European Journal of
Health Sciences
(EJHS)

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European Journal of Health Sciences
ISSN 2520-4645 (online)
Vol.5, Issue 2 No.3, pp 53-79, 2020
www.ajpojournals.org

EFFECTS OF STRUCTURED MANUAL HYPERINFLATION FOR IMPROVING RESPIRATORY PARAMETERS IN POST-OPERATIVE CORONARY ARTERY BYPASS GRAFT PATIENTS

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ABSTRACT

Purpose: Cardiopulmonary physiotherapy plays a crucial role in cardiac rehabilitation after surgeries. The deterioration of respiratory parameters occurs after coronary artery bypass grafting (CABG) procedure. Manual hyperinflation (MHI) is done according to clinical experiences and there are no specific guidelines for it. The objectives were to determine the effects of structured manual hyperinflation for improving respiratory parameters in post-operative CABG patients.

Methodology: Duration of study was 6 months (January 2019-June 2019) with a sample size of 76 post-operative CABG patients. Non-probability purposive sampling technique was used. Patients were divided into two groups' i-e MHI and VHI depending upon the treatment protocol. In protocol, endotracheal tube (ETT) suctioning was done followed by MHI and VHI in assigned group in randomized controlled trial design. Respiratory parameters were measured by ABG'S, equations for static lung compliance and alveolar-arterial oxygen tension difference. Data was recorded pre and post ETT suctioning, immediately, 30 min and 60 min post intervention. Both males and females were included. Inclusion criteria involves patient must be intubated, hemodynamically and vitally stable, and age range 55-77 years. Those were excluded who have past medical history of diagnosed pulmonary pathology and any post-operative complications. Patient was withdrawn from the study if any subject who have unstable cardiovascular status and high levels of respiratory support. Data was analyzed on SPSS 21.

Findings: All the respiratory parameters showed significant differences ($p<0.05$) in pre and post values of structured MHI. Significant difference ($p<0.05$) was observed immediately after intervention in terms of acidity (pH), partial pressure of carbon oxide ($PaCO_2$), partial pressure of oxygen (PaO_2), oxygen saturation and arterial oxygen to fraction of inspired oxygen ratio between the groups with scores higher for experimental group. HCO_3 showed significant difference ($p<0.05$) immediately after intervention and 30 min and 60 min post intervention with the scores higher for control group. Static lung compliance showed significant difference ($p<0.05$) at 30 min and 60 min post intervention with scores higher for control group. Alveolar-arterial oxygen tension showed no significant difference ($p>0.05$) between the groups at any point. No significant difference ($p>0.05$) was observed between the groups at any other point of measurement for all respiratory parameters. MHI and VHI are both effective in improving respiratory parameters in post-operative CABG patients but the values were more significant in MHI group. But the difference between the groups was not significant and conclusive.

Recommendations: This study should be conducted in different patient populations having different pulmonary conditions and other types of cardiac surgeries and in other patients who are intubated and mechanically ventilated. Moreover, the effects of both techniques on different variables must be studied after multiple numbers of sessions during the whole period of intubation.

Key words: *Manual hyperinflation, Ventilator hyperinflation, Respiratory parameters*

INTRODUCTION:

Coronary artery bypass graft (CABG) was first introduced in 1968. It is done in patients with severe coronary heart disease (CHD).[1] On a global scale, approximately 17.3 million people died of cardiovascular disease per year. Pakistan is listed in third world countries with a low-income population. A study conducted by WHO showed that approximately 80% of death in low income countries occurred due to cardiovascular disease and diabetes.[2]The ultimate broad goals of cardiopulmonary physical therapy treatment in the ICU includes prevention from any cardiopulmonary complications, having patient alert and oriented to person, time, and place, to make patient return to premorbid functional level to the greatest extent possible and to reduce morbidity, mortality and length of hospital stay.[3]

Bronchopulmonary complications are very common challenge faced by physiotherapist after CABG. Most respiratory dysfunction occurs at 48 hour and are partially recovered by fifth day.[4] The changes in lung volumes, capacities, oxygen saturation and arterial blood gases are seen in intubated patients.[5] The lung capacities are reduced by 30-60% and remain reduced by 12% for up to one year.[6, 7]. The etiology behind the worsening of pulmonary function after CABG has multiple factors such as reduction in rib cage expansion capacity, poor coordination in chest wall motion,[8] phrenic nerve injury that leads to diaphragmatic dysfunction, accumulation of pleural fluid and basal atelectasis.[9] Dysfunction of respiratory muscles is also the contributing factor for pulmonary function reduction. After CABG, the patient must be intubated until the condition is stabilized. The intubated patients are at higher risk of mucus retention in airways due to presence of endotracheal tube, administered drugs, muscle weakness, body positioning, less humidification of respiratory gases and immobility of patient.[10, 11] The retention of these secretions leads to serious respiratory complications.[12] Clinical algorithm of physiotherapy for pulmonary dysfunction involves reducing secretion during invasive ventilation, patient positioning, manual therapy and hyperinflation i-e for MHI < 7.5 cmH2O PEEP, and for VHI >7.5 cmH2O PEEP. In case of atelectasis patient positioning along with deep breathing and coughing with suctioning is recommended which is done by physiotherapist and suctioning by nurses. For ventilator associated pneumonia bed must be inclined at 30-40 degrees. In VAP, routine chest physiotherapy and open or close suctioning is not effective.[13]

Mostly cardiopulmonary physiotherapist utilizes manual or mechanical hyperinflation recruitment maneuvers for secretion clearance and improving respiratory parameters in intubated and mechanically ventilated patients[14] despite of the fact that there is lack of evidences that confirms the benefits of manual hyperinflation on clinical outcomes [15] as well as mechanical hyperinflation modes and its efficacy on clinical outcomes.[16]

Application of these recruitment maneuvers in mechanically assisted ventilated patients along with endotracheal suctioning are supposed to be beneficial. [17] However, delivery of tidal volumes and ventilator distribution is important physiological consideration while applying any type of lung hyperinflation techniques.[16, 18, 19] Endotracheal tube suctioning is a fundamental intervention in clearing airway secretions in patients who are on mechanical support. closed ETT suctioning is associated with less ABG's disturbances as compared to open ETT suctioning system and is also associated with maintenance of PaO2. [20-22].Manual hyperinflation is also known as "Bagging technique" as it engages the use of resuscitator bag to give larger tidal volumes and higher peak airway pressures but at slow rates of inflation along with the inspiratory pause. [23] There are number of circuits used to perform manual hyperinflation e.g. Magill circuit, [24] Laerdal circuit[25] and certain other types of Mapelson circuit systems. Some studies also suggest that Mapelson C system is more beneficial in improving respiratory parameters.[26]

Second hyperinflation recruitment maneuver is done via ventilator known as ventilator hyperinflation. It involves the manipulation of settings on ventilator parameters to provide tidal volume that must be larger than the baseline tidal volume.[27]

Matthew P.Linnane et al designed a study in 2019 to determine the effects of manual and ventilator hyperinflation on restoring lung volumes after endotracheal tube suctioning and the effects of both techniques on oxygenation. They performed a randomized crossover study on 9 patients. They performed endotracheal tube suctioning followed by manual and ventilator hyperinflations on these recruited patients. The results of their study showed that manual hyperinflation and ventilator hyperinflation are both effective in restoring lung volumes and must be considered after endotracheal tube suctioning. They also found that both techniques have no significant difference in improving respiratory parameters and oxygenation of patients.[28]. A survey was conducted in 2018 y K.O Donnel et al on ICU based physiotherapist for the use of hyperinflation techniques. They concluded that there are no specific guidelines for the use of manual or mechanical hyperinflation in ICU patients who are ventilated and sedated. They also found that the physiotherapists who are applying manual hyperinflation techniques didn't know the volumes they are delivering and also the subjective measures. When applying MHI, clinical expertise and patient stability are important components to be determined.[29]

Previously, physiotherapist are using MHI but with varying degree of guidelines and according to their own expertise and experiences This study will help. The study aims to find out the effects of structured manual hyperinflation using Mapelson C circuit for improving respiratory parameters and ABG's after endotracheal tube suctioning in patients undergone coronary artery bypass graft in Pakistan.Previous studies have significant limitations related to protocol, equipment, outcome measures and the higher risk of biasness. There is no specifc guidelines for the use of manual hyperinflation in intubated patients about the delivering volumes and subjective measures. Moreover, few studies clearly reported the changes in arterial blood gases and respiratory parameters after structured manual hyperinflation. Furthermore, previously the Mapelson B system was used for manual hyperinflation. Both Mapelson B and C systems are similar apart from that the B system having tubing between the reservoir bag and the fresh gas flow, which further acts as a reservoir. It was important to investigate the effects of MHI and VHI to achieve desired effects in ICU patients**.** By using randomized control trials, this study investigated the effects of structured MHI for improving respiratory parameters such as static lung compliance, alveolar-arterial oxygen tension difference and arterial oxygen to fraction of inspired oxygen ratio and ABG's after endotracheal tube suctioning.

METHODOLOGY:

It was randomized control trial with sample size of 76 (38 for each group) post-operative CABG patients. Study duration was 6 Months (January 2019-June 2019) and data was collected from Bahria international hospital, Rawalpindi. Sampling techniques was Non-probability purposive sampling technique and randomization was done by sealed envelope method. Inclusion criteria was Intubated, hemodynamically and vitally stable both males and females with age range of 55-77 years. Exclusion criteria was any past medical history included conditions that may have influenced lung compliance, severe asthma, severe chronic airflow limitation (CAL), any diagnosed pulmonary pathology and patient with post-operative complications e.g pulmonary hypertension, prolonged bypass time and sepsis. Withdrawal criteria was any subject who have unstable cardiovascular status (systolic blood pressure [SBP] <100 or >180 mmHg or mean arterial pressure [MAP] <60 or >110 mmHg), arrhythmias which compromise cardiovascular function, presence of a pneumothorax, excessive blood loss from subcostal catheters (>100 ml/hour), high levels of respiratory support (fraction of inspired oxygen [FIO2] > 0.7 and positive end expiratory pressure [PEEP] >7.5 cmH20)

Treatment protocol:

Single session of protocol was given in each group and immediate effects were noted. Protocol was applied approximately three to four hours after the surgery. During the time of measurements, administered drugs, patient position and mechanical support was kept constant. All the descriptive and operative data was recorded.

