JCS
J Caring Sci, 2021, 10(4), 216-222
doi: 10.34172/jcs.2021.034
https://jcs.tbzmed.ac.ir
TUOMS PRESS

Original Article

The Effects of Manual Lung Hyperinflation on Pulmonary Function after Weaning from Mechanical Ventilation among Patients with Abdominal Surgeries: A Randomized Clinical Trial

Mahboube Yazdani[1], Javad Malekzadeh[2*], Alireza Sedaghat[3], Seyed Reza Mazlom[4], Aliyeh Pasandideh Khajebeyk[1]

[1]Department Intensive Care Nursing, Faculty of Nursing and Midwifery, Mashhad University of Medical Sciences, Mashhad, Iran
[2]Department of Prehospital Emergency Care, Faculty of Nursing and Midwifery, Mashhad University of Medical Sciences, Mashhad, Iran
[3]Department of Anesthesia, Faculty of Medical Science, Mashhad University of Medical Science, Mashhad, Iran
[4]Department of Medical- Surgical Nursing, Faculty of Nursing and Midwifery, Mashhad University of Medical Sciences, Mashhad, Iran

Article Info
Article History:
Received: 13 Mar. 2021
Accepted: 17 June 2021
e-Published: 29 Sep. 2021

Keywords:
Manual hyperinflation, Atelectasis, Pulmonary function, Postoperative complication

***Corresponding Author:**
Javad Malekzadeh,
Email: MalekzadehJ@mums.ac.ir

Abstract
Introduction: After abdominal surgery, the patients who are separated from mechanical ventilation and provided with oxygen therapy via a T-piece are at risk for respiratory complications. Therefore, they need additional respiratory support. This study aimed to evaluate the effects of manual hyperinflation (MHI) on pulmonary function after weaning.
Methods: This randomized clinical trial included 40 patients who had undergone abdominal surgery and were receiving oxygen via a T-piece. Patients were selected from the intensive care units (ICU) of two hospitals in Mashhad, Iran. The subjects were randomly allocated to intervention (MHI) and control groups. Patients in the MHI group were provided with three 20-minute MHI rounds using the Mapleson C, while the control group received routine cares. Tidal volume (Vt), Rapid Shallow Breathing Index (RSBI), and the ratio of arterial oxygen partial pressure to fractional inspired oxygen (P/F ratio) were measured before the intervention, as well as 5 and 20 minutes after the intervention. Atelectasis prevalence was assessed before and 24 hours after the intervention. Data were analysed by SPSS software version 13.
Results: At baseline, there were no significant differences between the groups regarding Vt, RSBI, P/F ratio, and atelectasis rate. No significant difference was also found between the groups regarding atelectasis rate 24 hours after the intervention. However, at both posttests, Vt, RSBI, and P/F ratio in the MHI group were significantly better than the control group.
Conclusion: In patients with artificial airway and spontaneous breathing, MHI improves pulmonary function.

Introduction

Respiratory complications are among the leading causes of postoperative deaths.[1-3] Importantly, nearly 25% of postoperative deaths that occur in the first week after surgery are associated with pulmonary complications.[4] These complications are particularly prevalent after major abdominal surgeries.[5] The most important postoperative respiratory complications are atelectasis, pneumonia, and respiratory failure.[2,4] Postoperative atelectasis and pneumonia increase the risk for acute respiratory distress syndrome and the need for mechanical ventilation.[6]

Mechanical ventilation weakens respiratory muscles, impairs diaphragmatic function, damages airways, and causes infections.[7] Moreover, dependence on mechanical ventilation increases complication and mortality rates, prolongs hospital stay, increases healthcare costs, and reduces quality of life.[7,8] On the other hand, unsuccessful weaning and subsequent reconnection to mechanical ventilation exhaust respiratory muscles and place serious stress on vital organs particularly the respiratory and the cardiovascular systems.[8,9]

Respiratory muscle fatigue due to unsuccessful weaning, in turn, necessitates re-intubation and prolonged mechanical ventilation, reduces the success rate of the subsequent weaning, prolongs hospital stay, and increases mortality rate.[2,8,10,11] According to the research 15 percent of patients who were successfully weaned from mechanical ventilation with T-piece were re-intubated after 48 hours.

