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Original Article

Efficacy of closed endotracheal suctioning in critically ill patients: A clinical trial of comparing two levels of negative suctioning pressure

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ABSTRACT

Background & Aim: Although trachea-bronchial suctioning (TBS) is one of the important nursing procedures in intensive care units (ICU), it may be associated with some complications. Using closed system suctioning (CSS) is one of the ways to decrease the rate of complications due to continued ventilation and oxygenation at the time of suctioning. However, CSS' secretion removal is not efficient enough. Higher values of suction pressure have been recommended to enhance the efficacy of CSS. The aim of this study was to compare the efficacy of two levels of negative suction pressure in secretion removal of CSS used for mechanically ventilated (MV) patients.

Materials & Methods: Fifty eligible adult MV patients (twenty in each group) with Random allocation participated in this clinical trial study with cross-over design. Each patient was suctioned using CSS, connected to a central suction device, with 100 and 200 mmHg pressures with a two-hour interval. Efficacy of suctioning was measured by the absence of secretion flow at the end of suctioning. Volume of the secretions was measured and compared in each suctioning. Statistical analyses were done using Minitab and SPSS software considering the significance level of 0.05.

Results: CSS using 200 mmHg resulted in an efficacy of 96% for removing secretions, compared to 34% for 100 mmHg (P = <0.0001). Suctioning volume was increased significantly higher with 200 mmHg suction pressure compared to values with 100 mmHg (1.72 [95% confidence interval (CI): 1.4; 2.0]; P<0.0001).

Conclusion: Application of CSS with Suctioning pressure 200 mmHg is recommended for trachea-bronchial suctioning in mechanically ventilated patients, because nearly complete removal of respiratory suctioning in most subjects.

Introduction

Most of the critically ill patients undergoing mechanical ventilation need endotracheal tube to keep their airway open (1). Existence of endotracheal tube leads to blockage of spontaneous removal of secretions from endotracheal tree, resulted from suppression of cough reflex and an increase in mucus secretions (2-4). Tracheo-Bronchial Suctioning (TBS) is one of the most common and important procedures, performed for the patients to manage their airways by ICU nurses as one of the treatment team members (5-7).

Despite the necessity of TBS in patients undergoing mechanical ventilation, it is a procedure with several clinical complications, which influence patients' clinical stability (8). Cardiovascular instability, pain, desaturation and hypoxia, infection, Increased Intra Cranial Pressure (9), tracheal mucosal membrane damage and bleeding, discomfort (10), dysrhythmia (2), loss of lung volume and atelectasis, anxiety and dyspnea (11) are among these complications. Among afore-mentioned complications, hypoxia, atelectasis and hemodynamic instability are more prevalent and important (10). The main causes of hypoxia are patients' disconnection from

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ventilator during TBS, loss of lung volume and imposing negative pressure (12, 13).

For TBS, based on the type of catheter, there are two suctioning systems: open (conventional method) and closed suctioning systems. Closed-suctioning system (CSS) is a sterile multiple-use catheter, enclosed in a plastic sheath, is connected to ventilation circuit and patients' endotracheal tube by a connector, which makes the continuation of oxygenation during TBS procedure possible (14). As a result of continuation of ventilation during TBS, the chance of above-mentioned complications, especially hypoxia, atelectasis and loss of lung volume is less in CSS (2.5 folds lesser) (5). More convenience of use, shorter preparation time for the procedure, administration of suction by just one nurse, less leakage and splash of secretions, lower loss of post suctioning functional residual volume in patients who need high PEEP, less chance of cross-contamination (15), prevention of derecruitment (14) and more cardio-vascular stability (16-17) can be mentioned as other advantages of CSS.

