Combined Effects of Continuous Positive Airway Pressure and Cycle Ergometer in Early Rehabilitation of Coronary Artery Bypass Surgery Patients

Arjumand Bano¹, Anam Aftab², Wajeeha Sahar³, Zulfiqar Haider⁴, Muhammad Irfan Rashed⁵ and Hafiza Mahnoor Shabbir⁶

¹Department of Physical Therapy, Capital Diagnostic Center, Islamabad, Pakistan
²Faculty of Pharmacy, Allied Health Sciences, University of Sialkot, Sialkot, Pakistan
³Department of Physical Therapy, The University of Lahore, Lahore, Pakistan
⁴Department of Cardiac Surgery, Quaid-e-Azam Medical College, Bahawalpur, Pakistan
⁵Department of Medicine, DHQ, Toba Tek Singh, Pakistan
⁶Department of Physical Therapy, Islamabad Medical and Dental College, Islamabad, Pakistan

ABSTRACT

Objective: To determine the combined effects of continuous positive airway pressure (C-PAP) and physical exercise rehabilitation on a cycle ergometer on postcoronary artery bypass surgery patients.

Study Design: Randomised controlled trial.

Place and Duration of the Study: Rawalpindi Institute of Cardiology, from December 2020 to May 2021.

Methodology: Patients, who underwent coronary artery bypass graft surgery, were divided into two equal groups of each 51. The control group received standard physiotherapy from the 1st postoperative day which included breathing exercises, passive mobilisation in the sitting position, and ambulation. The interventional group also had standard physiotherapy from 1st postoperative day; but also the 2nd to 4th postoperative day had additional dynamic exercises on cycle ergometry in combination with CPAP (continuous positive airway pressure).

Results: There was a significant improvement in functional capacity measured by 6-minute walk test in the interventional group (p<0.001). Length of hospital and ICU stay mean rank (68.88 and 58) were also significantly decreased in the interventional group (p<0.001). There was no improvement in maximum inspiratory pressure and maximum expiratory pressure. One-minute sit-to-stand test was increased on 4th postoperative day in the interventional group. There was no significant difference observed in arterial blood gases between these two groups.

Conclusion: Cycle ergometry combined with continuous positive airway pressure (C-PAP) applied earlier on patients undergoing coronary artery bypass grafting improves the functional capacity, decreases the ICU and hospital length of stay and also improves lower limb muscle strength. But no difference in respiratory muscle strength and arterial blood gases was observed between the control and interventional groups.

Key Words: Aerobic exercise, Coronary artery bypass graft surgery, Continuous positive airway pressure.


INTRODUCTION

Coronary artery bypass grafting (CABG) is a major surgical operation where atheromatous blockages in a patient’s coronary arteries are bypassed with harvested venous or arterial conduits. The bypass restores blood flow to the ischemic myocardium which, in turn, restores function, viability, and relieves anginal symptoms. Almost 400,000 CABG surgeries are performed each year making it the most commonly performed major surgical procedure.¹

Coronary artery bypass grafting (CABG) is a major surgical operation where atheromatous blockages in a patient’s coronary arteries are bypassed with harvested venous or arterial conduits. The bypass restores blood flow to the ischemic myocardium which, in turn, restores function, viability, and relieves anginal symptoms. Almost 400,000 CABG surgeries are performed each year making it the most commonly performed major surgical procedure.¹

Coronary artery bypass grafting (CABG) is a major surgical operation where atheromatous blockages in a patient’s coronary arteries are bypassed with harvested venous or arterial conduits. The bypass restores blood flow to the ischemic myocardium which, in turn, restores function, viability, and relieves anginal symptoms. Almost 400,000 CABG surgeries are performed each year making it the most commonly performed major surgical procedure.¹

Coronary artery bypass grafting (CABG) is a major surgical operation where atheromatous blockages in a patient’s coronary arteries are bypassed with harvested venous or arterial conduits. The bypass restores blood flow to the ischemic myocardium which, in turn, restores function, viability, and relieves anginal symptoms. Almost 400,000 CABG surgeries are performed each year making it the most commonly performed major surgical procedure.¹

