



Acute Effects of Manual Lung Hyperinflation on Critically Ill Patients with Traumatic Brain Injury

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Abstract: Background: Most of hospitalized patients with TBI are admitted to ICU. Respiratory physiotherapy is important in mechanically ventilated and intubated patients in ICU including patients with TBI. Manual hyperinflation is one of chest physical therapy procedures that frequently used in management of a mechanically ventilated patient. **Purpose:** The purpose of this study was to determine the acute effects of Manual Hyperinflation technique on mechanically ventilated TBI patients. **Subjects and Methods:** Forty mechanically ventilated men patients with TBI had admitted to the national bank hospital-specialized medical centers ICU were randomly divided into two groups equal in number. All subjects in both groups were assessed through ABG analysis before and 15 min after treatment. Group A treated with traditional chest physical therapy program which include vibro-compression maneuver, positioning, vibration, percussion, and endotracheal suctioning. Group B treated with manual lung hyperinflation maneuver and traditional chest physical therapy program. **Results:** There was significant decrease in the PaCO₂ post treatment in compare to pretreatment of both groups. In comparison between groups there was a significant decrease in the PaCO₂ of group B compared with that of group A post treatment (p = 0.03). PaO₂ and SaO₂ there were significant increase post treatment in compare to pretreatment of both groups. In comparison between groups there was a significant increase in (PaO₂, SaO₂) of group B compared with that of group A post treatment (p = 0.02, p = 0.002) respectively. There was no significant change for other variables. **Conclusion:** Manual hyperinflation technique has significantly greater effect on increasing (PaO₂, SaO₂) and decreasing PaCO₂ in mechanically ventilated TBI patients.

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1. Introduction

Effort of inspiration increases in patients admitted to ICU with TBI and chest trauma such as rib fractures and pulmonary contusions. Also, maximal cough strength and lung volume decreases that leads to atelectasis. Increased immobility period and the medications prescribed due to trauma and sedation depress the respiratory functions and delay the recovery of lung function. So, the risk of pulmonary complications after trauma is high (Nyland et al., 2016).

Mechanical ventilation is commonly used in ICU to control hypoventilation in critically ill patients, MV and pulmonary secretion retention are major risk factors associated with prolonged ICU stay and may increase morbidity and mortality. Chest physiotherapy can improve secretion clearance and prevent pulmonary complications (Berti et al., 2012; Ambrosino and Clini, 2004).

Ventilator associated pneumonia (VAP) is a side effect of MV and is defined as hospital-acquired pneumonia develops in intubated patients who are receiving mechanical ventilation for at least 72 h. VAP is associated with increased mortality and length of stay in the (ICU) in critically ill patients (Wang et al., 2016).

The accumulation of secretions leads to increase in airway resistance and partial or total airway obstruction may happen, resulting in alveolar hypoventilation, hypoxemia, atelectasis, and increased work of breathing. Also, creating suitable environment for the proliferation of bacteria and development of pneumonia. All these changes prolong the weaning time from mechanical ventilation and make patient prognosis worsen (Oliveira et al., 2019).

Pulmonary atelectasis due to progressive alveolar collapse during mechanical ventilation is the

major cause of the decrease in lung compliance and the partial pressure of arterial oxygen (PaO₂). Atelectasis that occurs in the most dependent parts of the lung of 90% of patients, plays an important role in gas exchange abnormalities and reduced static compliance associated with acute lung injury. Also, general anesthesia and sedations are associated with impaired oxygenation even in patients with previously normal lungs (**Duggan et al., 2005**).

Pulmonary rehabilitation in the ICU could be divided into modalities aiming to remove retained airway secretions and exercise therapies aiming to improve respiratory function. To perform mobilization, pre-treatment by removing secretions is necessary in mechanically ventilated patients. So that, pulmonary rehabilitation is important in addition to physical therapy (**Schaller et al., 2016**).

There are several techniques used by ICU physiotherapists, the most common are: Postural drainage, Mobilization, Vibration, Percussion, Manual Hyperinflation (MHI), Suction and Breathing exercises. These techniques are usually combined. Physiotherapist should focus on the patient's condition to avoid lung complications (**Cerqueira-Neto et al., 2010**).

