although, the ETS is reported as a painful experience by critically ill patients (12), the results of the current study suggest that using MIETS instead of RETS led to less pain and use of medication in patients who were intubated.

One descriptive single group study showed the high mean pain intensity score during the ETS, similar to the RETS group in immediately after the ETS (12). Another study showed that the MIETS results in a lower incidence of recollection of the ETS compared that of the RETS (2).

It is reported that manual hyperinflation and installation of NS, used in the RETS, increase discomfort in patients during the ETS. Also, disconnection of patients from ventilator can cause agitation and discomfort (4). Hence, disconnecting the patients from the ventilator, and using manual hyper oxygenation and hyperventilation before the RETS led to prolonged disconnection of patients from the ventilator and probably more pain.

In addition, high negative pressure and deep ETS may be a potential factor to cause more pain in the RETS. Inserting the suction catheter to carina could lead to trauma and pain (19, 21, 22). Similarly, high negative pressure may cause damage to tracheal tissue (10, 20) and lead to pain. There-

fore, the higher level of pain and use of pain relief medications in the RETS may be attributed to the deep ETS and high negative pressure.

The main limitation of the study was that the results of the study can only be applied to the type of patients included, and should be generalized with caution to unconscious patients or to other patients unable to self-report their pain since such patients did not participate in the study. Future research should be focused on sedated and unconscious critically ill patients undergoing tracheal suctioning to explore their behavioral and physiological responses to this procedure since it causes pain in patients who are able to self-report.

In conclusion, the results of the study suggest that using MIETS instead of RETS in patients who were intubated caused a lower incidence of airway traumatization, use of pain relief medications and intensity of suction-related pain. In addition, MIETS was as sufficiently effective as RETS to remove airway secretions. Hence, MIETS may be useful to reduce the complications of ETS as long as being effective to remove airway secretions.

Acknowledgments

The authors would like to acknowledge their gratitude to all the patients for their participation and nurses for their continued support.

Footnotes

Authors' Contribution: Study concept and design: Mahdi Shamali; acquisition of data: Atye Babaii, Mahdi Shamali, Mohammad Akbari Kaji, Mohsen Shahriari and Mohammad Abbasinia; analysis and interpretation of data: Kim Oren Gradel, Atye Babaii, Mahdi Shamali and Mohammad Abbasinia; drafting of the manuscript: Atye babaii, Mahdi Shamali, Mohammad Abbasinia, Mohsen Shahriari and Mohammad Akbari Kaji; critical revision of the manuscript for important intellectual content: Atye babaii, Mahdi Shamali, Mohammad Abbasinia, Mohsen Shahriari and Kim Oren Gradel; statistical analysis: Atye babaii, Mahdi Shamali and Kim Oren Gradel; administrative, technical, and material support: Atye babaii, Mahdi Shamali and Mohammad Abbasinia; study supervision: Mahdi Shamali.

Financial Disclosure: The authors declared no financial disclosure regarding the materials and results of the current study.

Funding/Support: This project was funded by the research deputy of Isfahan University of Medical Sciences and healthcare services, Isfahan, IR Iran (grant no: 294003).

