Oxygenation Effects of Manual Hyperinflation on Mechanically Ventilated Patients

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Abstract

Background: The manual hyperinflation protocol used by physiotherapists, aims to manually inflate an intubated patient’s lungs, via an endotracheal tube or tracheostomy tube with resuscitation bag circuit with pressure lock. Volumes delivered are greater than those given by the ventilator or achieved by the patient. It is used to reinflate areas of atelectasis and Mobilise secretions.

Objective: To investigate the effect of manual hyperinflation on arterial oxygenation in mechanically ventilated patients.

Methodology: Forty mechanically ventilated patients were assigned to the study, the patients' age ranged from 40-60 years with mean age (52.5 ± 7.6), they were divided into two equal groups of twenty patients. The study group patients received manual hyperinflation and chest physiotherapy as three sessions daily for three successive days, control group patients received standard chest physiotherapy. Oxygenation parameters were assessed before and after physiotherapy program.

Result: The results of this study revealed that there were statistically significant changes in oxygenation in patients of the study group compared to control group.

Conclusion: The use of manual hyperinflation in combination with chest physiotherapy is a valuable tool to improve the arterial oxygenation in mechanically ventilated patients.

Key Words: Arterial oxygenation – Chest physiotherapy – Critically ill – Mechanically ventilated.

Introduction

VENTILATOR use is associated with a number of complications, which increase morbidity and mortality of such patients that include atelectasis, occlusion of the endotracheal tube, Ventilator Associated Pneumonia (VAP), nosocomial infection, barotrauma, and hypotension [1].

Physiotherapy intervention is regarded as an important component in the management of patients in the intensive care and had proven to provide both short and medium-term benefits [2].

Manual Hyperinflation (MHI) is defined as inflating the lungs using oxygen and manual compression to provide a tidal volume (Vt) exceeding baseline Vt, and using a Vt that is 50% greater than that delivered by the ventilator, requiring a peak inspiratory pressure ranged from 20 to 40cm H2O [3].

Manual hyperinflation can be used by physiotherapists to improve lung volume and mobilize secretions and has been shown to increase lung compliance in patients with ventilator-associated pneumonia [4].

Material and Methods

This study was conducted Critical Care Department, Cairo University in the period from 2007-2009.

Forty patients were divided randomly into two groups:

- Study group (twenty patients) received both manual hyperinflation and standard chest physiotherapy.
- Control group (twenty patients) received traditional chest physiotherapy only.

Inclusion criteria:

- Mechanical ventilation for 3 to 7 days before inclusion in the study and
- Positive End Expiratory Pressure (PEEP) levels not exceeding 10cm H2O.
- Stable hemodynamically through the study period.
Exclusion criteria:
• Contraindications to the technique which include:
  1 - Undrained pneumothorax.
  2- High peak airway pressures.
  3- Severe bronchospasm.
  4- (FiO₂) >0.6.
  5- Arterial oxygen saturation (SaO₂) <90.

Evaluation equipment:
Arterial blood oxygenation assessment using arterial blood gases analyzer:
• SO₂ (oxygen saturation) normal range from 92% to 100%.
• PaO₂ arterial oxygen pressure.
• PaO₂/FiO₂ (ratio of partial oxygen pressure and fraction inspired oxygen) normal range more than 400-500.

Training equipment:
• Bag valve resuscitation circuit locked at pressure =40cm H₂O.
• Oxygen supply 15L/min attached to the Bag valve resuscitation circuit.

Procedures:
1- Attach the resuscitation circuit to the oxygen flow meter and set the oxygen to 15L/minute. Any less than 15L/minute increases the time of bag reinflation which can lead to a delay in giving the next breath.
2- Disconnect the patient from the ventilator, attach the resuscitation circuit to the filter and attach to the patient airway (endotracheal or tracheostomy).
3- The hyperinflation breaths had a slow inspiration for three seconds duration; a three second end inspiratory pause (hold) was followed by an uninterrupted expiration during which the bag was held compressed. Hold the breath for three seconds at end of inspiration then a ‘quick release’ of the bag. Slow deep breaths and hold, maximizes collateral ventilation. The quick release’ increases the expiratory phase to mobilize secretions up the bronchial tree and stimulate cough.
4- Reconnect the patient to the ventilator.
5- The manual hyperinflation treatment time was 15 minutes for each session three time/day for three days for the study group.

Chest physiotherapy:
Chest physiotherapy in the form of percussion, vibration, positioning, suction and postural drainage were applied for all patients in both groups.

Data analysis:
The mean, standard deviation and the range will be calculated for all subjects. Paired " t" test will be used to determine the mean value of arterial blood gases for each patient before and after treatment program and to compare the changes with each group.

Results
This study included 40 patients, all patients were mechanically ventilated.

Subjects were divided into two groups:
• Study group (twenty patients) received both manual hyperinflation and chest physiotherapy. The patients' ages ranged from 40 to 60 years with a mean of 52.5±7.6 years.
• Control group (twenty patients) received chest physiotherapy only. The patients' ages ranged from 41 to 60 years with a mean of 51.8±6.5 years.