So the evidence shows that many patients need more respiratory support to maintain airway and spontaneous breathing for a long time.[12]

A key measure for preventing respiratory complications, improving weaning success rate, and promoting recovery in intensive care units (ICUs) is to strengthen respiratory muscles and promote pulmonary function through techniques such as chest physiotherapy, respiratory exercises, deep cough, incentive spirometry, positive end-expiratory pressure and continuous positive airway pressure.[13,14]

However, the results of studies into the effects of these techniques on postoperative patient outcomes are contradictory.[15-17] For instance, some studies found that these techniques can significantly reduce respiratory complications[18,19] and improve pulmonary function.[11,20]

However, some studies revealed that techniques involving lung expansion, cough, vibration, percussion, postural drainage, incentive spirometry and oscillatory and non-oscillatory systems were controversial regarding their efficacy as respiratory physiotherapy methods,[21] or shortening hospital stay,[22,23] and not preventing ventilator-associated pneumonia.[22]

However, most of these techniques cannot be used for patients with altered consciousness, patients with abdominal or thoracic surgeries, and patients who have recently been weaned from mechanical ventilation. Therefore, other techniques are needed for these patients.

Manual hyperinflation (MHI) is another technique for preventing respiratory complications and improving recovery.[21,24] In MHI, the patient is disconnected from mechanical ventilation and is ventilated using an Ambu bag. MHI consists of delivering a tidal volume larger than normal or ventilator tidal volume at a low inspiratory flow accompanied by an end-inspiratory pause and an expiration with maximum flow.[2,24-26] Previous studies reported that MHI maintains or improves pulmonary function, opens collapsed alveoli, facilitates airway clearance, and promotes lung compliance and alveolar gas exchange.[24-26] Unlike many other respiratory support techniques, the use of MHI necessitates neither mechanical ventilation nor patient consciousness. Accordingly, it can be used for patients who are just successfully weaned from mechanical ventilation and are receiving oxygen therapy through a T-piece. MHI can be particularly beneficial to patients who undergo abdominal or thoracic surgeries and hence are unable to cough deeply, receive chest physiotherapy, or use incentive spirometry due to altered consciousness or surgical incisions in the abdomen or the chest.[27,28]

Previous studies evaluated the effects of MHI solely on mechanically-ventilated patients and hence, there is limited data on MHI effects on patients who do not receive mechanical ventilation. Thus, the present study was done to evaluate the effects of MHI on pulmonary function among patients with abdominal surgeries after being weaned from mechanical ventilation.

Materials and Methods

This single-blind randomized clinical trial was done from September 2015 to April 2016. Study participants were selected by convenience sampling from among the patients who were hospitalized in the surgical ICUs of Imam Reza [peace be upon him (PBUH)] and Qaem (PBUH) hospitals, Mashhad, Iran. The inclusion criteria comprised an age of 18 or more, hospitalization in ICUs after an abdominal surgery, successful weaning from mechanical ventilation, and oxygen therapy for at least two consecutive hours through a T-piece. The participants were excluded if they were extubated, needed another surgery or mechanical ventilation, or developed hemodynamic instability.

Given the lack of previous studies into the study subject matter, the sample size was calculated using the results of a two-group pilot study on the following parameters: 1. The tidal volume of spontaneous respiration; 2. The ratio of the partial pressure of oxygen in arterial blood to the fraction of inspired oxygen (PaO_2/FiO_2); 3. The Rapid Shallow Breathing Index (RSBI) which is the ratio of respiratory rate to the tidal volume of spontaneous respiration; 4. Atelectasis prevalence rate.

The number of patients in both the control and the MHI groups of the pilot study was ten. Accordingly, with a confidence interval of 95% and a power of 0.8, the results of the sample size calculation formula for the comparison of two means[29] revealed that the largest sample size was related to the tidal volume of spontaneous respiration and was twenty for each group. Therefore, twenty patients were selected for each group and were randomly allocated to the control and the MHI groups using a table of random numbers.

Study data were collected using a pulmonary function characteristics form, the modified Radiological Atelectasis Score (m-RAS), an arterial blood gasometer (Gem PREMIER 3000, Werfen Co., USA), a pulse Oximeter (Alborz B9, Pooyandegan Rah Saadat Co., Iran), and an exhalometer (GaleMed Corporation, China), portable radiography device (Mobileart eco, Shimafzu Corporation, Germany). The m-RAS is standardized valid and reliable tool, the validity and reliability of which was assessed and confirmed in previous studies.[30] The reliability of the devices was also confirmed through internal calibration.

Before recruitment to the study, all patients in both groups had received oxygen therapy through a T-piece for at least two hours. At the beginning of the study, airway suctioning through the endotracheal tube was performed for all patients and they were placed in the supine position for half an hour. Then, tidal volume, spontaneous respiratory rate, and arterial blood gases (ABGs) were measured using the exhalometer and the gasometer devices. The results of these measurements were used to calculate baseline RSBI and PaO_2/FiO_2. Moreover, chest radiography was performed for all patients in both groups by radiology technicians. The chest radiography films were interpreted by a critical care sub-specialist in order to calculate m-RAS and determine the extent of atelectasis.

