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Effect of Modifying Mechanical Ventilator Trigger Sensitivity on Arterial Blood Gases in ICU Patients

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ABSTRACT

Background: Despite the fact that mechanical ventilation is an essential part in management of critically ill patients, mechanically ventilated patients have a higher risk of complications, which can lead to increased morbidity and mortality.

Objective: This study aimed to study the effect of training inspiratory muscle through modifying mechanical ventilator (MV) trigger sensitivity on arterial blood gases in mechanically ventilated patients.

Patients and Methods: Sixty adult patients diagnosed with acute respiratory failure, needed to be intubated and connected to mechanical ventilated. They were from both gender and their ages ranged from 50 to 70 years. The patient were chosen from Intensive Care Unit (ICU), Department of Chest Diseases, Cairo University Hospitals. They were randomly assigned into two equal groups. Group (A): included thirty patients who received training for inspiratory muscle through modifying MV trigger sensitivity plus usual physical therapy. Group (B): included thirty patients who received usual physical therapy only.

Results: The results showed a significant increase in partial arterial pressure (PaO_2) in both groups, this increasing was significantly higher in patients who received training for the inspiratory muscle plus the usual chest physical therapy than patients who only received usual chest physical therapy (P-value < 0.001). The results showed no significant change in neither power of hydrogen (pH) nor partial pressure of carbon dioxide ($PaCO_2$). **Conclusion:** Training to inspiratory muscles in mechanically ventilated patient through modifying mechanical ventilator trigger sensitivity can produce a significant increase in partial arterial pressure (PaO_2). Although it has no effect in pH nor $PaCO_2$.

Keywords: Arterial blood gases, Inspiratory muscle training, Intensive care unit, Mechanical Ventilation

INTRODUCTION

Intensive care unit (ICU), often known as critical care unit, is dedicated to the comprehensive management of patients with acute, life-threatening organ dysfunction or who are at risk of developing it. Intensive care employs a variety of technology to help failing organ systems, especially the lungs, cardiovascular system, and kidneys [(1)].

In intensive care units (ICU), mechanical ventilation (MV) is a very crucial medicine. It used clinically to preserve gas exchange in patients who need assistance in maintaining adequate alveolar ventilation. Although MV can be a life-saving intervention for patients suffering from respiratory failure, MV has been associated with both short- and long-term deleterious consequences [(2)]. In majority of cases, mechanical ventilation is used temporarily, lasting several hours, days, or weeks. The patients should weaned from mechanical ventilation as soon as they can breathe effectively on their own. However, some patients with permanent problems may need to be whole life mechanical ventilation dependent [(3)].

Physiotherapy has shown to be a crucial component in the management of ICU patients, with both short- and long-term advantages. Physiotherapy for the chest produces physiological changes such as changes in hemodynamic, respiratory, and intracranial parameters [(4)].

Most ICU patients are required to receive chest physiotherapy procedures such as manual chest manipulation, chest vibrations, chest percussions, manual hyperinflation, posture drainage and various coughing techniques in combination or individually to prevent pulmonary complications [(5)]. In mechanically ventilated patients, chest physical therapy applied aiming to improve airway clearance, thus helping to decrease work of breathing, promote the lungs expansion, and prevent complication [(6)].

Inspiratory muscle training (IMT) is a technique used to increase the strength and endurance of the diaphragm and other accessory inspiratory muscles [(7)]. Inspiratory muscle training applies a load to the diaphragm and accessory inspiratory muscles to increase their strength and endurance. Training to inspiratory muscle in the ICU have typically applied this load either via external devices that impose resistance or load to inspiratory muscles, or via modification of the mechanical ventilator trigger sensitivity so that patients can only initiate inspiratory flow by generating more negative intrathoracic pressure [(8)].

Arterial blood gas (ABG) analysis and continuous monitoring is a vital process in identifying and controlling high-risk patients. In arterial blood gases analysis, acid-base balance (pH), partial arterial oxygen

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pressure (PaO_2), and partial arterial carbon dioxide pressure ($PaCO_2$) are measured [9].

