Conventional Cardiac Rehabilitation Program Versus Addition of Alveolar Recruitment Maneuver Among Patients Undergoing Coronary Artery Bypass Surgery

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Abstract

Introduction: Cardiac rehabilitation (CR) is a worldwide standard practice, following cardiac surgery, however in Egypt we are still lagging behind such practice. Long term follow-up is a major determinant together with physician’s incompliance to such multi-disciplinary approach. Our goal was to highlight the importance of CR program, through a short term follow-up period. Prolonged mechanical ventilation can have numerous drawbacks following cardiac surgery, atelectasis is one of them and recruitment maneuvers (RM) can effectively re-expand atelectatic lung tissue and aid in early postoperative separation from mechanical ventilator. We examined the effectiveness of CR program alone versus recruitment maneuver added to the CR program in regards to functional capacity of the patients using 6 minutes walk test (6MWT).

Materials and Methods: 70 patients scheduled for elective coronary artery bypass graft using conventional cardiopulmonary bypass (CPB) were randomly allocated into two equal groups (Group A: CR alone n=35 & Group B: CR+RM n=35). Among both groups a CR program had been discussed, explained and handed to them. In Group (A) prior to discontinuation from CPB, mechanical ventilation was resumed, while in Group (B) a RM was performed (30 cm H \( \text{O}_2 \) for 15 s) and then mechanical ventilation was resumed. Patients were transported to ICU. PaO\( \text{O}_2 \)/FiO\( \text{O}_2 \) were recorded at following intervals (T-Base) following separation from CPB (T-CPB) 15 minutes following transfer to ICU (T-ICU) and 6 hours following extubation (T-EXT). Following separation from the ventilator, patients were asked to adhere to the CR program and a daily 6MWT was performed, the test was interrupted if any criteria of fatigue occurred. Spirometric values were also recorded at baseline and following thereafter. All patients were asked to show up once after 6 weeks and were reassessed.

Results: In the immediate postoperative period, patients in Group B demonstrated better PaO\( \text{O}_2 \)/FiO\( \text{O}_2 \), better exercise tolerance, greater 6MWT distances and better spirometric values compared to patients in Group A; however such values were comparable afterwards. Among all patients 6MWT distance, spirometric values and exercise tolerance had improved afterwards specially after 6 weeks.

Conclusion: CR program has added benefits to patients following CABG, a RM added to CR program temporary improves pulmonary functions and allows early ambulation which aids in the early beginning of CR. Recommendations: Benefits of CR program should be studied in Egypt in a larger and longer term study and its primary objective is to highlight morbidity, mortality and quality of life after surgery.

Key Words: Cardiac rehabilitation (CR) – Coronary artery bypass graft (CABG) – Recruitment maneuver (RM) – 6 Minutes Walk test (6MWT) – Functional capacity.

Introduction

ACCORDING to the World Health Organization (1964) definition, cardiac rehabilitation (CR) includes all actions undertaken to provide optimal physical, mental and social environment for the cardiac patient to let him or her regain maximal functional capacity in the society. Thus, cardiac rehabilitation should be multifaceted and comprehensive. It should be initiated with the first symptoms of cardiac disease, immediately following the life-threatening phase of an acute coronary event, or in the early period following invasive treatment. No temporal limits should be imposed on cardiac rehabilitation [1].

Modern cardiac rehabilitation should be: comprehensive; initiated as early as possible; continuous; staged; individualized depending on the clinical state and acceptable for the patient. In addition, comprehensive cardiac rehabilitation should include the following components: Clinical evaluation, optimization of pharmacotherapy, physical training, psychosocial rehabilitation, evaluation and reduction of coronary disease risk factors, life style modification, patient and family education [2,3].

These comprehensive goals require involvement of a multidisciplinary team that includes not only
physicians but also physiotherapists, psychologists, sociologists and dieticians. The primary goal of the therapeutic team is to develop an individualized therapeutic plan with the aim of regaining and maintaining optimal clinical status, as well as physical, mental and social capacity of the patient [2].

Physical rehabilitation is a major component of the comprehensive cardiac rehabilitation. During the last 30 years, a major breakthrough occurred in our thinking regarding the role of physical activity in patients with cardiovascular disease. Until 1960s, bed rest or major limitation of exercise was considered beneficial for the majority of patients. In contrast, moderate or even intense exercise training is currently used not only in the prevention of coronary heart disease, but also as a therapeutic measure following myocardial infarction, percutaneous coronary intervention (PCI), cardiac surgery, and permanent pacemaker or cardioverter-defibrillator implantations. For some years now, physical rehabilitation is also undertaken in patients with heart failure regardless of its etiology [4,5].

