Response of Mechanically Ventilated Respiratory Failure Patients to Respiratory Muscles Training

AMANY R. MOHAMED, M.D.*; HAMDY M.S. EL BASIOUNY, M.D.** and NAGUIB M. SALEM, M.D.*

The Departments of Physiotherapy, Cairo University* and Critical Care Medicine, Beniseuif University**

Abstract

Background and Purpose: Muscle training represents an important aspect of pulmonary rehabilitation in critically ill patients; it allows facilitating weaning process and helps patients to obtain their maximal functional capacities. The aim of this study was to investigate the response of mechanically ventilated respiratory failure patients to respiratory muscle training.

Methodology: Forty mechanically ventilated respiratory failure patients were randomly selected from Cairo University Hospitals (Critical Care Department). The patients were classified equally into study group and control group. Each patient of the study group received both respiratory muscles training using inspiratory muscle training (IMT) and standard chest physiotherapy, while patients of the control group received only standard chest physiotherapy. Pre and post study selected oxygenation parameters, respiratory muscles strength and outcomes parameters were measured for each patient of both groups.

Result: A significant improvement in the study group compared to control group regarding oxygenation, respiratory muscles strength and patient outcome and this improvement was highly significant in PaO$_2$ (108.9±9.5mmHg versus 132.3±11.45mmHg in Group A) and (104.5±5.99mmHg versus 122.85±10.67mmHg in Group B) and respiratory muscles strength parameter $p<0.0001$.

Conclusion: Respiratory muscles training in addition to standard chest physiotherapy could be a helpful tool to improve oxygenation and secondly outcome in mechanically ventilated respiratory failure patients.

Key Words: Respiratory failure – Mechanical ventilation – Respiratory muscles training.

Introduction

INVASIVE mechanical ventilation (MV) is associated with complications, and its abbreviation lessens hospital-acquired infections and mortality. The imbalance between increased workload and inspiratory muscle endurance is an important determinant of ventilator dependence. Low endurance may be present due to respiratory muscle atrophy and dysfunction caused by mechanical ventilation, critical illness or steroids. Inspiratory muscle training may increase or preserve endurance, in ambulatory and mechanically ventilated patients with stable clinical conditions who had failed weaning attempts [1]. Chang et al., [2], studied the effect of inspiratory muscle training on mechanically ventilated patients with a long-standing dependence on mechanical ventilation. Their study showed improved inspiratory muscle strength and almost all patients weaned successfully within several weeks of starting the training.

Patients and Methods

Study design: This is a randomized study that was prospectively conducted on 40 mechanically ventilated patients admitted to the Critical Care Department of Cairo University Hospitals in the period from May 2011 to December 2012. Informed written consents had been obtained from patients and the study was approved by the Hospital’s Ethical Committee.

Forty patients were divided into two groups: Study group (A): Twenty patients received both respiratory muscle training and standard chest physiotherapy and Control group (B): Twenty patients received standard chest physiotherapy only. Patients included in this study diagnosed with respiratory failure and hence Mechanically Ventilated for at least 48 hours, and should be vitally stable during the study period, conscious and respond to verbal command. The patients should be accepting, stable and can tolerate spontaneous breathing trial, with this setting FiO$_2$ 0.4 or less PEEP less than 5cmH2O, SpO$_2$ more than 90%. The study excludes Patients with unstable hemodynamics, unstable neurological problems,
lack of attention and cooperation, Flail chest and skipping of more than five training sessions for any cause.

Methods:
For each patient the following parameters were measured before and after the procedure: Blood gas analysis measuring (PaO\textsubscript{2}, SaO\textsubscript{2}\%, and calculating PaO\textsubscript{2}/FiO\textsubscript{2}). Muscle strength parameters like negative inspiratory pressure (NIP) and inspiratory muscle training (IMT) training pressure) were measured through ventilator reading and IMT training device, days of ventilation and ICU stay after physiotherapy.

1- Standard chest physiotherapy:
Standard chest physiotherapy was applied three times per day for both groups. Techniques used by physiotherapists were: Manual hyperinflation (MHI), percussion, vibrations, suction and various breathing exercises and muscle training (for upper and lower limb).

2- Procedure for respiratory muscles training:
According to Cader SA et al., [3]:
- The patient was positioned in relaxed half supine position with head support.
- Explain the procedure for the patient before training.
- Disconnect the patient from the ventilator and turn off the ventilator alarm. Immediately after disconnections start the procedure, connect the patient to the IMT device.
- Patients were instructed to maximally exhale before taking a breath and to try maximally fill the lungs fully with each inspiration.