Hyperinflation initiate the movements of coughing and move the secretions toward the upper airways. It can be done with the ventilator or manually. It is used to re-expand collapsed alveoli and prevent atelectasis, improve oxygenation, increase lung compliance, and distensibility, encourage movement of airway secretions and facilitate weaning (**Goñi et al., 2018**).

This maneuver aiming to mobilize secretions from smaller airways toward the trachea and it can be removed with airway suction or voluntary cough. It is also applied to open collapsed lung units not associated with airway secretion obstruction. There is no significant difference between manual hyperinflation and ventilator hyperinflation on the amount of secretions recovered, respiratory compliance, or oxygenation. (**Tucci et al., 2019**).

2. Subjects and Methods

This study was carried out on Forty men patients with traumatic brain injury were receiving mechanical ventilation and who were admitted to **national bank hospital-specialized medical centers** intensive care unit and randomly distributed into two equal groups. This study was conducted from August 2019 to December 2020.

Inclusion criteria:

- 1- Mechanically ventilated male patients with TBI (with stable haemodynamics and respiratory parameters).
- 2- Their age ranged from 40 to 60 years.
- 3- Glasgow coma scale < 8.
- 4- Adequately sedated and the ability to cough is inhibited.

Exclusion criteria:

- 1- Acute respiratory distress syndrome. (ARDS)
- 2- Patients with fulminant pulmonary edema.
- 3- Presence of Pneumothorax or a history of pneumothorax.
- 4- Unstable cardiovascular status. (defined as systolic blood pressure < 100 mmHg or > 180 mmHg, mean arterial pressure < 70 mmHg or > 110 mmHg, or HR < 70 bpm or > 120 bpm)
- 5- Raised intracranial pressure, or the potential to develop pathologically raised intracranial pressure.

Design of the study:

In this study the patients were randomly assigned to two equal groups in number (20 patients for each group)

Group A: (control group). The group who received only traditional chest physical therapy program:

- Vibrocompression maneuver. (manual chest compression–vibrations to airflow)
- Positioning / vibration / percussion.
- Endotracheal suctioning.

The physiotherapeutic maneuvers were subsequently applied for 20 minutes (10 minutes for each hemithorax).

Group B: (experimental group). The group who received manual lung hyperinflation maneuver and traditional chest physical therapy program.

Methods

A) Evaluation methods:

1. Arterial blood gases analysis. (ABG): a sample of blood was used to assess the level of (pH, PaO₂, SaO₂, PaCO₂ and HCO₃) through -cobas b 121 (ROCHE-OMINIC-9528)- blood gases analyzer for both groups A&B before and after treatment.

B) Treatment methods:

Group A :(control group)

Each patient was placed into a dorsal decubitus position, with head elevated at 30°.

The traditional physiotherapeutic maneuvers of:

1- Vibrocompression maneuver. (manual chest compression–vibrations to airflow)

It aimed to increase expiratory air flow by rapidly compressing the patient's chest at the beginning of expiration with oscillatory pressure until expiration is complete. Thus, improving central flow

of secretions, the mucus moved into the larger airways for removal by suction.

2- Positioning / vibration / percussion.

Percussion with cupped hands or the palm cup was used. Secretions shifted from the peripheral airway to the central airway and airway clearance improved. Vibrations performed manually and by mechanical devices.

3- Endotracheal suctioning

Open tracheal suctioning system was used, and 5 mL of isotonic saline was instilled then aspirations (suctioning) performed at a negative pressure of 200 cm H₂O for 20 secs, during which the catheter was gently rotated and withdrawn.

Group B: (experimental group)

Same treatment as group (A) plus **Manual Lung Hyperinflation Maneuver.**

Patient placed into a dorsal decubitus position, with head elevated at 30°. By using a manual resuscitator bag - connected to an O₂ source –five hyperinflations applied: three-second pause at the end of inspiration followed by a quick release as soon as the expiratory phase started. Patients were disconnected from the ventilator so; the bag was

connected to a flow of 100% oxygen at 15 L/min. Tracheal suctioning then applied for 20 secs.