Coronary artery bypass grafting (CABG) is a major surgical operation where atheromatous blockages in a patient’s coronary arteries are bypassed with harvested venous or arterial conduits. The bypass restores blood flow to the ischemic myocardium which, in turn, restores function, viability, and relieves anginal symptoms. Almost 400,000 CABG surgeries are performed each year making it the most commonly performed major surgical procedure.¹

Cardiovascular diseases (CVD) are one of the main causes of death around the globe.¹ Most common symptoms of coronary artery disease are chest pain, fatigue, palpitations, and shortness of breath. These symptoms are due to blockage in coronary arteries of the heart due to plaque formation in coronary arteries.² World Health Organization (WHO) provides evidence that around 17.9 million people die per year due to coronary artery disease, and it is predicted that 23 million deaths will occur by the year 2030.³

Cardiac rehabilitation is a complete program which includes individualised management along with patient education, both are necessary after CABG. Rehabilitation provides the tools, knowledge, and healthy routines to coronary artery disease patients.⁴ CABG is mostly performed in patients with complex multi-vessel disease where percutaneous coronary interven-
tion cannot be beneficial. Coronary artery bypass grafting (CABG) and coronary stenting are the procedures which help in re-establishing the blood flow to the area of the myocardium, but they cannot stop the atherosclerotic process.

Continuous positive airway pressure (CPAP) is a type of positive airway pressure which is applied to patients who are breathing spontaneously. This positive pressure helps to keep the airways open. It is a non-invasive ventilation technique which helps in the recruitment of more lung parenchyma in gas exchange.

Cycle ergometer is a safe and very effective walking-based rehabilitation. After cardiac surgery, constant and interval training by means of cycle ergometer and treadmill is a recommended form of rehabilitation but its intensity should not be more than the anaerobic threshold. Anaerobic threshold is a threshold where blood lactate concentration (BLC) reaches 4 mmol/l. Cycle ergometer is a cycle-type training equipment, and allows the measurement of heart rate, blood pressure, and cardiac electric activity through electrocardiogram.

Continuous positive airway pressure in combination with cycle ergometer in postoperative period in patients who undergo CABG, is very safe in improving the functional capacity of patients due to early recovery of lungs, improvement of arterial blood gases and strengthening of lower limb muscles.

It decreases the hospital and ICU length of stay. Therefore, cycling exercise with monitoring of cardiac hemodynamics and electrical stability, allowed earlier exercise and a safer strategy at this early stage of rehabilitation. The aim of this study was to determine the combined effects of continuous positive airway pressure and physical exercise on cycle ergometer in post CABG patients and to compare the effects of CPAP plus cycle ergometer with conventional physical therapy protocol.

**METHODOLOGY**

This randomised controlled trial (NCT04790656) was conducted on patients who underwent myocardial revascularisation, at Rawalpindi Institute of Cardiology, from December 2020 to May 2021 (Figure 1). Participants of both gender, age ≤75 years, left ventricle ejection fraction ≥35%, mechanical ventilation of ≤12 hours in postoperative period, no definite diagnosis of chronic obstructive pulmonary disease and without valvular pathology were recruited into the study. Patients who were operated on as urgent, had intraaortic balloon inserted pre- or postoperatively, were reopened for any reason, had perioperative myocardial infarction, had pre- or postoperative neurological dysfunction and preoperative musculoskeletal disorder were excluded.

A questionnaire was designed to assess the demographics of the patients. Factors included patients age, gender, body mass index (BMI), left ventricle ejection fraction and any comorbid condition of the patients. Modified Borg scale was used to assess the shortness of patients. The functional capacity was evaluated with 6-minute walk test. Lower limb muscle strength was assessed by 1-minute sit-to-stand test.

