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Effects of early mobilization on pulmonary parameters and complications post coronary artery bypass graft surgery

Running title: Early mobilization after CABG

Original research

Leyla ESMEALY, RN, BSc

MSc Student, Faculty of Nursing and Midwifery, Tabriz University of Medical Sciences, Tabriz, East Azerbaijan, Iran

Email: leylaesmealy@gmail.com

Atefeh ALLAHBAKHSHIAN, RN, BSc, MSc, PhD

Associate Professor, Faculty of Nursing and Midwifery, Tabriz University of Medical Sciences, Tabriz, Iran

Email: atefehbakhshian@gmail.com

Leila GHOLIZADEH, RN, BSc, MSc, PhD

Lecturer, IMPACCT, Faculty of Health, University of Technology Sydney, Sydney, Australia

Email: Leila.Gholizadeh@uts.edu.au

Azizeh FARSHBAF KHALILI

Assistance Professor, Faculty of Nursing and Midwifery, Tabriz University of Medical Sciences, Tabriz, Iran

Email: farshbafa@tbzmed.ac

Parvin SARBAKHSH

Assistant Professor, Department of Statistics and Epidemiology, School of Public Health, Tabriz University of Medical Sciences, Tabriz, Iran

Email: p.sarbakhsh@gmail.com

Corresponding author before publication

Leila Gholizadeh

15 Broadway, Faculty of Health, University of Technology Sydney, Sydney, NSW 2007, Australia

Email: Leila.Gholizadeh@uts.edu.au

Phone: 00612 9514 4814

Corresponding author after publication

Atefeh AllahBakhshian

Faculty of Nursing and Midwifery, Tabriz University of Medical Sciences, Tabriz, East Azerbaijan, IR

Email: atefehbakhshian@gmail.com

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Abstract

This study compared the effects of a four-phase and a three-phase early mobilization protocol on respiratory parameters and complications in patients following coronary artery bypass graft surgery. This is a three-arm, parallel-group, randomized controlled clinical trial with 120 candidates for coronary artery bypass graft surgery. Participants were randomly allocated to three groups: four-phase early mobilization protocol, three-phase early mobilization protocol, and control. Arterial blood gases, oxygen saturation, and incidence of pulmonary complications were compared among the groups. Mean arterial blood gases and oxygen saturation improved significantly over time in both four-phase early mobilization protocol and three-phase early mobilization protocol groups compared to control (p<0.05). There were observed trends for greater improvements in the study outcomes with three-phase early mobilization protocol than four-phase early mobilization protocol; however, did not reach statistically significant levels. The incidence of pulmonary complications was significantly in both intervention groups compared to control (odds ratio: 0.48, 95% CI 0.007- 0.537; p<0.001). Both four-phase early mobilization and the three-phase early mobilization protocols improved respiratory parameters and reduced pulmonary complications. Statistically insignificant trends were found trends in the three-phase early mobilization protocol, focusing on chest physiotherapy and breathing exercises.

Keywords: Early mobilization, coronary artery bypass graft, rehabilitation, pulmonary complications, nursing

Introduction

Cardiovascular disease (CVD) remains the number one cause of death and disability worldwide (Khan et al., 2020). In the same line, CVD, including coronary artery disease, accounts for nearly half of all deaths and 20%-23% of disease burden in Iran (Sarrafzadegan & Mohammmadifard, 2019). Coronary artery bypass graft (CABG) is a treatment option for a selected group of patients who have significant narrowings and blockages in their coronary arteries. It is the most common open-heart surgery performed internationally and in Iran (Darvish et al., 2015; Rani et al., 2017). CABG is associated with significant postoperative morbidities, including pulmonary complications, such as atelectasis, pleural effusion, and pneumonia (Sarkar & Prabhu, 2017). Some 63% of patients develop atelectasis and pleural effusion following CABG surgery. Pulmonary dysfunction and the subsequent hypoxemia occur in 30%-60% of the patients (Schmidt et al., 2016), contributing to postoperative mortality and morbidities (Mali & Haghaninejad, 2019).

