Original Article

Comparison of the effects of two levels of negative pressure in open endotracheal tube suction on the physiological indices among patients in intensive care units

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Abstract

Background: Most of the patients admitted in the intensive care units (ICUs) require an endotracheal tube and mechanical ventilation. In order to clear and maintain patency of the airways, endotracheal suctioning is required. Therefore, the least detrimental way of endotracheal tube suctioning which can diminish the complications should be selected. The present study aimed to compare the effect of two levels of negative pressure (100 mmHg and 200 mmHg) in open endotracheal tube suction on the physiological indices among patients in the ICUs.

Materials and Methods: In this single-blind clinical trial, 60 patients meeting the inclusion criteria were selected by convenience sampling and randomly allocated in two groups. First group of patients were suctioned with negative pressure of 100 mmHg and the second group with 200 mmHg. Effects of two levels of suction pressure on oxygen saturation (SPO2) and heart rate (HR) values were measured and recorded at four time points. Repeated measure analysis of variance (ANOVA), Chi-square test, and independent *t*-test were adopted to analyze the data.

Results: In the two groups consisting of totally 60 subjects (30 in each group), 34 subjects were males and 26 were females, with a mean age of 60.63 years (minimum 18 years and maximum 75 years). Repeated measure ANOVA showed a significant difference in the mean SpO2 and HR before, during, and 5 and 20 min after suction within each group ($P < 0.05$), but not between the two groups ($P > 0.05$).

Conclusions: The present study revealed that with regard to the detrimental effect of endotracheal tube suctioning on arterial oxygen saturation and HR, suctioning with negative pressure of 200 mmHg is considered to be a low-risk procedure compared to suctioning with negative pressure of 100 mmHg, if standard procedures in open suction system are followed.

Key words: Intensive care unit, physiological indices, suction

Introduction

Protection of airways and maintaining their patency for proper respiration in the intensive care unit (ICU) is the first priority.[1] Endotracheal tube is the most common artificial airway.[2] Existence of an artificial airway weakens the cough reflex and imposes dysfunction of hairy cells leading to accumulation of secretions as well as a disturbance in discharge of these secretions form the airways. As these patients are incapable of discharge of the secretions, they need periodical suctioning.[3] Suctioning the intubated patients under ventilation is a routine nursing intervention,[4] and is counted as a crucial care among these patients.[3] The most common endotracheal suctioning method in clinical setting in Iran is open system suction which needs patients' disconnection from ventilation device during suctioning.[5]

Although endotracheal tube suction facilitates discharge of secretions and airway patency, it can lead to numerous complications.[6] Major complications of endotracheal suction include hypoxia, change in heart rate (HR) and blood pressure (BP), cardiac arrhythmia, and cardiac and respiratory arrest.[7] The most common complication is hypoxia, which can cause changes in HR, cardiac arrhythmia and hemodynamic imbalance, and heart arrest

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and death.[8] Therefore, the level of arterial oxygenation and patients' vital signs should be monitored before, during, and after suctioning.[4] Studies emphasize on allocation of a safe pressure to remove secretions with the lowest risk of hypoxia, atelectasia, and tracheal tube injury. Negative pressure is appropriate to remove secretions; therefore, the level of pressure in suction can affect the amount of removed secretions. Use of inadequate pressure leads to ineffective secretion removal and unclean airway.[9] Suction with excessive negative pressure for a long time results in damages to tracheal tube, hypoxia, and cardiac arrhythmia, which can be modified by oxygenation with high concentration.[9] The size of suction catheter, the level of negative pressure, and length of suction time can directly affect endotracheal suction efficacy and potential complications.[10] Tenaillon claimed that negative pressure of 200-300 mmHg is safe for endotracheal suction, while Pedersen *et al*., with a more precautionary approach, determined 200 mmHg negative pressure as the upmost safe pressure.[9] Morrow *et al*. showed that increase of negative pressure from 200 mmHg to 360 mmHg increases the amount of suctioned secretions, but leads to an increase in negative pressure of lungs.[10] In another study, Seymour *et al*. used negative pressure of 200 mmHg.[11] Yazdannik *et al*. used two levels of negative pressure (100 mmHg and 200 mmHg) and measured the level of O2 saturation before and 1, 3, and 20 min after closed system suction. They concluded that negative pressure of 200 mmHg had no destructive effect on oxygenation of patients under ventilation hospitalized in the ICU. It was relatively safe and did not result in cardiovascular complications.[12] Lasocki *et al*. showed that open system endotracheal suction with negative pressure of 200 mmH_2O led to a reduction in parabolic pressure of arterial oxygen.[13] Therefore, recommendation of upmost negative pressure is based on experiments, as no clinical study supports a precise margin for it.[14] As observed, there are controversial studies and viewpoints in use of upmost safe negative pressure in open system endotracheal suction. Therefore, this study aimed to compare the effect of two levels of negative pressure in open endotracheal tube suction on the physiological indices among patients in the ICUs.