Subjects were randomly placed into the interventional group and the control group through the sealed envelope method. The control group performed the conventional physical therapy protocol which was standardised by the hospital team and physical therapists in immediate postoperative care of CABG patients in the ICU. These interventions consisted of breathing exercises, active and passive range of motion (ROM), ambulation, and incentive spirometry. These exercises were according to each postoperative day. Duration of these exercises was 25 minutes with two sessions per day, and the intensity of the exercise was determined by the heart rate. Exercises were immediately discontinued if the patient had any signs of dyspnea, fatigue, cyanosis, pallor, tachycardia, bradycardia, hypotension, and arrhythmias.

In addition to conventional physical therapy protocol subjects performed physical exercise on cycle ergometer and CPAP. Interventional group treatment protocol was started from the second postoperative day to the fourth postoperative day. A single daily session was performed in these subjects. From the 2nd postoperative day patients started walking, therefore dynamic exercises on cycle ergometer were started from the second postoperative day. On the fourth postoperative day, subjects were given the treatment protocols and assessed in the afternoon.

For the interventional group the duration of exercises was 20 minutes on the second post-operative day and 30 minutes on 3rd and 4th postoperative days of cardiac surgery. CPAP was functional through a face mask and pressure support levels were from 5 cm H₂O to 12 cm H₂O.

Physical exercise on cycle ergometer in combination with continuous positive airway pressure was applied once a day while...
conventional physical therapy protocol was applied two times a day. During the application of interventional physical therapy protocol, the heart rate of patients was allowed to increase by 20 beats/minute. Oxygen saturation of these subjects was up to 95% SPO₂ and mild dyspnea on Borg scale. If these patients presented any signs and symptoms of moderate dyspnea these interventions were immediately stopped.

The primary outcome of this study was the distance walked in the 6MWT. The secondary outcomes were respiratory muscle strength, lower limbs muscle resistance, mechanical ventilation time, length of stay in the ICU, and length of hospital stay. The sample size for this study was 102 which was calculated from post maximal expiratory pressure. After testing the data normality, Wilcoxon test was applied to compare within group differences while Mann-Whitney U test was used to compare between group differences. Independent sample t-test was applied to evaluate the mean and standard deviation of interventional and control group variables. Mann-Whitney U test was applied to the variable to compare the median, mean rank and interquartile range of both interventional and control groups.

RESULTS

One hundred and twenty patients were included in this study based on inclusion and exclusion criteria. They were divided into equal numbers (51) in each group. All patients received their treatment as per protocol, there was no dropout.

Baseline values of demographic data of both groups were comparable on the basis of mean ± std. deviation. Table I summarises the comparison of demographic variables like age, gender, height, weight, body mass index and left ventricle ejection fraction of participants across both groups. Mean age of the interventional group (CPAP and cycle ergometer) was 55.62 ± 7.62 years. There were 16 (31.4%) females and 35 (68.6%) males in the interventional group with mean body mass index of 24.6 ± 3.17 Kg/m². In the interventional group the minimum value of left ventricle ejection fraction was 40% and the maximum value was 60% (mean = 53.35 ± 6.39%). The mean age of the control group was 57.43 ± 9.15 years. There were 20 (39.2%) females and 31 (60.8%) males with mean body mass index of 23.4 ± 4.12 Kg/m². Minimum value of the left ventricle ejection fraction of the control group was 40% and the maximum value was 60% (mean=59.84 ± 6.00%). The Mean, standard deviation, and frequency values of both groups are shown in Table I, frequency of medical history of participants. Twenty-nine subjects in the interventional group (56.9%) were hypertensive compared to 31 (60.8%) patients in the control group. Twenty-five (49%) patients had diabetes mellitus in the interventional group compared to 31 (60.8%) in the control group.

There was one patient with chronic obstructive pulmonary disease in the interventional group and 2 such patients in the control group.

