

Effects of thoracic squeezing on airway secretion removal in mechanically ventilated patients

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ABSTRACT

Background: Accumulation of secretions in the airways of patients with an endotracheal tube and mechanical ventilation will have serious consequences. One of the most common methods of airway clearance is endotracheal suctioning. In order to facilitate discharge of airway secretion resulting in promotion of gas exchange, chest physiotherapy techniques can be used at the time of expiration before suction.

Materials and Methods: In this clinical trial with a cross-over design, 50 mechanically ventilated patients admitted to intensive care units (ICUs) were randomly divided into two groups of thoracic squeezing. In each patient, two interventions of endotracheal suctioning were conducted, one with and the other without thoracic squeezing during exhalation, with a 3 h gap between the two interventions and an elapse of three respiratory cycles between the number of compressions. Sputum secreted was collected in a container connected to a suction catheter and weighed. Data were recorded in data gathering forms and analyzed using descriptive and inferential statistics (Wilcoxon and independent *t*-test, Chi-square) in SPSS version 16.

Results: Findings showed that the mean weight of the suction secretions removed from airway without thoracic squeezing was 1.35 g and that of suction secretions removed by thoracic squeezing was 1.94 g. Wilcoxon test showed a significant difference regarding the rate of secretion between the two techniques ($P = 0.003$).

Conclusions: According to the study findings, endotracheal suction with thoracic squeezing on expiration helps airway secretion discharge more than suction alone in patients on mechanical ventilators and can be used as an effective method.

Key words: Endotracheal suctioning, intensive care unit, intubation, Iran, mechanical, mechanical ventilation, secretion removal, thoracic squeezing, thorax, ventilators

INTRODUCTION

The respiratory system is a vital system. The most important function of the respiratory system is gas exchange, which is possible when the airway is

open.^[1] In the case of respiratory disorders and problems, artificial airways are widely used to save the lives of the patients.^[2] Endotracheal intubation is a reliable method and a standard care for keeping the airway open,^[3] which stimulates the goblet cells in the respiratory mucosa leading to increased mucus secretion,^[4,5] damage to the respiratory cilia, and weakening of the cough reflex.^[6-8] Finally, with the accumulation of secretions in the airways and bronchial obstruction, ventilation of the more terminal airways is disturbed.^[7] Endotracheal intubation disturbs the glottic closure reflex; as a result, oropharyngeal secretions continuously enter the airways which act as a gateway for introducing pathogens to the lungs, making them susceptible to infection.^[4]

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One of the important goals in the care of the mechanically ventilated patients is to prevent airway obstruction and keeping it open,^[1] which is achieved through sufficient systemic fluid therapy, airway suctioning, patient position change, high moist oxygenation, encouraging cough, manual hyperinflation, and respiratory physiotherapy.^[9] The most effective of the aforementioned is tracheal suctioning that can be performed in the intensive care unit (ICU).^[5] According to the available literature, mechanically ventilated patients may require suctioning 3–24 times per 24 h.^[10] However, this necessary procedure may cause serious complications like hypoxemia, bronchospasm, increased intracranial pressure (ICP), airway trauma, and dysrhythmia,^[9] resulting in colonization of the airways with gram-negative bacteria and a 3.5-fold increase in ventilator-associated pneumonia (VAP),^[11] which all mandate long-term monitoring.^[12] There have always been debates on how to perform suctioning and the factors that make it more effective.^[1,5] Chest physiotherapy before suctioning makes tracheal suctioning more effective.^[1] One of the effective physiotherapy methods is the squeezing technique or manually assisted coughing, which includes manual compression of the thorax during expiration and leaving it at the end of expiration to help the movement of pulmonary secretions, facilitate active inhalation, and enhance alveolar ventilation.^[1,5,13,14] This method stimulates the normal cough mechanism through elevation of intrathoracic pressure.^[4] This technique is exclusively used for the thorax, and the hands are placed on the lower one-third of the thorax.^[15] This technique, which does not require any special equipment,^[1] increases the forced expiratory volume (FEV) by 30%.^[1,5] Based on the available literature, expiratory peak flow should be 10% more than inspiratory peak flow to move the secretions toward the oropharynx.^[6] Research has shown that this technique effectively prevents pulmonary collapse in mechanically ventilated patients and is associated with less risk when compared with pulmonary percussion and vibration^[1] and, therefore, is a safe method.^[1,5] It is also less costly and less invasive than bronchoscopy for the removal of secretions. This method does not require high airway pressure; as a result, it decreases the risk of alveolocapillary barrier disruption or barotrauma. Moreover, it is not necessary to disconnect the patient from the ventilating machine during the maneuver, which decreases the episodes of hypoxemia and the use of high fraction of inspired oxygen (FIO₂).^[16] A study showed that this technique had no side effects after being applied for 3 years in some patients.^[5] This maneuver can be even used immediately after the surgery.^[15]