After baseline assessments, MHI was implemented for patients in the MHI group in three twenty-minute rounds with twenty-minute intervals. In each MHI round, twelve respirations were given with an oxygen flow rate of 15-20 liters per minute and a tidal volume twice the tidal volume of spontaneous respiration measured using the exhalometer. Each MHI respiration was synchronized with the intended patient's spontaneous respiration and included an inspiration (1.5–2 seconds), an inspiratory pause (two seconds), and a high-flow expiration through the rapid release of the Ambu bag. The MHI technique was implemented using the Mapleson C breathing system. This circuit is also known as the Water's circuit without an absorber. It is similar in construction to the Mapleson B, but the main tubing is shorter. A fresh gas flow equal to twice the minute ventilation is required to prevent rebreathing. CO2 builds up slowly with this circuit.

Throughout the MHI technique, airway pressure was kept blow 40 cm H_2O as measured using an analogue barometer (Mediturf Co., Japan). Five and twenty minutes after the last MHI round, tidal volume, respiratory rate, and ABGs were measured and then, PaO_2/FiO_2 and RSBI were calculated. In other words, measurements were done at three time points, i.e. before, 5, and 20 minutes after the intervention (T1, T2, and T3, respectively). Moreover, another chest radiography was performed for each patient 24 hours after the last MHI round and was interpreted to determine the extent of atelectasis. The first author measured the outcomes and implemented the intervention, while radiology technicians performed chest radiography. (Figure 1)

Data analysis was carried out via the SPSS software (ver.13.0). The Kolmogorov-Smirnov and the Shapiro-wilk tests were employed for normality testing. Moreover, the groups were compared with each other through the independent-sample t, the Mann-Whitney U, the chi-square, and the Fisher's exact tests. The effects of pretest readings on posttest readings were removed through the analysis of covariance (ANCOVA). Within-subject comparisons were also made via the repeated measures analysis of variance (RM ANOVA). The level of confidence was set at higher than 0.95 and thus, *P* values less than 0.05 were considered significant.

Results

The mean (SD) of participants' age in the MHI and the

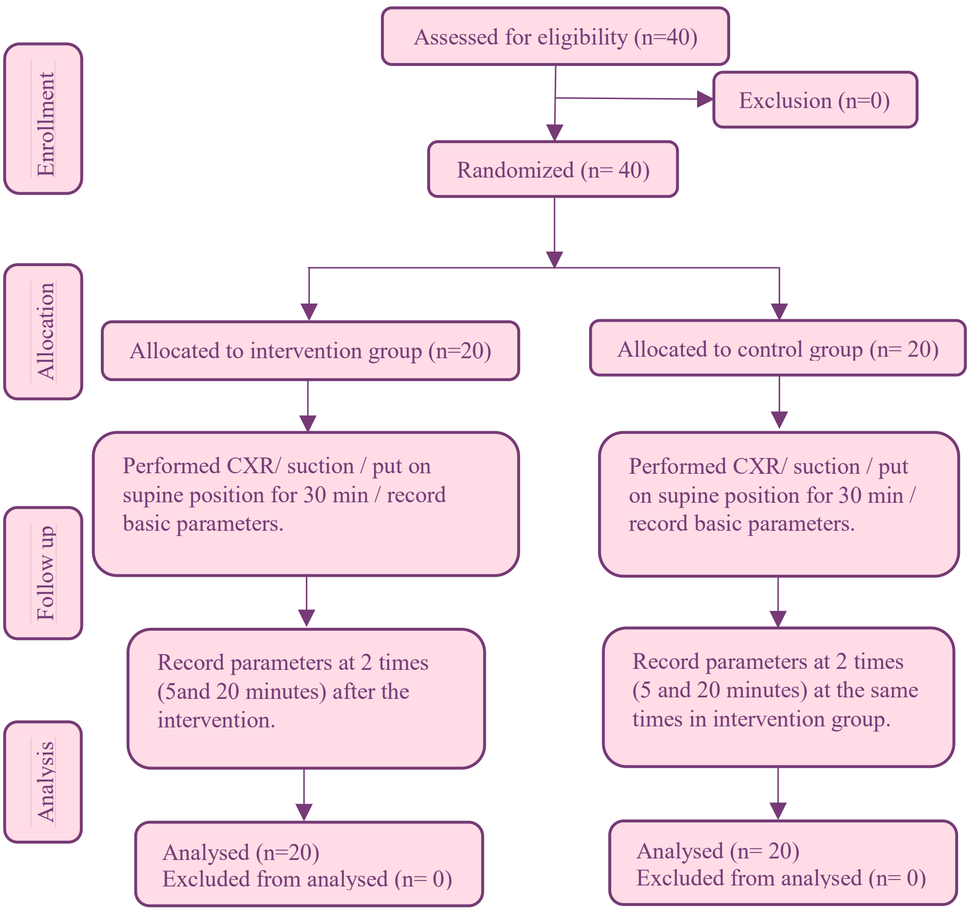

Figure 1. Flow chart of the study

control groups were 66.7 (8.3) and 67.5(9.0), respectively. The groups did not significantly differ with respect to the participants' demographic and clinical characteristics ($P > 0.05$). (Table 1)