Patients with coronary heart disease (CHD) who have experienced an acute myocardial infarction (AMI) or have undergone coronary artery bypass graft (CABG) surgery are prime candidates for CR services. Meta-analyses of randomized controlled trials have consistently shown that participation in CR programs improves mortality and morbidity outcomes and may favorably influence cardiac risk factors [6-10].

Recruitment maneuvers to re-expand atelectatic lung tissue during general anesthesia had been previously described to improve oxygenation and maintain lung volumes. The use of cardiopulmonary bypass (CPB) during cardiac surgery always involves discontinuation of mechanical ventilation, thus the effects of atelectasis that occur normally with anesthesia can be further accentuated [11,12].

Recently Intraoperative alveolar recruitment maneuvers (RM) have been proven to increase oxygenation indices due to reversal of atelectasia in patients undergoing CABG surgery with conventional CPB, extending from immediate postoperative to ICU discharge. However, effects of such maneuvers have never been related to functional capacity of patients [13].

The 6 minutes’ walk test (6MWT) is an easy and reliable method to assess functional capacity in patients who had undergone cardiac surgery. The reference value for such test varies considerably due to numerous factors including age, sex and cardiac procedure [14].

Accordingly, the aim of the present work is to compare addition of Intraoperative alveolar recruitment maneuvers (RM) to conventional cardiac rehabilitation program (CR) among patients undergoing elective CABG procedure.

**Materials and Methods**

A written informed consent from 70 patients scheduled for elective CABG procedure with normothermic cardiopulmonary bypass have been taken. Patients were randomly allocated into two equal groups using a closed envelope technique, Group A (CR group, n=35) and Group B (CR+RM, n=35). Exclusion criteria involved: patients with previous cerebrovascular strokes, impaired contractility (defined as ejection fraction <0.4), combined CABG and valve procedures, patients with recent myocardial infarction, Mitral incompetence (< 2 weeks) or chronic obstructive pulmonary disease (COPD).

**Patient preparation and pre-medication:**

In the preoperative visit, patients were met by anesthesiologist, cardiac surgeon and rehabilitation doctor. A spirometry for each patient will be done. The patient will be supplied with a rehabilitation booklet (Appendix 1). Patient and family were advised to read the booklet at their own leisure in order to fulfill any of their queries before being discharged from hospital.

All patients were fasted for 6 hours prior to procedure, patients regular medications were received as usual with 20 ml of water. All patients received lexotanil 3mg orally the night before surgery and 0.1mg/kg morphine sulphate, Intravenous (IV); prior to operating room transfer. In the preparation room all patients were monitored using 5 lead ECG electrodes placed on the back, non invasive arterial blood pressure and pulse oximetry. Oxygen was administered via a nasal cannula, 3L/min. The radial artery of the dependant hand was cannulated using a 20 G arterial cannula under local anesthetic (lidocaine 2%) and a baseline arterial blood gases (ABG) sample, random blood glucose and activated clotting time were done. The right internal jugular vein (IJV) was cannulated under local anesthesia and 0.05 mg/kg midazolam; Intravenous (IV); using the anterior approach technique with a triple lumen central venous catheter.
Patients were then transferred to the operating room.

Anesthesia and recruitment maneuvers (RM):

Bispectral index monitor (BIS) and sensor were applied to the forehead after skin preparation. Anesthesia was induced using thiopental sodium and fentanyl in an attempt to reach a BIS index value of 40-60. Tracheal intubation was facilitated using 0.2mg/kg Cisatracurium Besylate. Following induction of anesthesia, end-tidal CO2 cable was attached and oropharyngeal temperature probe was inserted. Lungs were mechanically ventilated, where the tidal volume and respiratory rates were adjusted to maintain end-tidal CO2 35-45 mmHg and FiO2 maintained at 0.5. Anesthesia was maintained using Sevoflurane in O2/Air mixture and fentanyl infusion to maintain a BIS index value 40-60. During CPB, anesthesia ventilator unit is switched off and Propofol 1% was infused to maintain BIS index value 40-60. Cisatracurium Besylate was infused continuously at a rate of 0.03mg/kg/hr till ICU transfer. Prior to separation from CPB, restoration of mechanical ventilation was done immediately in Group A (CR) patients. While those in Group B (CR+RM) received alveolar recruitment maneuver at a pressure of 30 cmH2O for 15 seconds, followed by restoration of mechanical ventilation.

After completion of surgery, patients were transferred to the ICU intubated and mechanically ventilated, the ICU physician was blinded to the experimental protocol and patients were extubated according to the study protocol.

