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Original Article

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Effect of Lung Manual Hyperinflation (MHI) on Oxygenation of Patients Following Abdominal Surgery and T-Tube Support

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Abstract

Background: Postoperative pulmonary complications (PPC) are of the major reasons for death. Prolonged mechanical ventilation (PMV) and delayed extubation are leading to the incidence of more seriously complications. The effect of hyperinflation has not been investigated in control of these complications in patients who have been weaned from mechanical ventilation and are undergoing T-tube support.

Aim: Investigation of MHI effect on oxygenation of patients following abdominal surgery and T-tube support.

Method: This clinical trial was performed on 40 patients undergoing abdominal surgery and T-tube support hospitalized in intensive care units of hospitals in Mashhad, Iran, in 2015-2016. The participants were divided randomly into two experimental and control groups. In the experimental group, MHI technique was performed using Mapleson circuit for three twenty-minute periods. The control group received routine hospital care. The two groups were compared for PaO_2, $PaCO_2$ and SpO_2 before intervention, 5 and 20 minutes after intervention. Data were analyzed using SPSS software.

Results: The mean age was 66.7±8.3 and 67.5±9.0 years in experimental and control groups, respectively. In intergroup comparison using independent t-test, the mean $PaCO_2$, PaO_2 and SpO_2 had no significant differences in the experimental group before the intervention. However, the means SpO_2 and PaO_2 at 5 and 20 minutes after intervention were significantly higher in the experimental group ($p<0.001$) than the control group. The mean $PaCO_2$ at 5 and 20 minutes after intervention decreased significantly in the experimental group ($p=0.03$).

Implications for Practice: The results showed that the MHI technique by increasing oxygenation and ventilation could improve lung function in the participants, resulting in shortening the duration of mechanical ventilation, accelerating the process of extubation, and thus faster patient recovery.

Keywords: Lung Hyperinflation, Abdominal Surgery, Oxygenation, Postoperative Pulmonary Complications

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Introduction

Nowadays, surgery is considered as selective treatment for many patients. Often following surgery, damage to vital body systems is inevitable, especially respiratory system; and instability of the systems will be further by expanding the surgery (1). Postoperative pulmonary complications (PPC) are of the major reasons for death, which are seen frequently after upper abdominal surgeries so that have been reported in more than 75% of patients (3). Some of the most important postoperative pulmonary complications are atelectasis, pneumonia and respiratory failure (2, 4). Disorders of gas exchange and oxygenation in the postoperative period vary from a slight decline in PaO_2 to life-threatening hypoxemia (5). The incidence rate of hypoxemia after abdominal surgery has been reported 30%-50% (6). The hypoxemia can lead to complications including postoperative delirium, wound infections, ECG changes and even MI (5). Therefore, one of the major postoperative concerns for patients is decreasing pulmonary complications and subsequent reduction of mortality. Mechanical ventilation is one of the most widely used postoperative treatments, because it can ensure acceptable gas exchanges within the lungs of the patients (7).

However, prolonged mechanical ventilation and hospitalization can increase hospital deaths by causing problems such as VAP (ventilator-associated pneumonia), damage to the airways and atelectasis (8). Extubation failure increases mortality rate up to 6 times. Thus improving lung function and oxygenation have an important role in successful weaning and extubation and are of the most important therapeutic targets in patients undergoing mechanical ventilation (9). The use of T-tube during the process of weaning from mechanical ventilation is a commonly used and approved method. It is used also in patients who have a tracheostomy and require oxygen therapy with no long-term mechanical ventilation (10). Accordingly, any action that would be effective in the prevention and treatment of pulmonary complications and the improvement of pulmonary ventilation and oxygenation can lead to short term mechanical ventilation and successful weaning and can have an important role in the recovery process (6).

A study on patients with abdominal surgery showed that any factor that causes dilation of the lungs after surgery could prevent the occurrence of atelectasis and subsequent lung volume reduction and improve its performance. Some of these methods are chest physiotherapy, training of breathing exercises, deep cough, incentive spirometry and positive end-expiratory pressure (PEEP) as well as the MHI (6).