1- Partial arterial oxygen pressure (PaO₂ in the study group vs control group:
Table (1) and Fig. (1) shows the comparison of PaO₂ between the two groups before and after intervention. There were no significant differences in PaO₂ before the application of either physiotherapy or physiotherapy plus MHI, PaO₂ was 94.7 mmHg ±8.33 in the study group versus 90.55 mmHg ±10.74 in the control group (p=0.2). While after MHI there were significant differences between both groups, in PaO₂ (143.8mmHg±41.39 versus 90.8±7.47 in study and control group respectively p<0.0001).

<table>
<thead>
<tr>
<th>Group</th>
<th>Study group</th>
<th>Control group</th>
<th>p-value</th>
</tr>
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<tbody>
<tr>
<td>PaO₂ Before MHI</td>
<td>94.7±8.33</td>
<td>90.55±10.74</td>
<td>0.2</td>
</tr>
<tr>
<td>After MHI</td>
<td>143.8±41.39</td>
<td>90.8±7.47</td>
<td>0.0001</td>
</tr>
<tr>
<td>% of change</td>
<td>34.1 increase</td>
<td>0.3 increase</td>
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Level of significance at p<0.05.
*: Significant.
**: Non significant.
2- Oxygen saturation (SaO₂ %) in the study group vs control group:

Table (2) shows the comparison of SaO₂ between the two groups before and after intervention. There were no significant differences before the application of either physiotherapy or physiotherapy plus MHI, SaO₂ was (94.86% ± 2.49) versus (93.9% ± 3.2) in study and control group respectively (p = 0.4) in contrast after MHI there was a significant difference between both group, SaO₂ was 98.48% ± 1.09 versus 96.7% ± 1.7 in study and control groups, respectively (p < 0.007), these results showed the great effect of MHI on SaO₂.

Table (2): Comparison of SaO₂ % before and after intervention in both groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Study group</th>
<th>Control group</th>
<th>p-value</th>
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</thead>
<tbody>
<tr>
<td>Pre MHI</td>
<td>94.86±2.49</td>
<td>93.9±3.2</td>
<td>0.4</td>
</tr>
<tr>
<td>Post MHI</td>
<td>98.48±1.09</td>
<td>96.7±1.7</td>
<td>0.007</td>
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</tbody>
</table>

Level of significance at p<0.05.

*: Significant.
**: Non significant.

3- Comparing (PaO₂/FiO₂) ratio between the study group and control group:

Table (3) shows the comparison of (PaO₂/FiO₂) ratio between the two groups before and after intervention. There were no significant difference before the application of either physiotherapy or physiotherapy plus MHI, the ratio was (227.8 ± 50.1) versus (226.1 ± 29.3) (p = 0.88), after MHI there was a significant change between both group, it was (346.9 ± 93.7) in the study group versus (227.2 ±26.8) in control group (p < 0.0001) these results showed the great difference done when we used manual hyperinflation. Also (Table 3) shows the % of improvement of PaO₂/FiO₂ ratio between the study group and control group.

Table (3): Comparing (PaO₂/FiO₂) ratio between the study group and control group.

<table>
<thead>
<tr>
<th>Group</th>
<th>Study group</th>
<th>Control group</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre MHI</td>
<td>227.8±50.1</td>
<td>226.1±29.3</td>
<td>0.88</td>
</tr>
<tr>
<td>Post MHI</td>
<td>346.9±93.7</td>
<td>227.2±26.8</td>
<td>0.0001</td>
</tr>
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</table>

% of change 34.3 increase 0.48 increase

Level of significance at p<0.05.

*: Significant.
**: Non significant.

Discussion

The deleterious effects of prolonged immobilization affect the heart, vascular system, musculoskeletal system, skin, and kidneys. Effects may also occur in the respiratory system such as nosocomial pneumonia, pulmonary thromboembolism, and hypoxemia that may increase the patient's morbidity and mortality. Another famous pulmonary complication of immobility is atelectasis [5].

Mechanical ventilation is indicated in respiratory failure and patients receiving mechanical ventilation may have an increased risk of sputum retention, atelectasis, and pneumonia, making ventilator weaning more difficult. Thus, every effort should be made to determine which patients can be rapidly extubated so as to keep the weaning period to a minimum [6].

Patients requiring mechanical ventilation for a long time are frequently deconditioned because of respiratory failure precipitated by the underlying disease, the adverse effects of medications, and a period of prolonged immobilization. Patients requiring mechanical ventilation often have substantial weakness of the respiratory and limb muscles that further impairs their functional status and health-related quality of life [7].

Atelectasis is a common clinical problem in the intubated and ventilated patient. Recruitment maneuvers such as manual hyperinflation have been shown to improve both atelectasis and static pulmonary compliance [8].