6 minutes walk test and spirometry in ICU and ward:

Following extubation, patients were assessed and given instructions to start ambulation as early as possible. The 6MWT was performed according to the standardized procedure [15]. The test was supervised by a physical therapist and the rehabilitation doctor when the need arised. Subjects were asked to walk at their own maximal pace along a 35-m long, flat and straight hospital corridor. No encouragement was offered. The test was symptom limited, so patients were allowed to stop if signs or symptoms of significant distress occurred (severe dyspnea, dizziness, angina, skeletal muscle pain), though they were instructed to resume walking as soon as they can. The distance covered during the test was recorded in meters. The test is repeated daily in ICU and ward till hospital discharge. Average of spirometry readings were recorded daily by a physical therapist.

Patient discharge and follow-up:

Prior to discharge, the rehabilitation program was thoroughly discussed with patients including review of risk factors (do's and don'ts seen in appendix 1), medication, psychosocial functioning, and return to work plan. Patients were taught how to do the exercises at the end of their booklet and timed for them. They were asked to repeat these exercises daily, record their timing and write it in the table at the end of their booklet. They were also taught how to measure their pulse before and after performing the exercises and were informed to stop any exercise if there is an increase in their pulse more than 20 beats/minute, dyspnea, dizziness, angina or skeletal muscle pain. Patients were asked to show up to the rehabilitation doctor; 6 weeks after discharge from the hospital; for further evaluation and follow-up using the 6MWT.

Measurements:

PaO2/FiO2 were recorded at baseline (T-Base) following separation from CPB (T-CPB), 15 minutes following transfer to ICU (T-ICU) and 6 hours following extubation (T-EXT). Heart rate and respiratory rate were monitored during the 6MWT to interrupt the test as appropriate. Frequency of interruption of 6MWT was recorded. Distances walked during 6MWT were also recorded. Spirometric readings, mechanical ventilation time, ICU stay, hospital stay and any associated complications were recorded.

Statistical analysis:

Data are expressed as mean ± SD, PaO2/FiO2, spirometry and distances walked during 6MWT were compared using repeated measure ANOVA; if statistical significance was reached, a tukey post hoc test was performed to identify level of significance. Time of mechanical ventilation, ICU stay and hospital stay were compared using unpaired student t-test. Frequency of interruption of 6MWT and associated complications were analyzed using chi-square or Fischer’s exact test (X2) as appropriate. p<0.05 was considered as statistically significant.

Results

Demographic data for patients enrolled are demonstrated in Table (1). Baseline PaO2/FiO2 (T-Base) among both groups were comparable (376.4 ± 42.1 vs. 378.7±38.6,. p<1.0 for groups A and B respectively). However, PaO2/FiO2 was significantly higher in group B during T-CPB, T-ICU and T-EXT compared to group A demonstrated in Fig. (1).
During ICU stay, 6MWT were completed in 99 out of 119 patients in Group B versus 85 out of 123 in patients of Group A ($p=0.008$). Following discharge from ICU, 6 minute walk tests were completed in ward among 101 out of 117 patients in group B versus 101 out of 126 of patients in Group A ($p=0.133$). All patients (100%) had completed the 6 minute walk test after 6 weeks (Table 2).

Fig. (2) showed that distances walked during 6 MWT were significantly higher among patients in Group B during their ICU stay compared to group A ($221.5\pm 19.4$ meters vs. $236.2\pm 34.7$ meters, $p<0.0001$). However there is no significant change in such distances during hospital stay and 6 weeks later. Both groups showed significant increase in distance traveled during the 6MWT in comparison to ICU. Distance walked after 6 weeks were also significantly higher compared to the distance walked in both ward and ICU.

Spirometry readings during ICU stay and hospital stay were significantly higher among patients in group B compared to Group A ($p<0.0001$). However, non significant differences in the spirometry values among both groups after 6 weeks ($p<0.36$). In groups A and B spirometry values had increased significantly with time (i.e. ICU<ward <6weeks values) which is demonstrated in Fig. (3).

ICU stay and hospital stay did not differ among both groups. However duration of mechanical ventilation was significantly lower among patients in group A ($p=0.03$) (Table 3).

![Distance walked during 6MWT](image)

Distance walked during 6MWT

* Significantly higher $p=0.03$ compared to Group A.

![Spirometry values](image)

Spirometry values

* Higher in group B compared to group A ($p<0.0001$).