A study that Margaret Mackay et al. (2005) conducted on open abdominal surgery in high-risk patients showed that postoperative respiratory physiotherapy had no positive impact on the reduction of pulmonary complications after open abdominal surgery (11). On the other hand, manual respiratory physiotherapy in patients undergoing chest surgeries is limited due to multiple incisions in the chest, bone fractures, instability of sternum and ribs (12). Pain after abdominal surgery has been identified as one of the causative agents of respiratory muscle dysfunction (13). In addition, the pain prevents deep breathing exercises in surgical patients (2). Incentive spirometry is a tool in which the patient breathes deeply through a device with visual feedback view (14). It should be noted that perfect consciousness and cooperation of the patient are essential for the efficiency of this method; such cooperation of the patients is not possible with decrease of consciousness. A systematic study conducted by Overend et al. in 2001 concerning the effect of incentive spirometry on postoperative pulmonary complications determined that the evidence does not support the effectiveness of incentive spirometry in preventing pulmonary complications after thoracic and upper abdominal surgeries (15).

The use of PEEP maintains alveolar distension capabilities at the end of exhalation and prevents alveolar collapse and generally hypoventilation and subsequent atelectasis (16). The use of CPAP compared with the conventional treatment for atelectasis control can reduce its level to half in patients undergoing abdominal surgery (5), but its necessity is applying mechanical ventilation by patient. Hemmes et al. (2014) examined the high and low levels of PEEP during general anesthesia in patients undergoing abdominal surgery and showed that the incidence rate of pulmonary complications had no significant difference between the two groups. On the other hand, a greater need for vasoactive drugs was found in the group with high PEEP due to hypotension (17). MHI is a technique in which breathing with slow inspiratory flow, further tidal volume, inspiratory pause and peak expiratory flow (2, 18-21) can improve lung function, help to reopen of poorly ventilated alveoli, facilitate the clearing and removal of secretions, improve oxygenation and gas exchange in the lungs (19, 20, 22-

24). This method can be used in mechanically ventilated patients or in those who have artificial airway but not supported by mechanical ventilation (Patients with spontaneous breathing). On the other hand, there is no need for consciousness and cooperation of patient to achieve the mentioned advantages. However, so far, all studies on the effects of the technique have been conducted on patients supported by mechanical ventilation and there is no study to evaluate the effect of this technique in patients who had successful weaning from mechanical ventilation and T-tube support. Accordingly, the present study was conducted to assess the MHI effect on oxygenation of patients following abdominal surgery and T-tube support.

Methods

In this randomized controlled clinical trial, the participants were selected among the patients admitted to the surgical intensive care units of Imam Reza and Ghaem hospitals in Mashhad, Iran, underwent abdominal surgery and T-tube support during the seven months from September 2015 to March 2016. The patients were enrolled in the study after explaining the project methods before starting the study and obtaining informed consent from the conscious patient or their first-degree relatives in the absence of consciousness. Given that, a similar study was not available, so the exact sample size was determined with regard to the dependent variables, including 1- partial pressure of oxygen (PaO_2) in arterial blood 2- partial pressure of carbon dioxide ($PaCO_2$) in arterial blood 3- arterial oxygen saturation (SpO_2) and using the formula of "determining sample size for comparing two independent population means". The pilot study was performed on 20 patients (10 in the experimental group and 10 in control group) and the sample size was calculated for each of the three above index. The largest sample size was related to arterial oxygen saturation, 20 patients in each group (40 in total), and the same number were recruited. In addition, confidence level of 95% and test power of 80% were considered to calculate the sample size.

Inclusion criteria were the patients undergoing abdominal surgery, weaned from mechanical ventilation, age over 18 years, oxygen intake via T-tube for at least two hours, no pulmonary pathologies (such as ARDS, acute lung edema, hemoptysis and pneumothorax), no cardiovascular disorders (hemodynamic instability, such as MAP less than 60 or arrhythmia such as, VT, Af with fast ventricular response and PSVT). Exclusion criteria included extubation criteria, need for repeated surgery, mechanical ventilatory support and hemodynamic instability during the study. The subjects were divided randomly into the two experimental (hyperinflation maneuver) and control (routine care) groups using random numbers table.

Content validity was used for research unit selection form, demographic information form and pulmonary function registration table. SOFA score and Richmond Agitation-Sedation Scale (RASS) are international standard tools for assessing disease severity and GCSC-agitation; their validity has been confirmed. It is worth mentioning that in this study contractually based on scores in Richmond criteria, the patients were divided into three levels 1-conscious and relatively conscious, 2-semi-coma and 3 - coma. The validity of the Gasometer (Gem PREMIER 3000) and Pulse Oximeter (SAADAT ALBORZ B9) devices were approved, since they were for reputable companies. On the other hand, Gasometer validity has been confirmed by studies to measure arterial blood gases (25). The SOFA score and Richmond criteria are international standard tools, and their reliability has been confirmed. The Gasometer and monitoring reliability were approved as internal calibration.

