

Response of Maximum Inspiratory Pressure and Functional Capacity to Positive End-Expiratory Pressure Device after Valvular Heart Surgery

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Abstract

Background: Pulmonary complications following valvular heart surgery are common and contribute to increased duration of hospital stay, rate of morbidity, and mortality. The purpose of the present study was to investigate the response of maximum inspiratory pressure and functional capacity to Positive End-Expiratory Pressure device in patients who underwent valvular heart surgery.

Materials and Methods: Thirty males and females who underwent valvular heart surgery aged from 12-18 years old and recruited from the National Heart Institute enrolled in this study. They were assigned into two matched groups: the intervention group consisted of 15 patients, received Positive End-Expiratory Pressure (PEEP) with the mouthpiece in addition to routine chest physiotherapy program; the control group consisted of 15 patients, received routine chest physiotherapy program only. The program continued for four weeks, then the results compared in two groups.

Results: According to the results of data analysis, there was a statistically significant difference between pretreatment and post-treatment data in both groups regarding inspiratory muscle strength and functional capacity ($p < 0.001$). There was no significant difference between groups regarding post-treatment data of Maximal Inspiratory Pressure (MIP), and VO₂ max ($p=0.084$, $p=0.325$), respectively.

Conclusion: According to the results, expiratory training using a PEEP device with mouthpiece improved inspiratory muscle strength and functional capacity after valvular heart surgery.

Key Words: Functional capacity, Inspiratory muscle strength, PEEP, Valvular heart surgery.

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1- INTRODUCTION

Acute Rheumatic Fever (ARF), and Rheumatic Heart Disease (RHD) are critical open wellbeing concerns worldwide. Despite the diminishing frequency, there's still a critical infection burden, particularly in developing countries (1). RHD is a chronic valvular heart disease, which causes numerous premature mortality in low- and middle-income countries (2). According to the World Health Organization (WHO), RF/RHD affects about 15.6 million people worldwide, with 282 000 new cases and 233 000 mortars each year (3). There are 2.4 million affected children 5-15 years old in developing countries. There are about two million people with RHD requiring repeated hospitalization and one million require surgery globally. In Egypt, the prevalence of RHD is still high and the use of devices and prosthetic materials is also growing (4).

Complications of cardiac procedures include renal complications (44.3%), lung (40.3%), anemia (35.9%), heart (34.4%), stomach (17.2%), brain (14.2%), the need for re-intubation chip (11.3%), infection (7.8%) required reoperation (5.9%), and vascular complications (1.4%), respectively (5). Pulmonary complications are common following heart surgeries and replacement of diseased valves is often associated with more significant morbidity, prolonged hospital stay, and mortality (6). Reduction in respiratory muscle strength is obtained using the measurement of maximal inspiratory pressure generated at the mouth and has been reported during the hospital stay after cardiac surgery (7). According to the reports, an 11% reduction in Maximal Inspiratory Pressure (MIP), and a 36% reduction in MIP were observed five and six days after surgery, respectively. Reduced respiratory muscle strength in the early postoperative period after cardiac surgery might be due to sternal pain that affects the possibility of

performing the respiratory muscle tests properly (8). MIP and functional capacity are sensitive measures of respiratory muscle strength, useful tests of respiratory muscle strength, and gaining interest as a therapeutic clinical trial endpoint for neuromuscular disease (9). Physiotherapy has been advocated as an important component in the prevention of Post-Operative Pulmonary Complications following surgery and has been regularly utilized in both pre and postoperative care (10). The respiratory muscle strengthening enhances better efficacy in airway clearance, maximal inspiratory and expiratory pressures, and prevents respiratory muscle fatigue (9).

Resistive breathing such as Positive End-Expiratory Pressure (PEEP) has been incorporated in routine postoperative care after open-heart surgery in many patients and was primarily used to mobilize secretions. PEEP therapy generates an increase in transluminal airway pressure by creating resistance to airflow during expiration. This increase in airway pressure prevents airway collapse, increases lung volumes, assists with secretion clearance, improves alveolar ventilation, and reduces right-to-left intrapulmonary shunting (11, 12). Therefore, this study was conducted to investigate the response of maximum inspiratory pressure and functional capacity to PEEP devices after valvular heart surgery.

2- MATERIALS AND METHODS

2-1. Method

The clinical trial study was conducted at the National Heart Institution for four weeks, with a sample size of thirty patients who underwent valvular heart surgery, with 12-18 years old. They were referred from the physician and randomly assigned into two matched groups; intervention group (A) received PEEP with mouthpiece and routine chest physiotherapy; control

group (B) received only routine chest physiotherapy. Informed consent was taken from all the patients who participated in the study. The practical part continued from January to March 2020. The study was approved by the ethical committee of the Faculty of Physical Therapy, Cairo University. NO; P.T.REC/012/002531. The inclusion criteria were male and female patients who underwent valvular heart surgery with 12-18 years old. While, the exclusion criteria were patients with congenital heart disease, pacemaker implantation, and neurological disorder.

2-2. The Procedure of the Study

Demographic data, clinical characteristics, and all medical history were collected from patients' files.