Table (1): Demographic data among patients enrolled.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group A (CR n=35)</th>
<th>Group B (CR+RM n=35)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>56.3±2.0</td>
<td>55.9±2.4</td>
</tr>
<tr>
<td>Sex</td>
<td>29 M: 6 F</td>
<td>28 M: 7 F</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>93.1±5.2</td>
<td>91.9±5.5</td>
</tr>
<tr>
<td>Number of grafts</td>
<td>3.5±0.9</td>
<td>3.3±0.8</td>
</tr>
<tr>
<td>Aortic-cross clamping (min)</td>
<td>56.2±7.6</td>
<td>57.1±8.5</td>
</tr>
<tr>
<td>Total operative time (min)</td>
<td>333.1±59.1</td>
<td>318.4±46.9</td>
</tr>
</tbody>
</table>

Fig. (1): $\text{PaO}_2/\text{FiO}_2$ among both groups. Group A (CR n=35), Group B (CR +RM n=35), T-Base= Baseline, T-CPB= 15 minutes following separation from cardiopulmonary bypass, T-ICU= 15 minutes following ICU transfer & T-ext= 6 hours following extubation.

* Denotes significance compared to group A ($p<0.0001$).
Table (2): Number and % of completed and interrupted 6MWT among both groups during ICU stay, hospital stay and 6 weeks after discharge from hospital. * denotes significance between Group A and B among patients in which 6MWT was interrupted.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group A (CR n=35)</th>
<th>Group B (CR+RM n=35)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Completed</td>
<td>Interrupted</td>
<td></td>
</tr>
<tr>
<td>ICU</td>
<td>85 (69.1%)</td>
<td>38 (30.9%)</td>
<td></td>
</tr>
<tr>
<td>Ward</td>
<td>101 (80.2%)</td>
<td>25 (19.8%)</td>
<td></td>
</tr>
<tr>
<td>6 weeks</td>
<td>35</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Table (3): Duration of mechanical ventilation, ICU stay and hospital stay among both groups.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group A (CR n=35)</th>
<th>Group B (CR+RM n=35)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration of mechanical ventilation (Hours)</td>
<td>9.4±2.3</td>
<td>8.2±2.0</td>
<td>0.03</td>
</tr>
<tr>
<td>ICU stay (Days)</td>
<td>3.5±0.9</td>
<td>3.4±0.7</td>
<td>0.55</td>
</tr>
<tr>
<td>Hospital stay</td>
<td>7.1±1.2</td>
<td>6.7±1.2</td>
<td>0.21</td>
</tr>
</tbody>
</table>

Discussion

The number of people who survive myocardial infarction or have undergone percutaneous coronary intervention (PCI) or coronary artery bypass graft surgery (CABG) is growing. These people require an adequate treatment and care not only pharmacologically but also non-pharmacologically; physiotherapeutic, psychological and educational. Comprehensive cardiac rehabilitation (CR) is designed to support patients with coronary heart disease (CHD) in their physical, psychological and emotional recovery after acute coronary events and to help them change lifestyle and to avoid risk factors, as well as to make them live a longer better quality life. Most published studies analyzing the effects of CR have revealed a reduction in total mortality by an average of 30% and cardiovascular mortality by an average of 40% [16] and also reduction in cardiovascular events risk [17].

Recently, not only mortality and morbidity but also health-related quality of life (QOL) has become a key goal for patients with CHD. Many published studies have revealed improvements in the health-related QOL of patients with CHD after different kinds of CR programs [18].

The main findings of our trial can be summarized as follows: 1) in group B receiving alveolar recruitment maneuvers in addition to CR, there were increased PaO₂/FiO₂, less duration of mechanical ventilation. 2) During ICU stay, the number of patients that completed the 6MWT and distances walked were greater among patients in Group B compared to Group A. 3) Spirometry values among patients in group B during ICU stay was significantly higher compared to those of group A. 4) Spirometry values, distances walked during 6MWT have increased among both groups with time (ICU<Ward<6 weeks). 5) No significant differences were detected among both groups as regards to hospital stay, ICU stay.

In this study, we also re-evaluated the cardiac rehabilitation (CR) program (Appendix 1). CR is usually assessed in terms of decreased postoperative complications, reduced morbidity, mortality and modulated life-style. However such parameters were not feasible in our trial, as to comment on such variables we need long follow-up time and good compliance from both surgeons and patients. This is the first trial to include a systematized CR program among patients undergoing CABG in Egypt. Thus as a first step we chose to simplify our objectives by choosing the 6MWT. The 6MWT as a clinical assessment tool of the functional capacity has a significant correlation with the most important global Left Ventricular systolic function parameters [19]. Although different factors can influence the distance covered in the 6MWT as age, sex and co-morbidity [20], however we believe that increase in the distance walked can be directly attributed to the CR program or CR+RM, as patients characteristics involved were comparable prior to surgery. Moreover, the % of patients that completed the test had also increased with time (i.e. functional capacity of patients is improving) and finally at 6 weeks all patients (100%) had completed the test. The distance walked in our trial can be correlated to most distances walked in similar trials [14,21].