Respiratory muscle training:
Starting intensity: Was 30% of NIP of each patient which measured by ventilator reading then increase the load on IMT device by 1-2CmH \textsubscript{2}O every session. Training consists of 5 to 6 sets of repetitions through the trainer. This training breath was repeated six times in each training set. Training breaths was completed for a total of 18 to 30 times per session for about 10 minutes. IMT sessions were conducted two times per day for about 12 sessions per week for each patient. Supplemental oxygen was used with the IMT device during training. Patients were returned to MV for rest between training sets as needed.

The IMT session was terminated if the patient had any of the following signs:
1- Respiratory frequency of more than 30 breaths per minute.
2- Arterial saturation below 90%.
3- Systolic blood pressure above 180mm Hg or below 90mm Hg.
4- Agitation, Tachycardia, Hemoptyasis.
5- Patients presenting signs of distress began the next session with a shorter programmed time and pressure less than that achieved in the previous training session.

Assessment of the results:
Assessment for study variables was done before starting physiotherapy sessions on both groups and at the end one week of twelve sessions of IMT or standard physiotherapy: Arterial blood gas analysis to measure (PaO\textsubscript{2}, SaO\textsubscript{2}\%, and calculating PaO\textsubscript{2}/FiO\textsubscript{2}).

Data analysis:
Statistical analysis was performed on the data obtained from 40 patients. All statistical analysis was performed using SPSS for Windows 16.0; paired t-test was carried out to determine the significance of the outcome measurements pre and post-study in the two groups. p-value of less than 0.05 was used to determine the significance of the outcome measurements between the two groups. Mean of group differences and confidence intervals were presented for Oxygenation muscle strength and outcomes parameters.

Results
The study group composed of 20 patients their age ranged from 50 to 60 years with a mean of 54.8±7.6 years (55% male and 45% female). The control group ages ranged from 50 to 60 years with a mean of 55.9±3.07 years (50% male and 50% female) with non significant difference between both groups.

A- Oxygenation parameters (PaO\textsubscript{2}, SaO\textsubscript{2}\%, PaO\textsubscript{2}/FiO\textsubscript{2}):
1- Partial arterial oxygen pressure (PaO\textsubscript{2}):
Physiotherapy interventions resulted in a significant improvement of PaO\textsubscript{2} in both groups, (108.9±9.5mmHg versus 132.3±11.45mmHg in Group A) and (104.5±5.99mmHg versus 122.85±10.67mmHg in Group B) Fig. (1) (p-value <0.001).

2- Oxygen saturation (SaO\textsubscript{2}):
Physiotherapy interventions resulted in a significant improvement in SaO\textsubscript{2} of both study and control groups, with slightly higher SaO\textsubscript{2} post IMT in Group A (92.7±2.5% versus 97.4±1.09%) while in Group B (92.3±2.3% versus 95.2±1.39%) (p-value <0.001) Fig. (2).
Fig. (1): PaO\textsubscript{2} value in both Groups (A & B).

PaO\textsubscript{2} value

<table>
<thead>
<tr>
<th>Value</th>
<th>Pre</th>
<th>Post</th>
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<tbody>
<tr>
<td>108.9</td>
<td>132.3</td>
<td></td>
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<tr>
<td>104.5</td>
<td>122.8</td>
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Fig. (2): Oxygen saturation SaO\textsubscript{2} value in both Groups (A & B).

SaO\textsubscript{2}%

<table>
<thead>
<tr>
<th>Value</th>
<th>Pre</th>
<th>Post</th>
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<tbody>
<tr>
<td>92.7</td>
<td>92.3</td>
<td></td>
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<tr>
<td>95.2</td>
<td>92.3</td>
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Fig. (3): Changes in oxygen saturation (SaO\textsubscript{2}) in both groups.

3- \textbf{(PaO\textsubscript{2}/FiO\textsubscript{2}) Ratio}:

Physiotherapy interventions resulted in a statistically significant improvement in PaO\textsubscript{2}/FiO\textsubscript{2} of both study groups, in Group A (272.35\pm23.73 versus 330.73\pm28.6) while in Group B (262.73\pm15.38 versus 307.1\pm26.6) (\textit{p}-value <0.001) Table (1).

Table (1): PaO\textsubscript{2}/FiO\textsubscript{2} ratio in both Groups (A & B).

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre PaO\textsubscript{2}/FiO\textsubscript{2}</th>
<th>Post PaO\textsubscript{2}/FiO\textsubscript{2}</th>
<th>\textit{p}-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group (A)</td>
<td>272.35\pm23.73</td>
<td>330.73\pm28.6</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Group (B)</td>
<td>262.73\pm15.38</td>
<td>307.1\pm26.6</td>
<td>&lt;0.001</td>
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Level of significance at \textit{p}<0.05.