Mean distance walked in the interventional group was 242.52 ± 46.99 metres, and 160.67 ± 44.50 metres was in the control group. Therefore, distance walked was statistically significant in the interventional group as compared to the control group (p = 0.001). The mean value of 1-minute sit-to-stand test was 13.94 ± 3.50 in the interventional group and 9.01 ± 2.50 in the control group. The value was statistically significant (p = 0.001). Independent sample t-test was applied to compare the variables of the 6-minute walk test. Mean and standard deviation values of systolic blood pressure - 6MWT - Post were 122.78 ± 9.21 mmHg in the interventional group and 130.11 ± 9.16 mmHg in the control group (p = 0.001). The values of variable HR -6MWT-POST, DBP-6MWT-POST, maximum inspiratory pressure, and PH were not statistically significant.

Length of stay in ICU was considerably lower in the interventional group (p = 0.001). Mean rank value of ICU length of stay of the interventional group was 46 and of the control group was 57. Length of stay in the hospital was significantly lower in the interventional group (p = 0.001). Mean rank value of hospital length of stay of the interventional group was 34.12 and of the control group was 68.88 as compared through the Mann-Whitney U test. HCO₃⁻ was significantly improved in the interventional group (HCO₃⁻, p = 0.011). Total ventilation time was significantly lower in the interventional group (p <0.001). No significant difference was observed in other variables (Table II).

The functional capacity measured by the distance walked on the 6MWT was significantly improved in the interventional group (p = .001) as compared with the control group. There was a significant improvement in 1-minute sit-to-stand test in the interventional group (p >0.001). Maximal expiratory pressure was significantly improved in the interventional group (p = 0.001). No significant difference was observed between the two groups regarding the other variables. Within the groups, SBP-6MWT-Baseline was significantly lower in the interventional group (p <0.05). Borg scale-6MWT-baseline was significantly improved in both groups (p <0.05) (Table III).

DISCUSSION

It is important to identify patients who would most likely benefit from CR and focus on their medical and social profiles to obtain maximum benefit and prevent drop-outs from the CR program. This study was unable to blind the patients and physical therapists to the type of treatment protocol.

The intent of this study was to investigate the effect of two physical therapy protocols on the rehabilitation of myocardial revascularisation postsurgical groups. One consisted of standardised and progressive exercises called the control group, which consisted of an individualised program of physiotherapeutic intervention during hospital rehabilitation for patients who underwent CABG. The authors compared this physical therapy protocol with a physical therapeutic intervention combined CPAP and cycle ergometer from the second to fourth postoperative day.

This study findings were shorter duration of stay in ICU, shorter duration of stay in hospital, improved functional capacity, and improved lower limb strength. In this study, there were no beneficial effects on respiratory muscle strength.
A similar result was demonstrated in another study in which the physical exercise was performed on cycle ergometer in the fowler position for 5 minutes which is not enough to achieve the expected results. In this study, the authors performed physical exercise on cycle ergometer twice a day.13

In this study, significant differences were observed in ICU and hospital length of stay in comparison with the control group. These results were not that significant because only 5 minutes of exercise is not enough to achieve the expected results. In this study, the authors performed physical exercise on cycle ergometer twice a day.13

As mentioned in previous studies that surgical procedures decreased respiratory muscle strength, peripheral resistance, and functional capacity. Functional capacity can be measured through the standardised test six-minute walk test. Surgical procedures decreased the six-minute walk distance which can be improved through therapeutic exercises.15 In this study, two combined physical therapy protocols, physical exercise on cycle ergometer with CPAP improved the six-minute walk distance in the interventional group as compared to the control group. Result analysis has shown that significant improvement occurred in functional capacity in the interventional group. Previous studies showed an cardiac rehabilitation improved the six minute walk test but it took longer time to improve.16 Another study showed the beneficial effects of single physical therapy intervention that study showed an increase in distance walked.