A. Evaluation Procedure

1-Measurement of Maximal inspiratory pressure (MIP)

It is a widely used noninvasive method in the clinic to evaluate the Respiratory Muscle Strength (RMS) (13).

Steps of Measuring

1.The device is at zero and calibrated before each measurement.

2.To measure the MIP, the patient sits upright and maximally inhales from RV into a handheld pressure manometer and sustain the effort for more than 1 sec. Nose clips are required. The patient is coached to ensure adequate lip seal around the mouthpiece and achieve maximum voluntary effort, and the effort is repeated until at least three measurements have < 20% variability between them. The highest mouth pressure achieved which could be maintained for at least 1 sec was collected for data processing.

2-Functional capacity

Functional capacity is measured during a maximal Graded Exercise Test (GXT),

which is considered the best method for measuring cardiorespiratory fitness (14). Nevertheless, direct measurement of VO₂max is restricted by expensive and sophisticated equipment, qualified examiners, and long duration of testing sessions. Due to the difficulty of performing this method in many settings, (15) the submaximal field exercise tests are useful alternatives to direct measurement of the VO₂ max (maximal oxygen uptake).

The 6-Min Walking Test (6 MWT) is a simple test, which does not require expensive equipment or advanced training and has been used for measuring functional capacity after cardiac surgery (16). The patients were informed to walk as far as possible along a 30-m straight, flat hospital corridor in 6-min. The test was symptom-limited, so the patients who became symptomatic (e.g severe dyspnoea, dizziness, and musculoskeletal pain) were told to stop walking and restart when possible. Encouragement was not given. The longest passed distance was measured to the nearest meter and recorded. Before the test, the patient's resting heart rate and blood pressure were monitored in a sitting position (17). The estimated equation used for predicting VO₂ max (maximal oxygen consumption):

$$\text{VO}_2 \text{ max (mL/kg/min)} = 12.701 + (0.06 \times 6\text{-minute walk distance m}) - (0.732 \times \text{body mass index kg/m}^2) \text{ (18).}$$

B- Treatment procedure

1- Positive End Expiratory Pressure therapy (PEEP)

PEEP consists of a valve, mouthpiece/face mask, resistors, manometer (-30: +30) with a t-connector. The discussions were given to all patients about the importance of the treatment program as a whole and specifically of this modality. Each patient in the intervention group was trained to use the PEEP device for 15-20 minutes

(gradual increase up to 20 minutes) for two sessions per day for four consecutive weeks.

PEEP was introduced to the patients as follows:

1. The patients sat comfortably and upright while holding the mouthpiece tightly between the lips.
2. The expiratory resistor dial was adjusted to the prescribed setting.
3. The patients had to breathe according to the diaphragm, taking in a larger compared to the normal tidal breath, while not filling the total capacity of the lungs.
4. The patients had to exhale gently so that the pressure was detected using the diameter of the valve (1.5-2mm). The diameter was estimated according to the information from the manufacturing company, which was used to normalize the reduced lung volumes and oxygenation which are the most common complications after cardiac surgery.
5. The exhalation lasted approximately 3 times longer than inhalation.
6. The patients had to perform 10–20 PEEP breaths, and then performed 2–3 forced exhalation maneuvers or huffs.
7. The patients had to repeat steps 3–6 until secretions were cleared, or until the predetermined treatment period had elapsed (19).

2- Routine chest physiotherapy was introduced to the patients as follows

Postural drainage includes placing a patient in a gravity-dependent position and percussing the chest wall over the area,

which is being drained, for 3–5 minutes. The patient is then asked to inhale deeply 3–4 times and on exhalation, the chest wall is vibrated; this is followed by directed coughing (20). Percussion is clapping the chest wall (at a frequency of about 5 Hz), and producing a shock wave that is transmitted through the thorax and is believed to loosen mucus from the airway walls (21). To reduce any adverse consequences, the technique should be performed for about 30 seconds (22). Vibration is shaking of the chest (at a frequency of about 12-16 Hz), and is another way of transmitting phasic energy through the thorax, usually on expiration (23).

2-3. Statistical Analysis

Collected data were recorded, coded, verified, and then analyzed using SPSS (V.18; SPSS Inc., Chicago, Illinois, USA) on Microsoft Windows 7.0. Data were presented in the form of mean and standard deviation. Data were checked for normality using the Shapiro-Wilk test before running any statistical test. Unpaired t-test was used to compare between groups regarding independent variables (demographic data, MIP, and VO₂ max). Besides, Paired t-test was used to compare between pretreatment and post-treatment data in each group. P-values were considered as statistically significant.

3- RESULTS

3-1. Demographic Data

According to the results of unpaired t-test, there was no significant difference between groups regarding age, height, and weight (The p-values were 0.636, 0.681, and 0.818, respectively **Table.1**).

Table-1: Baseline characteristics of participants.

Variables	Study group Mean ± SD	Control group Mean ± SD	T- value	P-value
Age (year)	15.93±1.58	15.67±1.39	0.49	0.636
Height (cm)	159.87±7.11	158.8±7.02	0.41	0.681
Weight (kg)	56.67±7.67	57.27±6.47	-0.23	0.818

SD: Standard deviation.

