Arterial oxygenation response to manual hyperinflation as an added procedure to chest physiotherapy in critically ill mechanically Ventilated patients

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Abstract: Background: Manual hyperinflation as a component of physiotherapy program is commonly applied but its value and its early use in treatment of mechanically ventilated remain unclear. 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. Oxygen saturation was 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.

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1. Introduction

One of the primary goals of mechanical ventilation is to improve arterial oxygenation. Improvement is achieved partly through the use of endotracheal intubation to ensure the delivery of oxygen to the airway and partly through an increase in airway pressure. Satisfactory oxygenation is easily achieved in most patients with airway obstruction. The main challenge arises in patients with alveolar-filling disorders **(Martin and Tobin, 2001).**

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, ventilation-associated pneumonia (VAP) and nosocomial infection, barotrauma, and hypotension **(Suzanne, 2006).**

The concentration of O_2 in arterial blood (CaO_2) can be described by the Equation using the arterial oxygen saturation (SaO_2) and arterial oxygen pressure (Pao_2) of arterial blood .

$$CaO_2 = (1.34 \times Hb \times SaO_2) + (0.003 \times PaO_2).$$

There are approximately 200 mL oxygen in each liter of arterial blood, and only 1.5% (3 mL) is dissolved in the plasma. The oxygen consumption of an average-sized adult at rest is 250 mL/min, which means that if we were forced to rely solely on the dissolved O_2 in plasma, a cardiac output of 89 L/min would be necessary to sustain aerobic metabolism. This emphasizes the importance of hemoglobin in the transport of oxygen **(Paul Marino, 2007).**

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 **(Hough, 2001).**

The main indications for physical therapy for patients in intensive care units (ICUs) are excessive pulmonary secretions or atelectasis. Timely physical therapy interventions may improve gas exchange and reverse pathological progression, thereby curtailing or avoiding artificial ventilation **(Wong , 2000)**.

The manual hyperinflation protocol is to be used by physiotherapists, which 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 **(Maddison, 2006)**.

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 of ranged from 20 to 40 cm H_2O (**Nunn, 2000).**

The MHI technique was initially designed to enhance clearance of airway secretions **(Maxwell and Ellis, 2003).**

Manual hyperinflation is also used by physiotherapists to improve lung volume and mobilise secretions and has been shown to increase lung compliance in patients with ventilator-associated pneumonia (**Choi and Jones, 2005).**

In addition, MHI produced no adverse events in the experimental groups, as none of the patients experienced pneumothorax, suffocation, or hypotension during or following MHI **(Maa *et al.*, 2005).**

2. Methodology

Forty patients were involved in this study, were divided randomly into two groups:

- Study group (twenty patients) received both manual hyperinflation and chest physiotherapy.
- Control group (twenty patients) received traditional chest physiotherapy only.
- All patients were mechanically ventilated for 3 to 7 days before inclusion in the study
- Age ranged from 40 to 60 years.
- All patients were on Positive end expiratory pressure (PEEP) not exceeding 10 cm H_2O.
- All patients should be hemodynamically stable through the study period.
- All subjects were medically free from any contraindications to the technique which include:
  1. Undrained pneumothorax.
  2. High peak airway pressures.
  3. Severe bronchospasm
  4. (FiO_2) > 0.6
  5. Arterial oxygen saturation (SaO_2) < 90

Evaluation Equipment:

Arterial blood oxygenation assessment using arterial blood gases analyzer:

- SO_2 (oxygen saturation) normal range from 92-100%.
- PaO_2 arterial oxygen pressure
- PaO_2/FiO_2 (Ratio of partial oxygen pressure and fraction inspired oxygen) normal range more than 400-500.

Training Equipment:

- Bag valve resuscitation circuit locked at pressure = 40 cm H_2O
- Oxygen supply 15 L /min attached to the Bag valve resuscitation circuit.

Procedures:

1. Attach the resuscitation circuit to the oxygen flow meter and set the oxygen to 15 L/minute. Any less than 15 L/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, and 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.