Few studies have evaluated the effect of thoracic squeezing technique during expiration on the effectiveness of

suctioning and have reported contradicting results.^[5,8,13,17] According to the studies of Unoki *et al.*^[13] in Japan on 31 patients connected to the ventilator and Genc *et al.*^[18] on 22 patients connected to the ventilator, thoracic squeezing prior to tracheal suctioning had no effect on the removal of airway secretions, while the results of the studies by Kohan *et al.*^[1] in Tehran on 70 patients connected to the ventilator and Avena Kde *et al.*^[15] in Brazil on 16 patients connected to the ventilator showed that the technique effectively increased expiratory flow and removal of the airway secretions and improved arterial blood gases.^[1] Considering the limited number of studies on the effect of thoracic squeezing on the effectiveness of suctioning and the contradicting results of the few conducted studies, we decided to conduct this study to determine the effect of thoracic squeezing on the amount of the removal of the secretions in mechanically ventilated patients hospitalized in the ICU ward of the selected teaching hospital. Considering the limited number of studies on the effect of thoracic squeezing on suctioning effectiveness and the contradicting results reported in these studies, the present study aimed at investigating the effect of thoracic squeezing on the amount of the removal of the secretions in mechanically ventilated patients hospitalized in two ICU wards (general and neurology) of the selected teaching hospital.

In this study, we hypothesized that thoracic squeezing advances suctioning effectiveness and the amount of secretion removed.

MATERIALS AND METHODS

This cross-over clinical trial registered in IRCT2012111911538N1 was performed on patients hospitalized in the ICU ward of a referral hospital and trauma center in Rasht, Guilan, north of Iran, between January and May 2013. With regards to Kohan's study using an error of 5% and a power of 80%, the sample volume was calculated as 55 individuals for comparison between the two groups.^[1] Of 514 patients hospitalized during the study period, 55 patients who met the inclusion criteria were recruited. Inclusion criteria were age between 18 and 65 years; having tracheal intubation; being connected to the mechanical ventilator with the volume mode for at least 48 h; stable hemodynamic status [mean arterial pressure (MAP) between 60 and 110 mmHg, heart rate less than 110 bpm, and pulse oximetry oxygen saturation (SPO₂) more than 90% if the inspiratory oxygen percentage of ventilator was less than 60%]; lack of chest tube, thorax injury and surgery, rib fracture, pneumothorax, embolus, subcutaneous emphysema, metastatic cancer, burn, skin graft and reconstructive surgery in the thorax; lack of spinal fusions, pregnancy, obesity, cardiac pacemaker,

severe scoliosis and unstable thorax, lung abscess and cyst; confirmation of the lung radiograph for infiltration and atelectasia by an anesthesiologist unaware of the study; no history of pulmonary diseases based on the patient's file; and a score of -4 or -5 based on the Richmond's criteria. [The Richmond Agitation and Sedation Scale (RASS) is a validated and reliable scale used to measure the agitation or sedation level of a patient. It is mostly used in mechanically ventilated patients in order to avoid over and under sedation. Mechanically ventilated patients who are deeply sedated (RASS of -3 or less) have been shown to remain intubated and mechanically ventilated for longer periods of time. Similarly, mechanically ventilated patients who are too agitated are at risk of self-extubation and of ventilator dyssynchrony.] Exclusion criteria were consumption of mucolytics (bromhexine and *N*-acetylcysteine) and neuromuscular blocking drugs; onset, termination, or change of bronchodilating agents during the study; change in the setting of the ventilating machine during the study; receiving endotracheal suctioning within an hour of the study; closed suctioning system; severe bronchospasm; raised ICP diagnosed by the physician; and fragile vasculature (petechiae, purpura, and ecchymoses).

