Ventilatory Function Response to Exercise Program Following Aortic Valve Replacement Surgeries

Azza F. Esmail* and Lotfy M. Eissa**
* Department of Cardiopulmonary Disorders and Geriatrics, Faculty of Physical Therapy, Cairo University.
** Consultant of Cardiothorcic Surgery, National Heart Institute.

ABSTRACT

Purpose: The purpose of this study was to identify the effect of aortic valve replacement surgery (A.V.R.) on ventilatory function in form of vital capacity (VC) and forced expiratory volume (FEV1). Subjects: Twenty male patients pre and post aortic valve replacement were included in this study selected randomly as volunteer from cardio-thoracic department in Kasr Eini hospital ranged age from 35 to45 years, their weight ranged from 60 to90 kg and their height from 159 to 186 cm, all patients on acceptant rang of body mass index (24.1± 2.1) kg /m^2. Methods: each patient had pre-operative program. The study extend for one month post-operative where the patients have the rehabilitation program in the form of hospitalization period program and after discharge program and measurement were taken for VC and FEV1 by using hand held computerized spirometer with an electronic memory to record the studied parameters. Conclusion: We conclude that, the measured ventilatory functions showed improvement after exercise for patients post aortic valve replacement.

INTRODUCTION

The cardiopulmonary system plays an important role in many physiological functions inside our bodies, even in movement through transporting oxygen to the skeletal muscle, that makes the abnormality of cardiovascular and pulmonary systems can produce limitation in physical function[1].

There are many factors can increase the cardiopulmonary problems as, smoking, hypercholesterolemia, obesity, hypertension, diabetes mellitus (DM), atherosclerosis, stresses and genetic disorders, so that, the need of more care of this system become very necessary[2].

Heart and blood vessels diseases will likely affect more people in varying degree, many patients don't respond well to pharmacological approaches, which makes them candidates for invasive surgical interventions[3].

Cardiothoracic operations are concerned with all structures that lies within the thoracic cage like ribs, lungs, heart or esophagus, it has two main categories, the first one is closed surgeries either cardiac or non cardiac and the second one is open heart surgeries[4].

Open-heart surgery is most common performed for coronary artery bypass graft, valve replacements and aneurysm repair[5].

Two types of surgery have the greatest impact on cardiopulmonary function, namely, thoracic and cardiovascular surgery, thoracic surgery refers to surgery necessitating opening of chest wall, mainly for lungs repair, while cardiovascular surgery involving the heart and great vessels, interrupt the flow of blood through cardiopulmonary system[6].

Aortic valve disease result in valvular stenosis, regurgitation or both, aortic and mitral valves are most commonly affected more than pulmonary and tricuspid valves, these valves can be diseased significantly and may even result in death. Aortic valve

replacement (AVR) is an open-heart procedure, performed by cardiothoracic surgeons for treatment of narrowing stenosis or leakage regurgitation of the aortic valve[7].

Pulmonary function test provides the clinical information about the airway integrity, state of respiratory musculature and condition of the lung tissues themselves through measurement the physiological functions of lungs, gas flow rate, gas diffusion and gas distribution[8].

All post-operative patients should be investigated from main seven dimensions including, physical functioning, physical health related to age, general health, vitality, social functioning, personal feelings and mental health. Scores compare with those expected for general population of a similar age to know the effect of surgery on patients' quality of life[9].

Most common symptoms of aortic stenosis (AS) are breathlessness, fatigue and cyanosis due to increase workload of the myocardium and lungs. There is risk of sudden death associated with aortic stenosis even if patient is free from symptoms[10].

Aortic valve replacement is performed through a median sternotomy, using cardio pulmonary bypass CPB, an aortotomy is made and the damaged valve is excised, the replacement valve is inserted and sutured into place, adequate seating of the valve, without a perivalvular leak is more important than avoidance of complete heart block, valve function is assessed before closing the aorta and CPB is withdrawn. Following aortic valve replacement, left ventricular hypertrophy gradually recedes, and left ventricular function eventually improves in a significant proportion of patients[11].