References

1. Ferreira A, Silvino Z, Christovam B, Lima D. Endotracheal suctioning in intensive care unit: An integrative review. *J Nurs UFPE on line*. 2013;7(4):4910-7.
2. Favretto DO, Silveira RC, Canini SR, Garbin LM, Martins FT, Dalri MC. Endotracheal suction in intubated critically ill adult patients undergoing mechanical ventilation: a systematic review. *Rev Lat Am Enfermagem*. 2012;20(5):997-1007. [PubMed: 23174846].
3. Hadian ZS, Sabet RS. The effect of endotracheal tube suctioning education of nurses on decreasing pain in premature neonates. *Iran J Pediatr*. 2013;23(3):340-4. [PubMed: 23795259].
4. 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].
5. Abbasinia M, Irajpour A, Babaii A, Shamali M, Vahdatnezhad J. Comparison the effects of shallow and deep endotracheal tube suctioning on respiratory rate, arterial blood oxygen saturation and number of suctioning in patients hospitalized in the intensive care unit: a randomized controlled trial. *J Caring Sci*. 2014;3(3):157-64. doi: 10.5681/jcs.2014.017. [PubMed: 25276759].
6. Ansari A, Masoudi Alavi N, Adib-Hajbagheri M, Afazel M. The gap between knowledge and practice in standard endo-tracheal suctioning of ICU nurses, Shahid Beheshti Hospital. *J Criti Care Nurs*. 2012;5(2):71-6.
7. Rafiee H, Iranmanesh S, Sabzevari S. Comparison of the endotracheal tube suctioning with and without normal saline solution on heart rate and oxygen saturation. *Iran J Crit Care Nurs*. 2011;4(3):117-20.
8. Zahran EM, El-Razik AA. Tracheal suctioning with versus without saline instillation. *J Am Sci*. 2011;7(8):23-32.
9. Reeve JC, Davis N, Freeman J, O'Donovan B. The use of normal saline installation in the intensive care unit by physiotherapists: a review of practice in New Zealand. *J Physiother*. 2008;36(2):78-95.
10. Couchman BA, Wetzig SM, Coyer FM, Wheeler MK. Nursing care of the mechanically ventilated patient: what does the evidence say? Part one. *Intensive Crit Care Nurs*. 2007;23(1):4-14. doi: 10.1016/j.iccn.2006.08.005. [PubMed: 17046259].
11. Irajpour A, Abbasinia M, Hoseini A, Kashefi P. Effects of shallow and deep endotracheal tube suctioning on cardiovascular indices in patients in intensive care units. *Iran J Nurs Midwifery Res*. 2014;19(4):366-70. [PubMed: 25183976].
12. Arroyo-Novoa CM, Figueroa-Ramos MI, Puntillo KA, Stanik-Hutt J, Thompson CL, White C, et al. Pain related to tracheal suctioning in awake acutely and critically ill adults: a descriptive study. *Intensive Crit Care Nurs*. 2008;24(1):20-7. doi: 10.1016/j.iccn.2007.05.002. [PubMed: 17689249].
13. Hjermstad MJ, Fayers PM, Haugen DF, Caraceni A, Hanks GW, Loge JH, et al. Studies comparing Numerical Rating Scales, Verbal Rating Scales, and Visual Analogue Scales for assessment of pain intensity in adults: a systematic literature review. *J Pain Symptom Manage*. 2011;41(6):1073-93. doi: 10.1016/j.jpainsymman.2010.08.016. [PubMed: 21621130].
14. Ferreira-Valente MA, Pais-Ribeiro JL, Jensen MP. Validity of four pain intensity rating scales. *Pain*. 2011;152(10):2399-404. doi: 10.1016/j.pain.2011.07.005. [PubMed: 21856077].
15. Page MG, Katz J, Stinson J, Isaac L, Martin-Pichora AL, Campbell F. Validation of the numerical rating scale for pain intensity and unpleasantness in pediatric acute postoperative pain: sensitivity to change over time. *J Pain*. 2012;13(4):359-69. doi: 10.1016/j.jpain.2011.12.010. [PubMed: 22424915].
16. Chuang LL, Lin KC, Hsu AL, Wu CY, Chang KC, Li YC, et al. Reliability and validity of a vertical numerical rating scale supplemented with a faces rating scale in measuring fatigue after stroke. *Health Qual Life Outcomes*. 2015;13:91. doi: 10.1186/s12955-015-0290-9. [PubMed: 26122080].
17. Gauld LM. Airway clearance in neuromuscular weakness. *Dev Med Child Neurol*. 2009;51(5):350-5. doi: 10.1111/j.1469-8749.2008.03260.x. [PubMed: 19379290].
18. Mahede T, Davis G, Rutkay A, Baxendale S, Sun W, Dawkins HJ, et al. Use of mechanical airway clearance devices in the home by people with neuromuscular disorders: effects on health service use and lifestyle benefits. *Orphanet J Rare Dis*. 2015;10:54. doi: 10.1186/s13023-015-0267-0. [PubMed: 25943355].
19. Branson RD. Secretion management in the mechanically ventilated patient. *Respir Care*. 2007;52(10):1328-42. [PubMed: 17894902].
20. Bourgault AM, Brown CA, Hains SM, Parlow JL. Effects of endotracheal tube suctioning on arterial oxygen tension and heart rate variability. *Biol Res Nurs*. 2006;7(4):268-78. doi: 10.1177/1099800405285258. [PubMed: 16581897].
21. Sonmez Duzkaya D, Kuguoglu S. Assessment of pain during endotracheal suction in the pediatric intensive care unit. *Pain Manag Nurs*. 2015;16(1):11-9. doi: 10.1016/j.pmn.2014.02.003. [PubMed: 24957815].
22. Gillies D, Spence K. Deep versus shallow suction of endotracheal tubes in ventilated neonates and young infants. *Cochrane Database Syst Rev*. 2011;6(7):003309.