Between-group comparisons, using the independent-sample *t* test, showed no significant differences between the groups regarding the tidal volume of spontaneous respiration at T1 ($P = 0.11$). However, at T2, the mean of tidal volume in the MHI group was significantly greater than that in the control group ($P = 0.01$), while at T3, between-group difference was again insignificant ($P = 0.44$). Given the probable effects of tidal volume at T1 on posttest readings, ANCOVA was used to remove T1 effects. ANCOVA results illustrated that between-group difference regarding tidal volume at T3 was also statistically significant ($P < 0.0001$). RM ANOVA revealed no significant between-group difference regarding tidal volume over time ($P = 0.57$). However, there was a significant difference between the measurement time points ($P < 0.0001$). The interaction of time and group was also statistically significant ($P < 0.001$). (Figure 2)

The independent-sample *t* test also revealed no significant difference between the groups regarding PaO_2/FiO_2 at T1 ($P = 0.91$). However, PaO_2/FiO_2 in the MHI group was significantly greater than the control group both at T2 ($P < 0.001$) and T3 ($P = 0.01$). RM ANOVA results illustrated a significant difference between the groups regarding PaO_2/FiO_2 ($P = 0.01$). The difference between time points along with the interaction of time and group were also statistically significant ($P < 0.001$). (Figure 2)

The results of the independent-sample *t* test also indicated that at T1, the groups did no differ significantly from each other respecting RSBI ($P = 0.18$). At T2, this difference was statistically significant ($P < 0.001$), while at T3, it was insignificant ($P = 0.06$). ANCOVA was performed to remove the probable effects of baseline RSBI values on posttest values. The results of ANCOVA revealed that after removing the effects of baseline RSBI values, between-group difference regarding RSBI at T3 was statistically significant ($P < 0.0001$). The RM ANOVA indicated no significant between-group difference regarding RSBI over time ($P = 0.24$). However, the effect of time and the interaction of time and group were statistically significant ($P < 0.001$). (Figure 2)

At T1, 40% of patients in the MHI group and 50% in the control group had atelectasis. The results of the chi-square test illustrated that this difference was not statistically different ($P = 0.75$). After the study intervention, these rates changed to 35% and 55%, respectively. This difference was also insignificant ($P = 0.49$). (Table 2)

Discussion

The current study aimed to evaluate the effects of MHI on pulmonary function among patients with abdominal surgeries after being weaned from mechanical ventilation. The findings revealed that MHI significantly improved the tidal volume of spontaneous respiration so that when compared to T1, tidal volume at T2 and T3 had increased by 42% and 22.1%, respectively.

One reason behind decreases in post-weaning tidal volume is alveolar collapse, and thereby decreased ventilation/perfusion ratio and hypoxia.[24] MHI can increase tidal volume through reopening the collapsed alveoli and involving them in ventilation. MHI-induced improvements in tidal volume and tissue oxygenation reduce the need for mechanical ventilation as well as complication and mortality rates. In line with our

Table 1. Comparing study groups in terms of participants' demographic characteristics

Variable	MHI group N (%)	Control group N (%)	*P* value
Age (years)[a]	8.3(66.7)	9.0(67.5)	0.75[b]
Gender			
Female	10(50)	9(45)	0.75[c]
Male	10(50)	11(55)	
Body mass index (kg/m²)[a]	24.8(3.8)	25(3.7)	0.87[b]
Length of surgery (hours)[a]	4.4(1.0)	4.2(1.5)	0.61[b]
Length of hospital stay (days)[a]	13.1(6.1)	10.9(6.2)	0.22[d]
Length of mechanical ventilation (days)[a]	10.3(5.9)	9.5(6.1)	0.51[d]
Airway system			
Endotracheal tube	11 (55)	12 (60)	0.74[c]
Tracheostomy	9 (45)	8 (40)	
Need for mechanical ventilation			
Yes	8 (40)	10 (50)	0.52[c]
No	12 (60)	10 (50)	
Type of surgery			
Laparotomy	5 (25)	4 (20)	0.81[c]
Whipple	2 (10)	3 (15)	
Peritonitis management	6 (30)	5 (25)	
Abdominal aortic aneurysm repairmen	2 (10)	3 (15)	
Gastrostomy	2 (10)	1 (5)	
Others	3 (15)	4 (20)	

[a] Mean (SD) was reported; [b] The independent-sample *t*-test; [c] The chi-square test; [d] The Mann-Whitney U test.

