Effect of inspiratory muscle training on weaning from mechanical ventilation in acute respiratory failure

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Objective This study aimed to evaluate the effect of inspiratory muscle training (IMT) on weaning time and success.

Patients and methods This is a prospective, randomized clinical study conducted in an ICU. A total of 15 patients were trained by inspiratory muscle exercise twice per day and 15 patients did not go under training (control group). Training was conducted through tuning the ventilator sensitivity based on the patients' maximal inspiratory pressure (MIP). The experimental group received IMT starting with an initial load of 30% of their MIP measured immediately after changing patients to pressure support mode of mechanical ventilation (MV) and increased up to 40% as tolerated by the patient. Training was conducted for 5 min, two sessions per day. In addition, these patients received usual care of MV patients. Sputum culture assessment for aerobic organisms was done immediately after intubation.

Results This is a prospective randomized control study that collected data on 30 patients with acute respiratory failure. Patients were randomly arranged into two groups (control and experimental). The mean MIP before initiation of weaning in both group was 16 cm H_2O. There is a significant difference in the final mean MIP between the experimental group (23.27 cm H_2O) and the control group (17.40 cm H_2O). There is also significant shortening in the weaning time in the experimental group and less frequent likelihood of reintubation, which was recorded in two cases of control group.

Conclusion The IMT during MV may assist in early weaning off MV among patients with acute respiratory failure, and also it improves the weaning success rate, with less frequent likelihood of reintubation.
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Introduction

Mechanical ventilation (MV) is a method that partially replaces spontaneous breathing in patients in the intensive care units who are critically ill. Weaning is the process of liberation of patients off MV and regaining spontaneous breathing. Successful weaning off MV is achieved when the patients can tolerate breathing spontaneously without ventilator support for at least 48 h [1]. The time spent in the weaning process occupies about half of the total time of MV. Approximately 70% of the patients are weaned off simply on the first trial without any accompanying difficulties [2].

Respiratory muscles, the essential component of the respiratory apparatus, are responsible for anatomical and configuration changes in the thorax by their contraction and relaxation activities, resulting in movement of air to and from the gas exchange units in the lung [3].

Increasing capacity, strength, and subsequently endurance of respiratory muscles to respiratory load can be achieved by muscle training using a load of at least 30% of the maximal inspiratory force. Respiratory muscle weakness and deconditioning are risk factors for weaning failure from MV [4].

Weaning difficulties are associated with multiple comorbidities: prolongation of ICU stay time, weakening of respiratory muscles, nosocomial infection, airway trauma, and death [5].

Among those who are discharged, inspiratory muscle dysfunction is a key prognostic factor for readmission to the ICU [6]. However, reduced force and endurance of the inspiratory muscles is recorded in weaned patients [7].

The respiratory muscle strength training and inspiratory muscle strength training apply a load on the diaphragm and accessory muscles of inspiration, enhancing their strength and capacity. Training of inspiratory muscles in the ICU has applied this load via either application of resistive or threshold loads by a device or via tuning of the ventilator sensitivity, so that patients can only initiate inspiratory flow by generating more negative intrathoracic pressure. Endurance may

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only need to be improved to a certain threshold to permit weaning [8].

Aim

This study aimed to evaluate the effect of inspiratory muscle training (IMT) on weaning time and success.

Patients and methods

This is a prospective, randomized clinical study conducted in an ICU. Fifteen patients were trained by inspiratory muscle exercise twice per day and 15 patients did not go under training (control group). Training was conducted through tuning the ventilator sensitivity based on the patients' maximal inspiratory pressure (MIP). The study was approved by the ethical committee of Faculty of Medicine, Al-Azhar University, and a written consent was taken from the relatives of each patient.

Each patient was randomly arranged into one of two groups: control with no IMT or cases with IMT.

MIP was measured before weaning process in both groups and after weaning process 30 min before extubation.