The researcher was trained on the proper implementation of hyperinflation maneuver under controlled conditions and monitoring the volume and pressure in skill lab unit to enter the study environment, and then the study began. At baseline, the researcher through interview and medical history collected basic data of participants, including demographic and disease data. Studying on two experimental and control groups was started with suction (without hyperoxygenation). Then the patient was placed in supine position (without any intervention) for half an hour. The researcher collected arterial blood gas samples from both groups, and arterial oxygen saturation was recorded using Pulse Oximeter.

After recording the basic data in the experimental group, the researcher applied the MHI technique for three twenty-minute periods with twenty-minute rest intervals. Thus, in each twenty-minute period, 12 breaths with delivery volume as twice as tidal volume of spontaneous breaths were presented using Mapleson C circuit that was connected to oxygen at a rate of 15 to 20 liters divided per minute coordinated with patient breathing. How to breathe was as follows; 1.5-2 seconds inhaling along with 2 seconds inspiratory pause and with a quick release of bag during exhalation. The airway pressure was monitored throughout the technique so that it did not exceed 40 cm water. The volumes given during the technique were monitored using Exhalometer device that had been placed in Mapleson circuit. At the end of the three periods, arterial blood gas samples were taken at 5 and 20 minutes after intervention and arterial oxygen saturation levels were recorded using Pulse Oximeter. Data were recorded in the control group at the same times without any intervention. Since the record of all data and intervention actions were carried out by the researcher, so blinded record was not possible. In addition, T-tube venturi in different patients had various FIO_2 levels. However, each patient underwent oxygen therapy by same venturi before and after intervention similar to during the intervention. The data were recorded in the same FIO_2 condition for each patient.

After ensuring the accuracy of data entry, data were analyzed using SPSS version 22 software. Normal distribution of quantitative variables was assessed using the Kolmogorov-Smirnov and the Shapiro-Wilk tests. To study the homogeneity of the two groups in terms of quantitative variables and normal distribution, independent t-test and variables without normal distribution, Mann-Whitney test were used. The homogeneity of qualitative variables were analyzed with chi-square, Fisher and Chi-square exact tests. Two groups were compared in terms of the dependent variables with independent t-test and in case of non-normal distribution with Mann-Whitney test. The intra-group comparison was carried out by repeated measures ANOVA. The ANOVA test was used to investigate the relationship between underlying and confounding variables between the two groups. Confidence interval of 95% (α=5%) was considered in the tests and thus the significance of differences was reported at $P<0.05$.

Results

The mean age of subjects was 67.1±8.5 years with a range of 50 to 86 years (52.5% males). Table 1 shows the data related to patients. There were no significant differences in these variables between the two groups (Table 1). It should be noted that participants in both groups were matched for atelectasis (p=0.220).

Before intervention using independent t-test, there was no significant difference in mean PaO_2 (p=0.86) in the two experimental (88.2±11.7) and control (87.7±8.8) groups. But after the intervention, the mean PaO_2 at 5 minutes after intervention (118.6 ±16.4 in the experimental group versus 87.5± 8.7 in the control group) and 20 minutes after intervention (104.3 ±14.8 in the experimental group versus 87.4± 8.4 in the control group) significantly ($p<0.001$) was higher in the experimental group compared with the control group. According to the repeated measures ANOVA, significant differences were found for mean PaO_2 in terms of group and time ($p<0.001$). The group ($p<0.001$) and time ($p<0.001$) alone had significant effect on PaO_2. A significant interaction was observed between group and time ($p<0.001$) on PaO_2 (Table 2). In other words, after the intervention, PaO_2 level increased in the experimental group compared with the control group ($p<0.001$). Also, according to LSD post hoc test result PaO_2 at 20 minutes compared to 5 minutes after the intervention decreased in the experimental group ($p<0.001$). At all these steps, PaO_2 remained almost constant at the control group and showed no significant difference. However, PaO_2 at 5 minutes after the intervention increased than before the intervention in the experimental group and decreased again at 20 minutes after intervention, but PaO_2 levels in the control group remained nearly constant at these times, indicating significant interactions ($p<0.001$).

