Original Article

# Comparing two levels of closed system suction pressure in ICU patients: Evaluating the relative safety of higher values of suction pressure

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## Abstract

**Background:** Endotracheal suctioning (ETS) is one of the most common supportive measures in intensive care units (ICU). ETS may be associated with complications including hypoxia and tachycardia. Closed system suctioning (CSS) decreases the rate of cardiorespiratory complication mainly due to continuation of ventilatory support and oxygenation during procedure. CSS has questionable efficacy, therefore higher values of negative pressure has been recommended to enhance the efficacy of CSS. This study was designed to evaluate the effects on gas exchange of 200 mmHg suctioning pressure compared with 100 mmHg in CSS.
**Materials and Methods:** Fifty mechanically ventilated (MV) ICU patients were selected for the study. Two consecutive ten seconds CSS using suction pressures of 100 and 200 mmHg, in random order applied in each subject with the two hours wash out period. Effects of two levels of suction pressure on gas exchange were measured by recording the SPo2 values at 4 times.
**Results:** Repeated measure analysis of variance didn't show any significant difference between two levels of pressure ($P = 0.315$), but within each groups (100 and 200 mmHg) SPO2 changes was significant ($P = 0.000$). There was a mild but significant and transient increase in heart rate following both suction pressures, but no significant difference between two groups.
**Conclusion:** The results show that CSS with suction pressure 200 mmHg has no detrimental effect on cardiorespiratory function of MV ICU patients. Since the safety of 200 mmHg suctioning pressure was approved, using 200 mmHg suction pressures is recommended for ETS of MV patients.

**Key words:** Intensive care units, intratracheal, Iran, mechanical ventilation, suction

## Introduction

Patients admitted to intensive care units require respiratory care and in particular endotracheal suctioning (ETS) to remove excess respiratory secretions and to improve respiratory function.[1] ETS is one of the most common supportive measures[2] and the most common procedures performed in patients with artificial airways.[3] Airway management of mechanically ventilated patients (MV) is one of the most important responsibilities of critical care nurses.[4] Incorrect airway management can lead to increased mortality and morbidity, lengthy hospital stay and extra cost. Although essential for critical patients, ETS may be associated with complications, sometimes leading to life threatening conditions.[5] Major complications following ETS include atelectasis, bronchospasm,[6] microbial contamination of lower respiratory tracts, ventilator associated pneumonia,[4] decreased SPO2, disrythmia,[7] anxiety and dyspnea.[8] Arterial hypoxemia is the most common and most important reported complication of suctioning[7,9] and may precipitate heart rate abnormalities and compromises in hemodynamic status.[7] ETS complications mainly results from reduction of Functional Residual Capacity (FRC) secondary to disconnecting the ventilator, and applying the negative suction pressure. In fact, removal of airway secretions invariably associated with suctioning the alveolar gas out of the lungs, resulting in alveolar collapse.[10] Disconnection of the patient from the ventilator is the most determinant of hypoxemia resulting from ETS.[11] Patients with high degrees of respiratory support and in particular those with high levels of PEEP are very sensitive to deleterious effects of TBS.

Different measures have been proposed to reduce ETS complications. For example, the likelihood of desaturation associated with TBS can be reduced by a brief pre-oxygenation period before initiation of ETS.[9]

In traditional method of ETS, patient discontinued from MV during ETS. Disconnecting from MV in critical patients

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with high levels of ventilator support, particularly those in need of high levels of PEEP, invariably leads to dramatic reduction of oxygenation due to decreasing lung volumes. To overcome this pitfall, some investigators recommend using a closed system.