3. Results

This study comprised of forty 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-Comparing Partial arterial oxygen pressure (PaO_2) between the study group and control group:

Table (1) and Fig.(1) shows The comparison of PaO_2 between the two groups before and after intervention .There was no significant difference before the application of either of physiotherapy or physiotherapy plus MHI , PaO_2 was (94.7 ± 8.33)in the study group versus (90.55±10.74)in the control group (P: 0.2). After MHI there was a significant changes between both groups, it was (143.8 ± 41.39) versus (90.8± 7.47) in study and control group respectively (P: 0.0001) these results shows the great effect of manual hyperinflation on PaO_2. Table (1) also shows the % of improvement of PaO_2 between the study group and control group.

Table (1): the mean value and standard deviation of PaO_2 between the study group and control group

PaO2 / *Group*	*Study Group*	*Control Group*	*P-value*
Befor MHI	94.7±8.33	90.55±10.74	0.2
After MHI	143.8±41.39	90.8± 7.47	0.0001
% of change	34.1 increase	0.3 Increase	

Level of significance at P<0.05. * = significant. ** = non significant

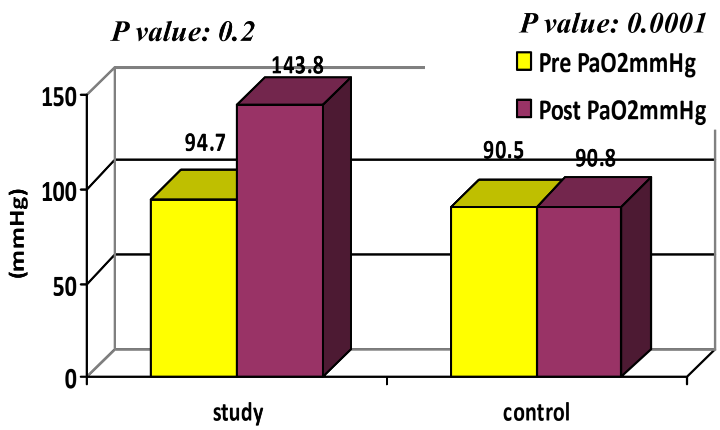

Fig. (1): the mean value of PaO_2 between the study group and control group

Table (2): the mean value & standard deviation of SaO_2 between the study group & control group

SaO2% / **Group**	Study **Group**	Control **Group**	**P-value**
Pre MHI	94.86±2.49	93.9±3.2	0.4
Post MHI	98.48±1.09	96.7± 1.7	0.007
% of change	3.6 increase	2.8 increase	

Level of significance at P<0.05 * = significant. ** = non significant

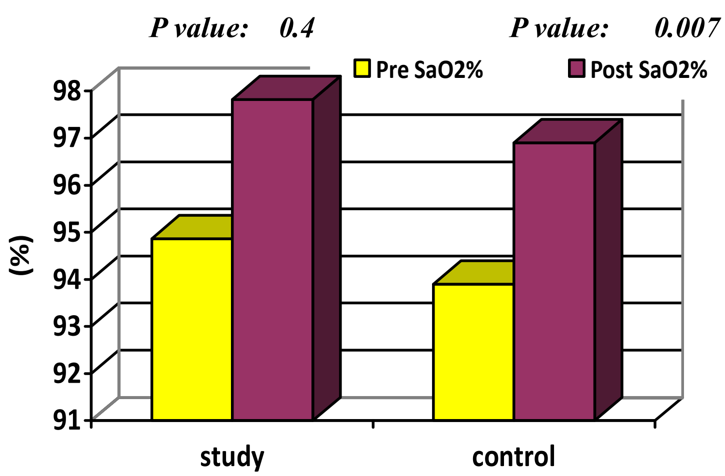

Fig (2): the mean value of SaO2% between the study group and control group

2- Comparing oxygen saturation (SaO_2 %) between the study group and control group.