Before intervention using independent t-test, there was no significant difference in mean $PaCO_2$ (p=0.14) in the two experimental (36.5± 6.0) and control (40.8±11.0) groups. But after the intervention, the mean $PaCO_2$ at the times of 5 minutes (35.5±7.0 in the experimental group versus 41.9±10.7 in the control group) and 20 minutes (35.7±6.4 in the experimental group versus 42.2±11.2 in the control group) after intervention was significantly lower in the experimental group than the control group (p=0.03). Based on the repeated measures ANOVA, significant differences were found for mean $PaCO_2$ in terms of group and time ($p <0.001$), but the time (p=0.44) as well as the group (p= 0.051) alone had no significant effect on the $PaCO_2$. In addition, group and time indicated significant interaction (p=0.007) on the $PaCO_2$ (Table 2). On the other hand, after the intervention, the $PaCO_2$ level decreased in the experimental group and increased in the control group, but non-significant (p=0.05). Also, the mean $PaCO_2$ after 20 minutes showed no significant changes compared to 5 minutes after invention in both groups (p=0.44). However, $PaCO_2$ at 5 minutes after the intervention decreased than before the intervention in the experimental group and increased again at 20 minutes after intervention, but $PaCO_2$ levels in the control group elevated at these times, representing significant interactions (p=0.007).

Table 1: Comparison of demographic characteristics and disease status of participants in both experimental and control groups

Variables		Groups		Test results
		Experimental	Control	
Age (Year) (mean ± SD)		66.7±8.3	67.5±9.0	0.75*
Gender	Female, N (%)	(50)10	(45)9	0.75**
	Male, N (%)	(50)10	(55)11	
BMI, kg/m^2 (mean ± SD)		24.8±3.8	25.0±3.7	0.87*
Level of consciousness (N) (mean ± SD)		7.2±0.9	6.6±1.3	0.19***
Operation duration (h) (mean ± SD)		4.4±1.0	4.2±1.5	0.61*
Hospitalization duration (day) (mean ± SD)		13.1±6.1	10.9±6.2	0.22***
Duration of mechanical ventilation (day) (mean ± SD)		10.3±5.9	9.5±6.1	0.51***
Type of airway, N (%)	Tracheal tube	(55)11	(60)12	0.74**
	Tracheostomy	(45)9	(40)8	
Repeated mechanical ventilation N (%)	Yes	(40)8	(50)10	0.52**
	No	(60)12	(50)10	
SOFA score, N (mean ± SD)		6.1±1.7	6.1±2.0	0.77***
Type of surgery, N (%)	Laparotomy	(25)5	(20)4	0.81****
	Whipple	(10)2	(15)3	
	Modified peritonitis	(30)6	(25)5	
	Modified abdominal aortic aneurysm	(10)2	(15)3	
	Gastrectomy	(10)2	(5)1	
	Others	(15)3	(20)4	

* Independent t-test, ** Chi-square test, *** Mann-Whitney test, **** Chi-square exact test

Before intervention, there was no significant difference in mean SpO_2 (p=0.71) in the two experimental (94.5±2.5) and control (94.8±2.5) groups. But after the intervention, the mean SpO_2 at the times of 5 minutes (98.2±1.0 in the experimental group versus 94.7±2.4 in the control group) and 20 minutes (97.5±1.4 in the experimental group versus 94.6±2.7 in the control group) after intervention was significantly higher in the experimental group than the control group (p<0.001). Regarding the repeated measures ANOVA, significant differences were found for mean SpO_2 in terms of group and time (p<0.001). The group (p=0.003) and time (p<0.001) alone had significant effect on SpO_2. A significant interaction was found between group and time (p<0.001) on SpO_2 (Table 2). Other words, after the intervention, SpO_2 level increased in the experimental group compared with the control group (p=0.003). Moreover, considering LSD post hoc test result SpO_2 at 20 minutes compared to 5 minutes after the intervention decreased in the experimental group (p<0.001). However, SpO_2 at 5 minutes after the intervention increased than before the intervention in the experimental group and decreased again at 20 minutes after intervention, but SpO_2 levels in the control group remained nearly constant at these times, showing significant interactions (p<0.001).