In recent years, two systems are available to perform ETS: The single-use, open suction system (OSS) and the multiple used, closed suction system (CSS).[2,4,5,9,12-18] The most common suctioning technique used is OSS, which involves disconnecting the ventilator,[7] followed by insertion of a suction catheter into the trachea while negative pressure is generated.[9] However, disconnecting the ventilator causes a large drop in airway pressure, loss of lung volume, and oxygen desaturation; so, open suctioning can be considered inappropriate for patients with acute respiratory distress syndrome. Open suction has partly been replaced by closed suctioning systems,[7] which was developed in the 1980s, obviates the necessity of disconnecting the patient from the ventilator,[19] thus decreasing the loss of lung volume and avoiding gas-exchange impairment during suctioning.[14] CSS has become increasingly popular in the past decade. In the United States, 58 and 4% of intensive care units used CSS and OSS respectively.[20] Causes of universal interest of critical care units to change from OSS to CSS are primarily CSS benefits reports in preventing hypoxia and alveolar collapse resulted by OSS in severe respiratory disease with high level of PEEP.[21] CSS consists of a suction catheter enclosed within a flexible plastic film sleeve. According to the manufacturer, CSS connected to the patient can remain in place up to 24hrs.[4] This catheter is placed between the endotracheal tube and the Y-piece of the ventilator circuit,[9] thus can be used for repeated ETS tries.[4] CSS is performed without barrier precautions, because a plastic envelope protects the catheter.[13] The benefits of CSS over OSS include the maintenance of positive pressure ventilation during suctioning, less desaturation, and a reduced risk of contaminating tracheobronchial tree.[13] In addition, many critical care nurses find CSS more convenient to use, less time-consuming and better tolerated by the patients than the traditional method of OSS.[21] Compared with OSS, the CSS results in fewer adverse changes in cardiorespiratory functions[7,22,23] and lower contamination of respiratory tracts.[24] Although CSS is a safe method of endotracheal suctioning, there is a concern of less effectiveness than open system in removing secretions.[14,21] This issue was investigated by an *in vitro* test, in which CSS recovered less material than OSS.[14] Another animal research indicates less efficacy for CSS at recovering thin and thick simulated secretions in the injured lung, irrespective of ventilation mode.[18] Sigismond's study, in patients with acute lung injury, confirms the result of animal studies and support the clinical hypothesis that OSS is more efficient than CSS for tracheal secretion removal.[11] Blackwood[25] and Web reported that nurses found the system poorly effective in 39% of the suctioning procedures performed. Researchers began to look for some optimization of CSS to increase its suctioning power.[26] One solution suggested generating more negative pressure during closed suctioning to produce adequate secretion removal.[21] Copnell and colleagues found that, suction pressure has less influence on loss of lung volume than catheter size in CSS.[17] It is recommended that the diameter of the suction catheter should be less than half that of the ETT.[27] Further studies by Sigismond and colleagues showed that CSS followed by a recruitment maneuver prevents hypoxia resulting from OSS but decreases secretion removal. Increasing suction pressure enhances suctioning efficiency without impairing gas exchange.[11] To prevent decrease in blood oxygenation caused by suctioning, induction of hyperoxygenation was recommended before, during and after open suctioning. As there is no disconnection from the ventilator during suctioning, administration of high inspired oxygen continues during the suctioning.[7] In clinical practice the patient should receive preoxygenation by the delivery of 100% oxygen for at least 30 seconds prior to, during and after the suctioning procedure.[10] Although numerous studies have been repeatedly performed to compare the effectiveness of OSS with CSS, the study on enhancing CSS efficiency by increasing suction pressure on human is limited and mostly has combined with recruitment maneuvers after CSS, which is not recommended in most guidelines. It must be pointed out that, these studies have rarely been carried out on clinical patients and mostly they have used animal laboratory models. Therefore there is a lack of enough knowledge regarding the safe and effective level of suction pressure in patients undergoing ETS with CSS. The purpose of this study was to compare the effects on gas exchange of two different negative pressures, applied during CSS with hyperoxygenation and without recruitments maneuvers as recommended by clinical guidelines, in MV adult patients admitted to a teaching hospital intensive care unit. To select the levels of suctioning pressure, the findings of several researches were studied.[10,11] According to these studies, if proper suctioning catheter is used, the level of suctioning pressure could be increased up to 200 mmHg. Therefore, the high level of suction pressure in this study was presupposed to be 200 mmHg.