Preventive measures are necessary during pre and postoperative phases (Sarkar & Prabhu, 2017). Until 1960, patients were recommended to stay in bed for three weeks after open-heart surgery, but nowadays, early mobilization is the focus of all post-surgery rehabilitation programs (Tariq et al., 2017). Early mobilization has been shown to improve breathing quality, pulmonary compliance, and alveolar ventilation, reducing the risk of pulmonary complications postoperatively. Early patient mobilization improves cardiac output, reduces the risk of arterial fibrillation, improves venous return, and reduces the risk of venous thromboembolism. The results of a meta-analysis study revealed that early mobilization following CABG improved the patients' respiratory parameters and physical function (Tariq et al., 2017). Early mobilization for CABG patients typically begins on day one post-surgery and is facilitated by a physiotherapist or a nurse twice daily (Tariq et al., 2017). In 2008, Morris et al. examined the feasibility and effectiveness of an early mobilization protocol for patients admitted to the Intensive Care Unit (ICU) with respiratory failure and undergone mechanical ventilators. Their four-phase protocol included passive range of motion, movements in the bed, sitting on the edge of the bed, active resistance exercises, active transfer to chair, and walking. The early mobilization protocol reduced the length of ICU and hospital stay and was found safe and feasible in the ICU setting (Morris et al., 2008). Later, Danatas et al. added cycle ergometer exercise to this protocol, making it a five-phase early mobilization protocol (Miranda Rocha et al., 2017). Early mobilization protocols often take a progressive approach and mainly consist of passive and active upper and lower limb exercises, patient ambulation, cycle ergometer, and then climbing stairs. Additional interventions may be added, such as chest physiotherapy, which often includes deep breathing exercises, inspiratory muscle training, and incentive spirometry.

Nurses play crucial role in preventing complications and helping patients attain complete recovery after CABG surgery. This includes early mobilization and ambulation of the patients as tolerated (McConnell et al., 2018). Nursing theorists emphasize that the main role of nurses should be to support patients gain independence as quickly as possible (Henderson, 1964). The nurse should steps in when the patient is incapable or limited in the provision of effective self-care (Orem, 1989). Due to the complicated nature of CABG surgery, endotracheal intubation and use of analgesics and sedatives, patients are heavily dependent on nurses for self-care performance post-surgery (Silva et al., 2016). Nurses support the patients to recover from surgery and gain independence in their self-care through the process that include starts with acting for and doing for patients, guiding them, supporting them, providing an environment promoting personal development to meet future needs, and teaching them

(Orem, 1989). In relation to patient mobility, the process may start with turning and repositioning the patient in the bed, performing passive range-of-motion exercises, and chest physiotherapy and end up with transferring the patient to a bedside chair and helping them to ambulate (Miranda Rocha et al., 2017).

Although early mobilization protocols have been generally shown to be effective and safe for CABG patients (Kanejima et al., 2020), the most effective early mobilization protocol that can be readily implemented in the ICU environment is still to be identified. This study compared the effects of two early mobilization protocols on respiratory parameters and pulmonary complications in patients following CABG surgery to help identify the more effective early mobilization protocol.

Materials and Methods

This is a three-arm parallel design clinical randomized controlled trial consisting of two interventions and one control group. Intervention group 1 received a four-phase early mobilization protocol (the 4-EMP), intervention group 2 received a three-phase early mobilization protocol (the 3-EMP), and the control group received routine care. Our primary outcomes were improvements in oxygen saturation and arterial blood gases (ABG). Pulmonary complications including atelectasis, pneumonia, and pleural effusion were considered as secondary outcomes. To be included in the study patients needed to be a candidate for CABG surgery, hemodynamically stable, and aged between 18 and 65 years. Patients with systolic blood pressure< 100 mmHg, diastolic blood pressure<40 mmHg, mean arterial blood pressure< 60 or> 100 mmHg, heart rate< 60 or> 100 beats/minute, respiration rate> 20 were excluded. Patients on inotropic or vasopressor therapy, body mass index< 20 and or> 30 kg/m2, those with arrhythmia, unstable angina, respiratory distress, respiratory infection, joint or neuromuscular problems, patients who had cardiac arrest during the surgery or after admission to the ICU, left ventricular ejection fraction< 40%, those with need for mechanical ventilation for more than 24 hours, and chest tube drainage> 100 millilitres within the first four hours after the surgery were also excluded.