Despite several afore-mentioned advantages of CSS, some studies reported less efficacy of this system in removing airway secretions, compared to OSS. Copnell et al reported less efficacy of CSS in removing secretions in an in-vitro study (18). Lindgren et al, in a study on damaged lungs of pigs, reported that efficacy of OSS with CPAP 0 cmH2O was higher than CSS with CPV and CPAP 10 (19). Lasocki et al emphasized on the higher efficacy of OSS in clearance of airways, compared to CSS (13), but a study reported no difference in the volumes of removed secretions between OSS and CSS (20). Increasing suctioning negative pressure is one of the strategies to modify this defect (13). In our previous study, the safety of higher values of the negative closed suctioning system pressure that was associated with hyper-oxygenation was proved and high inspiratory concentration of oxygen continues during the procedure (6).

Although numerous animal studies have compared the effectiveness of OSS with CSS, the study on enhancing CSS efficacy by increasing suction pressure on human is limited and mostly has been combined with recruitment manoeuvres. The purpose of this study was to compare the effectiveness of two levels of negative suctioning pressure 100 and 200 mmHg in removal of airways secretions applied during CSS with hyper-oxygenation in mechanically ventilated adult ICU patients.

Methods

After approval Isfahan University of Medical Sciences sampling started in general ICUs in 2016. The IRCT code is IRCT20160924029930N2 with research number of 390162. Because of inability to get the informed consent from the patients (unconscious patients), the form was signed by parents or Legal guardian of patients and after this step the patients were enrolled in the study. This is a double blind cross-over clinical trial. Fifty adult patients, aged 18 years and over, undergoing mechanical ventilation with no-pressure modes and with at least 24 hours passed after their connection to mechanical ventilation were recruited. Patients with no hemodynamic stability (mean arterial pressure <70 mmHg, 20 mmHg increase or decrease in systolic blood pressure and 20 b/min decrease in heart rate (21, 22)) and those who needed next suction earlier or later than two hours or were hypoxic (SpO2 < 88%, PaO2 <55 mmHg) (23) were excluded from the study. Patients whose families were dissatisfied with the study were also excluded.

In order to examine more precisely and to compare each sample with her/him using of two different negative suctioning pressures, a cross-over method was used for the study. Samples were randomly assigned to two groups (AB and BA) by minimization software. Through use of a cross-over design of AB-BA, each patient received 100 and 200 mmHg suction pressure in the order, determined by a minimization software(24) with a two hours wash-out between them. In order to balance the samples, the age, gender, base SpO2,

admission diagnosis, ventilator mode, and length of ICU stay variables were defined in the minimization software in order to allocate the groups (AB and BA). At the same time, the probability of 0.8 was determined for random allocation of samples in two groups. Setting the suction pressures for each round of suctioning, determined by the minimization program, was taken by one of the researchers, who did not participated in the act of suctioning and data recording. In this way, the variables entry of the samples in Minimization software and assignment of samples in two groups were done by the second researcher. She adjusted the suction pressure after determining the group for the sample. The person who performed the suctioning procedures and recorded patients' data (chief researcher) was not aware of the level of suction pressure and patient's defined group (AB or BA). In order to blind the chief researcher to the sample grouping and the negative pressure level set, the suction pressure monitor was covered with paper after the negative pressure tuning. Prior to the study, all central suction devices of ICUs were checked and calibrated by the responsible authority.

At each suctioning episode in both groups, TBS was performed through a closed suctioning system (vital-cath). Before suctioning, patients were placed in 45- degree fowler position, if not contraindicated. CSS, with respect to sterility, was connected to the patient's endotracheal tube from the side of connector and ventilator circuit was connected to the other side of connector. Syringe of saline normal was connected to irrigating port. In case the patients were conscious, the procedure was explained to him/her. One minute prior to procedure, patient was hyper-oxygenated with FIO2=1. Patients underwent endotracheal suctioning by CSS French 14 for 10 second. Hyper-oxygenation continued during and one min after. Suction connector was held by the non-dominant hand, and the catheter was inserted to endotracheal tube, from its sheath, by thumb and the pointing finger of the dominant hand. Catheter was inserted as far as it was blocked, and then, it was towed backward for 1 cm. Through negative pressure by pressing the control valve, suctioning was conducted for 10 seconds. Based on the best recommendations of the American Association of Respiratory Care, due to the increased risk of developing pulmonary infections, normal Saline instillation for airway suctioning was avoided. Next suctioning was conducted with a one-minute interval if needed. Removal of catheter was confirmed by observing the back pointer in the catheter sheath. Catheter was rinsed by irrigating port. Control valve was next locked, and catheter was separated from central suction port on the wall.