In analyzing the effects of group and confounding variables on the change in PaO_2, only RASS had significant interaction on the changes in PaO_2 (P=0.001) and all other variables showed no significant independent or interaction effect (P>0.05) on it (Table 3). By assessing the effects of group and confounding variables on the change in SpO_2 before intervention and 5 min after intervention, only RASS had significant interaction on the changes in SpO_2 (P=0.003) and all other variables showed no significant independent or interaction effect (P>0.05) on SpO_2 (Table 4).

Table 2: Comparison of oxygenation indexes of participants in both experimental and control groups

Variables	Steps	Groups (mean ± SD) Experimental	Control	Intra-group test(independent t-test)
Arterial oxygen pressure, PaO_2 (mmHg)	Before intervention	88.2±11.7	87.7±8.8	P=0.86
	5 min after intervention	118.6±16.4	87.5±8.7	P<0.001
	20 min after intervention	104.3±14.8	87.4±8.4	P<0.001
repeated measures ANOVA	Total effect: P<0.001	Effect of time: P<0.001	Effect of group: P<0.001	Interaction: P<0.001
Arterial carbon dioxide pressure, $PaCO_2$(mmHg)	Before intervention	36.5±6.0	40.8±11.0	P=0.14
	5 min after intervention	35.5±7.0	41.9±10.7	P=0.03
	20 min after intervention	35.7±6.4	42.2±11.2	P=0.03
repeated measures ANOVA	Total effect: P<0.001	Effect of time: P=0.05	Effect of group: P=0.44	Interaction: P=0.007
Arterial oxygen saturation, SpO_2 (%)	Before intervention	94.5±2.5	94.8±2.5	P=0.71
	5 min after intervention	98.2±1.0	94.7±2.4	P<0.001
	20 min after intervention	97.5±1.4	94.6±2.7	P<0.001
repeated measures ANOVA	Total effect: P<0.001	Effect of time: P<0.001	Effect of group: P=0.003	Interaction: P<0.001

Table 3: Comparison of mean and standard deviation of arterial oxygen pressure (PaO_2) before and 5 minutes after the intervention for consciousness level in the two control and experimental groups

	Group Experimental		Control		Total	
consciousness level based on Richmond Agitation and Sedation Scale (RASS)	Mean ± SD	No	Mean ± SD	No	Mean ± SD	No
conscious and relatively conscious	38.1±10.4	4	0.7±2.9	9	11.2±19.5	13
semi-coma	28.3±6.7	16	0.2±2.3	11	16.9±15.0	27
ANOVA results		Total effect	P=0.08	f= 9.56		
		Effect of group	P=0.10	f=38.1		
		Effect of variable	P=0.56	f=0.6		

	Interaction	P=0.01	f=7.2

Table 4: Comparison of mean and standard deviation of Arterial oxygen saturation (SpO_2) before and 5 minutes after the intervention for consciousness level in the two control and experimental groups

	Group					
	Experimental		Control		Total	
consciousness level based on Richmond Agitation and Sedation Scale (RASS)	Mean ± SD	No.	Mean ± SD	No.	Mean ± SD	No.
conscious and relatively conscious	1.2±1.8	4	0.2±0.6	9	0.5±1.1	13
semi-coma	4.3±1.9	16	0.2±1.4	11	2.4±0.5	27
ANOVA results	Total effect P=0.28 f= 4.49 Effect of group P=0.36 f=2.4 Effect of variable P=0.60 f=0.5 Interaction P=0.003 f=9.9					

Discussion

The results of the present study demonstrated that in general arterial oxygen pressure of patients undergoing abdominal surgery with T-tube support improved using manual hyperinflation (MHI) technique. In the experimental group, the PaO_2 level increased 34.5% at the 5 minutes after the intervention and 18.3% at the 20 minutes after the intervention compared to before the intervention. This means that hyperinflation maneuver has been able to re-open the alveoli and increase ventilation to perfusion ratio, improving oxygenation of the participants. The significant results at 20 minutes after intervention suggest that the MHI technique could maintain this improvement over time for a while. These results reflect the fact that if the technique is performed according to specific time and adequate frequency, it could have the maximum impact on improving lung function and oxygenation through the prevention and treatment of atelectasis in each range.

Raafat et al., in 2011 in Egypt examined the arterial oxygenation response to the lung hyperinflation as a method added to respiratory physiotherapy in intensive care unit patients under mechanical ventilation with positive end-expiratory pressure (PEEP) less than 10 and ages ranging from 40 to 60 years.