## Materials and Methods

This research was a double blind cross-over clinical trial in patients acting as their own controls.[7] After institutional approval and informed patient's family consent, 50 adult

ICU patients, older than 18 years, undergoing mechanical ventilation, using volume modes,[9,16,28,29] were studied. Patients with hemodynamic instability (DBP > 100 mmHg, ↑ or ↓ 20 mmHg in $SpO_2$ and ↑ 20 b/min in HR),[6] those requiring suctioning in wash out period (discussed below), and when the patient's family was unwilling to continue the research, they were excluded from the study. In addition patients must have MV duration for at least 24 hrs,[9,30] orotracheal intubation,[11,31] with no sever hypoxemia ($SpO_2$ < 85%, $PaO_2$ < 50 mmHg),[32] and stable hemodynamic condition (MAP > 70 mmHg, HR < 130/min)[9] to make them eligible for the trial. The study involved consecutive application of two different suction pressures of 100 and 200 mmHg to each patient. To make the carry over effect as low as possible, the order of applying suction pressure was randomly chosen for each subject. Therefore a cross-over model of AB-BA was used and patients were consecutively assigned to either AB or BA group, that is to receive either 100 mmHg suction pressures first, and then 200 mmHg, or the reverse order. Due to the relatively small sample size[33] and because of extreme time to time variability in physiologic conditions of ICU patients, we decided to use a minimization model. With an appropriate minimization model,[34,35] we can minimize the differences between two groups (AB, BA) and at the same time to enroll subjects randomly into groups, hence eliminating selection bias and the predictability of subject assignment. To further decrease the carry over effect, we incorporate a wash-out period of two hours between two episodes of suctioning. That is, the patients underwent tracheal suctioning with one level of suction pressure (say for example 100 mmHg) and after a wash-out period of two hours the next level of suction pressure was applied. Minimization factors included age, gender, base $SpO_2$, admission diagnosis, ventilator mode, and length of ICU stay. The minimization was performed using MinimPy – computer software carrying out the complex parts of minimization procedures.[36] The probability value of 0.7 was selected for assigning subject to the preferred treatment. Subjects were allocated to each group with equal allocation ratios. Biased coin minimization was selected as the probability method and marginal balance was used as the distance measure. Chief researcher, who performed the suctioning procedure, was blinded regarding the level of suction pressure and patient's assigned group. Assignment of subjects to each group and setting the suction pressure for each round of suctioning were carried out by the second researcher in position, who was not participated in the act of suctioning and data measurements.

Tracheal suctioning at each level of suction pressure was performed using a closed suctioning system. If not contraindicated, patients were placed in semi fowler position and procedure was explained to those who were conscious. The closed suction was attached to the circuit. Each suctioning episode was involved hyperoxygenation using inspired oxygen fraction of one, for two minutes before, during and after suctioning. ETS was performed using two different-size catheters: 14 French for 7.5, 8 mm endotracheal tubes and 16 French for 8.5 and 9 mm endortacheal tubes. During the closed suctioning procedure, patients remained connected to the ventilator, and the suction catheter was inserted into the endotracheal tube, via the Y-piece connector. Catheter advanced until resistant was encountered,[37] then withdrawn for 1-2 cm.[38] The duration of active suctioning was 10 second[39] during which the catheter was gently rotated and finally withdrawn. At the end of suctioning, the connector was closed and FIO2 was increased for two min. The catheter was then irrigated through the irrigation port with sterile normal saline while applying suction. After first round of suctioning, each patient was allowed to stabilize and the next suction episode was performed two hours later,[40] using the other suction pressure (group AB: 100-200 mmHg, group BA: 200-100 mmHg).

Age, gender, duration of ICU stay, diagnosis, and ventilator mode were recorded as baseline variables. $SpO_2$ and heart rate were recorded before and at one, three and twenty minutes after suctioning. Baseline $SpO_2$ was defined as the value at four minutes before endotracheal suctioning. Pulse oximetry probe was placed on the patient's middle finger in uncannulated hand. ECG, HR, and pulse oximetry were continuously monitored using standard ICU equipment.