Finally, its cap was placed with respect to sterility (2, 11, 14). After, two hrs, the patient underwent another ETS with above-mentioned method with 200 mmHg. In fact, first AB group were suctioned with 100 mmHg and after two hours with 200 mmHg, and the second AB vice-versa. Data regarding baseline characteristics (age, sex, diagnosis, length of hospitalization in ICU, ventilation mode, intubation length) were recorded in a relevant form. Continuation of secretion flow at the end of 10-second of suctioning was used as a qualitative indicator of efficacy of suctioning for that level of suction pressure for each suction pressure.

Therefore, presence of secretion flow at the end of 10- second suctioning was recorded as inefficient suctioning. Suctioned materials were collected in a bottle attached to suction device and its volume was measured as a quantitative indicator of efficacy of each suctioning. To evaluate and test methodology, data of each group were compared. In order to compare baseline characteristics between two groups of AB (100-200 mmHg) and BA (200-100 mmHg), chi-squared test and Z test and paired sample Student t-test was used by SPSS 16.

Continuous data were reported as mean ± standard deviation (SD) or Standard error

(SE) and categorical data as frequency (percentage).

Intervention, period and carryover effects were evaluated by specific statistical approach for analysis of 2 * 2 crossover design using Minitab 18. We also used McNemar test for analyzing suctioning flow (absent/present) variables. P<0.05 was considered statistically significant and was reported by two fraction digits.