The general aims of any physiotherapy program in the critical areas are to restore respiratory and physical independence, thus decreasing the risks of bed-rest associated complications. Physiotherapy treatment when started early helps to prevent weaning delay, limited mobility and total dependence on the ventilator [9]. The aim of lung hyperinflation is to re-expand atelectasis, mobilize secretions and prevent or reduce the incidence of nosocomial pneumonia in intubated patients [8].
The results in the present investigation revealed statistically significant changes in selected oxygenation parameters (\( \text{PaO}_2, \text{SaO}_2\%), \text{PaO}_2/\text{FiO}_2 \)) that showed improvement in both groups, but the improvement was significant in the study group. These benefits might have resulted from recruitment of alveoli, manual hyperinflation opens collateral channels within the lungs, which could theoretically recruit atelectatic lung regions and facilitate secretion mobilisation, improvement in gas transfer in the lung and improvement in the ventilation perfusion matching.

The study made by Patman et al., [10] revealed that when we used manual hyperinflation alone versus no hyperinflation on 100 intubated patients the study results showed greater improvement in \( \text{PaO}_2/\text{FiO}_2 \) ratio and alveolar-arterial oxygen gradient in all cases of the MHI group, similar results are found in our study which showed improvement in the oxygenation and improvement of \( \text{PaO}_2/\text{FiO}_2 \) in all cases of the study group after MHI.

The study made by Hodgson et al., [8] stated that when we used manual hyperinflation versus positioning on 18 mechanically ventilated patients, results show the great improvement in \( \text{O}_2 \) saturation in 90% of these patients, but our study revealed that the improvement in all cases received MHI.

In the study done to assess the safety and short-term effectiveness of manual lung hyperinflation in mechanically ventilated patients by Hodgson et al., [8], eighteen patients from the intensive care units of two tertiary institutions were included in that study. Manual hyperinflation treatment group involved patient positioning (side-lying), suctioning and manual hyperinflation. Side-lying treatment group involved patient positioning and suctioning alone. Patients received both treatments on the day of data collection. Results demonstrated significant improvement for Manual hyperinflation treatment in gas exchange (\( \text{PaO}_2/\text{FiO}_2 \) and \( \text{PaCO}_2 \)). These results go in hand to our results and signifying that MHI added to standard physiotherapy has a great effect on improvement of oxygenation.

In contrast to the above mentioned positive findings, an investigation executed by Paratz Lipman [11] established that when MHI was performed to seven mechanically ventilated patients with septic and cardiogenic shock, where diastolic and mean arterial pressure, pulmonary artery occlusion pressure, dynamic compliance, and arterial blood gases were recorded. These limited results showed that there were no significant changes in pulmonary artery occlusion pressure, mean arterial pressure, or \( \text{PaO}_2/\text{FiO}_2 \) and arterial blood gases this may be due to the haemodynamic instability of this cases, in contrast to our study we selected the haemodynamically stable cases only so the results were so different than the above study.

**Conclusion:**

Traditional chest physiotherapy was sufficient to result in positive changes in the arterial blood oxygenation (\( \text{PaO}_2, \text{SaO}_2\%), \text{PaO}_2/\text{FiO}_2 \)) but this improvement was increased with the use of manual hyperinflation plus traditional chest physiotherapy for mechanically ventilated patient.

These results, together with observations of other trials, suggest that manual hyperinflation is safe intervention that can be considered for mechanically ventilated patients and it can help in weaning from the ventilator and decrease the time spent in intensive care unit also decrease morbidity of these cases.

**Recommendations:**

Our findings indicate that a simple and inexpensive manual hyperinflation using resuscitation bag with oxygen delivery showed significant improvement in arterial oxygenation in mechanically ventilated patients.

More research to investigate the effect of manual hyperinflation on mechanically ventilated patients with specific diagnosis, on pulmonary mechanics and on weaning parameter.

**References**


الملخص العربي

الهدف من البحث هو دراسة تأثير التنفيخ اليدوي على مدى تشيع الدم بالأكسجين لدى مرضى جهاز التنفس الصناعي.

أجريت هذه الدراسة على أربعين مريضاً من مرضى جهاز التنفس الصناعي تتراوح أعمارهم ما بين أربعين إلى ستين عاماً وتتم تقسيمهم إلى مجموعتين متساويتين: المجموعة الأولى التي تلقى التنفيخ اليدوي لمدة 15 دقيقة مع العلاج الطبيعي للصدر لمدة 15 دقيقة، والمجموعة الثانية وهي المجموعة الضابطة والتي تلقى العلاج الطبيعي للصدر لمدة 15 دقيقة. وكانت مدة الجلسات ثلاث جلسات في اليوم لمدة ثلاث أيام. تم قياس معدل تشيع الدم الشرياني قبل بدأ العلاج وبعد الانتهاء منه. وقد أظهرت النتائج وجود تحسن ملحوظ في معدل أكسجين الدم الشرياني لدى المجموعتين ولكن هذا التحسن مع وجود تغييرات ذات دلالات إحصائية عالية في المجموعة الأولى التي تلقى التنفيخ اليدوي مع العلاج الطبيعي للصدر، لذلك يوصى بإضافة التنفيخ اليدوي مع العلاج الطبيعي للصدر لدى مرضى جهاز التنفس الصناعي.