Subjects in the experimental group, in addition to planned physical therapy, received hyperinflation technique for three 15-minutes periods divided per day for three consecutive days (with duration of 3 seconds inhalation and 3 seconds inspiratory pause). The results showed statistically significant improvement in mean arterial oxygen pressure using this maneuver. Therefore, the mean arterial oxygen pressure was 143.8±41.3 and 90.8 ± 7.4 in the experimental group immediately after the intervention and at the same times in the control group, respectively (26).

Although the patients in the present study were not undergoing mechanical ventilation and surgery as well as MHI technique for a shorter time (three twenty-minute periods for 2 hours), but the results (34%) were similar to the findings of Raafat, indicating greater effect of this maneuver in In patients with spontaneous breathing.

Patman et al. in Australia (2000) investigated the effect of MHI technique on respiratory parameters in 100 patients after coronary artery bypass surgery undergoing mechanical ventilation and hospitalization in ICU; the MHI technique implemented after the suctioning and data logging for a period of 4 minutes on patients in the intervention group. There was significant difference in mean difference of alveolar and arterial oxygen pressures (PO2 (A-a)) between the two groups immediately after the intervention. In fact, mean PO_2 (A-a) in the test group at 5, 10, 20, 30 and 60 minutes after the hyperinflation had been improved compared to before the intervention in this group, but not-significant statistically. This change was accompanied with a slight improvement over time in the control group, which was not statistically significant (24). This improvement in the control group of Patman research could be due to the complete withdrawal of the patient from anesthesia and elimination of drug effects during anesthesia. In fact, despite the downward trend in the arterial oxygen pressure levels during 60 minutes, the pressure levels in these times were higher than before the intervention.

However, despite declining trend over time in the present study, increase in arterial oxygen pressure up to 20 minutes after the intervention had significant difference, which reflects the efficiency of manual hyperinflation technique especially in spontaneous breathing after weaning from the mechanical ventilation. Based on the comparison of the results, this technique had less persistence in improving the ventilation/perfusion ratio in patients undergoing mechanical ventilation with PEEP or CPAP. But in this research that the hyperinflation technique was studied in patients with Breathing problems undergoing abdominal surgery and with spontaneous breathing supported by oxygen through T-tube, the significant influence was evident for longer time that indicates further usefulness and importance of this method in this group of patients.

The results of present study revealed that in general the SpO_2 level increased in patients undergoing abdominal surgery and T-tube support using the manual hyperinflation (MHI) technique. The SpO_2 level in the experimental group showed 4.25% increase at 5 minutes after intervention and 3% increase at 20 minutes after intervention than before the intervention. This means that the MHI technique led to further cooperation of collapsed alveoli in ventilation and improvement of lung function. The increase at the 20 minutes after intervention is indicative of persistence and usefulness of this maneuver in spontaneously breathing patients.

It can be claimed that the three to four percent increase would not be useful clinically, but according to OxyHemoglobin Dissociation Curve (OHDC) and non-linear relationship between PaO_2 and SpO_2 and thus depending on the changes level in SpO_2, the PaO_2 changes will vary according to the patient's conditions (e.g., pH and temperature). It can be concluded that three or four percent increase in the level of SpO_2 will lead to further changes in the level PaO_2 in the range of arterial blood oxygen saturation between 90 and100, which is clinically important from this point of view.

In the study of Raafat et al. (2011) that was conducted to evaluate the arterial oxygenation response to lung hyperinflation as a method added to respiratory physiotherapy, the results showed that the mean SpO_2 was improved significantly in patients due to hyperinflation maneuver. In their study, the SpO_2 level in the participants immediately after the intervention showed 3.73% increase compared to pre-intervention and the increase in arterial oxygen saturation was significant. However, this level of increase in the present study at 5 and 20 minutes after the intervention was higher than the results of Raafat (26). Raafat et al. did not examine the persistence of the MHI technique effects. The reason for increased oxygen saturation might be the immediate improvement of oxygenation after temporary cooperation of collapsed alveoli in ventilation.But in the present study, significant increase in oxygen saturation at 20 minutes after intervention shows persistence of this method. Raafat, did intervene three times a day for three days with 3-second inspiratory pause after respiratory physiotherapy in mechanically ventilated patients with PEEP support. In the study of Raafat, the patients were under mechanical ventilation. However, MHI technique in the current study in patients with spontaneous breathing showed similar results with the study of Raafat. This means that the hyperinflation technique had better and more effective impact in spontaneous breathing status after weaning from mechanical ventilation.