B- Muscle strength parameter (NIP and training pressure):

1- \textbf{Negative inspiratory pressure (NIP)}:

Physiotherapy interventions resulted in a statistically significant improvement in NIP of both study Groups (A and B), although it was slightly Higher in Group (A). The mean value was (20.95\pm3.05CmH\textsubscript{2}O) versus (29.4\pm1.78CmH\textsubscript{2}O) respectively, whereas in Group (B) the mean value was (19.1\pm2.6CmH\textsubscript{2}O) versus (21.25\pm1.41CmH\textsubscript{2}O) respectively (\textit{p}-value <0.001). While comparing the degree of NIP changes in both groups post physiotherapy NIP increased by 30.3% in Group A compared to Group B, (confidence interval 95%; from 19.8 to 40.9%) this was highly significant, (\textit{p}-value <0.001) Fig. (4).

Table (2): Training pressure of IMT value in Group (A).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Starting training pressure of IMT</th>
<th>End training pressure of IMT</th>
<th>\textit{p}-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group (A)</td>
<td>10.9\pm1.43</td>
<td>20.4\pm2.08</td>
<td>&lt;0.001</td>
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Level of significance at \textit{p}<0.05.
C. Outcome parameters:

1. Mechanical ventilation days after physiotherapy:

   There was a significant decrease in ventilation days in Group (A) compared to Group (B); (3.3±1.6 days for Group A versus 10.4±2.5 days for Group B; p-value <0.001).

2. Days of ICU stay after physiotherapy:

   Days ICU stay after physiotherapy, was significantly decreased in Group (A) compared to Group (B); (4.45±0.9 days for Group A versus 10.25±2.8 days for Group B, p-value <0.001).

Discussion

There is increasing evidence to show that mechanical ventilation itself may adversely affect the respiratory muscle structure and function, which has been termed ventilator-induced diaphragmatic dysfunction. The combination of positive pressure ventilation and positive end-expiratory pressure may unload the respiratory muscle therefore subjecting it to changes in myofibre length, which may account for its rapid atrophy. In addition, patients who undergo prolonged periods of ventilation demonstrate a decrease in respiratory muscle endurance and are at risk of respiratory muscle fatigue. Inspiratory muscle training (IMT) is a technique that targets the muscles of inspiration—namely the diaphragm and accessory inspiratory muscles—with the aim of increasing respiratory muscle strength and endurance [4].

Our present investigation was designed to study the response of mechanically ventilated respiratory failure patients to inspiratory muscle training with the hypothesis that there may be no effect of respiratory muscle training on oxygenation, respiratory muscle strength and outcome parameters of mechanically ventilated respiratory failure patients. The results in the present investigation revealed statistically significant changes in both study groups in Oxygenation parameters (PaO2, SaO2%, and PaO2/FiO2), respiratory muscles strength parameters (NIP and training pressure) and outcome parameters (days of ventilation and ICU stay after physiotherapy).

Few studies have investigated the benefits and efficacy of physiotherapeutic intervention for patients on mechanical ventilation, resulted in very large effect on oxygenation. The study made by Hodgson et al., [5] stated that when they used chest physiotherapy on 18 mechanically ventilated patients, results revealed a high improvement in O2 saturation in 90% of these patients, our study revealed that physiotherapy interventions improved oxygen saturation of both groups, with a tendency towards more improvement in the study group than control group.

The study done by Maa et al., [6] to examine the potential benefits of physiotherapy in a group of intubated patients, had statistically significant improvement in respiratory system capacity and improvement of PaO2/FiO2 compared to the control groups. These results emphasized our result that showed the improvement in PaO2/FiO2 of both groups, in study Group A (272.35±23.73 versus 330.73±28.6) while in control Group B (262.73±15.38 versus 307.1±26.6) (p-value <0.001).

In contrast to the above mentioned positive findings, an investigation executed by Paratz, and Lipman [7], established that when chest physiotherapy was performed to seven mechanically ventilated patients with septic and cardiogenic shock, the arterial blood gases were recorded and the results showed that there were no significant changes in arterial blood gases. This may be due to the hemodynamic instability of the cases. In our study the careful selection of patients, and exclusion of unstable patients excluded such effects on oxygenation parameters.

Regarding the effect on respiratory muscle strength, which showed significant improvement and reduced weaning time in all cases of the study group compared to control group. These results go in hand with the randomized controlled study done by Martin et al., [8] to test whether inspiratory muscle strength training (IMT) would improve weaning outcome in failure to wean (FTW) patients. IMT was performed with a threshold inspiratory device, set at the highest pressure tolerated and progressed daily. Groups were comparable on demographic and clinical variables at baseline. The IMT and control groups respectively received 41.9±25.5 vs. 47.3±33.0 days of MV support prior to starting intervention, Results revealed that a higher percent of weaning in IMT subjects than of control group.