Table 2. Atelectasis prevalence rate before and 24 hours after the study intervention

Atelectasis	Before		24 hours after	
	MHI group No. (%)	Control group No. (%)	MHI group No. (%)	Control group No. (%)
No	12 (60)	10 (50)	13 (65)	9 (45)
Yes	8 (40)	10 (50)	7 (35)	1 1(55)
Total	20 (100)	20 (100)	20 (100)	20 (100)
P value[a]	0.75		0.49	

[a] Chi-square test was used.

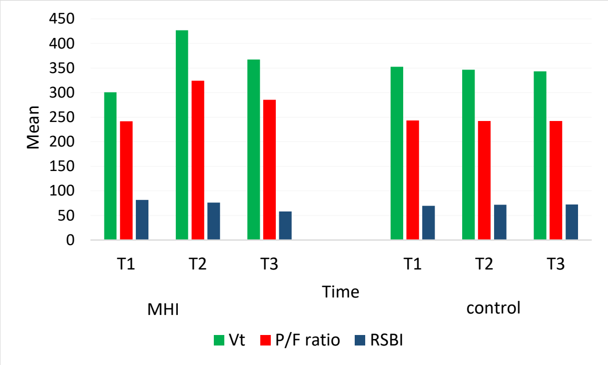

Figure 2. Comparing study groups in terms of pulmonary function parameters

findings, Assmann et al., found a significant increase in expiratory tidal volume (EVt) immediately after ventilator hyperinflation among patients under mechanical ventilation. Of course, they did not monitor the effects of their intervention over time.[31] Maa et al., also reported that MHI significantly improved tidal volume.[24] Our MHI intervention was implemented for three 20-minute rounds with 20-minute intervals while Maa and colleagues' intervention was a twenty-minute MHI three times a day for five consecutive days. Both our findings and theirs showed that significant post-MHI increases in tidal volume were accompanied by gradual decreases, denoting that for long-term improvements in oxygenation and ventilation, MHI needs to be implemented in longer periods of time. Jellema et al., also assessed the effects of MHI among mechanically-ventilated patients with septic shock and found that five minutes after MHI, ventilator tidal volume improved significantly, while fifteen minutes afterwards, the tidal volume returned to its baseline value.[32] The discrepancy between our findings and the findings reported by Jellema et al., may be due to the differences in the participants in these two studies with respect to their underlying conditions (abdominal surgery vs. septic shock) and ventilation types (spontaneous vs. mechanical).

Our findings also showed that compared to T1, MHI significantly improved PaO_2/FiO_2 by 34.2% at T2 and 18.3% at T3. An explanation for this finding may be the fact that MHI increases the number of alveoli involved in ventilation, improves ventilation/perfusion ratio, facilitates airway clearance, and thereby, improves oxygenation and PaO_2/FiO_2. Similarly, Raafat & Elbasiouny reported that MHI significantly improved PaO_2/FiO_2 among mechanically-ventilated patients from mean (SD) of 227.8 (50.1) to 346.9 (93.7).[33] Patman et al., also found that MHI for mechanically-ventilated patients significantly improved PaO_2/FiO_2 from 272.4 at baseline to 329.7 at the first post-MHI minute.[34] However, PaO_2/FiO_2 in their study significantly decreased to 303.5 at the fifth post-MHI minute and remained at almost the same level until 60 minutes after MHI. The difference between our findings and the findings reported by Patman et al., is due to the differences in the study participants in that our participants were conscious patients with spontaneous respiration while their participants were patients who had just undergone a surgery and were achieving recovery from anesthesia. These findings imply that MHI effects on patients with spontaneous respiration sustain for longer periods of time compared with mechanically-ventilated patients. Moreover, unlike our findings, Pattanshetty and Gaude found that compared to routine physiotherapy, multimodality chest physiotherapy did not significantly improve PaO2/FiO2.[35] The insignificant effects of their intervention on PaO2/FiO2 is attributable to the use of MHI for patients in both groups.

Another finding of the current study was significant decreases in RSBI following MHI, denoting the positive effects of MHI on pulmonary function. This finding can also be attributed to the effectiveness of MHI in opening collapsed alveoli and thereby improving tidal volume and ventilation/perfusion ratio. Conversely, Maa et al., found that though their five-day MHI decreased RSBI from 216.59 to 150.21, i.e. by 66.28 points, this decrease was not statistically significant.[24] The comparison of our findings and theirs shows that patients with spontaneous respiration respond more rapidly to MHI than patients with atelectasis caused by mechanical ventilation. Pattanshetty and Gaude also found no significant difference between routine chest physiotherapy and multimodality chest physiotherapy with respect to RSBI and attributed this insignificant finding to the fact that their study sample consisted of different patient populations. Moreover, they provided MHI to patients in both groups.[35]