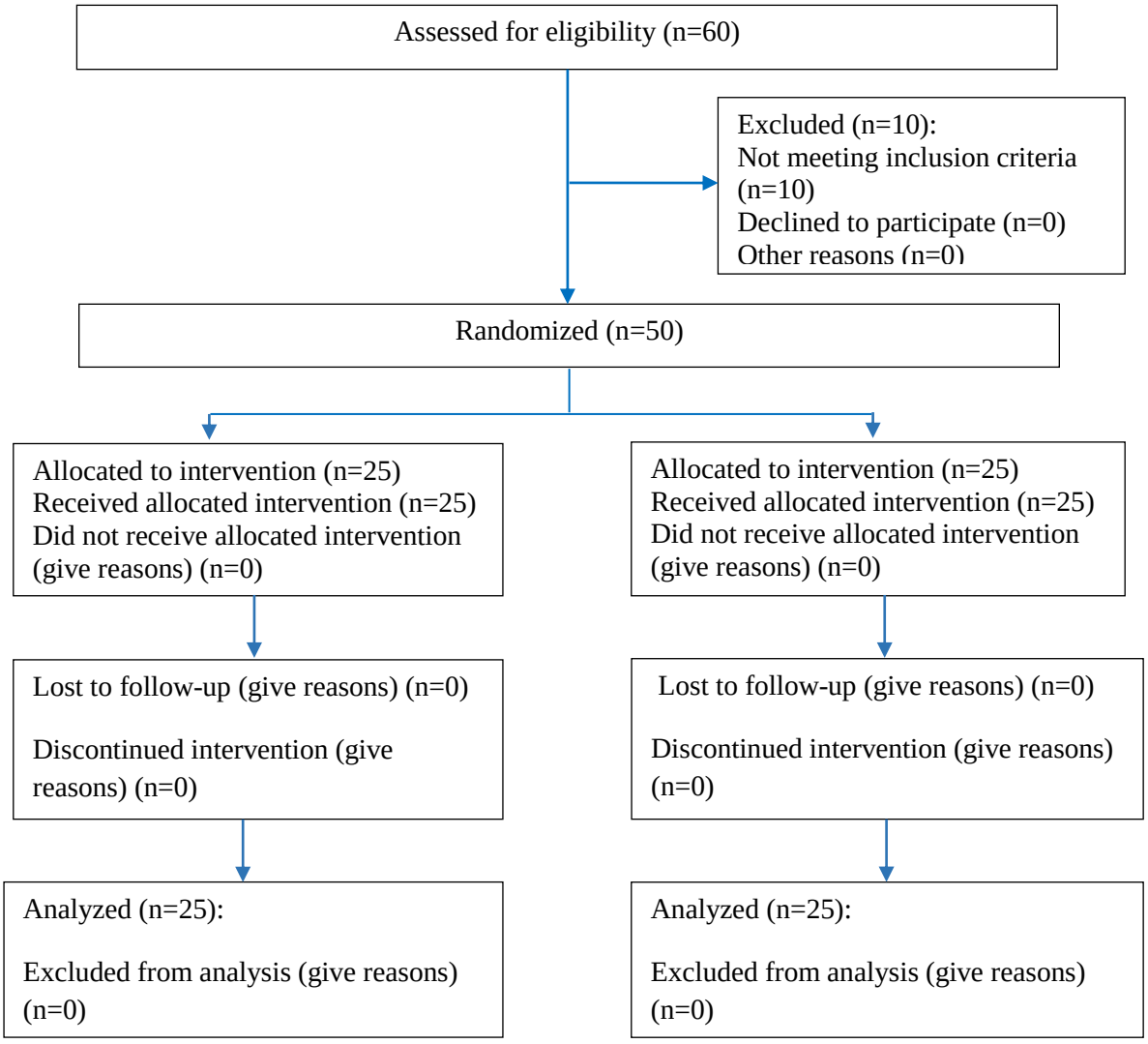

Figure 1. CONSORT flowchart diagram

Results

Overall, 60 eligible mechanically ventilated adult patients were identified. Ten of them did not met inclusion criteria and were excluded from the study. Finally, 50 adult patients completed the crossover study (60% male and 40% female), with a mean age (SD) of 54.92 (18.95) (range, 21-95) years. Baseline characteristics of participants who completed the study are summarized in table 1. As is evident, no significant difference existed between the two groups of AB and BA (n=25, n=25) concerning the baseline characteristics of sex, ventilation mode, age, hospitalization length, and the length of intubation (day). Table 2 demonstrates the mean (SD) of suctioning volume (ml) with 100 and 200 mmHg suction pressures.

Mean (SD) of suctioning volume (ml) with suctioning pressure 100 mmHg in AB group was 1.92 (1.73) and in BA group was 2.21 (1.45). Mean (SD) of suctioning volume (ml) with suctioning pressure 200 mmHg in AB group was 3.54 (1.86) and in BA group was 4.02 (2.37).

Table 1. Comparing baseline characteristics between two groups of AB (100-200 mmHg) and BA (200-100 mmHg), data are Mean ± SD or n (%)

Groups	Age (Year) Mean (SD)	ICU stay (Day) Mean (SD)	Intubation Time (Day) Mean (SD)	Gender		Ventilator Mode		Pulmonary Disease	
				M N (%)	F N (%)	SIMV N (%)	SPONT N (%)	Yes N (%)	No N (%)
AB group	55.05 (19.6)	8.95 (9.8)	6.22 (5.8)	15(60)	10(40)	16(64)	9(36)	10(40)	15(60)
BA group	54.79 (18.3)	9.76 (10.3)	6.34 (6.4)	15(60)	10(40)	16(64)	9(36)	8(32)	17(68)
P value	0.95	0.62	0.69	1.00		1.00		0.71	

Table 2. Mean (SD) of suctioning volume (ml) with 100 and 200 mmHg suction pressures, values are Mean (SD)

Sequence	Suctioning volume		
	N	Mean (SD)	Mean (SD)
AB (100-200)	25	1.92 (1.73)	3.54 (1.86)
BA (200-100)	25	4.02 (2.37)	2.21 (1.45)

The mean treatment effect of suction pressure 100 mmHg compared to 200 mmHg on suctioning volume has demonstrated in table 3. Suctioning volume was increased significantly (1.72 [95% confidence interval (CI): 1.4; 2.0]; P<0.0001).