Retrospective analysis of 49 consecutive patients evaluated the benefits of IMT in combination with whole body physical therapy. Training was initiated using a threshold device when patients were able to breathe spontaneously for more than 2hr. The regimen involved twice daily sessions with resistance set at one-third of the patient’s maximum negative inspiratory pressure (NIP). The maximum NIP improved significantly. Because this study also included outcome measures directly related to limb muscle strength and ambulation.
Findings suggest a potential link between the benefits of IMT, weaning and mobility outcomes [9].

The study done Bissett and Leditscke, [10] described the use of specific inspiratory muscle training to enhance weaning from mechanical ventilation in patients who had failed conventional weaning strategies. A program of daily inspiratory muscle training was initiated. The mean training threshold increased progressively during the program and simultaneously the periods of unassisted breathing achieved gradually increased. By day 27, mechanical ventilation was no longer required. They concluded that respiratory muscle training can be implemented effectively in the difficult to wean patient and should be considered for patients who have failed conventional weaning strategies.

Our findings differ from the randomized clinical trial by Caruso et al., [1] in an adult clinical-surgical intensive care unit. 11 patients trained the inspiratory muscles twice a day and 13 patients did not (control). Training was performed adjusting the sensitivity of the ventilator, and the outcomes were the duration of the weaning period and the rate of re-intubation in critically ill patients. The experimental and control groups did not differ significantly in terms of the weaning period \( (p = 0.24) \), and the respiratory muscle strength final value \( (p = 0.34) \). Although, the IMT group showed a trend toward a lower reintubation rate and weaning duration. One possible explanation was due to inspiratory muscle training via reduction of sensitivity of the pressure support trigger only offers an initial resistance to the opening of the valve of the system, while respiratory muscle training with IMT device maintains resistance to the respiratory system for the period of the inspiration.

The third parameter measured in our study was days of ventilation and ICU stay, which revealed a significant decrease in ventilation days and ICU stay in Group (A) compared to Group (B).

The study done by Malkoc et al., [11] aimed to assess the effect of physiotherapy on ventilator dependency and length of intensive care unit (ICU) stay. Patients were divided into two groups. The data of control patients who were not receiving physiotherapy were obtained from the hospital records. The intervention group was prospectively taken into the chest physiotherapy program. A total of 5 10 patients who were hospitalised in the ICU were included in the study. The extubation time and length of ICU stay were compared between the two groups. Control patients had a longer period of ventilator dependency than the intervention patients and this difference was statistically significant \( (p < 0.05) \). It was noted that the resulting length of stay in the ICU was significantly lower in the intervention group than in the control group \( (p < 0.05) \). Although patients had similar diagnoses and physical features, the length of stay in the ICU was significantly lower in the intervention group.

All patients of our study were subjected to standard chest physiotherapy treatment, but the study group was subjected to standard chest physiotherapy and respiratory muscles training. Comparing ventilation days post physiotherapy in both groups showed a significant decrease in ventilation days in study Group (A) compared to control Group (B), \( (3.3±1.6 \text{ days vs. } 10.4±2.5 \text{ days}) \) respectively \( (p = 0.001) \). Also days of ICU stay after physiotherapy was significantly decreased in Group (A) compared to Group (B), \( (4.45±0.9 \text{ days vs. } 10.25±2.8 \text{ days}) \) respectively \( (p = 0.001) \).

On the other hand Notoumenopoulas et al. [12] carried out a study on 46 patients who were receiving mechanical ventilation after trauma and were randomly allocated to a group that received standard nursing care and chest physiotherapy, or standard nursing care alone. The outcome measurements included blood gas analysis, the incidence of nosocomial pneumonia, the number of days when mechanical ventilation was provided and the length of stay in the ICU. No statistical differences were found between the groups in the length of time when mechanical ventilation was provided (mean 6.1 days physiotherapy group, 5.2 days control group), the length of stay in the ICU (mean 7.4 days physiotherapy group, 6.8 days control group) or the mortality rate in the ICU (for both groups).

This differs from our study findings mostly due to that the patients of our study were subjected to standard chest physiotherapy treatment, so improvement done to both groups but higher and significant in study group.

Conclusion:

Respiratory muscles training produced a significant improvement in oxygenation and respiratory muscles strength parameter in mechanically ventilated respiratory failure patients.

Traditional chest physiotherapy was sufficient to result in positive changes in oxygenation and respiratory muscles strength. Such achievements can be potentiated with the use of respiratory muscles training plus traditional chest physiotherapy for mechanically ventilated respiratory failure patients.
References