Aortic stenosis is the most common cause of left ventricular outflow obstruction, stroke volume (SV) is maintained by compensatory mechanism of LV hypertrophy, till hemodynamic dearrangement occurs to produce left ventricular (LV) failure. Aortic stenosis increases the retention of blood in the left side of the heart which leads to pulmonary congestion leading to pulmonary hypertension that reflects the breathlessness of aortic stenosis (AS) patients as a primary patient complain[12].

Post-sternotomy ventilatory dysfunctions for patients undergoing cardiothoracic surgery, where lungs are of primary concern during hospital recovery due to anesthesia, surgical manipulation, and pain that will all affect patient's lung function after surgery[13].

Impairment of ventilatory function is one of the most significant post-operative complications of open-heart surgery especially in form of slow vital capacity SVC, forced vital capacity FVC and FEV1[14].

There is a significant reduction in nearly all lung volumes followed open-heart surgery mainly for, vital capacity (VC), which reduce from 40% to 55% less than the previous subject measurements, forced vital capacity (FVC), about 30%-40% from normal subject values, forced expiratory volume at the first second (FEV1)[15].

The purpose of this study was to identify the effect of aortic valve replacement surgery (A.V.R.) on ventilatory function in form of vital capacity (VC) and forced expiratory volume (FEV1) for male patients.

MATERIALS AND METHODS

Subjects

Twenty pre and post aortic valve replacement male patients included in this study selected randomly as volunteer from cardio-thoracic department in Kasr Eini hospital ranged age from 35 to45 years, their weight ranged from 60 to90 kg and their

height from 159 to 186 cm, all patients on acceptant range of body mass index (24.1± 2.1) kg /m^2.

Measures

VC and FEV1 records for each group 3 times/session and take the mean.

- Pre operative.
- Post operative, at day 7, 15 and 30 of hospitalization period.

Subjects

Patients who had chest infection following surgery, excluded from the study.

Instrumentation

- Weight and height scale to calculate body mass index (BMI) to exclude obese subjects (↑30) BMI=Wt (kg)/ht (m^2).
- Hand held computerized spirometer with an electronic memory to record the studied parameters.

Methods

Each patient had pre-operative program as learning the correct technique of effective huff and cough and all types of segmental breathing exercises specially diaphragmatic one and learn patients how to deal with suture post-operative to avoid complications.

The study extend for one month post-operative where the patients have the rehabilitation program.

Hospitalization period

All patients had a post-operative rehabilitation program, through gradually increase level and repetition of exercises as following:

3rd day post-operatively:

A) Breathing exercises (segmental expansion) in form of diaphragmatic and lateral costal breathing it was done three times per day every time applied five repetitions with rest in between followed by two successful cough with wound support.
B) Ankle pumping exercises (isotonic) for 10 repetitions every hour.
C) Quadriceps muscle contraction 10 repetitions every hour.

5th day post-operatively:

A) Deep breathing exercise through incentive spirometer training with hold for a count of three to five seconds.
B) Postural drainage with gentile percussion for 10 minutes.
C) Dynamic arm exercises in all directions except horizontal abduction.
D) Turning inside the bed comfortably from supine to side lying to sitting position to stable chair beside the bed.
E) Walking around the bed, inside the room for two minutes.

7th day post-operatively:

A) Walking from five to seven minutes under supervision of caregiver whatever nursing or member of his/her family.
B) Walking down a stair for one flight.
C) Self-care activates with assistance (washing face, bathing, showering, dressing, show wear).

9th day post-operatively:

A) Rolling from side to side with flexed knees (crock lying).
B) Walking from 10-15 minutes.
C) Walking up a stair for one flight.
D) Self-care activates with assistance.

All exercises at hospitalization period applied within the limit of fatigue, with rest in between and under monitoring, to not increase pulse rate 20 beats per minute from the pre-exercise value.

After discharge:

A) Self-care activates without assistance under supervision.

B) Aerobic exercises with increase intensity, duration and frequency gradually,

- Mood of exercises: jogging, cycling, climbing stairs or swimming.
- Intensity: within the limit of fatigue.
- Duration: 30-40 minutes started by five minutes warming up (breathing exercises, exercises connected with breathing and brisk walking) and ended by cooling down for five minutes, with rest in between exercises.
- Frequency: from three to five times per week.