After obtaining the consent of the participants, all ICU patients were evaluated for the presence of inclusion criteria. Since the participants were in different stages of coma, consent was obtained from their guardians. The participants were randomly divided into two groups of A and B. Patients in group A were suctioned without thoracic squeezing during expiration followed by suctioning with thoracic compression during expiration after 3 h. Patients in group B were suctioned with thoracic squeezing during expiration followed by suctioning without thoracic squeezing during expiration after 3 h.

Each mechanically ventilated patient using the synchronized intermittent mandatory ventilation (SIMV) mode in a random sequence received both procedures of suctioning with and without thoracic squeezing during expiration. The two procedures were done on the same day with an interval of 3 h.

Thoracic squeezing was performed if the patients had not received tracheal suctioning, bronchodilators, and food and drug gavage within the past hour. Before performing the maneuver, the researcher in charge of data collection learned the procedure of thoracic squeezing practically in a short-term educational course. To determine the amount of pressure on the thorax, the researcher observed three to five respirations and adjusted the amount of pressure that was applied during expiration accordingly (in all respirations,

whether mechanically assisted or spontaneous) using the hands unilaterally on the lower one-third of the thorax (anteriorly and posteriorly), proportionate to the patient's body to increase the expiratory tidal volume by 30% (as shown on the monitor). The pressure was removed at the end of each expiration to allow free inspiration. This technique was performed 10 times with an interval of three respiratory cycles after every compression for each research unit.^[15] The patients were positioned based on the pulmonary radiologic findings (atelectasia or infiltration) by an anesthesiologist, who was unaware of the study, before the intervention in such a way that the most involved part of the lung (the part with atelectasia or infiltration) was positioned higher.^[1] All patients received oxygen 100% on the ventilator for 1 min before and after suctioning to prevent hypoxia.

Airway suctioning was performed twice with an interval of 3 h on the same day for 10 s for each patient (as required) using a Nelaton catheter that is half the size of the endotracheal tube, with a vacuum pressure of 80–120 mmHg applied using an open suction system by central suction in the general ICU ward and with a portable suctioning machine in the neurology ICU ward. The secretions were collected in a container connected to the catheter and weighed by a scale. A researcher who was blind to randomization and the type of intervention helped to weigh and document the weight of the secretions.

A two-part form was used for data collection. The first part included personal and respiratory information such as age, gender, duration of receiving mechanical ventilation, ventilator mode, pressure support (PS), peak inspiratory pressure (PIP), positive end expiratory pressure (PEEP), disease diagnosis, and size of the endotracheal tube that was collected by the researcher. The second part included a table in which the weight of the secretions with and without compression was registered. The MH-Series QC PASS Scale (Aosai, ATP168 with a precision of 0.01 gr, China) with a precision of 0.01 g was used for weight measurement and all suctioning machines and weights were calibrated before use.

Ethical considerations

The study was approved by the Ethics Committee of Guilan University of Medical Sciences. As all the study participants had impaired levels of consciousness, the aim and process of the study were explained to their immediate relatives. They were assured of the confidentiality of their own and their patients' personal information. They were also assured to be completely free whether to participate in, decline participation, or leave the study. We also guaranteed that rejecting participation or withdrawing

from the study would never affect the course of treatment. Finally, written informed consent forms were obtained from them.

Analysis of data

SPSS version 16.00 was employed for data analysis using descriptive (frequency, percentage, mean, and standard deviation) and inferential statistics, Chi-square, Wilcoxon test, independent *t*-test, and Pearson's correlation coefficient.

RESULTS

We excluded two patients as they required suctioning, two patients due to change in the ventilator mode in less than 3 h, and one patient for dysrhythmia. In the end, statistical analysis was performed on the results of 50 patients. Both groups were matched for age, sex, diagnosis, PEEP, PS, and size of endotracheal tube, and only the duration of mechanical ventilation did not have a similar distribution between the groups ($P = 0.033$).