Physiotherapy protocol prior to interventions:

Before treatment, baseline measurements were recorded. Prior to hyperinflation techniques, percussion, vibration and ETT suctioning of the patient were performed. The patient was first moved to modified postural drainage (30° head- up) position [30] and nebulization was done via ventilator.

Percussion and vibration was performed in the 45° supine position, while slightly laterally lying. [31] The lung was then drained using percussion and vibration. Percussion was given on the chest wall. The hand was cupped properly as if to hold water but with the palm facing down so that percussion was less painful for patient. The cupped hand curved to the chest wall and trapped a cushion of air to soften the clapping. It was done with steady beat. The physiotherapist took percussive movement with wrist and relaxed arm so that it's less tiring for physiotherapist and more effective for patient.

After percussion, vibration was done with the flattened hand. The physiotherapist placed a firm hand on the chest wall and tensed the muscles of the arm and shoulder and created a fine shaking motion then, applied a light pressure over the area being vibrated.

Percussion was done for three minutes and followed by vibration over the same area for approximately 15 seconds, and then endotracheal aspiration was performed in the supine position. [32] Special attention was given in performing percussion and vibration so that it didn't affect the sternotomy wound and sternum.

ETT suctioning was done with closed ETT suctioning system and the size of catheter used for suctioning was standardized. In patients whose endotracheal tube diameter was 7.0-8.5mm, 12F catheter was used and in patients whose tube internal diameter was 9.0-9.5mm, 14F catheter was used. The patient was pre-oxygenated with 100% FiO2 for about 2 min. Suction was done twice. Each suction catheter administration was done for six seconds and there was five second interval between both suctions. Suction was continuous and negative pressure of 150mmHg was applied at the time of suction catheter withdraw. After ETT suctioning, set of baseline measurements was recorded. MHI and VHI were then performed as per randomization order. [28]

Experimental group:

MHI was done in supine position with Mapleson C circuit system which has manometer in line and the flow of oxygen was set at 15L/min. The recruited patients received four sets; each comprised of one minute and consisted of eight hyperinflation breaths. Prior to give hyperinflation breath, physiotherapist washed hands and prepared equipment. Mapleson C bag was attached to 15L/min via the O2 port. Manometer was connected. Leaks in the bag or other faults were checked prior to attaching the bag to the patient. The expiratory valve was closed maximally and compressed the bag to assess that there are no functional concerns with the apparatus. Connect the Mapleson C bag to the endotracheal tube via the catheter mount. The bag was positioned securely to minimize the amount of movement or drag, which will take place in the apparatus. Patient was positioned supine while Performing MHI breaths. Each breath had three seconds of inspiration to peak inspiratory pressure of 35-40cmH2O along with two seconds of inspiratory pause. Decompression of the bag was released quickly to simulate the forced expiratory technique. Full passive expiration was allowed prior to next MHI. In between each MHI set, patients received tidal breathing for 1 minute which was same as respiratory rate and PIP was given by ventilator at baseline. Ventilatory support was restored; ensuring adequate tidal volume and minute volume were maintained. Cardiovascular status and vital signs were monitored throughout the process.

The data was recorded immediately after MHI and then 30 minutes and 60 minutes post MHI.[28]

Control group:

VHI was done in supine position in synchronized intermittent mandatory ventilation with volume control mode. The FiO2 was increased to 100%, and the respiratory rate was decreased to eight breaths per minute and inspiratory flow rate was reduced to 20 L/min. the tidal volume was increased until PIP reached 35-40

European Journal of Health Sciences
ISSN 2520-4645 (online)
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cmH2O. When the target pressure was achieved, the tidal volume was kept constant for eight breaths along with 2 seconds of inspiratory pause. VHI was given in four sets of one-minute duration. In between each set, patients received tidal breathing for 1 minute which was same as the baseline parameters of ventilation. [28]PEEP and pressure support setting was remained unchanged during the whole study. Data was collected immediately after VHI and then 30 minutes and 60 minutes post VHI. All the ETT suctioning, MHI and VHI interventions was done by same physiotherapist.

CONSORT diagram:

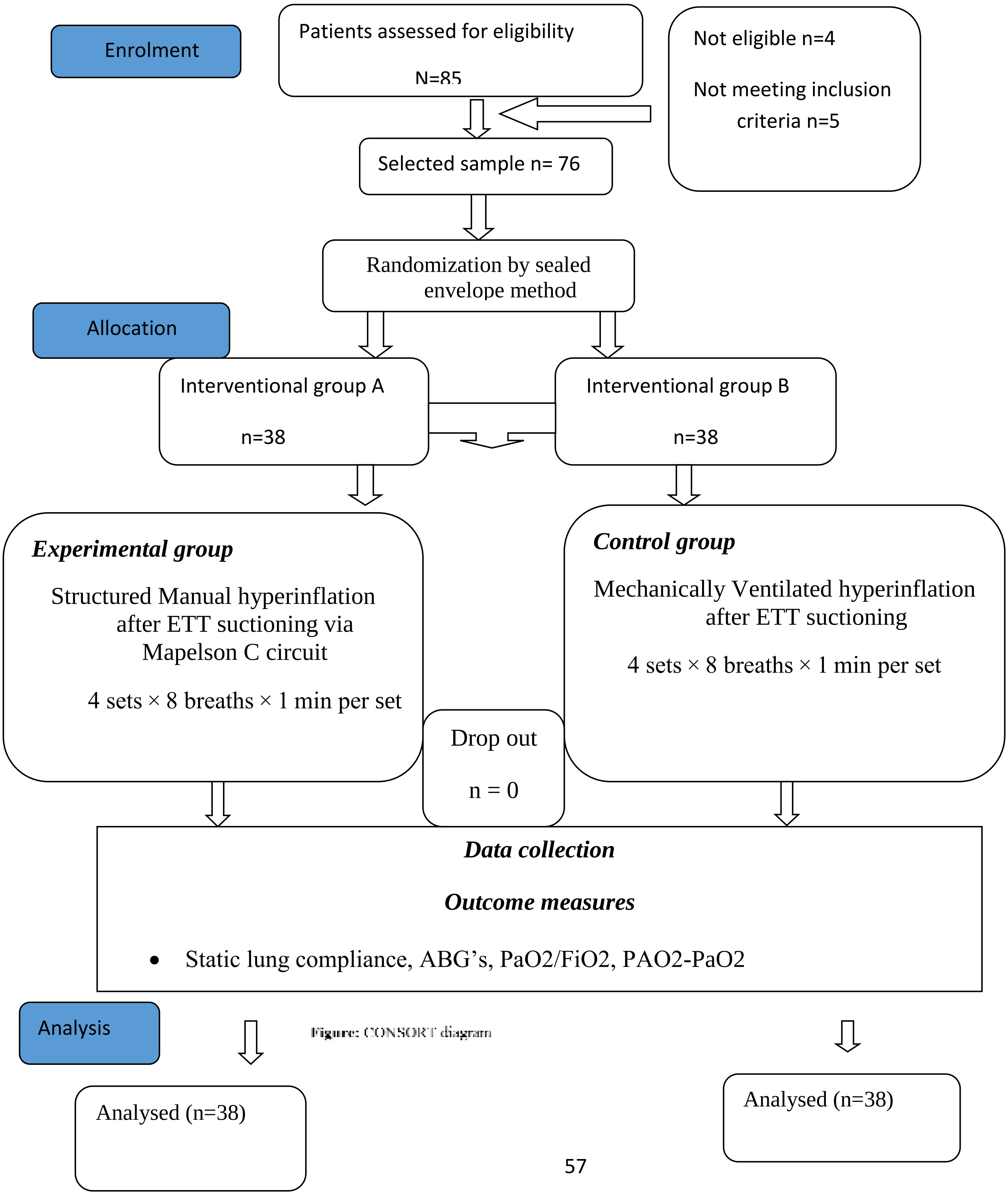

Figure: CONSORT diagram

European Journal of Health Sciences
ISSN 2520-4645 (online)
Vol.5, Issue 2 No.3, pp 53-79, 2020
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RESULTS:

Participant characteristics and demographics:

Normality of participant characteristics and demographic information in both the groups was determined using Shapiro-Wilk test of normality. If either one of the two groups exhibited distribution that was not normal for a single variable, non-parametric test of significance (Mann Whitney U test) was used for inter group comparison and averages were reported in the form of Median (IQR). On the other hand, if both the groups exhibited normal distribution averages was reported in the form of Mean (S.D) and parametric test of significance (Independent t-test) was used for inter-group comparison. Only Body Mass Index (BMI) and tidal volume were found to be normally distributed ($p>0.05$), and all other variables were found not have a normal distribution ($p<0.05$) (Table 1).

Moreover, in terms of inter group comparison of participant characteristics and demographics no significant differences were observed between any of the variables between the two groups indicating baseline similarity, except for positive end expiratory pressure and body mass index (Table 2).