Materials and Methods

This is a clinical trial. After obtaining an introduction letter from School of Nursing and Midwifery, the researcher referred to the management of Al-Zahra Hospital and started sampling after explanation about the study objectives to the authorities. Then the informed consent was obtained from the subjects or their fellows. The study population consisted of all intubated patients hospitalized in the ICU of Alzahra Hospital affiliated to Isfahan University of Medical Sciences in 2013. The subjects comprised all adult male and female intubated patients connected to ventilators in the ICU. The subjects (n = 30 in each group, total N = 60) were selected through convenient sampling and assigned to two groups through random allocation. Inclusion criteria were hospitalization in the ICU, being orally intubated and connected to ventilator, age of 18–75 years, no history of blood coagulation diseases or thrombocytopenia, and having a stable hemodynamic status (HR ≤120, SPO_2 ≥90).

In case of endotracheal tube removal or disconnection from ventilator, the patients were excluded. Data collection tool was a data collection form including three sections. The first section contained demographic characteristics like subjects' age and sex. The second section included patients' clinical characteristics such as length of hospitalization in the ICU, cause of hospitalization in the ICU (diagnosis), intubation time length, endotracheal tube size, and the mode of ventilation. The third section contained subjects' arterial O_2 saturation measurement results and HR which were filled in different stages through imposing negative pressure. After getting a letter of introduction from the nursing school, subjects meeting the inclusion criteria were selected through researcher's daily referral to the ICU.

The subjects were explained about the research goal and a written informed consent was obtained from patients' parents. Finally, patients' demographic information form was filled by use of their medical file records (and if needed, by taking help from patients' accompanying person). The patients were randomly assigned to two groups (group 1 and group 2). Firstly, the first section of data collection form was filled through referring to hospital medical files and observation of endotracheal tube as well as ventilator settings. Then, the patients' need of endotracheal tube suction was assessed, and if needed, suction was administered. Groups 1 and 2 were suctioned twice by 100 and 200 mmHg negative pressure, respectively, based on a standard method and appropriate catheter.. patients' arterial O_2 saturation and HR were measured just before, during, and 5 and 20 min after suctioning with the endotracheal tube, and recorded in the third section of data collection form by a co-researcher (the study was single blinded).

With regard to the content validity of the data collection tool, an initial draft was prepared by referring to articles and scientific texts in the related context, and then was revised by the academic members of the nursing and midwifery school, and the final data collection form was prepared. A single monitoring device (Pooyandegan Rah Saadat Co., Ltd. Tehran; Iran) to monitor the vital signs and a central endotracheal suction system (open suction system), which were weekly calibrated by related experts, were adopted.