RESULTS

This study comprised 20 patients had open-heart surgeries selected from Cardio-thoracic department in Kasr-El-Aini hospital. The data was collected from patients' files and classified into pre and repetitive post surgery values. Statistical analysis of data by using paired t-test to determine the difference between each time of measurement.

Table (1): Shows the mean and SD of the age, weight, height and BMI for the studied patients.

	Mean ± SD
Age (years)	39.6 ± 3.43
Weight (Kg)	72 ± 9.01
Height (m)	1.72 ± 0.07
BMI (Kg/m²)	24.15 ± 1.17

Table (1) shows the mean and standard deviation of the age, weight, height and body mass index for the patients being enrolled in the study, these data include the following:

Their age ranged from 35 to 45 years with a mean of 39.6 ± 3.43 years, their weight ranged from 56 to 90 Kg, with a mean of 72 ± 9.01 Kg, their height ranged from 1.59 to 1.88 m. with a mean of 1.72 ±0.07 m. and body mass indices (BMI) ranged from 22.6 to 25.92 Kg/m², with a mean of 24.15 ± 1.17 Kg/m².

Table (2) show the mean and standard deviation (SD) values of ventilatory function test for VC and FEV1 at the pre-operative state, 7 days, 15 days and 30 days post operatively.

Table (2): Shows the mean and standard deviation (SD) values of ventilatory function test for VC during various treatment periods.

Variable	Pre Mean ± SD	7 days post Mean ± SD	15 days post Mean ± SD	30 days post Mean ± SD
VC	2.48±0.66	1.56±0.32	2.8±0.65	3.1±0.612
FEV1	2.4±0.66	1.39±0.25	2.77±0.62	2.9±0.67

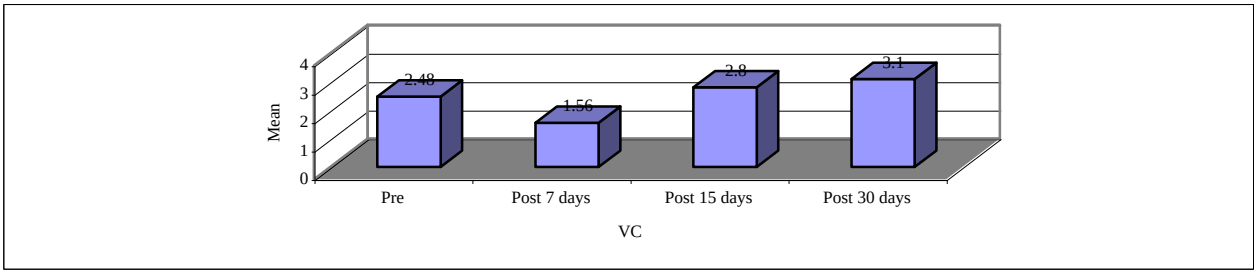

Fig. (1): Shows the difference of ventilatory function test for VC at the pre-operative state, 7 days, 15 days and 30 days post operatively.

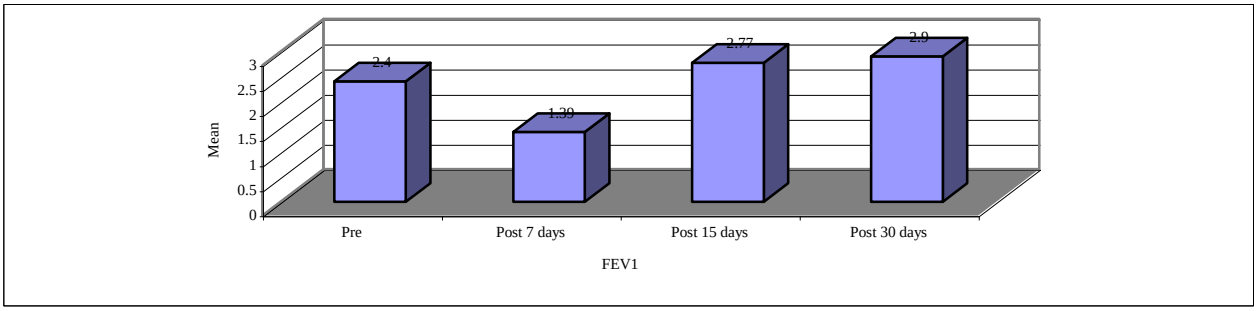

Fig. (2): Shows the mean and standard deviation (SD) values of ventilatory function test for FEV1 at the pre-operative state, 7 days, 15 days and 30 days post operatively.