Table 1: Normality analysis of baseline participant characteristics and demographic information using Shapiro-Wilk test of normality

Variable	Group	Statistic	P-Value
Age	Manual Hyperinflation	.906	.004
	Mechanical Hyperinflation	.954	.123
BMI	**Manual Hyperinflation**	**.965**	**.272**
	Mechanical Hyperinflation	**.975**	**.543**
Time on Ventilator	Manual Hyperinflation	.860	.000
	Mechanical Hyperinflation	.854	.000
FiO2	Manual Hyperinflation	.866	.000
	Mechanical Hyperinflation	.924	.013
Tidal Volume	**Manual Hyperinflation**	**.977**	**.610**
	Mechanical Hyperinflation	**.953**	**.114**
Positive End Expiratory Pressure	Manual Hyperinflation	.746	.000
	Mechanical Hyperinflation	.689	.000
Pressure Support	Manual Hyperinflation	.443	.000
	Mechanical Hyperinflation	.473	.000
Inspiratory Flow Time	Manual Hyperinflation	.782	.000
	Mechanical Hyperinflation	.683	.000

European Journal of Health Sciences
ISSN 2520-4645 (online)
Vol.5, Issue 2 No.3, pp 53-79, 2020

Table 2: Comparison of baseline participant characteristics and demographic information between Manual Hyperinflation and Mechanical Hyperinflation using Mann-Whitney U test and Independent t-test. (*indicates p-values from Independent t-test)

Variable	Manual Hyperinflation	Mechanical Hyperinflation	P-value
	Median (IQ)	**Median (IQ)**	
Age	72.00(4.50)	70.50(9.25)	0.387
Time on Ventilator	4.00(2.00)	4.50(2.00)	**0.219**
FiO2	68.00(5.50)	68.00(3.00)	**0.549**
Positive End Expiratory Pressure	5.00(1.00)	7.00(1.00)	**<0.001**
Pressure Support	15.00(1.00)	15.00(0.00)	**0.306**
Inspiratory Flow Time	62.50(5.50)	60.00(5.00)	**0.240**
	Mean (S.D)	**Mean (S.D)**	
BMI	22.11(4.43)	23.82(3.94)	**0.019***
Tidal Volume	506.89(19.18)	502.61(17.61)	**0.313***

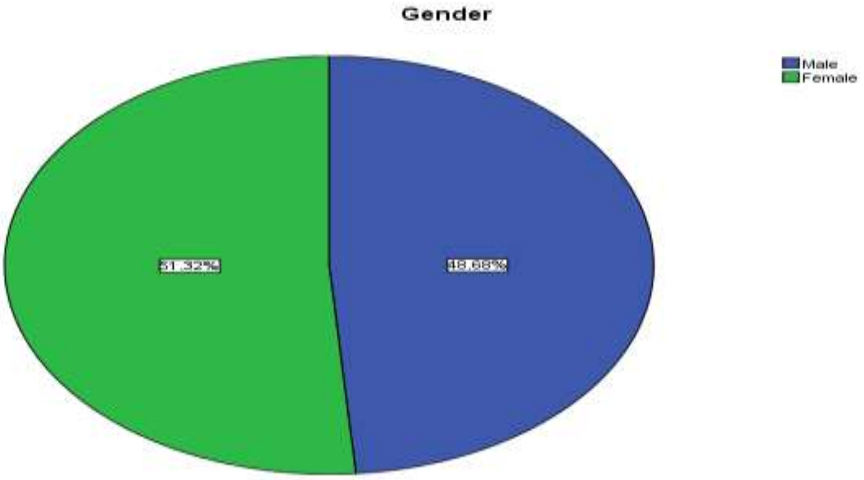

Fig 1: Distribution of study participants on basis of gender.

Inter and intra group comparison:

Normality of variables in both the groups was determined using Shapiro-Wilk test of normality. If either one of the two groups exhibited distribution that was not normal for a single variable, non-parametric tests of significance (Mann Whitney U test and Friedman test) were used for inter and intra group comparison and averages were reported in the form of Median (IQR). On the other hand, if both the groups exhibited normal distribution averages was reported in the form of Mean (S.D) and parametric tests of significance (Independent t-test and Repeated measures ANOVA) were used for inter-group and intra group comparison

pH:

A p-value of less than 0.05 showed all the variables not having a normal distribution and non-parametric tests of significance were used (Table 3). Moreover, in terms of inter group comparison of participant pH scores no significant differences were observed between any of the variables between the two groups, except for pH scores immediately after intervention (Table 4).

In terms of pre and post analysis of pH of the participants in the manual hyperinflation group, as pH scores at all of the points of measurements were not normally distributed, non-parametric test of significance (Friedman test) was used and a p-value of less than 0.05 indicated a significant difference between the pH scores for the participants in the manual hyperinflation group at different points of measurement (Fig.2)

Table 3: Normality analysis of pH of participants using Shapiro-Wilk test of normality.

Variable	Group	Statistic	Sig.
pH (Pre endotracheal tube suctioning value)	Manual Hyperinflation	.932	.023
	Mechanical Hyperinflation	.965	.284
pH (Post endotracheal tube suctioning value)	Manual Hyperinflation	.929	.019
	Mechanical Hyperinflation	.919	.009
pH (Immediately after intervention)	Manual Hyperinflation	.884	.001
	Mechanical Hyperinflation	.963	.232
pH (30 mins post intervention)	Manual Hyperinflation	.929	.019
	Mechanical Hyperinflation	.946	.063
pH (60 mins post intervention)	Manual Hyperinflation	.942	.049
	Mechanical Hyperinflation	.946	.063

Table 4: Comparison of pH of participants between Manual Hyperinflation and Mechanical Hyperinflation using Mann-Whitney U test.

Variable	Manual Hyperinflation	Mechanical Hyperinflation	P-value
	Median (IQR)	Median (IQR)	
pH (Pre endotracheal tube suctioning value)	7.38 (0.03)	7.38 (0.03)	0.685
pH (Post endotracheal tube suctioning value)	7.35 (0.02)	7.36 (0.03)	0.983
pH (Immediately after intervention)	7.39 (0.02)	7.38 (0.02)	0.006
pH (30 mins post intervention)	7.38 (0.03)	7.38 (0.03)	0.302
pH (60 mins post intervention)	7.38 (0.02)	7.38 (0.03)	0.276

European Journal of Health Sciences
ISSN 2520-4645 (online)
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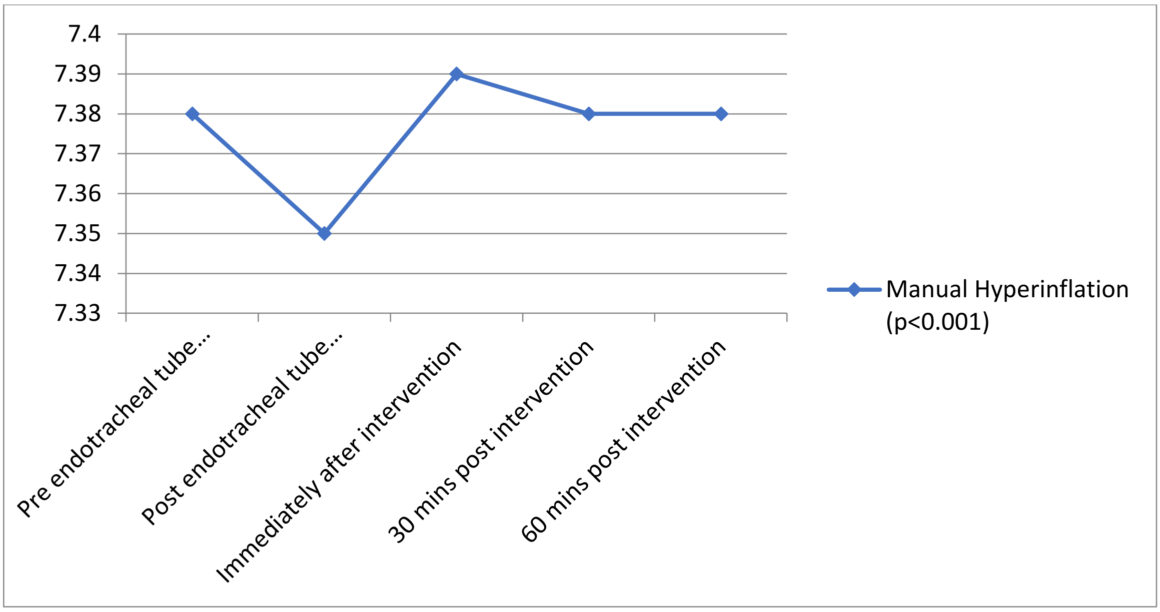

Fig 2: Pre and post analysis of pH scores of participants in the Manual Hyperinflation group using Friedman Test.

pCO2:

A p-value of less than 0.05 was observed only for pre endotracheal suctioning and immediately after intervention scores (Table 5). Moreover, in terms of inter group comparison of participant pCO2 scores no significant differences were observed between any of the variables between the two groups, except for pCO2 scores immediately after intervention (Table 6).

In terms of pre and post analysis of pCO2 of the participants in the manual hyperinflation group, as pCO2 scores at all of the points of measurements were not normally distributed, non-parametric test of significance (Friedman test) was used and a p-value of less than 0.05 indicated a significant difference between the pCO2 scores for the participants in the manual hyperinflation group at different points of measurement (Fig. 3).

Table 5: Normality analysis of pCO2 of using Shapiro-Wilk test of normality.

Variable	Group	Statistic	P-value
pCO2 (Pre endotracheal tube suctioning value)	Manual Hyperinflation	.954	.121
	Mechanical Hyperinflation	.932	.023
pCO2 (Post endotracheal tube suctioning value)	Manual Hyperinflation	.954	.120
	Mechanical Hyperinflation	.961	.209
pCO2 (Immediately after intervention)	Manual Hyperinflation	.833	.000
	Mechanical Hyperinflation	.905	.003
pCO2 (30 mins post intervention)	Manual Hyperinflation	.969	.378
	Mechanical Hyperinflation	.949	.082
pCO2 (60 mins post intervention)	Manual Hyperinflation	.969	.378
	Mechanical Hyperinflation	.949	.082

European Journal of Health Sciences
ISSN 2520-4645 (online)
Vol.5, Issue 2 No.3, pp 53-79, 2020

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Table 6: Comparison of pCO2 of participants between Manual Hyperinflation and Mechanical Hyperinflation using Mann-Whitney U test and Independent t-test. (*indicates p-values from Independent t-test).