Statistical analysis

Descriptive statistics and unpaired t-test were conducted for comparison of subject characteristics between both groups. Normal distribution of data was checked using the Shapiro-Wilk test. Levene's test for homogeneity of variances was conducted to ensure the homogeneity between groups. Unpaired t-test was conducted to compare the mean values of pH, PaCO₂, PaO₂, HCO₃ and SaO₂ between group A and B. Paired t-test was conducted for comparison between pre and post treatment in each group. The level of significance for all statistical tests was set at $p < 0.05$. All statistical analysis was conducted through the statistical package for social studies (SPSS) version 25 for windows (IBM SPSS, Chicago, IL, USA).

3. Results

Subject characteristics:

Forty male patients participated in this study. Table (1) showed the subject characteristics of the group A and B. There was no significant difference between both groups in the mean age and GCS ($p > 0.05$).

Table (1): Comparison of subject characteristics between group A and B:

	Group A	Group B	MD	t- value	P-value
	Mean ± SD	Mean ± SD			
Age (years)	50.5 ± 4.81	51.5 ± 4.87	-1	-0.65	0.51
GCS	6.45 ± 1.5	6.3 ± 1.8	0.15	0.28	0.77

SD, Standard deviation; MD, Mean difference; p value, Probability value

Effect of treatment on pH, PaCO₂, PaO₂, HCO₃ and SaO₂:

Within group comparison:

There was a significant decrease in PaCO₂ and a significant increase in PaO₂ and SaO₂ in the group A and B post treatment compared with that pretreatment ($p < 0.0001$). The percent of change of PaCO₂, PaO₂ and SaO₂ in group A was 3.23, 3.01 and 2.42% respectively and that in group B was 9.78, 8.24 and 4.95% respectively. There was no significant change in pH and HCO₃ between pre and post treatment in both groups ($p > 0.05$).

Between groups comparison:

There was no significant difference in all variables between groups pre-treatment ($p > 0.05$). Comparison between groups post treatment revealed a significant decrease in PaCO₂ and a significant increase in PaO₂ and SaO₂ of the group B compared with that of the group A ($p < 0.05$) while there was no significant difference in pH and HCO₃ between groups post treatment ($p > 0.05$).

Table (2): Mean pH, PaCO₂, PaO₂, HCO₃ and SaO₂ pre and post treatment of the group A and B:

	Pre	Post	MD	% of change	p value
	Mean ± SD	Mean ± SD			
pH					
Group A	7.362 ± 0.073	7.364 ± 0.06	-0.002	0.027	0.56
Group B	7.345 ± 0.092	7.349 ± 0.086	-0.004	0.054	0.24
MD	0.017	0.015			
	p = 0.53	p = 0.52			
PaCO₂ (mmHg)					
Group A	41.44 ± 3.81	40.1 ± 3.68	1.34	3.23	0.0001
Group B	41.51 ± 4.85	37.45 ± 4.15	4.06	9.78	0.0001
MD	-0.07	2.65			
	p = 0.96	p = 0.03			
PaO₂ (mmHg)					
Group A	86.3 ± 8.92	88.9 ± 8.15	-2.6	3.01	0.0001
Group B	86.75 ± 9.27	93.9 ± 5.25	-7.15	8.24	0.0001
MD	-0.45	-5			
	p = 0.87	p = 0.02			
HCO₃ (meq/L)					
Group A	23.77 ± 2.74	23.91 ± 2.42	-0.14	0.58	0.38
Group B	22.61 ± 3.78	22.62 ± 3.71	-0.01	0.04	0.93
MD	1.16	1.29			
	p = 0.27	p = 0.2			
SaO₂ (%)					
Group A	93.05 ± 3.36	95.3 ± 2.53	-2.25	2.42	0.0001
Group B	92.95 ± 2.58	97.55 ± 1.66	-4.6	4.95	0.0001
MD	0.1	-2.25			
	p = 0.91	p = 0.002			