Given the significant improvements in tidal volume, PaO_2/FiO_2, and RSBI in the current study, we also expected significant decreases in atelectasis prevalence. However, the study findings indicated that post-MHI decrease in atelectasis prevalence was statistically insignificant, though the decrease can be clinically significant. Paulus et al., also reported the same finding.[2] The insignificant effects of our MHI intervention on atelectasis prevalence may be due to our inability to accurately diagnose all cases of atelectasis due to the low quality of chest radiography films. It is noteworthy that chest radiographies in the current study were performed by different radiology technicians who used different and even personal radiation protocols. Accordingly, radiography films were of different qualities. Moreover, the films were interpreted using the m-RAS, which is a tool for assessing atelectasis at lobar level. More precise atelectasis assessment tools and chest radiography protocols might produce different results. Besides, implementing MHI for longer periods of time could probably reduce atelectasis prevalence rate. Contrary to our findings, Maa et al., and Soundararajan & Thankappan found that MHI significantly decreased atelectasis.[24,36] This contradiction can be attributed to the differences in the samples and the interventions of the studies. For instance, Soundararajan & Thankappan conducted their study on patients with lung collapse and their intervention included vibration and shaking in addition to MHI.[36]

The limitation of the current study was how to take the chest x ray, unfortunately we did not manage to handle it by one person. However, we attempted to position patients in near-standard position with minimal rotation.

Conclusion

The findings of the present study indicate that MHI promotes pulmonary function among patients who are weaned from mechanical ventilation, have spontaneous respiration, and receive oxygen therapy through T-piece. MHI improves tidal volume, PaO_2/FiO_2, and RSBI and thereby, reduces the need for mechanical ventilation, facilitates early exudation, and improves recovery. Further studies are needed to determine the long-term effects of MHI, its effects on hemodynamic status, or both.

Acknowledgements

This study was done with the financial support of the Research Deputy of Mashhad University of Medical Sciences, Mashhad, Iran. Hereby, we would like to express our immense gratitude to the administrators of Mashhad University of Medical Sciences and Mashhad Faculty of Nursing and Midwifery, the authorities and the staff of the ICUs of Imam Reza (PBUH) and Qaem (PBUH) hospitals, and the participants of the study.

Ethical Issues

This study was registered in the Iranian Registry of Clinical Trials (registration code: IRCT2015103024790N1). The Ethics Committee of Mashhad University of Medical Sciences, Mashhad, Iran, approved the study. All participants or their immediate families (in case of a reduced level of consciousness) were informed about the aim and the methods of the study and were ensured of the safety of the intervention, confidential management of the data, and voluntariness of participation in and the right to withdraw from the study (code of ethics: IR.MUMS.REC.1394.247). Informed consent was obtained from all participants. During the study, we continuously assessed them and monitored their health status.

Conflict of Interest

The authors declare no conflict of interest in this study.

Authors' Contributions

MY, JM: Conception and design; MY, APKH: Acquisition of data; SRM, AS, JM, MY: Analysis and interpretation of data; MY, JM: Drafting the article; JM: Review the article and find approval.

Research Highlights

What is the current knowledge?

Despite many supportive strategies, we still see re-intubation and the need for mechanical ventilation support in patients who have successfully completed these procedures. One of these techniques that has been shown to be effective in mechanically ventilated patients is the MHI technique.

What is new here?

MHI promotes pulmonary function among patients who are weaned from mechanical ventilation, have spontaneous respiration, and receive oxygen therapy through T-piece. This is important to reduce the need for mechanical ventilation, facilitates early extubation, and improves recovery.