The result of the comparison of the continuation of secretion flow after 10 sec between suctioning pressure 100 mmHg and 200 mmHg has summarized in table 4.

McNemar test result showed that the percentage of efficient suctioning (absent of continuation of secretion removal flow after 10 sec) changed from 34% in suctioning pressure 100 mmHg to 96% in suctioning pressure 200 mmHg and this change was significant (p<0.0001).

Table 3. Comparative effects of suction pressure 100 mmHg and 200 mmHg on suctioning volume of study participants

Suctioning volume	Mean difference (SE)	CI (95 %)	Carry over effect	P value	
				Treatment effect	Period effect
	1.724 (0.164)	(1.392, 2/000)	0/443	< 0/0001*	0.596

*Significant at the level of 0.05. SD=Standard deviation; SE=Standard error; CI=Confidence interval

Table 4. Comparison of the continuation of secretion flow after 10 sec between suctioning pressure 100 mmHg and 200 mmHg

Continuation of secretion flow		N (%)	Pvalue
100 mmHg	Absent	17 (34)	< 0/0001*
	Present	33 (66)	
200 mmHg	Absent	48 (96)	
	Present	2 (4)	

*significant at the level of 0.05.

Discussion

The main outcome measure of this study was to compare the efficacy of closed suctioning system with two different levels of suction pressure.

The results of this study showed that closed suctioning system with a 100 mmHg negative pressure may not be as effective as a suction pressure of 200 mmHg in terms of suctioned volume and efficacy of secretion clearance. CSS using 200 mmHg resulted in an efficacy of 96% for removing secretions, compared to 34% for 100 mmHg (P = 0.000). Suctioning volume was increased significantly higher with 200 mmHg suction pressure compared to values with 100 mmHg (1.72 [95% confidence interval (CI): 1.4; 2.0]; P<0.0001).

As indicated in aforementioned studies, oxygen desaturation, alveolar collapse and inadequate ventilation are among the most important complications of airways suctioning. In CSS, there is less probability of desaturation and a drop in alveolar volume due to continuation of ventilation during suctioning, compared to OSS(3). This issue is of great importance, especially among the patients with acute lung injury and pulmonary hypoxic acute failure, under ventilator, with high FIO2 and PEEP, who are at a higher risk of suction complications (3, 5).

Lasocki et al (2006) reported the advantage of CSS in reduction of lung volume loss and improvement of gas exchange, compared to OSS. Evans et al (2014), Afshari et al (2014), Ozden and Gorgulu (2015), Seyyed Mazhari et al (2010) and Khamis et al (2011) indicated to a three-fold increase in heart rate and mean arterial pressure in OSS, compared to CSS, dramatic changes in heart rate in OSS, dramatic effect of OSS on heart rate and mean arterial pressure, lower effect of CSS on patients' hemodynamic changes, compared to OSS, and the least negative effect on cardio-pulmonary parameters and more stability of physiologic parameter in CSS, compared to OSS, respectively in addition to better efficacy of CSS on oxygenation and gas exchange, compared to OSS (9, 10, 16, 17).

All above-mentioned studies emphasized on the positive effect of CSS in hemodynamic stability during endotracheal suctioning, compared to OSS. In patients' endotracheal suctioning, in addition to consideration of the least complications occurring during suctioning, selection of the appropriate catheter concerning its efficacy in removing the secretions with least manipulation of the patients is of great importance.