Variable	Manual Hyperinflation	Mechanical Hyperinflation	P-value
	Median (IQR)	**Median (IQR)**	
pCO2 (Pre endotracheal tube suctioning value)	39.00(3.00)	39.00(4.00)	0.929
	Mean (S.D)	**Mean (S.D)**	
pCO2 (Post endotracheal tube suctioning value)	40.97(2.19)	40.97(2.70)	0.100*
	Median (IQR)	**Median (IQR)**	
pCO2 (Immediately after intervention)	45.00(2.00)	43.00(3.25)	<0.001
	Mean (S.D)	**Mean (S.D)**	
pCO2 (30 mins post intervention)	39.84(2.05)	39.47(2.75)	0.510*
pCO2 (60 mins post intervention)	39.84(2.05)	39.47(2.75)	0.510*

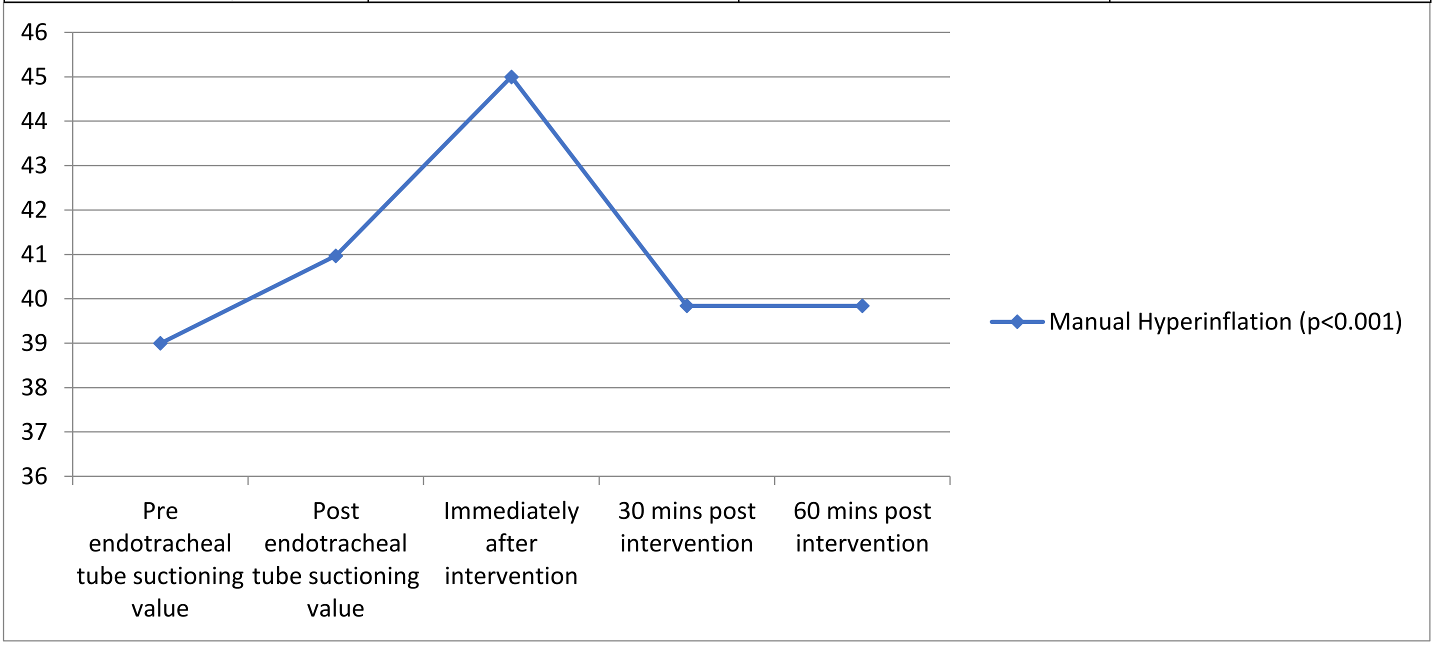

Fig 3: Pre and post analysis of pCO2 scores of participants in the Manual Hyperinflation group using Friedman Test.

pO2:

A p-value of less than 0.05 showed all the variables not having a normal distribution and non-parametric tests of significance were used (Table 7). Moreover, in terms of inter group comparison of participant pO2 scores, no significant differences were observed between any of the variables between the two groups, except for pO2 scores immediately after intervention (Table 8).

In terms of pre and post analysis of pO2 of the participants in the manual hyperinflation group, as pO2 scores at all of the points of measurements were not normally distributed, non-parametric test of significance (Friedman test) was used and a p-value of less than 0.05 indicated a significant difference between the pO2 scores for the participants in the manual hyperinflation group at different points of measurement (Fig. 4).

Table 7: Normality analysis of pO2 of using Shapiro-Wilk test of normality.

Variable	Group	Statistic	Sig.
pO2 (Pre endotracheal tube suctioning value)	Manual Hyperinflation	.894	.002
	Mechanical Hyperinflation	.874	.001
pO2 (Post endotracheal tube suctioning value)	Manual Hyperinflation	.959	.171
	Mechanical Hyperinflation	.925	.014
pO2 (Immediately after intervention)	Manual Hyperinflation	.904	.003
	Mechanical Hyperinflation	.909	.005
pO2 (30 mins post intervention)	Manual Hyperinflation	.901	.003
	Mechanical Hyperinflation	.947	.072
pO2 (60 mins post intervention)	Manual Hyperinflation	.901	.003
	Mechanical Hyperinflation	.947	.072

Table 8: Comparison of pO2 of participants between Manual Hyperinflation and Mechanical Hyperinflation using Mann-Whitney U test.

Variable	Manual Hyperinflation	Mechanical Hyperinflation	P-value
	Median (IQR)	Median (IQR)	
pO2 (Pre endotracheal tube suctioning value)	97.00(8.50)	98.00(7.5)	0.442
pO2 (Post endotracheal tube suctioning value)	92.50(7.25)	92.50(6.50)	0.700
pO2 (Immediately after intervention)	100.50(6.15)	98.00(7.00)	<0.001
pO2 (30 mins post intervention)	98.00(7.50)	100.00(8.00)	0.243
pO2 (60 mins post intervention)	98.00(7.50)	100.00(8.00)	0.243

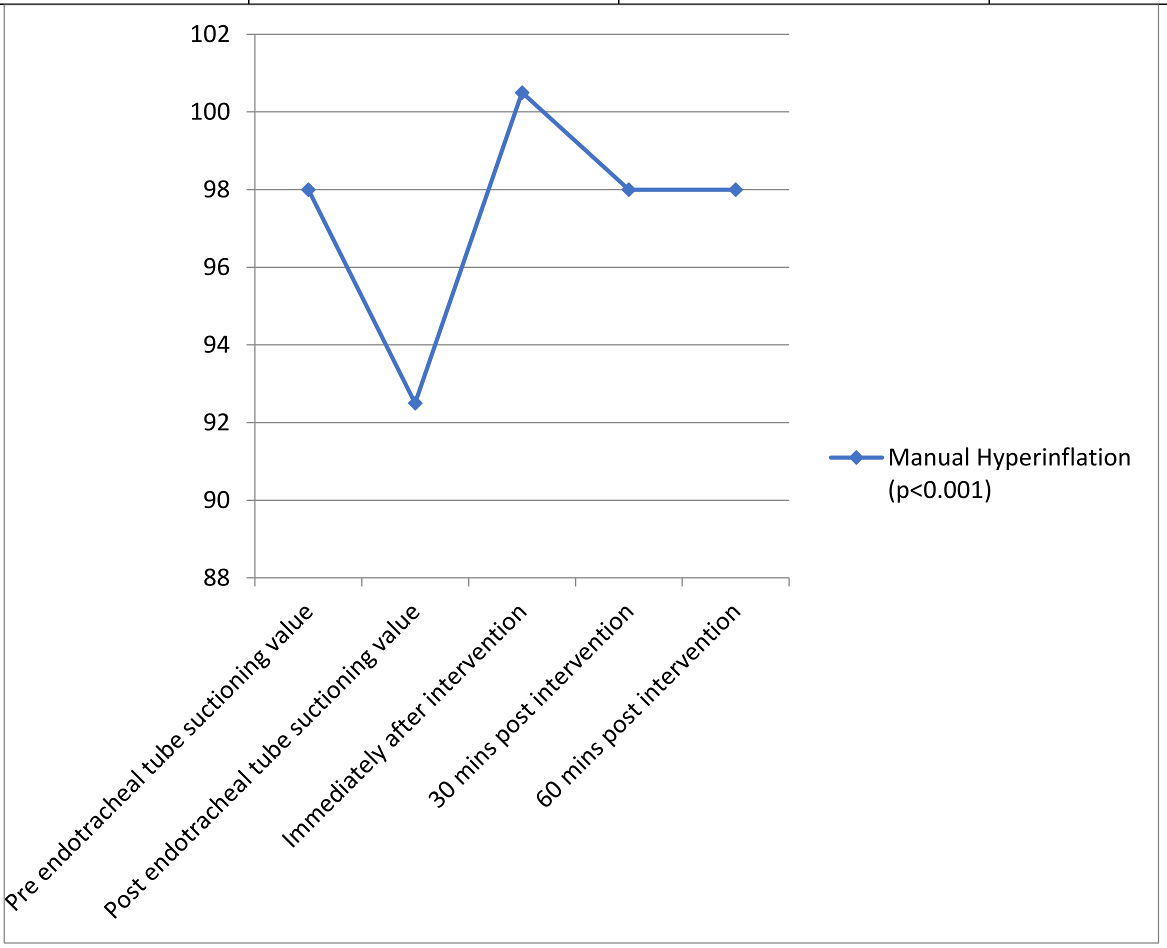

Fig 4: Pre and post analysis of pO2 scores of participants in the Manual Hyperinflation group using Friedman Test.