This study aimed to study the effect of training inspiratory muscle through modifying mechanical ventilator (MV) trigger sensitivity on arterial blood gases in mechanically ventilated patients.

PATIENTS AND METHODS

Sixty adult patients, between the ages of 50 and 70, were mechanically ventilated for more than 48 hours after being diagnosed with acute respiratory failure. They were from both gender. They were chosen from Intensive Care Unit, Department of Chest Diseases, Cairo University Hospitals. The research was carried out between August 2020 and July 2021.

Patients who met the following criteria were chosen to participate in this study: The patients were diagnosed with acute respiratory failure due to chronic obstructive pulmonary diseases (COPD) exacerbation and required mechanical ventilation for more than 48 hours. Their age were between 50 and 70. They were vitally stable. They were conscious and could respond to verbal command. All the patients can tolerate pressure support (PS) mode of MV with this setting (Positive end-expiratory pressure (PEEP)) less than 8 cm H_2O, FiO_2 0.4 or less, SpO_2 higher than 90).

The patient was ruled out of the study if met one of the following criteria: Poor attention and lack of cooperation, unstable neurological problems, unstable hemodynamics, and missing more than five sessions.

Ethical consideration:

For patients or their guardians, the potential dangers and advantages were completely explained. They signed a consent document. The confidentiality of the information was guaranteed. The work was approved by the Academic and Ethical Committees at Cairo University. This work has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for studies involving humans.

The participant were randomly assigned into two equal groups:

Group (A): Included 30 patients who received training to inspiratory muscle through modifying mechanical ventilator trigger sensitivity beside usual chest physical therapy.

The training to inspiratory muscle was performed as the following:

(1) Elevating the head of the bed to angle higher than 45 degrees. (2) Describing the technique to the patient. (3) Measure the maximal inspiratory pressure to the patient. "from lung mechanics in the MV itself". (4) Shifting the mode of MV to pressure support PS mode, then changing the trigger sensitivity to 40% of maximal inspiratory pressure measured for the patient [8, 9]. (5) Instruct the patient to inhale as maximally as he/she can after maximal expiration. (6) The training comprised of 4-5 sets, with each set asking the patient to take 6 to 10 breaths. As needed, the patient could take rest between sets; the mode of MV may be altered to the prior mode during the rest [9].

Group (B): Included 30 patients who received only the usual chest physical therapy.

The following techniques were used as a usual chest physical therapy depending on patient's requirements: (1) Postural drainage or modified postural drainage according to the patient's needs. (2) Percussion: applied with a "cupped-hand position" on the chest wall, applied for two and half minutes for every lung segment. Its frequency should be 3-7 beats per second. (3) Vibration: therive 717 mechanical vibrator was used. It was placed on the chest wall (anterior, lateral and posterior). If the patient had accumulation of secretion, technique was applied on affected segment for about 5 minutes. (4) Muscle training for upper and lower limbs: for 10 minutes[10].

The session was ended if the patient displayed any of the following symptoms:

(1) Increasing respiratory rate to higher than 35 breath/minute (2) Decreeing of saturation to less than 90. (3) Rising of heart rate to higher than 120 beat/minute. (4) Increasing in systolic blood pressure to higher than 180 mmHg or dropping to lower than 90 mmHg. (5) Paradoxical breathing.

Arterial blood gases (pH, PaO_2 and $PaCO_2$) were measured before the study and at end of the study "at time of weaning or after 10 days of training for failed weaning patients".

Statistical analysis

The collected data were coded, processed and analyzed using the SPSS (Statistical Package for the Social Sciences) version 25 for Windows® (IBM SPSS Inc, Chicago, IL, USA). Quantitative data were expressed as mean $\pm$ standard deviation and were compared by independent t-test when comparing the 2 groups or the paired t-test when comparing between pre and post-treatment in the same group. Qualitative data were expressed as number and percentage and were compared by Chi-squared test. P value < 0.05 was considered significant.