On the contrary, despite the afore-mentioned advantages of CSS, several studies emphasized on less efficacy of secretion removal during endotracheal suctioning followed by CSS, compared to OSS. Copnell et al, in their study, reported lower efficacy of CSS in removal of both thin and thick pulmonary secretions, regardless of ventilation mode in injured lungs, compared to OSS (18).

Lindgern et al reported lower efficacy of CSS in pressure modes concerning removal of secretions but lower complications, compared to OSS (19). Both studies were in vitro with low number of subjects. Lasocki et al (13) in a study on 9 patients with acute lung injuries, reported that CSS could prevent gas exchange disturbance although its efficacy in removal of airways secretions is lower than OSS. Meanwhile, in Lasocki's et al study recruitment maneuver was adopted in CSS and the number of subjects was limited. In the former study (6), with increase of suctioning pressure from 100 mmHg to 200 mmHg in CSS with hyper-oxygenation before and after suctioning, we found out that an increase in pressure not only did not lead to gas exchange disturbance but patients' SPO2 with suction pressure of 200 mmHg significantly remained higher than baseline SPO2 and SPO2 with 100 mmHg till 20 min after suctioning.

This result was reported without recruitment maneuvers. In the present study, through quantitative and qualitative investigation of secretion removal in CSS with two levels of pressure, a significant

increase of secretion volume was observed with negative pressure of 200 mmHg, compared to 100 mmHg. This issue can explain higher SPO2 after CSS with pressure of 200 mmHg, compared to 100 mmHg and can be resulted from almost complete clearance of airway with this level of suctioning pressure. Endo-tracheal suctioning should be carried out with the least manipulation and if really needed, as it is an invasive procedure with complications. Two major factors affecting the amount of secretion removal in endotracheal suctioning and its post-procedure complications are the level of negative pressure and the size of catheter. Using a higher-size catheter can have more negative effect, compared to increase of negative pressure during suctioning. Therefore, selection of an appropriate size of catheter and negative pressure are of great importance in removal of adequate secretion and administration of this procedure as fewer as possible.

Through selection of appropriate size of catheter (less than half of tracheal tube internal diameter), complications can be prevented and controlled to a high extent. Since efficacy of CSS is directly associated with the imposed negative pressure, and selection of a safe level of negative pressure is of great importance; therefore based on our results, we emphasize on the efficacy of 200 mmHg suctioning pressure in CSS for efficient clearance of the airway among the patient under ventilation.

As imposing a higher suctioning pressure is not safe and necessary, further studies on different levels of pressure and their relevant complications seem essential. On the other hand, the results of the present study may not be capable of being generalized to different modes of ventilation, especially positive pressure modes as well as the patients who need high respiratory support.

Our obtained results showed that CSS with 200 mmHg suctioning pressure leads to almost complete clearance of respiratory secretions nearly in all patients. As safety of 200 mmHg suctioning pressure has been proved in previous studies, its application is recommended for trachea-bronchial suctioning in all patients under ventilation. Efficient clearance of airway leads to a lower number of needed suctions and less manipulation of the patients, and consequently, less complication.

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Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

References

1. Sole ML, Bennett M, Ashworth S. Clinical Indicators for Endotracheal Suctioning in Adult Patients Receiving Mechanical Ventilation. American Journal of Critical Care. 2015;24(4):318-24.
2. Potter PA, Perry AG, Stockert P, Hall A. Fundamentals of nursing. Elsevier Health Sciences; 2016.
3. 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. Iranian journal of nursing and midwifery research. 2015;20(2):195-9.
4. Farsi Z, Kalroozi F, Nezamzadeh M, et al. Effect of clinical audit process on level of endotracheal suctioning skill in nurses and anesthesia technicians working in intensive care units. Nurs Pract Today. 2015; 2(2): 76-83.
5. Maggiore S, Volpe C. Endotracheal suctioning in hypoxemic patients. Réanimation. 2011;20(1):12-8.
6. Yazdannik AR, Haghighat 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. Iranian journal of nursing and midwifery research. 2013;18(2):117-22.
7. Haghighat S, Yazdannik A. The practice of intensive care nurses using the closed suctioning system: An observational study. Iranian journal of nursing and midwifery reseach. 2015;20(5):619-25.