European Journal of Health Sciences
ISSN 2520-4645 (online)
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HCO3:

A p-value of less than 0.05 showed all the variables not having a normal distribution and non-parametric tests of significance were used (Table 9). Moreover, in terms of inter group comparison of participant HCO3 scores, a significant difference was observed between the two groups, at immediately after intervention, 30 minutes after intervention and 60 minutes after intervention (Table 10).

In terms of pre and post analysis of HCO3 of the participants in the manual hyperinflation group, as HCO3 scores at all of the points of measurements were not normally distributed, non-parametric test of significance (Friedman test) was used and a p-value of less than 0.05 indicated a significant difference between the HCO3 scores for the participants in the manual hyperinflation group at different points of measurement (Fig. 5).

Table 9: Normality analysis of HCO3 using Shapiro-Wilk test of normality.

Variable	Group	Statistic	Sig.
HCO3 (Pre endotracheal tube suctioning value)	Manual Hyperinflation	.905	.004
	Mechanical Hyperinflation	.912	.006
HCO3 (Post endotracheal tube suctioning value)	Manual Hyperinflation	.911	.005
	Mechanical Hyperinflation	.895	.002
HCO3 (Immediately after intervention)	Manual Hyperinflation	.930	.020
	Mechanical Hyperinflation	.925	.014
HCO3 (30 mins post intervention)	Manual Hyperinflation	.914	.007
	Mechanical Hyperinflation	.913	.006

Table 10: Comparison of HCO3 of participants between Manual Hyperinflation and Mechanical Hyperinflation using Mann-Whitney U test.

Variable	Manual Hyperinflation	Mechanical Hyperinflation	P-value
	Median (IQR)	Median (IQR)	
HCO3 (Pre endotracheal tube suctioning value)	24.00(1.48)	24.00(1.25)	0.122
HCO3 (Post endotracheal tube suctioning value)	25.00(1.25)	25.00(1.00)	0.30
HCO3 (Immediately after intervention)	23.00(1.00)	24.00(1.00)	0.003
HCO3 (30 mins post intervention)	23.00(2.25)	24.00(1.00)	0.003
HCO3 (60 mins post intervention)	23.00(2.25)	24.00(1.00)	0.002

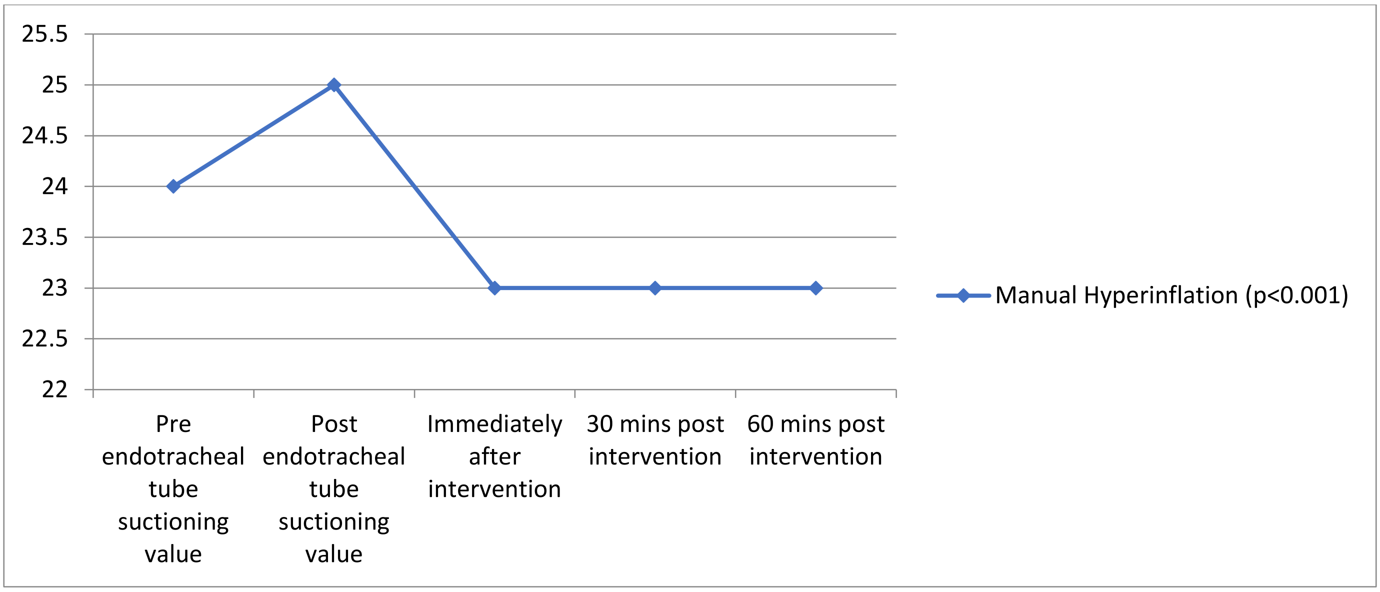

Fig 5: Pre and post analysis of HCO3 scores of participants in the Manual Hyperinflation group using Friedman Test.

Oxygen Saturation:

A p-value of less than 0.05 showed all the variables not having a normal distribution and non-parametric tests of significance were used (Table 11). Moreover, in terms of inter group comparison of participant oxygen scores no significant differences were observed between any of the variables between the two groups, except for oxygen saturation scores immediately after intervention (Table 12).

In terms of pre and post analysis of oxygen saturation of the participants in the manual hyperinflation group, as oxygen saturation scores at all of the points of measurements were not normally distributed, non-parametric test of significance (Friedman test) was used and a p-value of less than 0.05 indicated a significant difference between the oxygen saturation scores for the participants in the manual hyperinflation group at different points of measurement (Fig. 6).

Table 11: Normality analysis of Oxygen Saturation using Shapiro-Wilk test of normality.

Variable	Group	Statistic	P-value
Sat O2 (Pre endotracheal tube suctioning value)	Manual Hyperinflation	.873	.000
	Mechanical Hyperinflation	.848	.000
Sat O2 (Post endotracheal tube suctioning value)	Manual Hyperinflation	.918	.008
	Mechanical Hyperinflation	.843	.000
Sat O2 (Immediately after intervention)	Manual Hyperinflation	.452	.000
	Mechanical Hyperinflation	.844	.000
Sat O2 (30 mins post intervention)	Manual Hyperinflation	.817	.000
	Mechanical Hyperinflation	.856	.000
Sat O2 (60 mins post intervention)	Manual Hyperinflation	.797	.000
	Mechanical Hyperinflation	.195	.000

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Table 12: Comparison of oxygen saturation of participants between Manual Hyperinflation and Mechanical Hyperinflation using Mann-Whitney U test.

Variable	Manual Hyperinflation	Mechanical Hyperinflation	P-value
	Median (IQR)	Median (IQR)	
Sat O2 (Pre endotracheal tube suctioning value)	98.00(1.00)	98.00(2.00)	0.308
Sat O2 (Post endotracheal tube suctioning value)	96.00(2.00)	96.00(2.00)	0.774
Sat O2 (Immediately after intervention)	100.00(2.00)	99.00(1.00)	<0.001
Sat O2 (30 mins post intervention)	98.00(0.25)	98.00(2.00)	0.920
Sat O2 (60 mins post intervention)	98.00(0.25)	98.00(2.00)	0.611

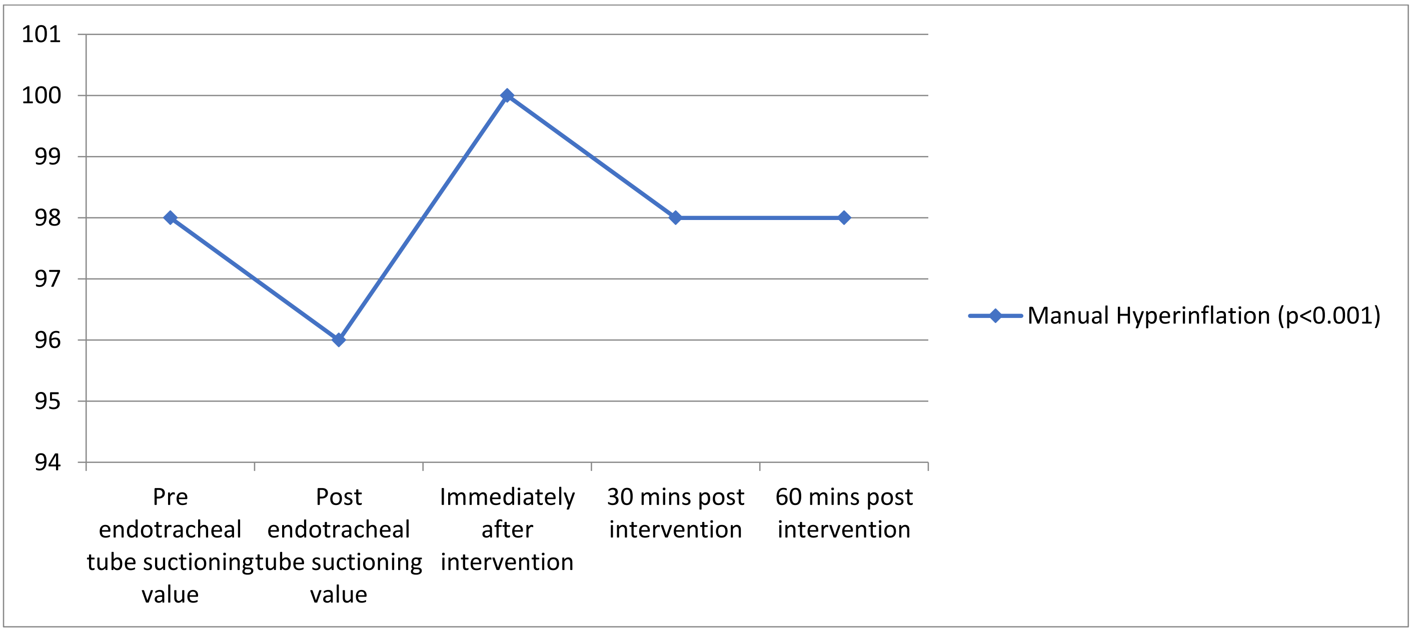

Fig 6: Pre and post analysis of oxygen saturation scores of participants in the Manual Hyperinflation group using Friedman Test

European Journal of Health Sciences
ISSN 2520-4645 (online)
Vol.5, Issue 2 No.3, pp 53-79, 2020

Static Lung Compliance:

A p-value of less than 0.05 showed all the variables not having a normal distribution and non-parametric tests of significance were used (Table 13). Moreover, in terms of inter group comparison of participant static lung compliance scores were found to have a significant difference at 30- and 60-minutes post intervention only (Table 14).