SD, Standard deviation; MD, Mean difference; p value, Probability value

4. Discussion

The purpose of this study was to find out the acute effects of manual lung hyperinflation on mechanically ventilated patients with TBI through measuring arterial blood gases analysis (pH, HCO₃, PaCO₂, PaO₂, SaO₂) pre and post treatment for both groups. Forty mechanically ventilated men patients with TBI were randomly divided into two groups equal in number. Group A treated with traditional chest physical therapy program which include vibro-compression maneuver, positioning, vibration, percussion and endotracheal suctioning for 20 minutes (10 minutes for each hemithorax). Group B treated with manual lung hyperinflation maneuver and traditional chest physical therapy program.

The result of this study was significant decrease in the PaCO₂ post treatment in compare to pretreatment of both groups. In comparison between groups there was a significant decrease in the PaCO₂ of group B compared with that of group A post treatment (p = 0.03). PaO₂ and SaO₂ there were significant increase post treatment in compare to pretreatment of both groups. In comparison between

groups there was a significant increase in (PaO₂, SaO₂) of group B compared with that of group A post treatment (p = 0.02, p = 0.002) respectively. There was no significant change for other variables.

Goñi et al. (2018) demonstrated that, association of postural drainage with vibration and percussion improves forced vital capacity, arterial oxygenation, exercise tolerance and other aspects according to Nici et al. (2006). And association of MHI together with suctioning for intubated patients promotes better alveolar recruitment, reduces resistance in the airway and improves lung compliance according to Choi and Jones. (2005) and Stiller (2013) that's support our study.

The improvement may be explained by the fact that manual hyperinflation might open collateral channels within the lungs, which could theoretically recruit atelectatic lung regions and facilitate secretion mobilization (Maa et al., 2005).

Study by Elgendy et al. (2020) reported significant increase in PaO₂ and SaO₂ and decrease in PaCO₂. There was no significant difference in PH and HCO₃. The study was conducted to analyze the

acute effect of chest physical therapy on arterial blood gases of mechanically ventilated patients.

There is another possibility for explaining our results. The volume of moving air in lungs increases when airways are clear from secretions. Also, collapsed alveoli open that resulting in promoting good oxygenation and carbon dioxide exchange (Wang et al., 2018).

Zaman (2016) through two studies into the efficiency of chest physiotherapy the aim of chest physiotherapy is minimizing pulmonary secretion retention, expanding atelectatic lung segments, and maximizing oxygenation. concluded that chest physiotherapy is very effective in intubated patients with acute lobar collapse.

Mohamed and Abdalmoniem. (2015) claimed that manual hyperinflation is a safe intervention that can be applied for mechanically ventilated critical ill patients, and it can help weaning from mechanical ventilator and decrease the time spent in intensive care unit also decrease morbidity. His study included significant improvement in the mean values of the three oxygenation parameters (PaO₂, SaO₂% and PaO₂/ FiO₂).

Malekzadeh et al. (2016) stated that, SpO₂ and PaO₂ increase evidence that hyperinflation maneuver able to re-open collapsed alveoli, increase ventilation to perfusion ratio and improving oxygenation while PaCO₂ decrease evidence that MHI technique could improve gas exchange and reduce PaCO₂ through improved ventilation.

Hodgson et al. (2000) had stated that total static respiratory system compliance and sputum clearance were improved by the addition of manual hyperinflation to a physiotherapy treatment in mechanically ventilated patients without compromise to gas exchange.

Unoki et al. (2005) used the same concept of treatment to see the effect of expiratory rib-cage compression on airway-secretion removal, oxygenation, and ventilation in mechanically ventilated patients but there was no significant effect.

The results of this present study were contradicted with Genc et al. (2011). No significant differences were seen in PaCO₂ and PaO₂ between pre- and post-interventions. The difference in results may be because the study sample was less than in our study and treatment time was less than our study. Also, patient position was different the author used side lying position, but we used supine lying with head elevated.

Conclusion

Manual hyperinflation technique has significantly greater effect on increasing (PaO₂,

SaO₂) and decreasing PaCO₂ in mechanically ventilated TBI patients.

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