The experimental group received IMT starting with an initial load of 30% of their MIP measured immediately after changing patients to pressure support mode of MV and increased up to 40% as tolerated by the patient. Training was conducted for 5 min, two sessions per day. In addition, these patients received usual care of MV patients.

Sputum culture assessment for aerobic organisms was done immediately after intubation.

Inclusion criteria

The following were the inclusion criteria:

(1) Patient who had undergone MV for 48 h or more in a controlled mode.
(2) Patients had been intubated owing to acute or acute-on-chronic respiratory failure.
(3) Patients could not generate maximum inspiratory pressure more than 20 cm H_2O.

Exclusion criteria

The following were the exclusion criteria:

(1) Patients with comorbidities interfering and compromising weaning, like cardiac arrhythmia, pericardial effusion, congestive heart failure, or unstable acute coronary syndrome.
(2) Patients who have inadequate training performance of the inspiratory muscle such as those having myopathy or neuropathy.
(3) Patients who had tracheostomy tube during the course of MV before the initiation of weaning or had a major neurological deficit.
(4) Age less than 18 years.

The trial of IMT begins with application of a load of 30% of the patient's MIP, which can be increased up to 40% as tolerated by the patient.

The trial lasts for 5 min, two times per day, at everyday per week, starting from the beginning of the weaning period till extubation occurs. Supplemental oxygen was delivered to keep adequate oxygenation.

The training trial was stopped when any of the following was developed:

(1) Respiratory distress with respiratory rate more than 35 breaths/min or higher during the trial or development of paradoxical breathing.
(2) Desaturation with SpO_2 less than 90%; heart rate more than 140 beats/min or increased more than 20% from the base, or great change in systolic blood pressure being more than 180 mmHg or less than 90 mmHg.
(3) Diaphoresis, irritability, depression, arrhythmia, convulsions, or sweating.

If any of these alarming signs occur during the trial, the trial was stopped immediately, and the load was not increased in the next training trial.

The training trial was resumed the next day after alarming signs disappear with regaining of the previous readings.

No training trial except for ordinary ventilatory care was delivered for the control group.

All patients were investigated by routine investigation (complete blood count, arterial blood gas, renal and liver function tests, and coagulation profile), and sputum sample were obtained by suction of endotracheal aspirate just after endotracheal aspiration for culture and sensitivity.

The primary outcome in the current study was the change in measurement of MIP along the weaning time and the total time of weaning.

Statistical analysis

Statistical analysis was done using the SPSS computer package version 19.0 (SPSS Inc., Chicago, Illinois, USA). For descriptive statistics, the mean±SD was used for quantitative variables, whereas the number and percentage were used for qualitative variables. In univariate analyses, qualitative variables were compared by χ^2-test or Fisher's exact test when appropriate, and quantitative variables were compared by independent samples *t*-test. Sensitivity, specificity, accuracy, and positive and negative predictive values were calculated. The statistical methods were verified, assuming a significant level of *P* value less than 0.05 and a highly significant level of *P* value less than 0.001.

Results

Patients were randomly arranged into two groups (control and experimental). Comparison between case group and control group regarding demographic data and comorbidities is shown in Tables 1 and 2.

Among both groups, the most prevalent comorbidities were chronic obstructive pulmonary disease (COPD) and surgical operation. Overall, nine patients from both groups were operated on for surgical correction of lower limb bone fracture after motor car accident.

Klebsiella and *Pneumococci* spp. were the most frequent organisms detected in sputum culture results. In six patients in either group, no organism could be detected in the sputum culture. Reintubation was reported in two cases of control group (Table 3).

Comparison between case group and control group regarding MIP before and after weaning is shown in Table 4, where the mean MIP before initiation of weaning in both the groups was 16 cm H_2O. There is a significant difference in final MIP between the two groups.