In terms of pre and post analysis of static lung compliance of the participants in the manual hyperinflation group, as static lung compliance scores at all of the points of measurements were not normally distributed, non-parametric test of significance (Friedman test) was used and a p-value of less than 0.05 indicated a significant difference between the static lung compliance scores for the participants in the manual hyperinflation group at different points of measurement (Fig. 7).

Table 13: Normality analysis of static lung compliance using Shapiro-Wilk test of normality.

Variable	Group	Statistic	Sig.
Static lung compliance (Pre endotracheal tube suctioning value)	Manual Hyperinflation	.943	.054
	Mechanical Hyperinflation	.949	.083
Static lung compliance (Post endotracheal tube suctioning value)	Manual Hyperinflation	.943	.053
	Mechanical Hyperinflation	.949	.081
Static lung compliance (Immediately after intervention)	Manual Hyperinflation	.929	.018
	Mechanical Hyperinflation	.950	.087
Static lung compliance (30 mins post intervention)	Manual Hyperinflation	.929	.018
	Mechanical Hyperinflation	.942	.048
Static lung compliance (60 mins post intervention)	Manual Hyperinflation	.929	.018
	Mechanical Hyperinflation	.950	.087

Table 14: Comparison of static lung compliance of participants between Manual Hyperinflation and Mechanical Hyperinflation using Mann-Whitney U test.

Variable	Manual Hyperinflation	Mechanical Hyperinflation	P-value
	Median (IQR)	Median (IQR)	
Static lung compliance (Pre endotracheal tube suctioning value)	16.20(0.98)	16.51(1.03)	0.057
Static lung compliance (Post endotracheal tube suctioning value)	16.18(1.00)	16.47(1.03)	0.057
Static lung compliance (Immediately after intervention)	16.28(0.98)	16.55(1.00)	0.089
Static lung compliance (30 mins post intervention)	19.18(0.98)	21.45(1.00)	<0.001
Static lung compliance (60 mins post intervention)	19.18(0.98)	21.45(1.00)	<0.001

European Journal of Health Sciences
ISSN 2520-4645 (online)
Vol.5, Issue 2 No.3, pp 53-79, 2020
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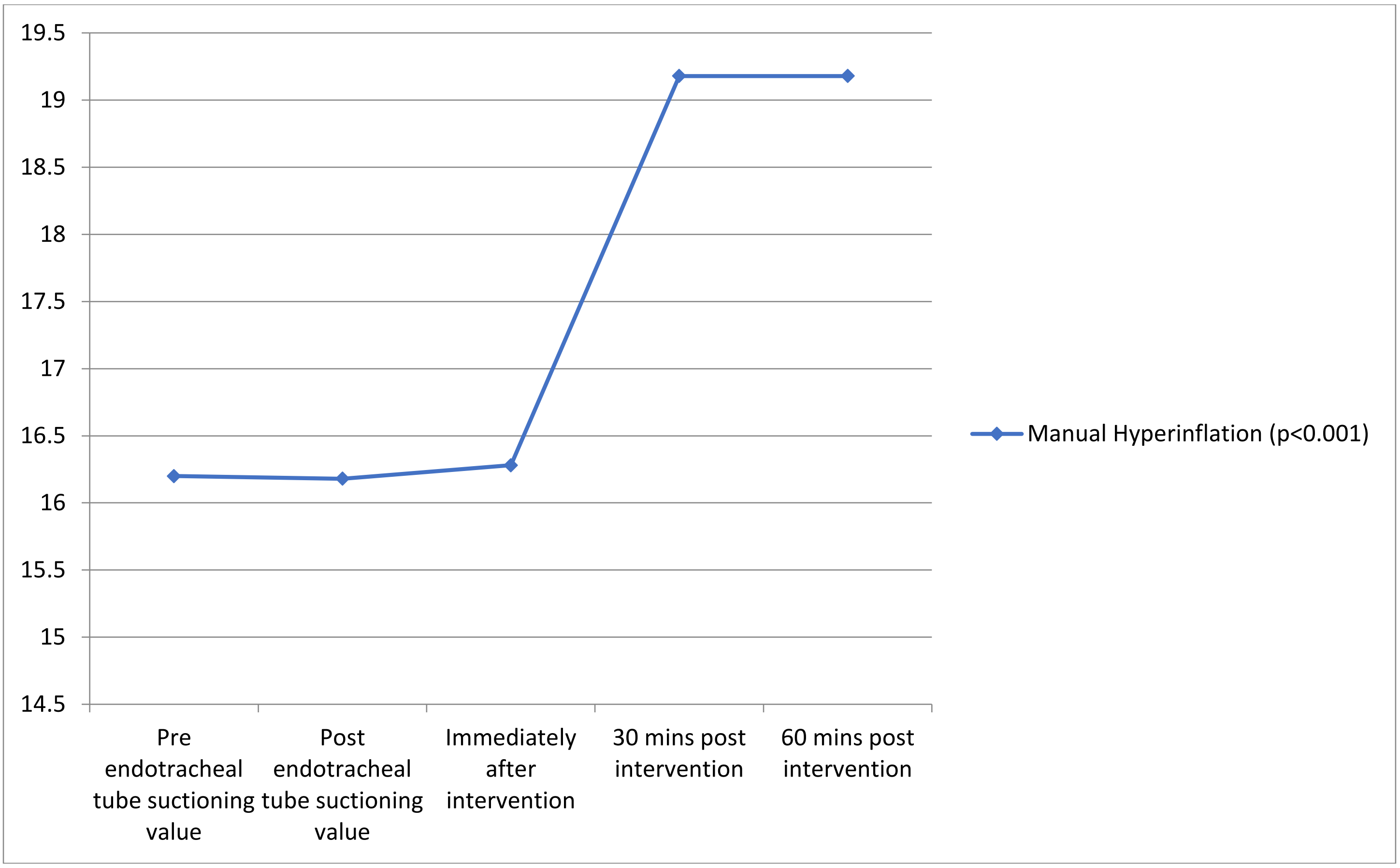

Fig 7: Pre and post analysis of static lung compliance scores of participants in the Manual Hyperinflation group using Friedman Test.

pO2:FiO2:

A p-value of less than 0.05 showed all the variables not having a normal distribution and non-parametric tests of significance were used (Table 15). Moreover, in terms of inter group comparison of participant pO2:FiO2 scores no significant differences were observed between any of the variables between the two groups, except for pH scores immediately after intervention (Table 16).

In terms of pre and post analysis of pO2:FiO2 of the participants in the manual hyperinflation group, as pO2:FiO2 scores at all of the points of measurements were not normally distributed, non-parametric test of significance (Friedman test) was used and a p-value of less than 0.05 indicated a significant difference between the pO2:FiO2 scores for the participants in the manual hyperinflation group at different points of measurement (Fig. 8).

Table 15: Normality analysis of pO2:pFiO2 of using Shapiro-Wilk test of normality.

Variable	Group	Statistic	P-value
pO2:FiO2 (Pre endotracheal tube suctioning value)	Manual Hyperinflation	.894	.002
	Mechanical Hyperinflation	.621	.000
pO2:FiO2 (Post endotracheal tube suctioning value)	Manual Hyperinflation	.944	.058
	Mechanical Hyperinflation	.917	.008
pO2:FiO2 (Immediately after intervention)	Manual Hyperinflation	.942	.049
	Mechanical Hyperinflation	.906	.004
pO2:FiO2 (30 mins post intervention)	Manual Hyperinflation	.894	.002
	Mechanical Hyperinflation	.961	.199
pO2:FiO2 (60 mins post intervention)	Manual Hyperinflation	.894	.002
	Mechanical Hyperinflation	.961	.199

Table 16: Comparison of pO2:FiO2 of participants between Manual Hyperinflation and Mechanical Hyperinflation using Mann-Whitney U test.