References

1. Ferreyra G, Long Y, Ranieri VM. Respiratory complications after major surgery. Curr Opin Crit Care. 2009; 15(4): 342-8. doi: 10.1097/MCC.0b013e32832e0669
2. Paulus F, Veelo DP, de Nijs SB, Beenen LF, Bresser P, de Mol BA, et al. Manual hyperinflation partly prevents reductions of functional residual capacity in cardiac surgical patients--a randomized controlled trial. Crit Care. 2011; 15(4): R187. doi: 10.1186/cc10340
3. Kim TH, Lee JS, Lee SW, Oh YM. Pulmonary complications after abdominal surgery in patients with mild-to-moderate chronic obstructive pulmonary disease. Int J Chron Obstruct Pulmon Dis. 2016; 11: 2785-96. doi: 10.2147/copd.s119372
4. Chandler D, Mosieri C, Kallurkar A, Pham AD, Okada LK, Kaye RJ, et al. Perioperative strategies for the reduction of postoperative pulmonary complications. Best Pract Res Clin Anaesthesiol. 2020; 34(2): 153-66. doi: 10.1016/j.bpa.2020.04.011
5. Boden I, Robertson IK, Neil A, Reeve J, Palmer AJ, Skinner EH, et al. Preoperative physiotherapy is cost-effective for preventing pulmonary complications after major abdominal surgery: a health economic analysis of a multicentre randomised trial. J Physiother. 2020; 66(3): 180-7. doi: 10.1016/j.jphys.2020.06.005
6. Ferreyra GP, Baussano I, Squadrone V, Richiardi L, Marchiaro G, Del Sorbo L, et al. Continuous positive airway pressure for treatment of respiratory complications after abdominal surgery: a systematic review and meta-analysis. Ann Surg. 2008; 247(4): 617-26. doi: 10.1097/SLA.0b013e3181675829
7. Elbouhy MS, AbdelHalim HA, Hashem AMA. Effect of respiratory muscles training in weaning of mechanically ventilated COPD patients. Egypt J Chest Dis Tuberc. 2014; 63(3): 679-87. doi: 10.1016/j.ejcdt.2014.03.008
8. Park SH. Perioperative lung-protective ventilation strategy reduces postoperative pulmonary complications in patients undergoing thoracic and major abdominal surgery. Korean J Anesthesiol. 2016; 69(1): 3-7. doi: 10.4097/kjae.2016.69.1.3
9. Routsi C, Stanopoulos I, Kokkoris S, Sideris A, Zakynthinos S. Weaning failure of cardiovascular origin: how to suspect, detect and treat-a review of the literature. Ann Intensive Care. 2019; 9(1): 6. doi: 10.1186/s13613-019-0481-3
10. Khemani RG, Sekayan T, Hotz J, Flink RC, Rafferty GF, Iyer N, et al. Risk factors for pediatric extubation failure: the importance of respiratory muscle strength. Crit Care Med. 2017; 45(8): e798-e805. doi: 10.1097/ccm.0000000000002433
11. Tusman G, Böhm SH, Warner DO, Sprung J. Atelectasis