Comparison between case group and control group regarding duration of MV and weaning duration by days is shown in Table 5. The table shows the total period of MV and the time expended in weaning process in the two groups, being longer in the control group, with significant shortening in the weaning time in the experimental group and accordingly the less total time of MV.

Discussion

MV is a supportive medical technique that helps the patients to improve ventilation and oxygenation while the treatment of the underlying condition is ongoing.

Overall, 40% of the total time of MV is occupied by weaning off the MV [9].

One of the commonest causes of weaning failure from MV is the inspiratory muscles weakness, particularly of the diaphragm, in addition to other accessory muscles of inspiration [5].

Many studies (Martin *et al.* [10]; Bisset and Leditchke [7]; and others) have examined the effect of IMT on weaning success in MV patients.

The studies showed an increase in MIP resulting from IMT and subsequently aiding in weaning off MV. These results in such studies agree with the present study.

The present study included thirty patients who have respiratory failure (acute or acute on chronic) and not fit for or failed noninvasive ventilator support.

The main cause for acute respiratory failure was pneumonia in almost all patients, which was diagnosed by new radiological infiltration; fever; and leukocytosis with or without positive sputum culture.

Five patients were excluded who had sudden death before the initiation of weaning program owing to worsening of sepsis, septic shock, arrhythmias, and multiorgan failure.

This study shows significant difference between the two groups regarding final maximum inspiratory

Table 1 Comparison between case group and control group regarding demographic data

	Case group (*N*=15) [*n* (%)]	Control group (*N*=15) [*n* (%)]	χ^2/*t**	*P* value
Sex				
Female	5 (33.3)	4 (26.7)	0.159	0.690
Male	10 (66.7)	11 (73.3)		
Age (years)				
Mean±SD	48.47 (9.56)	46.53 (9.98)	0.542*	0.592
Range	35 (62)	30 (65)		

*Independent *t*-test. $P>0.05$, nonsignificant. $P<0.05$, significant. $P<0.01$, highly significant.

Table 2 Comparison between case group and control group regarding comorbidities

	Case group (*N*=15) [*n* (%)]	Control group (*N*=15) [*n* (%)]	χ^2-Test	*P* value
Comorbidities				
No	1 (6.7)	2 (13.3)	13.466	0.092
COPD	4 (26.7)	5 (33.3)		
Hypertensive	1 (6.7)	0 (0.0)		
IHD, DM, and hypertensive	1 (6.7)	0 (0.0)		
ILD	2 (13.3)	3 (20.0)		
Bronchial asthma	1 (6.7)	0 (0.0)		
Postoperative	4 (26.7)	5 (33.3)		
Pregnant	1 (6.7)	0 (0.0)		

COPD, chronic obstructive pulmonary disease; DM, diabetes mellitus; IHD, ischemic heart disease; ILD, interstitial lung disease.

Table 3 Comparison between case group and control group regarding sputum and reintubation results

	Case group (*N*=15) [*n* (%)]	Control group (*N*=15) [*n* (%)]	χ^2-Test	*P* value
Sputum c/s				
No growth	6 (40.0)	6 (40.0)	2.500	0.475
MRSA	0 (0.0)	2 (13.3)		
Klebsiella spp.	4 (26.7)	4 (26.7)		
Pneumococci spp.	5 (33.3)	3 (20.0)		
Reintubation				
No	15 (100.0)	13 (86.7)	2.143	0.143
Yes	0 (0.0)	2 (13.3)		

C/S, culture/sensitivity; MRSA, methecillin resistant staph aureus.

Table 4 Comparison between case group and control group regarding maximal inspiratory pressure before and after weaning

	Case group (*N*=15)				Control group (*N*=15)				Independent *t*-test	*P* value
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum		
MIP preweaning	16.40	1.12	15	18	16.60	1.06	15	18	−0.503	0.619
MIP postweaning	23.27	1.44	21	25	17.40	0.83	16	19	13.696	<0.001

MIP, maximal inspiratory pressure.