Table (3): Shows the analysis of ventilatory function test for VC at the pre-operative state, 7 days, 15 days and 30 days post operatively.

	Mean ± SD	**t-value**	**p-value**
Pre-7 days post	0.91 ± 0.45	9.1	0.001
Pre - 15 days post	0.35 ± 0.24	6.4	0.001
Pre- 30 days post	0.64 ± 0.26	0.8	0.001
Post 7 days --15days	1.27 ± 0.45	2.5	0.001
Post 7 days—30 days	1.56 ± 0.44	5.5	0.001
Post 15days—30 days	0.2 ± 0.17	7.03	0.001

Level of significance at P<0.05.

Table (4): shows the analysis of ventilatory function test for FEV1 at the pre-operative state, 7 days, 15 days and 30 days post operatively.

	Mean ± SD	**t-value**	**p-value**
Pre-7 days post	1.04 ± 0.49	9.54	0.001
Pre - 15 days post	0.33 ± 0.19	7.73	0.001
Pre- 30 days post	0.49 ± 0.23	9.6	0.001
Post 7 days --15days	1.38 ± 0.46	13.2	0.001
Post 7 days—30 days	1.53 ± 0.50	13.7	0.001
Post 15days—30 days	0.15 ± 0.14	4.8	0.001

Level of significance at P<0.05.

DISCUSSION

The progression of care about the cardiopulmonary system extends to the progression of the surgical techniques. This improvement in surgical techniques and in management of emergency case will considerably enhance the surgical outcome in our population[16].

Improvement of left ventricular function after surgery depends on, whether the preoperative left ventricular dysfunction was due to aortic stenosis alone or due to a complication condition, for instance, patients with no prior myocardial infarction have a low surgical mortality and a significant improvement in left ventricular ejection fraction postoperatively, on the contrary, patients with aortic stenosis and a history of preoperative myocardial infarction have much poorer outcomes[17].

The major task of the lung is to oxygenate the blood and eliminate carbon dioxide from it, this is accomplished by an exchange of gas between the gas in the lung

(alveolar gas) and the pulmonary capillary blood, air is brought down into the alveoli through cyclic breathing and oxygen in the inspired gas diffuses through the alveolar epithelial wall, the interstitial tissue, and the capillary endothelial wall, as well as the plasma, finally reaching the hemoglobin inside the red blood cells, carbon dioxide CO2 diffuses in the opposite direction, from the blood cells and the plasma to the alveolar gas phase, and is expired. To establish a gas exchange in the human lung that need well ventilation of the alveoli, diffusion through the alveolar capillary membranes and circulation of perfusion of the pulmonary capillary bed, size of the alveolar area available for diffusion and quality of the alveolar-capillary barrier are importance for gas exchange process, if ventilation and perfusion are not matched, gas exchange will be affected, the most common cause of oxygenation impairment is indeed ventilation perfusion ratio (V_A/Q) mismatch, low V_A/Q ratio will impede oxygenation because ventilation is too small to oxygenate the blood fully, the degree of impairment is dependent on the degree of mismatch, ventilation perfusion (V_A/Q) mismatch is considered the most common cause of hypoxaemia, that evoke worse ventilatory manifestation, hypoxaemia stimulates increased ventilation, which returns the partial pressure of arterial carbon dioxide $PaCO_2$ to normal or near normal partial pressure of arterial oxygen (PAO_2)[18].

The lung is regularly affected by anesthesia and mechanical ventilation in all four areas of function: ventilation, distribution, diffusion, and circulation, this already occurs in the healthy volunteer or the patient with no cardiopulmonary disease, and sometimes the dysfunction can be sufficiently severe to cause life threatening hypoxaemia, the impairment of arterial oxygenation during anesthesia is generally considered to be more severe at higher ages; obesity worsens the oxygenation of blood and smokers show more gas exchange impairment than non-smokers[19].