Variable	Manual Hyperinflation	Mechanical Hyperinflation	P-value
	Median (IQR)	Median (IQR)	
pO2:FiO2 (Pre endotracheal tube suctioning value)	143.06 (26.85)	143.38(16.17)	0.339
pO2:FiO2 (Post endotracheal tube suctioning value)	136.03(21.39)	136.29(14.23)	0.540
pO2:FiO2 (Immediately after intervention)	147.79(17.67)	143.70(14.83)	0.008
pO2:FiO2 (30 mins post intervention)	143.38(26.02)	147.38(16.65)	0.659
pO2:FiO2 (60 mins post intervention)	143.38(26.02)	147.38(16.65)	0.659

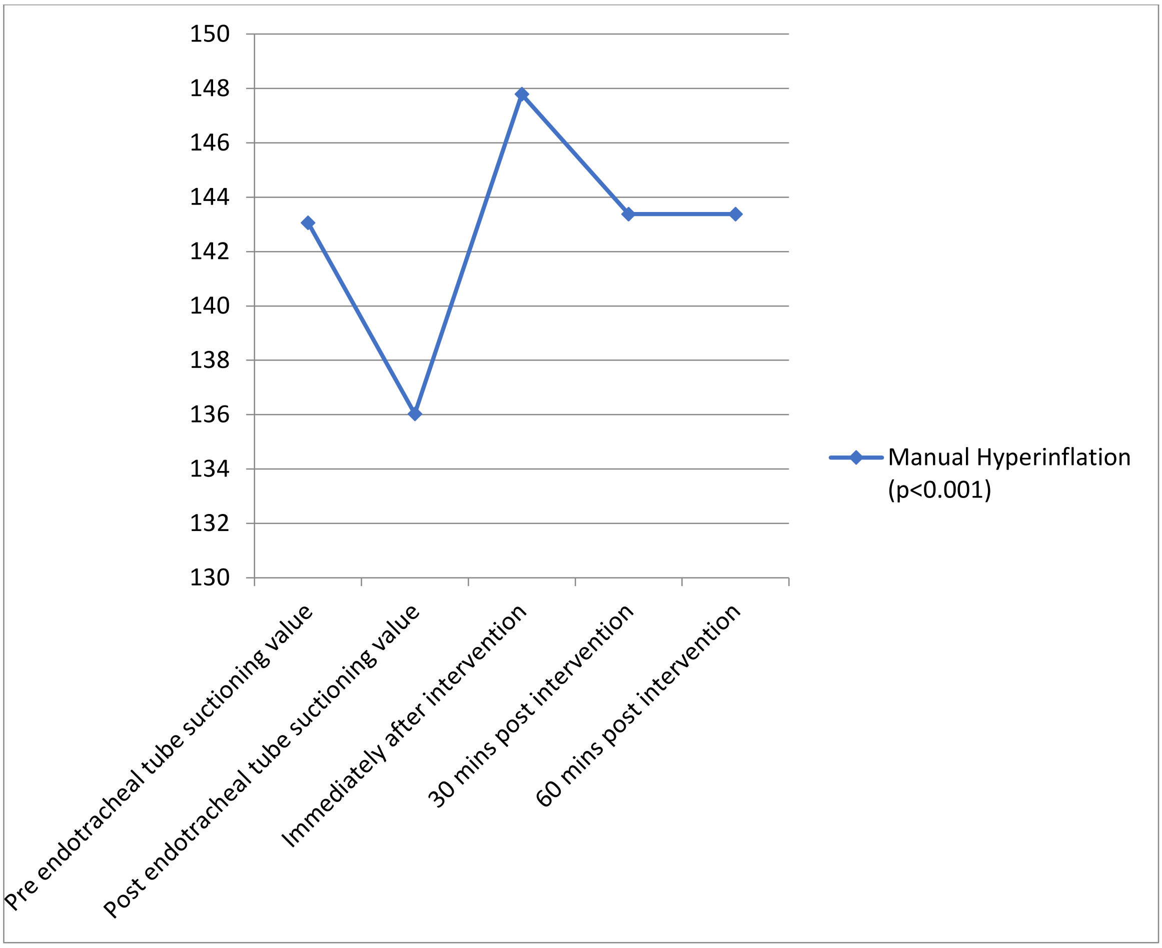

Fig 8: Pre and post analysis of pO2:FiO2 scores of participants in the Manual Hyperinflation group using Friedman Test.

Alveolar-Arterial oxygen tension:

A p-value of less than 0.05 showed all the variables not having a normal distribution and non-parametric tests of significance were used (Table17). Moreover, in terms of inter group comparison of participant alveolar-arterial oxygen tension scores no significant differences were observed between any of the variables between the two groups (Table18).

In terms of pre and post analysis of alveolar-arterial oxygen tension of the participants in the manual hyperinflation group, as alveolar-arterial oxygen tension scores at all of the points of measurements were not normally distributed, non-parametric test of significance (Friedman test) was used and a p-value of less than 0.05 indicated a significant difference between the alveolar-arterial oxygen tension scores for the participants in the manual hyperinflation group at different points of measurement (Fig. 9).

European Journal of Health Sciences
ISSN 2520-4645 (online)
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Table17: Normality analysis of alveolar-arterial oxygen tension of using Shapiro-Wilk test of normality.

Variable	Group	Statistic	Sig.
Alveolar-Arterial oxygen tension (Pre endotracheal tube suctioning value)	Manual Hyperinflation	.916	.007
	Mechanical Hyperinflation	.926	.015
Alveolar-Arterial oxygen tension (Post endotracheal tube suctioning value)	Manual Hyperinflation	.908	.004
	Mechanical Hyperinflation	.930	.019
Alveolar-Arterial oxygen tension (Immediately after intervention)	Manual Hyperinflation	.918	.008
	Mechanical Hyperinflation	.944	.056
Alveolar-Arterial oxygen tension (30 mins post intervention)	Manual Hyperinflation	.918	.008
	Mechanical Hyperinflation	.924	.013
Alveolar-Arterial oxygen tension (60 mins post intervention)	Manual Hyperinflation	.918	.008
	Mechanical Hyperinflation	.924	.013

Table18: Comparison of alveolar-arterial oxygen tension of participants between Manual Hyperinflation and Mechanical Hyperinflation using Mann-Whitney U test.

Variable	Manual Hyperinflation	Mechanical Hyperinflation	P-value
	Median (IQR)	Median (IQR)	
Alveolar-Arterial oxygen tension (Pre endotracheal tube suctioning value)	337.09(51.03)	337.09(26.55)	0.596
Alveolar-Arterial oxygen tension (Post endotracheal tube suctioning value)	339.34(47.97)	338.72(29.36)	0.557
Alveolar-Arterial oxygen tension (Immediately after intervention)	328.22(46.62)	331.78(27.17)	0.067
Alveolar-Arterial oxygen tension (30 mins post intervention)	335.34(50.34)	333.72(27.24)	0.823
Alveolar-Arterial oxygen tension (60 mins post intervention)	335.34 (50.34)	333.72(27.24)	0.823

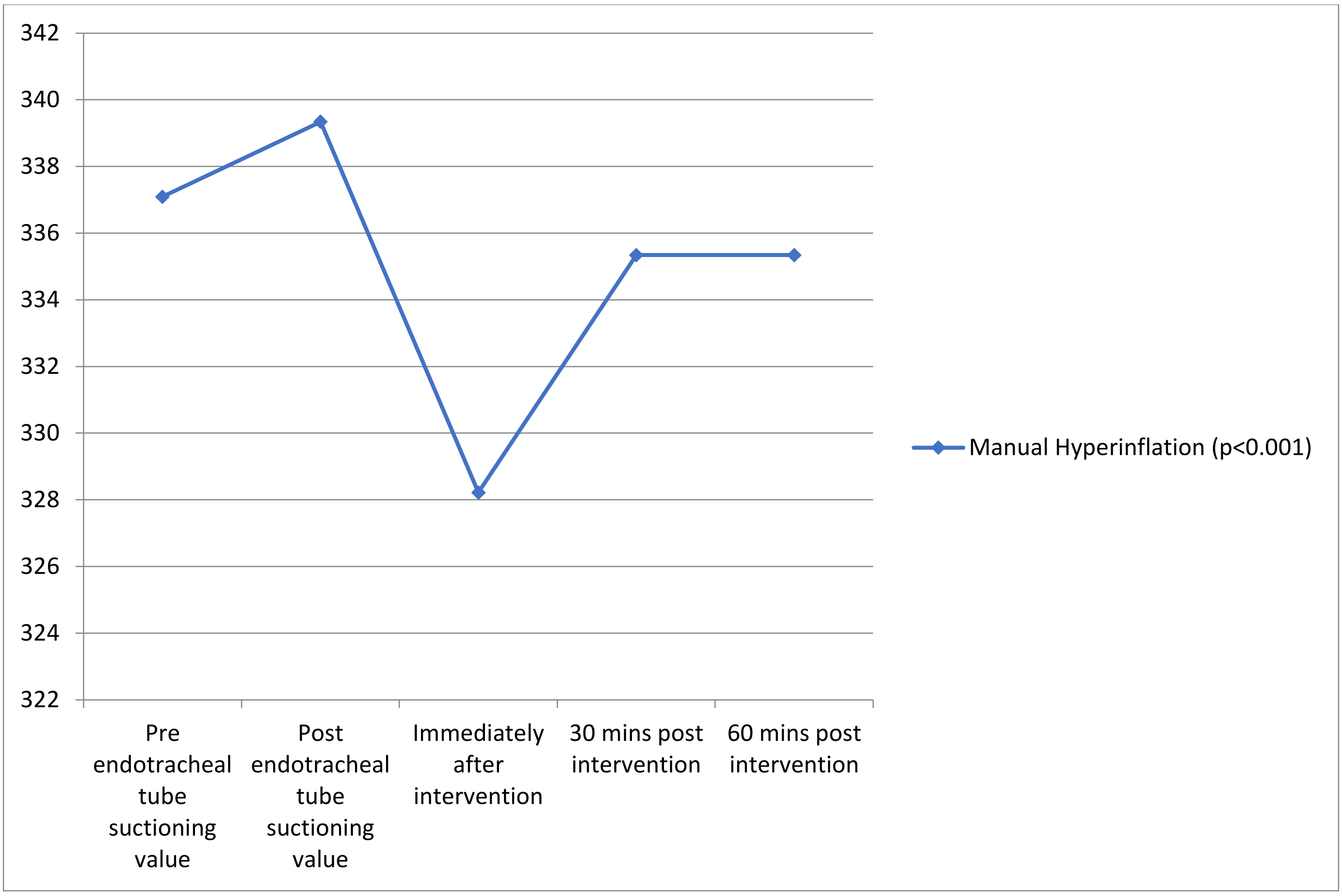

Fig 9: Pre and post analysis of alveolar-arterial oxygen tension scores of participants in the Manual Hyperinflation group using Friedman Test

DISCUSSION:

Manual hyperinflation is a commonly used technique in the management of critically ill, mechanically ventilated and intubated patients [19]. Mechanical ventilation causes movement of secretions from smaller to larger airways [33, 34], resulting in removal of secretions with airway suction [19]. The current study was conducted to determine the effects of structured manual hyperinflation in post-operative coronary artery bypass graft (CABG) patients following endotracheal tube suctioning, to improve respiratory parameters as well as arterial blood gases (ABGs) including pH, pCO2, pO2, oxygen saturation, bicarbonate , alveolar-arterial oxygen tension, static lung compliance and pO2:FiO2. Literature has shown manual hyperinflation to be effective in terms of improving airway secretion clearance, pulmonary compliance, pO2, oxygen saturation, decreased cardiac output, diastolic blood pressure, systemic vascular resistance, alveolar-arterial oxygen tension, increased central venous pressure, and decreased hear rate [19, 35-39]. On the other hand literature has shown no improvement of manual hyperinflation in terms of cardiac output, airway secretion clearance, oxygen saturation, heart rate, incidence of pneumonia, cardiac output, incidence of pneumonia, pulmonary compliance, pO2, systemic blood pressure, central venous pressure, pulmonary artery wedge pressure, oxygen saturation or decreased length of stay in the intensive care unit (ICU) [19, 40, 41]. In terms of the current study however, a significant difference ($p<0.05$) was observed in terms of pre and post intervention scores of all outcome variables including pH, pCO2, pO2, oxygen saturation, bicarbonate, alveolar-arterial oxygen tension, static lung compliance and pO2:FiO2 in post CABG patients that received structured manual hyperinflation.