The mean weight of the removed secretions with thoracic squeezing was significantly more than that of the secretions removed without squeezing (Wilcoxon test, $P = 0.003$) Figure 1.

Evaluation of the effect of sex and disease diagnosis on the amount of secretion removal showed a significant difference in the weight of the removed secretions with and without compression only in patients with cerebral problems (independent *t*-test, $P = 0.04$) [Table 1].

Upon evaluation of the effect of quantitative variables on the amount of removed secretions, a reverse weak correlation was found between the amount of removed

secretions with PEEP ($P = 0.021$) in the compression procedure and PIP at 5 ($P = 0.016$) and 25 ($P = 0.021$) min in the non-compression procedure (Pearson's correlation coefficient) [Table 2].

DISCUSSION

The findings showed that the removed secretions weighed more in the procedure of suctioning with thoracic squeezing when compared with suctioning without squeezing. Performing this technique during expiration increases the removal of the airway secretions through increasing the expiratory flow.^[19] According to MacLean *et al.*, thoracic squeezing during expiration affects expiratory peak flow in such a way that it increases expiratory peak flow from 73.3 l/min to 109 l/min in patients with endotracheal intubation, which facilitates the removal of the secretions and results in better ventilation.^[20] The results of a study by Uzawa *et al.* also showed that the technique of thoracic squeezing increased the expiratory peak flow in intubated

Table 1: Evaluation of amount of removed secretions based on the qualitative variables in the compression and non-compression procedures

Variable	Mean (SD)		P value
	With compression	Without compression	
Sex			
Female	1.58 (1.46)	1.04 (0.74)	0.08
Male	2.25 (1.75)	1.61 (2.09)	0.10
Disease diagnosis			
Cerebral	2.06 (1.64)	1.38 (1.64)	0.04
Internal	1.65 (1.68)	1.28 (1.64)	0.21

SD: Standard deviation

Table 2: Pearson's correlation coefficients of quantitative variables with the amount of removed secretions in the compression and non-compression procedures in all patients

Variable	With compression		Without compression	
	P value	R	P value	R
Age (years)	0.296	0.151	0.884	0.021
Size of the endotracheal tube (mm)	0.115	0.226	0.624	0.071
Duration of hospitalization (days)	0.216	-0.178	0.364	-0.131
PEEP (cmH ₂ O)	0.021	-0.326	0.175	-0.195
PS (cmH ₂ O)	0.554	0.086	0.949	0.009
PIP (cmH ₂ O)				
1 min before	0.625	-0.710	0.398	-0.122
5 min after	0.765	-0.043	0.016	-0.340
25 min after	0.642	-0.067	0.021	-0.326

PEEP: Positive end expiratory pressure, PS: Pressure support, PIP: Peak inspiratory pressure

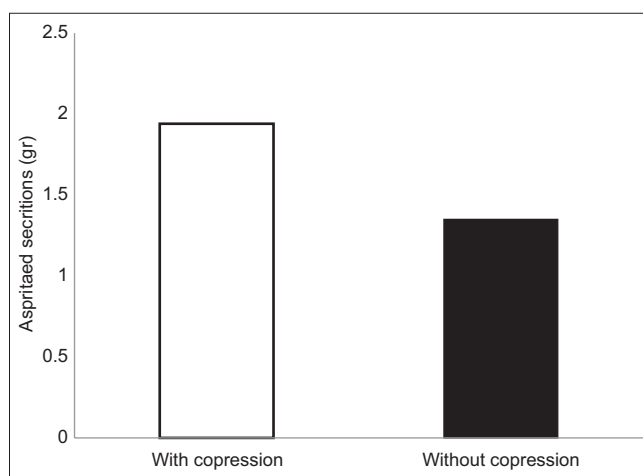


Figure 1: The mean weight of the removed secretions (g) in the compression and non-compression procedures

patients. This study also revealed the benefits of this technique in removing airway secretions in patients without voluntary cough.^[21]