Table I: Data are presented as mean ±SD or n (%). P=0.05 indicates statistical significance.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Interventional group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean ±SD</td>
</tr>
<tr>
<td>Age (years)</td>
<td>51</td>
<td>55.62±7.6217</td>
</tr>
<tr>
<td>Weight Kg</td>
<td>64.392±9.22676</td>
<td>64.28±8.86468</td>
</tr>
<tr>
<td>Height</td>
<td>162.43±10.58349</td>
<td>156.60±9.31682</td>
</tr>
<tr>
<td>Body mass index Kg/m²</td>
<td>24.60±3.16854</td>
<td>23.45±4.1208</td>
</tr>
</tbody>
</table>

Table II: Independent sample t-test and Mann Whitney U test.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Interventional group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean ±SD</td>
<td>Mean ± SD</td>
</tr>
<tr>
<td>SBP-6MWT-POST</td>
<td>122.78±9.21</td>
<td>130.11±9.16</td>
</tr>
<tr>
<td>HR-6MWT-POST</td>
<td>92.25±13.17</td>
<td>91.62±12.53</td>
</tr>
<tr>
<td>DBP-6MWT-POST</td>
<td>84.09±11.84</td>
<td>84.43±11.47</td>
</tr>
<tr>
<td>Distance</td>
<td>242.52±46.99</td>
<td>160.67±44.50</td>
</tr>
<tr>
<td>1 Min sit to stand repetitions</td>
<td>13.94±3.50</td>
<td>9.01±2.50</td>
</tr>
<tr>
<td>Maximum inspiratory pressure</td>
<td>24.15±3.54</td>
<td>23.66±3.48</td>
</tr>
<tr>
<td>PH</td>
<td>7.43±0.10</td>
<td>7.45±1.09</td>
</tr>
</tbody>
</table>

Mann Whitney U test

<table>
<thead>
<tr>
<th>Variable</th>
<th>Interventional group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>Mean rank</td>
</tr>
<tr>
<td>Number of times stopped</td>
<td>0.00</td>
<td>38.1</td>
</tr>
<tr>
<td>Borg scale-6MWT-POST</td>
<td>85.00</td>
<td>50.52</td>
</tr>
<tr>
<td>Spo2-6MWT-POST</td>
<td>97.00</td>
<td>52.28</td>
</tr>
<tr>
<td>Duration of ventilation</td>
<td>18.00</td>
<td>66.24</td>
</tr>
<tr>
<td>ICU length of stay</td>
<td>4.00</td>
<td>46.00</td>
</tr>
<tr>
<td>Hospital length of stay</td>
<td>7.00</td>
<td>34.12</td>
</tr>
<tr>
<td>Max expiratory pressure</td>
<td>12.00</td>
<td>59.62</td>
</tr>
<tr>
<td>Po2</td>
<td>40.12</td>
<td>52.11</td>
</tr>
<tr>
<td>Hco3</td>
<td>25.80</td>
<td>44.05</td>
</tr>
</tbody>
</table>

Table III: Paired sample t-test (with in the group comparison) group 1.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean ± SD</th>
<th>Variable</th>
<th>Mean ± SD</th>
<th>Mean Difference</th>
<th>Sig. (2 tailed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBP-6MWT-Baseline</td>
<td>122.78±9.21</td>
<td>SBP-6MWT-post</td>
<td>130.11±9.16</td>
<td>7.33</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>DBP-6MWT-Baseline</td>
<td>84.09±11.84</td>
<td>DBP-6MWT-POST</td>
<td>91.62±12.53</td>
<td>0.63</td>
<td>0.80</td>
</tr>
<tr>
<td>HR-6MWT-Baseline</td>
<td>92.25±13.17</td>
<td>HR-6MWT-POST</td>
<td>91.82±11.37</td>
<td>0.34</td>
<td>0.88</td>
</tr>
<tr>
<td>Borg scale-6MWT-baseline</td>
<td>242.52±46.99</td>
<td>Borg scale-6 MWT-POST</td>
<td>160.67±44.50</td>
<td>81.85</td>
<td>0.001</td>
</tr>
<tr>
<td>Wilcoxon test (with in the group comparison) (control group)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SBP-6MWT-Baseline</td>
<td>16.09</td>
<td>SBP-6MWT-post</td>
<td>14.73</td>
<td>1.36</td>
<td>0.39</td>
</tr>
<tr>
<td>DBP-6MWT-Baseline</td>
<td>13.88</td>
<td>DBP-6MWT-POST</td>
<td>11.33</td>
<td>2.75</td>
<td>0.04</td>
</tr>
<tr>
<td>HR-6MWT-Baseline</td>
<td>11.44</td>
<td>HR-6MWT-POST</td>
<td>13.29</td>
<td>1.85</td>
<td>0.16</td>
</tr>
<tr>
<td>Borg scale-6MWT-baseline</td>
<td>13.00</td>
<td>Borg scale-6 MWT-POST</td>
<td>0.00</td>
<td>13.00</td>
<td>0.001</td>
</tr>
</tbody>
</table>
but took longer time to improve the six-minute walk test. This study improved the functional capacity and physical conditions at the time of hospital discharge in the interventional group as compared to the control group.