Table (2) & Fig. (2) shows The comparison of SaO_2 between the two groups before and after intervention .There was no significant difference before the application of either physiotherapy or physiotherapy plus MHI, SaO_2 was (94.86 ± 2.49)versus (93.9±3.2) in study and control group respectively (P; 0.4) But after MHI there was significant improvement between both group, it 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 SaO_2. Also table (2): shows the % of improvement of SaO_2 between the study group and control group after treatment.

3- Comparing (PaO_2/FiO_2) ratio between the study group and control group.

Table (3) & Fig.(3) shows The comparison of (PaO_2/FiO_2) ratio between the two groups before and after intervention. There was 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 Fig (3) shows the % of improvement of PaO_2/FiO_2 ratio between the study group and control group.

Table (3): The mean value & standard deviation of PaO2/FiO2 between the study group & control group

Group / PaO2/FiO2	Study Group	Control Group	P-value
Pre MHI	227.8±50.1	226.1±29.3	0.88
Post MHI	346.9±93.7	227.2±26.8	0.0001
% of change	34.3 increase	0.48 increase	

Level of significance at P<0.05
* = significant. ** = non significant

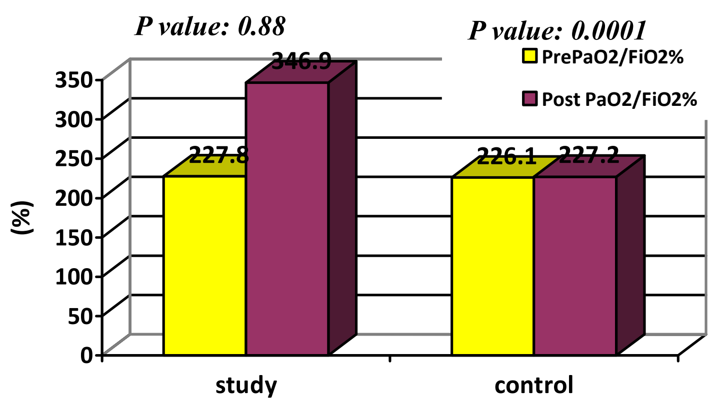

Fig (3): the mean value of PaO2/FiO2 between the study group and control group

4. 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. **(Raoof *et al.,* 1999)**

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**(Maa *et al.,* 2005)**.

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 **(Chiang , 2006).**

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 **(Hodgson *et al.*, 2000).**

The general aims of any physiotherapy program in the critical areas is 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 **(Stiller *et al.*, 2000)**. The aim of lung hyperinflation is to re-expand atelectasis **,** mobilize secretions and prevent or reduce the incidence of nosocomial pneumonia in intubated patients. **(Hodgson *et al.*, 2000).**

The results in the present investigation revealed statistically significant changes in selected oxygenation parameters (PaO_2, SaO_2 %, PaO_2 / 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.* (2000)** revealed that when we used manual hyperinflation alone versus no hyperinflation on 100 intubated patients the study results showed greater improvement in PaO_2/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 PaO_2 / FiO_2 in all cases of the study group after MHI.

The study made by **Hodgson *et al.* (2000)** stated that when we used manual hyperinflation versus positioning on 18 mechanically ventilated patients, results show the great improvement in 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.* (2000) ,** 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 (PaO_2/FIO_2 and $PaCO_2$). These results go in hand to our results and signifying that MHI added to standard physiotherapy has a great affect on improvement of oxygenation.

In contrast to the above mentioned positive findings, an investigation executed by **Paratz Lipman (2006)** established that when MHI was performed to seven mechanically ventilated patients with septic and cardiogenic shock . 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 PaO_2/FiO_2 and arterial blood gases this may be due to the heamodynamic instability of the cases. In our study we selected the haemodynamics stable cases only so the results were so better than that study.

Conclusion

Traditional chest physiotherapy was sufficient to result in positive changes in the arterial blood oxygenation (PaO_2, SaO_2 %, PaO_2 / 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 the observations of other trials, suggest that manual hyperinflation 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 unite 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 selected 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.

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