Data were represented as mean (SD) or n (%) where applicable. Means of quantitative variables were compared between two levels of suction pressure using repeated measure analysis of variance with two factors, one for the level of suction pressure (two levels) and the other for different times at which the variable was measured (four levels). Other quantitative data were compared between two levels of suction pressure using paired sample Student *t*-test. Frequency data were compared between two levels of suction pressure using an appropriate Chi-square statistic. To test the balance of cross-over method, data were compared between two orders of applying suction pressure (AB versus BA). Marginal balance was used to represent the efficacy of minimization model for assigning subject to cross-over groups. All statistical tests were performed on a personal computer using SPSS version 16. $P < 0.05$ was considered as statistically significant. *P* values were reported with a precision of three decimal figures. If the exact *P* value was not known the relative expressions of $P < 0.05$, $P < 0.01$, etc., was used.

## Results

A total of 50 patients were studied. Twenty five subjects received 100 mmHg suction pressure as their first suction episode and 200 mmHg as the next (16 male and nine female), and 25 subject received the reverse order of suction pressures (16 male and nine female). Two groups of suction pressure orders were comparable with respect to demographic and basal physiologic variables [Table 1].

Repeated measure analysis of variance with one factor for the level of suction pressure and another for the repeated measurement didn't show any significant difference between two levels of pressure (100 and 200 mmHg), but within each group $SpO_2$ changes was significant compared to the basal values. Hyperoxygenation before and after suctioning transiently and significantly increased $SpO_2$ and returned to baseline value 20 minutes after the suctioning [Figure 1].

There was a mild but significant increase in heart rate following application of both 100 and 200 mmHg suction pressures, which returned to basal value after three minutes in 100 mmHg groups but remained elevated for three minutes in 200 mmHg group [Table 2].

## Discussion

The result of this study shows that in CSS with hyperoxygenation before, during and after the procedure, a suction pressure of 100 mmHg is comparable to 200 mmHg with respect to $SpO_2$ levels and HR changes. In both levels of suction pressure, an initial hyperoxia and mild tachycardia developed, due to the baseline values within approximately three minutes after termination of suctioning. Evidence for this is comparable means of SpO2 and HR for two levels of suction pressures. It seems that increasing the level of suction pressure to 200 mmHg has no detrimental effect on cardiorespiratory function of mechanically ventilated ICU patients. It seems that in CSS, suction pressure up to 200 mmHg is relatively safe and does not produce cardiorespiratory disturbances.

The fact that ventilatory support and high inspired oxygen concentration, continue during CSS, is the main cause of more cardiorespiratory stability in CSS compared with OSS. This has been approved by previous studies, which show the superiority of CSS versus OSS in terms of cardiorespiratory functions.[7,9,11,30] Sigismond *et al.*,[11] showed that during CSS hypoxia does not occur compared to frequent episodes of desaturation, observed with OSS. In the study by Fernandez *et al.*, in contrast to large decrease in lung volumes with OSS, they observed relative maintenance of lung volumes during CSS. In Demir's study the expected fall in $PaO_2$ and $SaO_2$ levels was not seen when closed suction was used even in the absence of hyperoxygenation. Nazmiyeh *et al.*, were able to demonstrate a rise in $PaO_2$ coupled with a decrease in arterial $CO_2$ tension using closed endotracheal suctioning.

It seems that provision of enough CPAP during CSS is necessary to prevent loss of lung volumes and subsequent desaturation as observed by Lindgren *et al*. Copnell *et al.*,