Table 5 Comparison between case group and control group regarding the duration of mechanical ventilation and weaning duration by days

	Case group (*N*=15)				Control group (*N*=15)				Independent *t*-test	*P* value
	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum		
Duration of MV	8.33	2.02	6	14	10.80	3.19	6	16	−2.529	0.017
Weaning duration	4.00	0.85	3	6	5.67	1.29	4	8	−4.183	<0.001

MV, mechanical ventilation.

pressure, which is directly reflected on the weaning time, and accordingly on the total time of MV.

The experimental group that underwent IMT program showed shorter time of weaning (mean: 4 days) than the control group (mean: 5.6 days).

In spite of the nearly equal initial MIPs in the two groups (mean: 16 cm H_2O), the final MIP was significantly more increased in the trained group than the control group (mean: 23.2 and 17.4 cm H_2O, respectively).

These results also coincide with Samaria A. Kader *et al.* (2010).

They conducted a study on 40 elderly patients who were intubated and MV for 48 h or more in ICU.

They started with an initial load of 30% of their MIP and increased 10% everyday. The trial lasted for 5 min, two times per day, everyday in the week throughout the weaning process until liberation from MV.

They found significant increase in MIP in the experimental group versus the control group. The mean difference was 7.6 cm H_2O (95% confidence interval: 5.8–9.4), with a significantly shorter weaning time in the experimental group versus the control group. The mean difference was 1.7 days (95% confidence interval: 0.4–3.0).

On the contrary, Pedro Caruso *et al*., 2005, found that IMT was ineffective in MV critically ill patients regarding time and success of weaning. They studied 25 patients arranged in 2 groups: 12 in experimental group and 13 in control group.

The disagreement with the present study may be related to the early application of IMT shortly after initiation of MV (i.e. on the second day of MV), which is not the case in the present study where the training of inspiratory muscles started after decision to begin the weaning process. Overtraining and fatigue may be the cause if the IMT begins early in unready weanable patients.

Weaning is considered successful when the patient is extubated and can take his own breath without any signs of respiratory distress for at least 48 h. If the patient needs reintubation in the period of the 48 h, it is considered a weaning failure.

Weaning failure, indicated by reintubation in this study, was recorded in 2 cases in the control group (13.3%).

The two cases had positive sputum culture results for methecillin resistant staph aureus (MRSA) with lowest MIP before the initiation of weaning (15 CmH2O).

The two cases were MV owing to infective exacerbation of COPD. One of them died after reintubation whereas the other needed tracheostomy after prolonged MV.

These results coincide with [15], with significant difference in weaning failure, being higher in the control group (45%) than the trained group (10%). The higher incidence in weaning failure in control group may be attributed to selection of control group population with severe COPD exacerbation. Pedro Caruso *et al*., 2005, conducted a study on 34 patients (17 as experimental group and 17 as control group) and recorded the IMT effect on weaning success, measured by need of reintubation. The incidence of reintubation was 18% in the experimental group and 29% in the control group.

There is no statistically significant effect of IMT on mortality rate in the current study.

However, the training of inspiratory muscles can shorten the total time of MV with its associated complications by increasing muscle endurance and strength so, it results in decreased mortality [10].

Three studies [12–14] with data on 150 participants have examined the effects of IMT on survival. There is no significant effect but favored IMT [15].

The best effect on MIP was mostly observed in the experimental group patients with age less than 40 years having negative sputum culture results, whereas the least effect was observed in three of four patients with COPD and in a pregnant woman.

The least effect observed in patients with COPD may be attributed to ventilator dependence and use of systemic steroid in these patients [11].

In conclusion, the IMT during MV may assist early weaning in patients on MV owing to acute respiratory failure, and also it improves weaning success rate with less frequent likelihood of reintubation.

This effect may be because of the improvement of inspiratory muscle function and higher MIP.

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Conflicts of interest
There are no conflicts of interest.

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