Results

The present study was conducted on 60 subjects in two groups that were suctioned by 100 mmHg negative pressure ($n = 30$) and 200 mmHg negative pressure ($n = 30$), respectively. There were 34 male (56.7%) and 26 female (43.3%) subjects, with a mean age of 60.63 years (range 18-75 years). With regard to the type of disease, 31.7% had gastrointestinal diseases, 26.7% had brain diseases, 13.3% had renal diseases, 8% had multiple traumas, 5% had intoxication, 5% had cardiac diseases, and 10% had other diseases. Among the subjects, 58.3% had Synchronized Intermittent Mandatory Ventilation (SIMV) mode of ventilation, 35% had Continious Positive Air Pressure (CPAP) mode, and 6.7% received ventilation with Assist-Control Ventilation (ACV) mode. Subjects' mean length of hospitalization in the ICU was 3.85 (1.66) days, which ranged 1-7 days. Mean length of subjects' intubation longevity was 3.33 (1.29) days, which ranged 1-6 days. Independent *t*-test was used to c ompa re subjects' age, intubation time length, hospitalization length, and endotracheal tube size in the two groups, and showed no significant difference ($P > 0.05$). Chi-square test was used to determine homogeneity of subjects' sex, hospitalization reason, and mechanical ventilation mode, and showed no significant difference in the distribution frequency of the above-mentioned items in the two groups ($P > 0.05$). Repeated measure analysis of variance (ANOVA) showed a significant difference in the SPO_2 mean scores at different time points (before, during, and 5 and 20 min after suction) in each group of 100 mmHg and 200 mmHg negative pressures ($P < 0.001$), but the difference was not significant between the two groups ($P = 0.779$). Independent *t*-test showed no significant difference in mean values of SPO_2 before, during, and 5 and 20 min after suction in the two groups ($P = 0.362$, $P = 0.53$, and $P = 0.302$ and $P = 0.139$, respectively), which indicates that the groups had similar changes in SPO_2. The highest difference in SPO_2 was during suction, which had a descending trend and was observed more in the group receiving negative pressure of 200 mmHg. Mean values of SPO_2 showed a significant reduction during suction compared to before suction in the two groups ($P < 0.001$), which was more in the group receiving negative pressure of 200 mmHg. In group 1, mean values of SPO_2 at time points of 5 and 20 min after suction showed an increase compared to before suction, which was not significant ($P = 0.101$ and $P = 1.000$, respectively).

In group 2, mean values of SPO_2 at time points of 5 and 20 min after suction showed an increase, which was not significant ($P = 0.11$ and $P = 0.20$, respectively) [Table 1].

Repeated measure ANOVA in the two groups of 100 mmHg and 200 mmHg negative pressures showed a significant difference in HR values at different time points (before, during, 5 and 20 min after suction) in each group ($P < 0.001$), but no significant difference between the groups ($P = 0.702$). Independent t-test showed no significant difference in HR values before, during, and 5 and 20 min after suction ($P = 0.954$, $P = 0.275$, and $P = 0.792$ and $P = 0.974$, respectively), and the groups had similar changes in HR values. Mean HR values showed a significant increase during suctioning compared to before in both the groups ($P < 0.001$), and the increase was more in the group administered 200 mmHg negative pressure. In group 1, mean HR values showed a reduction at 5 and 20 min after suctioning compared to before suctioning, which was not significant ($P = 1.000$,$P = 1.000$). In group 2, mean HR values showed a reduction at 5 and 20 min after suctioning, which was not significant ($P = 1.000$, $P = 1.000$) [Table 2].

Table 1: Comparison of mean and SD of arterial O_2 saturation in repeated measure ANOVA in the two groups of open suction with negative pressures 100 mmHg and 200 mmHg, respectively

Group / Time		Negative pressure (mmHg)		Independent *t*-test	
		Group 1 (100)	Group 2 (200)	*P* value	*t*
Just before suction		90.60±15.03	90.80±11.39	0.954	−0.058
During suction		95.43±15.27	99.37±12.24	0.275	−1.10
5 min after suction		90.33±13.97	91.17±10.12	0.792	−0.264
20 min after suction		90.47±13.73	90.57±10.04	0.974	−0.032
Repeated measure ANOVA	Between groups		*P* value=0.702 *F*=0.148		
	P *F*		*P* value=0.000 *F*=3.15		

ANOVA: Analysys of variance, SD: Standard deviation

Table 2: Comparison of mean and SD of HR/min in repeated measure ANOVA in the two groups of open suction with negative pressures 100 mmHg and 200 mmHg, respectively