Participant recruitment

The study received ethics approval from the research ethics committee of Tabriz University of Medical Services (IR.TBZMED.REC.1398.613) and was registered in the Iranian Clinical Trial Registration Center (IRCT20160110025937N5). Participants were recruited from the surgical wards of Shahid Madani Cardiovascular Centre, Tabriz, Iran, from October 12, 2019, to November 10, 2019, while awaiting their CABG surgery. The researchers explained the study to patients who met the study inclusion criteria and invited them to participate in the research. Those who were interested in the study provided written consent and were enrolled in the study. A random allocation scheme was generated on a 1: 1: 1 ratio using random generator software. We used the permuted block randomization method, with block sizes of three and six. Allocation concealment was ensured by placing the allocations in sequentially numbered, sealed, and opaque envelopes. A research team member who was not involved in participant recruitment or provision of the study interventions completed the allocations via phone. The outcome assessor and data analyst were blind to the group allocations; the researcher who provided the study interventions became aware of the participant allocation when the patient was admitted to the ICU after surgery.

Sample size

A pilot study with 30 participants (10 participants in each group) was conducted to help with sample size calculation. The sample size was calculated using G*Power software.

Based on the improvement in arterial blood oxygen saturation measured immediately after intervention on the first day of surgery, $\alpha=0.05$, and power of 95%, a sample size of 32 per group was specified; 40 participants were recruited for each group to make up for likely attrition (Figure 1). All participants completed the study, meaning that data analysis was performed on 120 participants.

Interventions

Participants in the 4-EMP Group received a four-phase early mobilization protocol which was adapted from the studies by Morris et al. (Morris et al., 2008) and Ziyaeifard et al. (Ziyaeifard et al., 2018). In Phase I, passive range of motion exercises were applied on the upper and lower extremities (10 times), and the head of the bed was elevated 30 degrees for 15 minutes. If the patient tolerated this phase, the researcher proceeded to Phase II, which included applying active range of motion exercises on both extremities (10 times), the elevation of the head of the bed 45 degrees for 15 minutes, and then 90 degrees for the next 15 minutes. If the patient tolerated this phase, the researcher moved forward to Phase III, in which the patient was assisted to sit at the edge of the bed with the feet hanging off for 15 minutes. Upon successful completion of this phase, the researcher commenced Phase IV. In this phase, the patient was transferred to a bedside chair and stayed in this position for one minute, and then with encouragement and assistance of the researcher, the participant walked up to 20 meters in the ward, depending on their tolerance.

Participants in the 3-EMP Group received a three-phase protocol adapted from the study by Tariq et al. (Tariq et al., 2017) and consisted of a combination of chest physiotherapy and physical activity. Phase I included deep breathing exercises; the participant was educated to put one hand on their chest and another hand on their abdomen, breath in through their nose, hold their breath for 3 seconds and then breathe out slowly through pursed lips while pressing gently on their abdomen. Breathing exercises continued for 2 minutes, followed by bottle-blowing for the next 2 minutes. Then, chest physiotherapy was applied, which included light percussion on the chest wall (back, front, and area under the arms) for 5 minutes. The patient was then encouraged to cough to remove airway secretions while protecting their suture line with a pillow. If the patient tolerated this phase, the researcher proceeded to Phase II, which included assisting the patient to sit on the edge of the bed with their feet hanging off for five minutes. Upon successfully completing this phase, the researcher moved to Phase III, which included assisting the patient to a standing position for 1-2 minutes, followed by ten steps of static walk.

Both interventions commenced on day one post-surgery when participants had regained their full consciousness (aware of time, place, and person, and a Glasgow Coma score of ≥14) and were extubated. The interventions were provided twice daily on day one and day two post-surgery. i.e., each participant received a total of four sessions of mobilization intervention. Interventions were scheduled around 10 am and 5 pm to avoid interfering with the ward round, visiting hours, and shift turnover. During the interventions, participants' heart rate and oxygen saturation were continuously monitored by a portable pulse oximetry device, and the integrity of catheters and chest drains was assured.