A study conducted by Hodgson et al determined the effects of manual hyperinflation in critically ill patients in terms of sputum clearance, gaseous exchange, mean arterial pressure, pulmonary compliance and heart rate. The study found significant improvements in pulmonary compliance, sputum clearance, mean arterial pressure, heart rate, pCO2 and pO2:FiO2 [35]. These findings were in accordance with the current study which also showed significant improvements in pCO2 and pO2:FiO2. In the current study pCO2 increased significantly on measuring immediately post structured manual hyperinflation intervention and then slightly decreased back again after 30 minutes and then stagnated when measured again at 60 minutes. This is similar to the findings of Hodgson et al study in which pCO2 increased significantly post manual hyperinflation and then again decreased slightly when measured at 20 minutes post intervention [35]. Similarly, in terms of pO2:FiO2 scores, the pO2:FiO2 increased significantly on measuring immediately post structured manual hyperinflation intervention and then slightly decreased back again after 30 minutes and then stagnated when measured again at 60 minutes. This was once again in accordance with Hodgson's study in which pO2:FiO2 increased significant post manual hyperinflation and then again decreased slightly when measured at 20 minutes post intervention [35].

Another study conducted by Patman et al determined the effects of manual hyperinflation as compared to control in terms of pO2:FiO2, alveolar- arterial oxygen tension and lung compliance in patients who underwent coronary artery surgery, and were medically stable and mechanically ventilated [37]. The findings showed a significant improvement in pO2:FiO2, alveolar- arterial oxygen tension and lung compliance, and the measurements were taken immediately post intervention, and 5 minutes, 10 minutes, 20 minutes, 30 minutes and 60 minutes post intervention [37]. In Patman study pO2:FiO2 scores increased significantly on measuring immediately post manual hyperinflation intervention and then decreased back again at 5 and 10 minutes post intervention and then again increased at 30 minutes and then gradually stagnated when measured again at 60 minutes [37]. This was in accordance with the findings of the current study in which pO2:FiO2 increased significantly on measuring immediately post structured manual hyperinflation intervention and then slightly decreased back again after 30 minutes and then stagnated when measured again at 60 minutes; however, there were no measurements recorded and 5 and 10 minutes post intervention. Moreover, in terms of alveolar-arterial oxygen tension, Patman's study showed a remarkable decrease immediately post intervention which than increased slightly and gradually stagnated over 5, 10, 30 and 60 minutes respectively [37]. These findings are in perfect harmony with the findings of the current study in which a remarkable decrease was noted in alveolar- arterial oxygen tension immediately post intervention which than increased slightly and gradually stagnated over 30 and 60 minutes respectively; however there were no measurements recorded and 5 and 10 minutes post intervention in the current study.

A study conducted by Barker also evaluated the effects of manual hyperinflation, but the patients considered in the study were with acute lung injury. The outcome measures in this study included pCO2, pO2:FiO2, heart rate, lung compliance, oxygen saturation and blood pressure [38]. Measurements were recorded at baseline and 10, 30 and 60 minutes post intervention[38] as compared to immediately after intervention, 30 and 60 minutes after intervention in the current study. In terms of pCO2 significant changes were noted in pre and post intervention scores ($p=0.026$) [38], similar to the findings of the current study ($p<0.001$). Moreover, significant changes were noted in terms of pre and post scores of oxygen saturation as well ($p<0.05$) [38], similar to the findings of the current study ($p<0.001$). However, no significant changes were reported in terms of pre and post intervention scores of pO2:FiO2 ($p>0.05$) [38], unlike the findings of the current study in which statistically significant changes were noted in the pre and post intervention scores of pO2:FiO2 ($p<0.001$). Moreover, in Baker study statistically significant changes were also reported in participants receiving manual hyperinflation in terms of heart rate and systemic blood pressure, however those changes were not clinically significant [38].

A study conducted by Blattner determined the effects of manual hyperinflation in patients following myocardial revascularization [39] and found pO2 to be 17.5 mmHg greater, and static lung compliance to be 8.5ml/cmH2O greater in the manual hyperinflation group than the control group. However, no significant differences were observed between the two groups in terms of relative risk of post-operative pulmonary complications [39]. These findings are in accordance with the current study which has also shown manual hyperinflation to be effective in terms of pre and post scores of pO2.

Another study conducted by Choi JSP et al determined the effects of manual hyperventilation on mechanically ventilated patients and found significantly positive effects of manual hyperinflation in terms of static lung compliance and inspiratory resistance, with an increase in static lung compliance and decrease in inspiratory resistance [36]. The measurements were recorded immediately and 30 minutes after manual hyperinflation similarly to the current study [36], however measurements were also recorded 60 minutes post intervention in the current study.

In addition to determining the effects of structured manual hyperinflation in post-operative CABG patients, the current study also compared the effects of structured manual hyperinflation and mechanical hyperinflation following endotracheal tube suctioning in post-operative CABG patients at pre endotracheal tube suctioning, post endotracheal tube suctioning, Immediately after intervention, 30 minutes post intervention and 60 minutes post intervention intervals. A significant difference ($p<0.05$) was observed between manual and mechanical hyperinflation groups only immediately after intervention in terms of pH, pCO2, pO2, oxygen saturation and pO2:FiO2, with scores for manual hyperinflation group being higher than the mechanical hyperinflation group. Moreover, for HCO3 a significant difference ($p<0.05$) was noted immediately after intervention, 30 minutes post intervention and 60 minutes post intervention, and mechanical hyperinflation group scores were greater than manual hyperinflation group, and for static lung compliance scores in which there was a significant difference ($p<0.05$) at 30 minutes post intervention and 60 minutes post intervention, and mechanical hyperinflation group scores were greater than manual hyperinflation group. Alveolar-arterial to oxygen tension showed significant difference in structured manual hyperinflation group while it showed no significant results between the groups. Moreover, it is also imperative to point out that no significant difference ($p>0.05$) was observed between manual and mechanical hyperinflation at any other point of measurement.

A randomized controlled trial was conducted by Ahmed et al comparing the effects of manual and mechanical hyperinflation in post cardiac surgery patients, and found no significant differences ($p<0.05$) between the two groups in terms of static and dynamic lung compliance, pO2:FiO2, pCO2 and pH [42], which were in accordance with the findings of the current study as mentioned previously.

Another study conducted by Dennis et al compared the effects of manual and mechanical hyperinflation, but this time in intensive care unit patients in terms of sputum net weight, lung compliance, tidal volume, airway pressure and pO2:FiO2 [43]. The findings of this study showed no significant differences ($p<0.05$) in terms of sputum net weight, lung compliance, tidal volume, heart rate, respiratory rate and mean arterial pressure. However, a significant difference was observed between the manual and mechanical hyperinflation in terms of mean airway pressure and time dependent pO2:FiO2 ($p<0.05$) [43]. Just like the findings of the current study, in Dennis study as well both the interventions were found to be effective, but the results were no conclusive enough to establish one technique to be superior to the other.

Berney et al also conducted a research comparing the effects of manual and mechanical hyperinflation on ventilated intensive care patients in terms of static lung compliance. Even though both manual and mechanical hyperinflation were found to be significantly effective in terms of sputum production and static pulmonary compliance, however no significant differences were observed between the two treatment groups [18]. However, in the current study a significant difference ($p<0.05$) was observed in terms of static lung compliance scores at 30 minutes post intervention and 60 minutes post intervention, in which mechanical hyperinflation group scores were found to be greater than manual hyperinflation group.

In light of the findings of the current study and the existing literature, it is safe to conclude that structured manual hyperinflation is an effective technique in improving lung compliance following endotracheal tube suctioning in post CABG patients, in terms of pH, pCO2, pO2, oxygen saturation, HCO3, static lung compliance and pO2:FiO2. There are significant differences in overall values of all variables in structured manual hyperinflation group at different intervals. Moreover, the differences between the two groups are not remarkable and conclusive but the values are comparatively higher for structured MHI group.

CONCLUSION:

This study indicates that both structured MHI and VHI are found to be effective in improving respiratory parameters following ETT suctioning. However, the results are much more significant in structured MHI. Furthermore, for improving static lung compliance, VHI is more effective. But the difference between the groups was not significant and conclusive.

RECOMMENDATIONS:

This study should be conducted in different patient populations having different pulmonary conditions and other types of cardiac surgeries and in other patients who are intubated and mechanically ventilated. Moreover, the effects of both techniques on different variables must be studied after multiple numbers of sessions during the whole period of intubation. Furthermore, finding out the effects of both techniques on HCO3 using more appropriate apparatus and guidelines are also warranted.

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