8. Davies K, Monterosso L, Leslie G. Determining standard criteria for endotracheal suctioning in the paediatric intensive care patient: an exploratory study. Intensive and Critical Care Nursing. 2011;27(2):85-93.
9. 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. Australian Critical Care. 2014;27(2):70-4.
10. Afshari A, Safari M, Oshvandi K, Soltanian AR. The effect of the open and closed system suctions on cardiopulmonary parameters: time and costs in patients under mechanical ventilation. Nursing and midwifery studies. 2014;3(2):e14097.1-6.
11. Lippincott. Lippincott's Nursing Procedures. Ed t, editor.: Lippincott Williams & Wilkins (LWW); 2015.
12. Innovation NAfC. Suctioning an Adult ICU patient with an artificial airway. In: 2067 CN, editor. Australia. Albert Avenue; 2014. p. 40.
13. Lasocki S, Lu Q, Sartorius A, Fouillat D, Remerand F, Rouby J-J. Open and Closed-circuit Endotracheal Suctioning in Acute Lung InjuryEfficiency and Effects on Gas Exchange. The Journal of the American Society of Anesthesiologists. 2006;104(1):39-47.
14. Care AARC. AARC Clinical Practice Guidelines. Endotracheal suctioning of mechanically ventilated patients with artificial airways 2010. Respiratory care. 2010;55(6):758-64.
15. Hlinková E, Nemcová J, Bielená K. Closed Versus Open Suction System of The Airways in The Prevention of Infection in Ventilated Patiients.Cent Eur J Nurs Midw. 2014;5:63-71.
16. Özden D, Görgülü RS. Effects of open and closed suction systems on the haemodynamic parameters in cardiac surgery patients. Nursing in critical care. 2015;20(3):118-25.
17. Khamis GM, Waziry OG, Badr-El-Din A-HA, El-Sayed MM. Effect of Closed Versus Open Suction System on Cardiopulmonary Parameters of Ventilated Neonates. J Am Sci. 2011;7(4):525-34.
18. Copnell B, Tingay DG, Kiraly NJ, Sourial M, Gordon MJ, Mills JF, et al. A comparison of the effectiveness of open and closed endotracheal suction. Intensive care medicine. 2007;33(9):1655-62.
19. Lindgren S, Almgren B, Högman M, Lethvall S, Houltz E, Lundin S, et al. Effectiveness and side effects of closed and open suctioning: an experimental evaluation. Intensive care medicine. 2004;30(8):1630-7.
20. Paula LCSd, Ceccon MEJ. Randomized, comparative analysis between two tracheal suction systems in newborn. Revista da Associação Médica Brasileira. 2010;56(1):434-9.
21. Urden LD, Stacy KM, Lough ME. Critical Care Nursing, Diagnosis and Management, 7: Critical Care Nursing. Elsevier Health Sciences; 2013.
22. David D, Samuel P, David T, Keshava SN, Irodi A, Peter JV. An open-labelled randomized controlled trial comparing costs and clinical outcomes of open endotracheal suctioning with closed endotracheal suctioning in mechanically ventilated medical intensive care patients. Journal of critical care. 2011;26(5):482-8.
23. oxygen Therapy-Clinical Best Practice guidline [internet]. College of Respiraatory Therapist of Ontarion. 180 Dundas Street West, Suite 2103, Toronto, Ontario.2013 – [cited 2013 Sep] Available from:http://www.crto.on.ca/pdf/PPG/Oxygen_Therapy_CBPG.pdf
24. Saghaei M, Saghaei S. Implementation of an open-source customizable minimization program for allocation of patients to parallel groups in clinical trials. Journal of Biomedical Science and Engineering. 2011;4(11):734-4.