There are several reasons for the shortfall in cardiac rehabilitation provision in the United Kingdom. There has never been any national plan for
Cardiac rehabilitation has not been driven by purchasers keen to provide rehabilitation for their heart patients but has been driven by the enthusiasm of nurses, physiotherapists and occupational therapists that have perceived the need in their area and set up programs to meet this need often without the support of their cardiologist colleagues. Even since the publication of the National Service Framework targets in the United Kingdom, cardiologists are very seldom involved with the promotion or delivery of cardiac rehabilitation. Guidelines and audit standards have been introduced but not generally followed and cardiac rehabilitation programs are not often an integral part of the cardiac department nor a recognized step in the patient’s care pathway [22]. In accordance with the above researches, we faced lots of difficulties among cardiac surgeons when we tried to introduce this CR program to their patients and to the present day some specific surgeons won’t allow us to use CR with their patients. Considering our limited funding and resources, we can’t prove much to change their old beliefs regarding this area.

The incidence of Intraoperative pulmonary collapse is elevated in patients undergoing surgery under general anesthesia with muscle relaxation/paralysis. This complication is associated with worsening intra-operative gas exchange and in some cases, there is a need for prolonged postoperative respiratory support [23]. During CPB, the lungs are not ventilated, promoting further atelectasis [24]. The use of alveolar recruitment maneuvers have been known to reverse atelectasis developing under general anesthesia. Rothen and colleagues [11,12] were among the first to evaluate effects of such maneuver in two hallmark trials, concluding that such maneuver can help re-expand atelectatic tissue with the aid of computerized tomography scan [12] and in another trial the authors demonstrated that such effects can be preserved for at least 40 minutes following the maneuver [11].

Recruitment maneuvers among cardiac patients have been debated for fear of hemodynamic disturbances associated with elevated intrathoracic pressure, however Celebi and colleagues [21] evaluated sixty patients undergoing coronary artery bypass surgery. They were randomized into three groups after the operation into CPAP-40 group, PEEP-20 group and 5 cm H₂O PEEP. The mean arterial blood pressure of the CPAP-40 group was lower than that of the PEEP-20 (p<0.01) and PEEP-5 groups (p<0.01) during the interventions. Oxygenation was higher in both recruitment groups than in the PEEP-5 group during the mechanical ventilation period. There was no significant difference among the groups beyond that period. The atelectasis score of the PEEP-5 group (1.3 ±0.9) on postoperative day 1 was higher than that of the CPAP-40 (0.65±0.6; p=0.01) and PEEP-20 (0.65±0.5; p=0.01) groups. In the current trial our results emphasizes Celebi & colleagues [21] findings, where benefits of recruitment maneuvers were observed during mechanical ventilation period, however we did not demonstrate hemodynamic changes as our maneuver was at lower pressure and shorter period of time (15 seconds). They also found that atelectasis score is lower in patients who received RM. This may explain why there is better PaO₂/FiO₂, spirometric values, 6MWT success, 6MWT distance and shorter duration of mechanical ventilation among patients that received a recruitment maneuver. Also, in support to our findings, Minkovich and colleagues [13] evaluated recruitment maneuver among patients requiring elective cardiac surgery with cardiopulmonary bypass (CPB). Ninety-five patients were randomly allocated to either RM or control groups. In the RM group, lung inflation at pressure of 35 cmH₂O was sustained for 15 seconds before separation from CPB and at 30 cmH₂O for 5 seconds after admission to the intensive care unit (ICU). RM resulted in better arterial oxygenation extending from the immediate postoperative period to approximately 24 hours after surgery at the time of ICU discharge.

The main limitation of our trial was that it involved a small patient population and was of short term 6 weeks as compared with the current recommendations of 8 to 12 weeks [25]; however we chose to imply a simple and short term program to induce awareness among patients and attending physicians to the positive role of postoperative multi-disciplinary CR approach and also to study the effect of RM in addition to CR.

Our trial was a single-center trial which allows less heterogeneity in the distribution of interventions. Therefore, a more precise intervention effect may be detected. The weakness, however, is that single-center trials may have less external validity (pragmatic effect). In future studies, we hope that we may be able to implement an aggressive program, involving all cardiac patients, including heart failure, coronary angiography and higher risk population and in such program we will focus on main primary outcome goals, including morbidity and mortality, in an attempt to have an Egyptian experience and reference values for such program.
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