Anesthesia causes an impairment of pulmonary function, where the patient in breathing spontaneously or is ventilated mechanically after muscle paralysis. Impaired oxygenation of blood occurs in most subjects who are anaesthetized, static compliance in the total respiratory system (lungs and chest wall) is reduced from 95 to 60ml/cm H_2O during anesthesia. It has therefore become routine to add oxygen to the inspired gas[20].

The resting lung volume, or functional residual capacity (FRC), is reduced during anesthesia due to decreased intrathoracic blood volume and the supine body position by itself reduces FRC by 0.7-0.8 liter through its reducing to chest diameter, compared with the upright position, so that the further decrease of 0.4-0.5 liter caused by the anesthesia decreases the FRC to near the awake residual volume, reduction in FRC occurs with spontaneous breathing and whether the anesthetic is inhaled or given intravenously. Several studies suggest that the diaphragm is moved cephalad during anesthesia, and so contributes to the decrease in FRC this cephalad shift of the diaphragm may be explained by loss of respiratory muscle tone, allowing the abdominal contents to push the diaphragm carnally[21].

Invasive surgical procedures through median sternotomy incision affect, chest wall recoil, dynamic hyperinflation, blood gases (PaO2-PaCO2) and acid-base measurement, in addition to, the pulmonary functions including, total lung capacities (TLC), maximum voluntary ventilation (MVV), vital capacity (VC), forced vital capacities (FVC), forced expiratory volume (FEV1), residual volume (RV) and the peak flow rate[22].

Lung function remains impaired postoperatively and clinically significant pulmonary complications can be seen from 1-2% after minor surgery up to 20% after upper abdominal and thoracic surgery that may causing acute respiratory failure (ARF) or acute respiratory distress syndrome (ARDS)[23].

There are many signs limited cardiopulmonary exercises testing following open-heart surgical interference as, changes of the pulmonary functions, gas exchange, and reduce lungs hyperinflation, that influences the work of breathing during exercise, reduction of exercise performance, affect activity of daily living (ADL) and change the quality of life[24].

Incentive Spirometer remains a widely used technique for the prophylaxis and treatment of respiratory complications in post operative patients. Its use in the United States was reported that 95 % of hospitals in which cardio-thoracic and abdominal surgery was performed using Incentive Spirometer in the post-operative care. Also 44% of hospitals in which coronary bypass graft surgery was carried out in the United Kingdom[25].

The effect of cardiac rehabilitation programs on health-related quality of life and return to work in patients with coronary artery disease, showed that, cardiac rehabilitation participants had significantly higher scores in general health, physical functioning and social functioning[26].

So, it is obvious that the male patient after aortic valve replacement surgery showed highly significant improvement in (FEV1) and (VC) post-operatively that could be explained due to pain relief, post-operative rehabilitation program that was done for patients in form of encouragement ventilation and ambulation as early as possible that helped to improve the strength, endurance and efficacy of respiratory muscles, and improved the psychological condition, which was directly related to relieve the patient's symptoms.

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الملخص العربي

دراسة تغيرات الوظائف التنفسية للرجال عقب تغير الصمام الأورطى

هدف البحث هو دراسة تتابع معدلات التغير في الوظائف التنفسية عقب جراحة تغير الصمام الأورطى. أجرى البحث على 20 حالة من الرجال الذين يعانون من ضيق في الصمام الأورطى ويحتاجون إلى عملية تغيير صمام. وكانت مدة الدراسة أربعة أسابيع تلقى خلالها جميع المرضى برنامج علاج طبيعي تأهيلي وتم خلالها قياس وظائف الرئة (السعة الرئوية وقوة الهواء المندفعة في الثانية الأولى من الزفير) ثمان مرات متتالية ، مرة قبل إجراء الجراحة بيومين و 3 مرات بعد إجراء الجراحة بالتتابع الآتي : (7– 15 –30) أيام بعد الجراحة حيث يظل المريض داخل المستشفى. أظهرت النتائج وجود فروق ذات دلالة إحصائية تشير بتحسن في قياس وظائف الرئة بعد إجراء الجراحة بشهر. لذلك يوصى استخدام برنامج تأهيلي متكامل للعلاج الطبيعي عقب جراحات القلب المفتوح يساعد على تحسن الوظائف الرئوية ويعجل في عودته لحالته الطبيعية.