RESULTS

***Subject characteristics*:**

There was no significant variation in age or sex between both groups (Table 1).

Table (1): Age and gender characteristics of participants

Age	N	Mean	SD	Min	Max	Range
Group A	30	59.77	4.932	51	69	18
Group B	30	59.60	4.415	53	68	15
Total	60	59.68	4.641	51	69	18

			Gender		Total
			Male	Female	
Group	A	Count	20	10	30
		percentage %	66.7%	33.3%	100.0%
	B	Count	18	12	30
		percentage %	60.0%	40.0%	100.0%
Total		Count	38	22	60
		percentage %	63.3%	36.7%	100.0%

***Treatment effects*:**

1- pH:

There was no significant difference in pre- and post-treatment pH between both groups (Table 2).

Table (2): Descriptive statistic and independent samples test for pH

Groups		Mean	SD
Pre pH	A	7.380	0.033
	B	7.379	0.027
Post pH	A	7.378	0.016
	B	7.380	0.021

	Levene's Test		t-test		
	F	P	t	Mean difference	P (2-tailed)
Pre pH	1.013	0.318	0.170	0.001	0.866
Post pH	2.365	0.130	-0.473	-0.002	0.638

There was no significant difference between pre and post treatment in both groups as regard pH (Table 3).

Table (3): Paired sample t-test to compare pre and post treatment pH

Group	Mean difference	% of change	t	P (2-tailed)
A	0.002	0.03	0.35	0.72
B	0.001	0.01	-0.22	0.83

2- PaO_2:

There was no significant difference in pre-treatment PaO_2 between both groups. However there was a significant difference in post-treatment PaO_2 between the 2 groups (Table 4**).**

Table (4): Descriptive statistic and independent samples test for PaO_2

Groups		Mean	SD
Pre PaO_2	A	62.67	7.13
	B	62.60	5.88
Post PaO_2	A	75.00	9.13
	B	65.27	8.04

	Levene's Test		t-test		
	F	P	t	Mean difference	P (2-tailed)
PrePaO_2	2.089	0.154	0.040	0.067	0.696
postPaO_2	0.559	0.458	4.382	9.733	<0.001

In group A there was a significant difference between pre and post treatment regarding PaO_2, while in group B the difference was insignificant (Table 5).

Table (5): Paired sample t-test to compare pre and post treatment PaO_2

Group	Mean difference	% of change	t	P (2-tailed)
A	12.33	19.67	7.68	<0.001
B	2.67	4.27	1.74	0.092

3- PaCO2:

There was no significant difference in pre- and post-treatment $PaCO_2$ between both groups (Table 6).

Table (6): Descriptive statistic and independent samples test for $PaCO_2$

Groups			Mean		SD
Pre $PaCO_2$	A		38.97		4.38
	B		40.07		4.29
Post $PaCO_2$	A		39.77		2.81
	B		40.80		3.43
	Levene's Test		**t-test for Equality of Means**		
	F	**P**	**t**	Mean difference	P (2-tailed)
Pre $PaCO_2$	0.248	0.621	-0.983	-1.100	0.330
Post $PaCO_2$	1.133	0.291	-1.276	-1.033	0.207

There was no significant difference between pre and post treatment in both groups as regard $PaCO_2$ (Table 7).

Table (7): Paired ample t- test to compare pre and post treatment $PaCO_2$

Group	Mean difference	% of change	t	P (2-tailed)
A	0.80	2.05	0.86	0.39
B	0.73	1.82	0.77	0.45

DISCUSSION

Approximately 40% of patients who are admitted to intensive care unit (ICU) require mechanical ventilation at some stage of their treatment. Those patient who received mechanical ventilation support are at higher risk to develop chest infections, atelectasis, as well as sputum retentions, which make weaning from mechanical ventilation more difficult and result in higher morbidity and mortality rate [10].