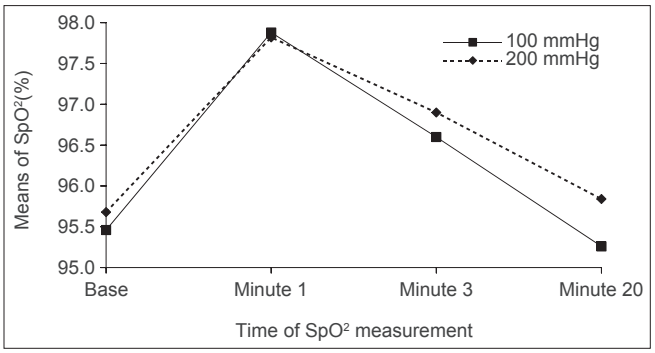


**Figure 1:** Trends of $SpO_2$ for two levels of suction pressure in different times

**Table 1: Comparing demographic and basal physiologic variables between two groups of suction pressure order**

| | AB group (100-200) | | BA group (200-100) | | *P* |
|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | |
| Age (year) | 52.96 | 19.8 | 52.68 | 18.5 | 0.95 |
| ICU stay (day) | 8.60 | 9.2 | 9.88 | 10.2 | 0.64 |
| Intubation (day) | 5.80 | 5.4 | 6.52 | 7.4 | 0.70 |
| | N % | | N % | | |
| Gender | | | | | |
| Male | 16 | 64 | 16 | 64 | 1.00 |
| Female | 9 | 36 | 9 | 36 | |
| Mode | | | | | |
| SIMV | 18 | 72 | 18 | 72 | 1.00 |
| CPAP | 7 | 28 | 7 | 28 | |
| Respiratory | | | | | |
| Yes | 3 | 12 | 2 | 8 | 0.64 |
| No | 22 | 88 | 23 | 92 | |

**Table 2: Comparing means of heart rate between two levels of suction pressure in different times**

| Time | 100 mmHg | | 200 mmHg | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Base | 93.48 | 15.3 | 94.42 | 15.5 |
| Minute 1 | 95.06 | 15.1* | 95.62 | 14.6* |
| Minute 3 | 93.66 | 15.5 | 95.42 | 15.6* |
| Minute 20 | 92.38 | 16.1 | 92.70 | 15.9 |

No significant differences between two groups,* *P*=0.000 compared to the base values

failed to demonstrate the beneficial effect of CSS on cardiorespiratory functions during TBS in neonatal piglets using ordinary suction catheters used in clinic for adults patients, which signifies the importance of suction catheter diameter relative to the size of tracheal tube, as indicated by Van Veenendaal *et al*.[41]

Continuation of ventilatory support during CSS seems to be the main cause of lower effectiveness of ETS observed with CSS compared to OSS. In fact the positive pressure resulted from ventilatory support counteracts the negative pressure produced by the suction apparatus and the precise result would be less effective suctioning of respiratory secretion[11,42] Sigismond *et al*., showed that suction pressure of more than 150 mmHg is necessary to enhance the efficacy of CSS in removing respiratory secretions, although these findings were not supported in animal studies (Lindgren *et al*), which is attributable to differences between small animals and clinical patients in size of respiratory tract relative to catheter diameter.

Since CSS does not preclude disconnection of the patient from the ventilator, the loss of lung volume resulting from endotracheal suctioning is significantly lower compared with OSS. Loss of lung volume is one of the most important factors for endotracheal suctioning induced hypoxemia. Majority of studies comparing CSS with OSS, report that in optimal situation, such as suitable catheter size, and hyperoxygenation, suctioning induced hypoxemia will not occur in CSS. We can enhance CSS efficacy with increasing the suction pressure without gas exchange impairment, with the catheter size less than half of the ETT internal diameter. Based on $SpO_2$ changes, our results demonstrate that CSS didn't induce significant deleterious changes in gas exchange during the procedure itself, as shown in our study.

Since the effectiveness of tracheal suctioning is directly proportional to the applying negative pressure and owing to the relative safety of higher suction pressure for CSS, as shown in this study, we can safely recommend a suction pressure of 200 mmHg for using with CSS in mechanically intubated ICU patients. Further increases in suction pressure may not be safe and necessary; although further clinical investigations seem necessary to evaluate the advantages and disadvantages of higher suction pressures.

The result of this study may not generalize to ICU patients who require excessive ventilatory support. Further trials are needed to reliably conclude the relative safety and efficacy of CSS in ICU patients in need of heavy ventilatory supports.

In conclusion, the result of this study shows the safety of 200 mmHg suction pressure for using during closed suction procedures in mechanically ventilated adult ICU patients. It is recommended that future clinical trials of CSS take into account other more important outcomes, such as duration of mechanical ventilation and ICU/hospital stay, and final mortality of patients. In addition it seems logical to have a preview of relative cost/benefit of CSS compared with OSS.

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