Group / Time		Negative pressure (mmHg)		Independent *t*-test	
		Group 1 (100)	Group 2 (200)	*P* value	*T*
Just before suction		15.03±90.60	90.80±11.39	0.954	−0.058
During suction		15.27±95.43	99.37±12.24	0.275	−1.10
5 min after suction		13.97±90.33	91.17±10.12	0.792	−0.264
20 min after suction		13.73±90.47	90.57±10.04	0.974	−0.032
Repeated measure ANOVA	Between groups		*P* value=0.702 *F*=0.148		
	P *F*		*P* value=0.000 *F*=3.15		

ANOVA: Analysys of variance, SD: Standard deviation, HR: Heart rate

Discussion

The results of repeated measure ANOVA showed a significant difference in pulse oximetry and HR before, during, and 5 and 20 min after suctioning in each group ($P < 0.05$), but the difference was not significant between the two groups ($P > 0.05$). This finding is consistent with the results of the study by Yazdannik *et al.* comparing two levels of suctioning pressures (100 mmHg and 200 mmHg negative pressure) in closed system suction in patients hospitalized in the ICU.[12] These findings reveal no difference between the two groups concerning arterial O_2 saturation and HR in the four above-mentioned time points with two levels of negative pressure. Therefore, with regard to the above-mentioned results, application of 200 mmHg negative pressure, when standard protocol of this procedure is precisely followed, is recommended in patients with stable hemodynamic status hospitalized in the ICUs. Our results also showed a significant reduction in arterial O_2 saturation values during suction compared to before suction in each group ($P < 0.001$) and a significant increase in mean HR values during suction compared to before suction in each group ($P < 0.001$). In a literature review study conducted by Pagotto *et al.*, out of six studies on arterial O_2 saturation changes during suctioning process, five reported a notable reduction in arterial O_2 saturation during open system suctioning process.[15] This literature review study also points to the study of Cereda *et al*. which reported a notable increase in HR during open system endotracheal suctioning which is consistent with the above results.[16] Etemadifar *et al*. showed a significant reduction in mean arterial O_2 saturation during suction compared to before suction ($P < 0.001$) and a significant increase in HR during suction compared to before suction ($P < 0.001$), which is consistent with results of the present study.[17] Lee *et al*. showed a significant increase in HR immediately after suctioning[18] ($P < 0.05$).

The arterial O_2 saturation levels changes and HR values after endotracheal suction seem to have originated from disconnection of the patient from ventilator, obstruction of airways which resulted from inserting the catheter in endotracheal tube, stopping of oxygenation to the patient during endotracheal tube suctioning, and lowered respiratory volume due to application of negative pressure suctioning, especially 200 mmHg negative pressure suctioning. It is recommended to administer suction if needed and to hyperoxygenate the patient before and after suction, and to conduct suctioning for a fewer times with an endotracheal catheter of appropriate size. Our results showed an increase in mean arterial O_2 saturation 5 and 20 min after suction compared to before suction in each group, which was not significant, and returned to before suction level at the 20th min post suction, which is consistent with the report of Yazdannik *et al*.[12] Increase of SPO_2 on the 5th and 20th min after suction seems to be due to administration of 100% oxygenation 2 min before and after suctioning. Not only a reduction was not observed in SPO_2 in 200 mmHg negative pressure suction, but also an increase was seen, possibly due to better discharge of secretions from the airways and improvement of ventilation. Therefore, the researcher recommends administration of 100% oxygenation before and after open system suction based on patients' clinical conditions to prevent the negative effects of negative pressure suction. Lasocki *et al.* showed an average of 18% reduction in O_2 parabolic pressure compared to baseline values in open system suction with 200 cm H_2O negative pressure which continued until 15 min after suctioning, and is consistent with the present study.[13]

Conclusion

The results of this study showed that hyperoxygenation of the patients based on standard protocol of this care (in case of patients' need) in open system suction before and after this procedure, selection of catheter size appropriate to patients' tracheal tube, paying attention to permitted suction timing (10-15 s), and appropriate number of suctions should be considered.

Also, 200 mmHg negative pressure suction is applicable as a safe and low-risk negative pressure for ICU hospitalized patients. With regard to the limitations to the present study, further comparative studies to define the effect of various open system suction negative pressure levels on patients' vital signs, the amount of the secretions removed from the endotracheal tube, ventilation-associated pneumonia, and mortality among patients hospitalized in the ICU are suggested.

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