The results of this study confirmed that in mechanically ventilated patients, training the inspiratory muscles through modifying mechanical ventilator trigger sensitivity in addition to usual chest physical therapy is more effective in increasing PaO_2 than only using usual chest physical therapy. The result also showed that, neither training to inspiratory muscle nor usual chest physical therapy has effect on pH or $PaCO_2$.

This result agreed with the result in a study by **Elbouhy *et al.*** [11] who studied the effect of training inspiratory muscles in mechanically ventilated COPD patients through adjusting mechanical ventilator trigger sensitivity. In their study they found that the training of inspiratory muscles is effective in increasing PaO_2, O_2 saturation, tidal volume TV and maximal inspiratory pressure (MIP). And also effective in decreasing respiratory rate (RR) and facilitate weaning form mechanical ventilation. Unfortunately they did not include neither pH nor $PaCO_2$ in their study.

Also the finding of this study coincided with result in study by **Ibrahiem *et al.*** [12]**.** Who studied the effect of respiratory muscle training on mechanically ventilated patients. In their study the training applied through an external device (Threshold inspiratory muscle training IMT device) and the result of their study showed a significant increase in oxygenation parameter (PaO_2, P/F ratio and oxygen saturation) on both study and control group but the increasing was significantly higher in study group, also their result showed a significant improving "increasing" in negative inspiratory pressure NIP.

This also coincide with **Abd El-Kader** [13] who have studied the effect of resistive respiratory muscle training on patients with complete spinal cord injury at the levels from C5 to C8. The training applied by using threshold positive expiratory pressure device. The training continued for six weeks. The result of their study showed a significant increase in PaO_2, also there were a significant increase "improve" in forced vital capacity (FVC), forced expiratory volume in the first second (FEV1).

In contrast to the finding in the present study, the result of the study by **Abd El- Kader** [(13)] showed a significant reduction in both $PaCO_2$ and pH. This variation in result regarding $PaCO_2$ and pH may be due to the variation in patient group who had spinal cord injury in their study while in the present study the patient group was acute respiratory failure patients. Also there are a variation in method of applying the training, which is in **Abd El-Kader** study[(13)] was performed by external device (threshold positive expiratory pressure device); the training with this device apply loading to expiratory muscle more than inspiratory muscles while in the present study the training was applied by modifying mechanical ventilation trigger sensitivity, which apply more load in inspiratory muscle rather than expiratory one.

Abdeen *et al.* [(14)] studied the acute effect of chest physical therapy on patients on mechanically ventilation. In their study, there was a significant increase in PaO_2 and oxygen saturation (SpO_2) and they also found no significant change in pH, which agreed with the finding in this present study. However the result of their study showed a significant reduction in $PaCO_2$, which disagreed with the finding in the present study. This may be due to the variation in time of measuring variable i.e. in **Abdeen *et al.*** [(14)]**,** study the arterial blood gases were measured immediately after the session to detect the acute effect of the treatment.

In a study by **Farag *et al.***[(15)] they studied the effect of training inspiratory muscle on COPD patient. The training was applied through threshold inspiratory muscles training IMT device. The result in their study showed a significant increase in PaO_2 in the study group, which agreed with finding in present study, but in contrast the result of their study showed a significant decrease in $PaCO_2$ and significant increase in pH which disagreed with the finding in this present study. This variation in result may be due to the difference between patients group i.e. in their study although the patients were diagnosed with COPD but their condition were not exacerbated and they were not on mechanical ventilation support. Also there are a difference in duration of applying the training, the duration of present study were around a week while in **Farag *et al.***[(15)] study the training duration was two months.

CONCLUSION

Training the inspiratory muscles in mechanically ventilated patients through modifying mechanical ventilator trigger sensitivity can produce a significant increase in PaO_2. Although it has no effect on neither pH nor $PaCO_2$.

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