Paulus et al. in the Netherlands (2010) conducted a study to evaluate the manual hyperinflation performed by trained and professional nurses and its effects on 74 patients with stable condition and admitted to the surgical ICU. Their results indicated that the oxygen saturation did not change significantly with the implementation of this maneuver (27). The results are not in line with the current study, because most of the subjects in Paulus study needed to the suction after technique, which in turn causes a drop in oxygen saturation as transient under normal circumstances. However, Pallas results showed no loss in SpO_2 after the suction, showing the effect of MHI maneuver in prevention of SpO_2 loss after the suction. It can be said that if the subjects did not require suctioning, the results could be significant.

The results of present study on the arterial carbon dioxide pressure showed that the pressure was reduced using the MHI technique. In the experimental group, the $PaCO_2$ level showed 2.7% decrease at five minutes after intervention and 2% at 20 minutes after the intervention than before the intervention. These results suggest that the lung MHI technique could improve gas exchange and reduce $PaCO_2$ through improved ventilation; while in the control group, which there was no intervention for ventilatory support, the arterial carbon dioxide was increased, indicating impaired ventilation and gas exchange after two hours than before. The results are clinically important in the control group, even if there was no reduction in $PaCO_2$ in the experimental group. Because according to the results, continued spontaneous breathing and fatigue increased $PaCO_2$ in the control group due to impaired ventilation/perfusion ratio caused by fatigue and hypoventilation of the patients. However, this technique prevented the occurrence of this disorder in the experimental group and reduced the level of carbon dioxide partial pressure. In fact, hyperinflation technique in the experimental group made more cooperation of alveolar ventilation and improved ventilation/perfusion ratio, which lasted significantly up to 20 minutes after the intervention, probably due to a significant reduction in the carbon dioxide pressure level at 5 minutes later resulting from hyperinflation occurred during the technique. However, the reason for its significance after 20 minutes was the improved persistency of the ventilation/perfusion ratio.

Ahmed et al. in India (2010) showed that the level of $PaCO_2$ in the MHI group had 1.7% decrease immediately after the intervention and 0.8% at 20 minutes after the intervention than before the intervention. In addition, the decline was 1.4% in VHI group immediately and 20 minutes after the intervention than before, but the difference between MHI and VHI was not statistically significant (21). The reason for failing to reduce carbon dioxide pressure may be implementation of manual hyperinflation in a group and ventilator hyperinflation in another one. They kept constant minute volume due to the sedation of patients and reduced respiratory rate along with 1.5-fold increase in tidal volume, which it can also be another reason for the lack of change in carbon dioxide pressure. The study duration was 3 minutes.In the present study, hyperinflation maneuver was carried out in accordance with the patient's breaths and double tidal volume for three twenty-minute periods. Differences in the types of patients, duration of technique, number of maneuvers and tidal volume were causing the effects of hyperinflation in the present intervention can lead to improve ventilation and $PaCO_2$ level so that the improvement was visible in statistical results.

According to the studies mentioned above, it was observed that the levels of persistency and improved ventilation/perfusion ratio were lower in the short-term interventions and were observed for a limited time. In contrast, long-term interventions led to improve ventilation/perfusion ratio and more persistency of the improvements over time. These results suggest that the MHI technique should be performed as programmed with adequate frequencies to achieve the maximum improvement and effectiveness in patients.

The limitation of this study was a two-hour intervention that could interfere with nursing and confounding factors such as suction and repositioning. Therefore, we tried to coordinate the interventions with nursing as well as to do interventions at times with the lowest probability of interference with nursing actions.

Implications for Practice

In the present study, we were able to improve oxygenation and ventilation in spontaneously breathing patients using the MHI technique without the need to increase FiO_2, apply high PEEP and $PaCO_2$ retention. In fact, it can be concluded that this technique with the cooperation of collapsed alveoli in ventilation and improvement of gas exchange can lead to significant improvement of ventilation/perfusion ratio and thereby improve lung function in patients with respiratory problems. As a blueprint for future research, it is recommended to evaluate the effect of this technique on mechanical ventilation duration, other populations or the length of stay at the intensive care units.

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Conflict of interest

The authors declare that there is no conflict of interest.

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