Concerning the respiratory muscle strength of both the inspiratory and expiratory muscles, there was little improvement in expiration but no improvement in inspiration. A similar study was performed that showed similar results because it took a longer time for inspiratory muscles to improve. Further studies are needed in context. Cardiac surgery causes changes in ventilatory mechanics and pulmonary volume changes occur. These changes cannot be improved by the fifth postoperative day and further time is needed to improve these functions after discharge from the hospital.

In terms of peripheral muscle strength, previous study showed that cardiac surgery results in loss of muscle strength and compliance, this is mostly due to an increase in bed rest after surgery. Peripheral muscle strength is a very important factor in functional capacity and daily life. There is very little current evidence present on peripheral muscle strength. Similar results were reported in another study in which they used one month of cardiac rehabilitation after CABG in patients which improved lower limb strength and balance in patients and this increase in muscle strength improved activities of daily living. In this study, peripheral muscle resistance was significantly improved in the combined physical exercise on cycle ergometer with CPAP when compared with the control group. This improved lower limb muscle resistance and increased the six-minute walk distance. Thus, this study CPAP in combination with cycle ergometer showed beneficial effects.

Regarding the arterial blood gases, previous study showed postoperative pulmonary physiotherapy in addition to incentive spirometry, CPAP, and noninvasive intermittent positive pressure breathing (IPPB) improved the arterial blood gases in all groups. In this study, no significant differences were observed in ABGS in both groups but HCO₃ was significantly improved in the interventional group as compared to the control group, because in this study ABGS were done on the 3rd post-op day. Multi-centred study should be done. More follow-ups should be added to get better findings.

By comparing all studies, it shows that the results of the current study are like many previous studies which showed statistically significant differences but more specifically in the functional capacity of the patients as measured through the six-minute-walk test. There was greater improvement in functional capacity and hospital and ICU length of stay. This is very important data and can be explored in further research, given that the utilisation of CPAP in association with exercise is poorly explored in these patients.

**CONCLUSION**

Continuous positive airway pressure in combination with cycle ergometer is a very effective and safe technique if applied early in CABG patients. This technique has very significant results on maximum distance walked, and reducing ICU length of stay, and improving lower limb muscle resistance.

**ETHICAL APPROVAL:**

Approval for research proposal “Effects of Continuous Positive Airway Pressure and Cycle Ergometer in Myocardial Revascularization Post-Surgical Patients” was obtained with Ref. # Riphah/RCRS/REC/00874, from the Riphah International University, Islamabad.

**PATIENTS’ CONSENT:**

Written informed consent were taken from all patients.

**COMPE'TING INTEREST:**

The authors declared no competing interest.

**AUTHORS’ CONTRIBUTION:**

AB: Project concept and data collection.

AA: Supervision.

WS: Statistical analysis and manuscript editing.

ZH: Supervision and manuscript editing.

HMS, MIR: Manuscript writing.

All the authors have approved the final version of the manuscript to be published.

**REFERENCES**


7. Pantoni CB, Di Thommazo L, Mendes RG, Catai AM, Luzzi S, Amaral Neto O, et al. Effects of different levels of positive airway pressure on breathing pattern and heart rate varia-