and perioperative pulmonary complications in high-risk patients. Curr Opin Anaesthesiol. 2012; 25(1): 1-10. doi: 10.1097/ACO.0b013e32834dd1eb
12. Madani SJ, Saghafinia M, Sedighi Nezhad H, Ebadi A, Ghochani A, Fazel Tavasoli A, et al. Validity of integrative weaning index of discontinuation from mechanical ventilation in Iranian ICUs. Thrita. 2013; 2(4): 62-8. doi: 10.5812/thrita.12827
13. Setak-Berenjestanaki M, Bagheri-Nesami M, Gholipour Baradari A, Mousavinasab SN, Ghaffari R, Darbeheshti M. The prophylactic effect of different levels of positive endexpiratory pressure on the incidence rate of atelectasis after cardiac surgery: a randomized controlled trial. Med J Islam Repub Iran. 2018; 32: 20. doi: 10.14196/mjiri.32.20
14. Odor PM, Bampoe S, Gilhooly D, Creagh-Brown B, Moonesinghe SR. Perioperative interventions for prevention of postoperative pulmonary complications: systematic review and meta-analysis. BMJ. 2020; 368: m540. doi: 10.1136/bmj.m540
15. Yazdannik A, Mohammadi Bollbanabad H, Mirmohammadsadeghi M, Khalifezade A. The effect of incentive spirometry on arterial blood gases after coronary artery bypass surgery (CABG). Iran J Nurs Midwifery Res. 2016; 21(1): 89-92. doi: 10.4103/1735-9066.174761
16. Alaparthi GK, Augustine AJ, Anand R, Mahale A. Comparison of diaphragmatic breathing exercise, volume and flow incentive spirometry, on diaphragm excursion and pulmonary function in patients undergoing laparoscopic surgery: a randomized controlled trial. Minim Invasive Surg. 2016; 2016: 1967532. doi: 10.1155/2016/1967532
17. Kendall F, Abreu P, Pinho P, Oliveira J, Bastos P. The role of physiotherapy in patients undergoing pulmonary surgery for lung cancer. A literature review. Rev Port Pneumol (2006). 2017; 23(6): 343-51. doi: 10.1016/j.rppnen.2017.05.003
18. Thakur MR. A comparative study to assess the effectiveness of deep breathing exercise incentive spirometer among post operative patients undergone abdominal surgery in selected hospital of Indore (MP). Int J Med Sci Diag Res. 2019; 3(7): 18-21. doi: 10.32553/IJMSDR/v3i7.6
19. Boden I, Skinner EH, Browning L, Reeve J, Anderson L, Hill C, et al. Preoperative physiotherapy for the prevention of respiratory complications after upper abdominal surgery: pragmatic, double blinded, multicentre randomised controlled trial. BMJ. 2018; 360: j5916. doi: 10.1136/bmj.j5916
20. Duymaz T, Karabay O, Ural IH. The effect of chest physiotherapy after bariatric surgery on pulmonary functions, functional capacity, and quality of life. Obes Surg. 2020; 30(1): 189-94. doi: 10.1007/s11695-019-04165-z
21. Goñi-Viguria R, Yoldi-Arzoz E, Casajús-Sola L, Aquerreta-Larraya T, Fernández-Sangil P, Guzmán-Unamuno E, et al. Respiratory physiotherapy in intensive care unit: bibliographic review. Enferm Intensiva (Engl Ed). 2018; 29(4): 168-81. doi: 10.1016/j.enfi.2018.03.003
22. Pozuelo-Carrascosa DP, Torres-Costoso A, Alvarez-Bueno C, Cavero-Redondo I, López Muñoz P, Martínez-Vizcaíno V. Multimodality respiratory physiotherapy reduces mortality but may not prevent ventilator-associated pneumonia or reduce length of stay in the intensive care unit: a systematic review. J Physiother. 2018; 64(4): 222-8. doi: 10.1016/j.jphys.2018.08.005
23. Boujibar F, Bonnevie T, Debeaumont D, Bubenheim M, Cuvellier A, Peillon C, et al. Impact of prehabilitation on morbidity and mortality after pulmonary lobectomy by minimally invasive surgery: a cohort study. J Thorac Dis. 2018; 10(4): 2240-8. doi: 10.21037/jtd.2018.03.161
24. Maa SH, Hung TJ, Hsu KH, Hsieh YI, Wang KY, Wang CH, et al. Manual hyperinflation improves alveolar recruitment in difficult-to-wean patients. Chest. 2005; 128(4): 2714-21. doi: 10.1378/chest.128.4.2714
25. Cruz RV, de Andrade F, de Menezes PD, Gonçalves BO, da Silva Almeida R, Santos AR. Manual hyperinflation and the role of physical therapy in intensive care and emergency units. Fisioter Mov. 2017; 30(Suppl 1): 241-8. doi: 10.1590/1980-5918.030.S01.AO23
26. Tucci MR, Nakamura MA, Carvalho NC, Volpe MS. Manual hyperinflation: is it effective? Respir Care. 2019; 64(7): 870-3. doi: 10.4187/respcare.07152
27. Grams ST, Ono LM, Noronha MA, Schivinski CI, Paulin E. Breathing exercises in upper abdominal surgery: a systematic review and meta-analysis. Rev Bras Fisioter. 2012; 16(5): 345-53. doi: 10.1590/s1413-35552012005000052
28. Physiopedia. Incentive spirometry. 2019 [cited 2020 Feb 25]. Available from: https://www.physio-pedia.com/Incentive_Spirometry.
29. Sakpal TV. Sample size estimation in clinical trial. Perspect Clin Res. 2010; 1(2): 67-9.
30. Parke RL, McGuinness SP, Milne D, Jull A. A new system for assessing atelectasis on chest X-ray after sternotomy for cardiac surgery. Med Imaging Radiol. 2014; 2(1): 2. doi: 10.7243/2054-1945-2-2
31. Assmann CB, Vieira PJ, Kutchak F, Rieder Mde M, Forgiarini SG, Forgiarini Junior LA. Lung hyperinflation by mechanical ventilation versus isolated tracheal aspiration in the bronchial hygiene of patients undergoing mechanical ventilation. Rev Bras Ter Intensiva. 2016; 28(1): 27-32. doi: 10.5935/0103-507x.20160010
32. Jellema WT, Groeneveld AB, van Goudoever J, Wesseling KH, Westerhof N, Lubbers MJ, et al. Hemodynamic effects of intermittent manual lung hyperinflation in patients with septic shock. Heart Lung. 2000; 29(5): 356-66. doi: 10.1067/mhl.2000.109697
33. Raafat A, Elbasiouny HS. Arterial oxygenation response to manual hyperinflation as an added procedure to chest physiotherapy in critically ill mechanically ventilated patients. Am J Sci. 2011; 7(12): 585-90.
34. Patman S, Jenkins S, Stiller K. Manual hyperinflation--effects on respiratory parameters. Physiother Res Int. 2000; 5(3): 157-71. doi: 10.1002/pri.196
35. Pattanshetty RB, Gaude GS. Effect of multimodality chest physiotherapy on the rate of recovery and prevention of complications in patients with mechanical ventilation: a prospective study in medical and surgical intensive care units. Indian J Med Sci. 2011; 65(5): 175-85. doi: 10.4103/0019-5359.106608
36. Soundararajan LR, Thankappan SM. Effect of manual hyperinflation on arterial oxygenation in paediatric patients with upper lobe collapse after cardiac surgery. Eur J Gen Med. 2015; 12(4): 313-8 doi: 10.15197/ejgm.01370