3-2. VO2max and MIP Results

A paired t-test on VO2max and MIP revealed that there was a statistically significant difference between pretreatment and post-treatment data in both groups where the P-value was less than 0.0001. An unpaired t-test revealed that there was no significant difference between groups regarding pretreatment

data of VO2max, and MIP (P-values were 0.746 and 0.118), respectively. Besides, there was no statistically significant difference between the two groups regarding post-treatment data of VO2max and MIP where (P-values were equal to 0.325 and 0.084, respectively **Table. 2 and Table. 3**).

Table-2: VO2 max results.

Group	Mean ± SD (Before intervention)	Mean ± SD (4 weeks after intervention)	T- value	P- value
Study	1.19±2.4	11.66±1.95	23.37	<0.0001*
Control	0.9±2.42	10.94±1.95	16.54	<0.0001*
T- value	- 0.33	- 1		
P- value	0.746	0.325		

SD: Standard deviation, VO2: maximal oxygen consumption.

Table-3: MIP results.

Group	Mean ± SD (Before intervention)	Mean ± SD (4 weeks after intervention)	T- value	P- value
Study	60.27±31.72	69.13±33.41	11.55	<0.0001*
Control	44.33±21.49	50.53±22.29	7.99	<0.0001*
T value	-1.61	-1.79		
P value	0.118	0.084		

SD: Standard deviation, MIP: Maximal inspiratory pressure.

4- DISCUSSION

This study aimed to investigate the response of maximum inspiratory pressure and functional capacity to the Positive End Expiratory Pressure (PEEP) device in patients who underwent valvular heart surgery. Data analysis revealed that there was a statistically significant difference between pretreatment and post-treatment data in both groups regarding inspiratory

muscle strength and functional capacity (p<0.001). Besides, there was no significant difference between the groups regarding post-treatment data of Maximal Inspiratory Pressure (MIP), and VO2max (p=0.084, p=0.325), respectively. Breathing exercises are regularly prescribed for the post-operative period after cardiac surgery in Sweden. Hourly deep breathing exercises performed using a PEEP device were reported to be first

choice treatments at the hospital stay period (24). PEEP device is to expire against resistance, for example against half-closed lips (pursed lips breathing) is frequently used by patients with chronic obstructive disease. The expiratory resistance slows down expiration and increase lung volume, and may prevent or reduce airway collapse (25). Since the original PEEP devices were developed and described, the design of the PEEP device has been modified to allow the patient to interface with either a face mask or a mouthpiece. The traditional main components of the device, however, remain the same, and consist of a one-way valve connected to either a small-exit orifice or, more commonly, an adjustable expiratory resistor. A disposable or permanent manometer incorporates between the one-way valve and the resistor to measure the expiratory pressure (26).

The current study showed that there was no significant variation of MIP and functional capacity between groups while they had improved within groups; the possible explanation is that MIP and functional capacity are significantly correlated as shown in studies conducted by (27, 28). The study group showed an increase of inspiratory muscle strength after four weeks due to the following possible explanations: PEEP device applies more positive pressure at the end of expiration that helps to activate or recruit more alveoli, keep them open, consequently increase functional residual capacity, and improves ventilation-perfusion matching.

Furthermore, it encourages patients to huff or cough for getting rid of secretions, so it prevents airway collapse and helps the resolution of atelectasis which is the most common complication after cardiac surgery. Besides, it helps to redistribute the extra-vascular lung water due to the positive pressure it applies which help to move fluid from peri-vascular lymph

vessels (less compliant) which has less capacitance to more compliant peribronchial lymph vessels, hence PEEP reduces the incidence of pulmonary edema which is another postoperative pulmonary complication after cardiac surgery. Moreover; it shifts the pressure-volume curve to the left and down because it changes the volume of the lung with less pressure, so it improves lung compliance (19). The results of this study come in agreement with the study conducted by Ferreira et al. (29) which concluded that patients who were submitted to Incentive Spirometer in addition to Expiratory Positive Airway Pressure presented less dyspnea and lower sensation of effort after 6 Minute Walking Test, as well as improvement in life quality 18 months after coronary artery bypass graft. A study conducted by Urell et al. (30) showed that there is a relationship between lung function and respiratory muscle strength after discharge following cardiac surgery. Ali et al. (19) conducted a randomized controlled trial on 60 male patients underwent CABG surgery using PEEP with facemask versus that with the mouthpiece, the study concluded that PEEP application improved respiratory muscle strength, walking distance, and dyspnea index at rest and activity.

5- CONCLUSION

Patients who underwent valvular heart surgery exhibited reductions in postoperative inspiratory muscle strength and functional capacity. So expiratory training using PEEP device with the mouthpiece in comparison with the routine chest physiotherapy intervention alone can improve inspiratory muscle strength and functional capacity for those patients after valvular heart surgery.

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7- AUTHOR CONTRIBUTIONS

All authors contributed equally in all parts of this study.

8- CONFLICT OF INTEREST: None.

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