In a study on the effects of thoracic squeezing before endotracheal suctioning on airway secretion removal in mechanically ventilated patients, Kohan *et al.* showed that thoracic squeezing increased expiratory peak flow in intubated patients,^[1] resulting in the disruption of glycoprotein molecules, reduced mucus viscosity, and increasing the movement of the secretions.^[8] However, the results of studies by Unoki *et al.*,^[13] Genc *et al.*,^[18] and Guimarães *et al.*^[21] to evaluate the effect of thoracic squeezing during expiration on oxygenation, ventilation, and removal of the airway secretions in mechanically ventilated patients showed that the technique did not increase removal of the secretions in these patients.^[13,18,19] The difference in the results may be due to the difference in the pressure applied on the thorax. Kohan *et al.* quoted from Watts that in the thoracic squeezing technique, it is important to increase the FEV by about 30% to stimulate the cough reflex and increase removal of the secretions.^[1] We also achieved a pressure of 30% in our study.

Our findings on expiratory peak volume showed that significantly more secretions were removed upon thoracic squeezing in patients with brain problems in comparison with that in patients with internal problems. The reason for this finding may be that most people who are hospitalized for internal disease in special wards have many physical problems and are older than patients with brain problems and, therefore, have more co-morbidities that could affect the outcome of the technique. In 2012, Silva *et al.* reported that the thoracic squeezing technique in chronic obstructive pulmonary disease (COPD) patients resulted in a decrease of expiratory peak flow and collapse of the smaller airways,^[8] while patients with brain problems and incidents are often younger and are hospitalized due to trauma, and therefore, the technique could facilitate the removal of the secretions.

Our findings showed a significant reverse correlation between PEEP in the compression procedure and the amount of the removed secretions in such a way that with an increase in PEEP upon suctioning with compression, the volume of the removed secretions decreased. PEEP moves bronchial secretions through improving pulmonary compliance, expiratory peak pressure, and arterial oxygenation.^[9] However, in a study conducted in Brazil on “expiratory peak flow and respiratory system resistance in mechanically ventilated patients,” Silva *et al.* showed that the role of PEEP in increasing the volume of removed secretions was not clear.^[8] Moreover, Dasenbrook

et al. reported that increasing PEEP, besides having advantages like increasing expiratory peak flow, could result in damages like pulmonary damage due to excessive expansion, multiple organ failure, and ventilator-related damage.^[22] Similarly, Babik *et al.* believe that increasing PEEP decreases the cardiac output and, therefore, weakens the dynamic respiratory compliance, changes the elastic recoil of the lungs and respiratory system, and increases airway resistance.^[23,24] Nonetheless, it seems that the effect of PEEP on the removal of secretions is still unclear and further studies with larger sample volumes are required in this regard.

In addition, the findings regarding the relationship of PIP and the amount of the removed secretions showed a significant reverse correlation between PIP at 5 and 25 min in the non-compression procedure and the amount of removed secretions. In fact, it could be stated that the volume of the removed secretions decreases with increase in the PIP in the non-compression procedure. According to the conducted studies, the pulmonary resistance increases following increasing the PIP, hindering the removal of the secretions.^[15] Therefore, it is not unexpected to observe a decrease in the removal of secretions following an increase in the PIP.

Limitations

This study evaluated the short-term effects of the thoracic squeezing technique. We suggest that a study should be conducted to assess the long-term effects of the technique, including the duration of receiving mechanical ventilation and duration of ICU hospitalization. Moreover, we suggest that hemodynamic indices (heart rate, respiratory rate, and blood pressure), dynamic and static compliance, peak inspiratory pressure and plateau pressure, and respiratory volumes and capacities (PIP and expiratory peak pressure) should be investigated in future studies. Since the present study was conducted on 50 patients and the technique was only applied once, it is suggested to perform future studies on a higher number of participants by using the technique more than once along with arterial blood gas analysis and chest X-ray after thoracic squeezing and comparison should be made of the results before and after the technique with no control group and no treatment for atelectasia, in order to use it as a guideline for proper application of this technique in special wards.

CONCLUSION

The results of this study showed suctioning with thoracic squeezing during expiration increased airway secretion removal significantly. This finding can help in choosing the best technique for removing secretion from airway in mechanically ventilated patients. This finding can be of

use for future researches about various effective airway suctioning techniques too.

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Conflicts of interest

There are no conflicts of interest.

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