Participants in the control group received routine care, which included encouraging and assisting the patient out of bed twice a day after sitting on the edge of the bed with the feet hanging off for a few minutes. The patient then sat on a bedside chair, and when ready, they were assisted to walk in the ward depending on their tolerance. Participants in the control group did not receive the range of motion exercises or chest physiotherapy. The study outcomes, including oxygen saturation and ABG values, were measured consistently across the groups before, immediately, and 15 minutes after ambulation on day one and day two post-surgery. All blood samples for the ABG analysis were taken from the radial artery. Pulmonary complications were assessed before and after interventions on day two post-surgery.

Instruments

A researcher-developed questionnaire was used to collect information about the participants' age, gender, body mass index, education, marital status, comorbidities of hypertension, hyperlipidemia, diabetes, smoking, previous myocardial infarction ejection fraction, and duration of CABG surgery. Oxygen saturation (SpO_2) was measured using a portable pulse oximeter with the probe attached to the participant's finger. The accuracy of the pulse oximeter was assessed by comparing the SpO_2 results of ten participants with SaO_2 in their ABG results. Pulmonary complications were determined by assessing participants' clinical signs and symptoms and examining their chest x-rays, taken by a German-made Siemens device with a power of 90 kilovolt and current intensity of 20 milliamperes. The patient's doctor confirmed the presence of pulmonary complications. ABG analysis was performed to measure the partial pressure of oxygen (PaO_2) and partial pressure of carbon dioxide ($PaCO_2$), and pH of the arterial blood. To evaluate the validity of ABG data, two samples with blind identities from two patients were sent to the laboratory; the measurements yielded similar results for the same patients ($r=0.755$).

Data analysis

Data analysis was performed using the IBM SPSS Statistics Package Version 16. Demographic and disease-related data were summarised using frequencies and percentages, and repeated measures ANOVA was used to compare changes in the study outcomes over time. The Tukey HSD test was used for post hoc tests. The significance level for all tests was considered as $p<0.05$. For data, which lacked normal distribution, such as extubation time, Kruskal-Wallis non-parametric test was used.

Results

Participants in the study groups were primarily comparable in the demographic and clinical characteristics (Table 1). There were slightly more participants with a history of myocardial infarction in the 4-EMP group than the 3-EMP group and slightly more participants with hypertension and hyperlipidemia in the 3-EMP group than the 4-EMP group; the differences were not statistically significant.

The effect of time on SpO2 values was statistically significant ($p=0.001$), indicating that SpO2 values increased over time in all the groups. There was no statistically significant difference in SpO2 values by group ($p=0.46$); nevertheless, the group and time interaction was statistically significant ($p<0.001$), meaning that a statistically significant difference was observed in SpO2 values between the intervention groups and control over time. The improvements in SpO2 values were greater in the 3-EMP group compared to the 4-EMP, although the differences between the two groups did not reach statistically significant levels (Table 2).

The effect of group on PaO2 values was not statistically significant ($p=0.99$), but the examination of the effect of time ($p<0.001$) and the group and time interaction showed statistically significant results ($p<0.001$). The results indicate that PaO2 values increased in all study groups over time; however, the improvements were greater in the intervention groups compared to the control, with an absolute benefit increase of 7.2 kPa in the 3-EMP, 3.5 kPa in the 4-EMP, and 3.2 kPa in control. The improvement in PaO2 values was greater in the 3-EMP group compared to the 4-EMP, although the difference between the two groups did not reach a statistically significant level (*p*=0.34).

The effects of group (*p*=0.54) and time (*p*=0.34) on PaCO2 values were not statistically significant; however, the examination of the effect of the group and time interaction showed a statistically significant difference in PaCO2 values (*p*=0.006). PaCO2 values decreased significantly over time in both the 3-EMP and the 4-EMP, while it increased in control group participants (*p*<0.05). The improvements in PaCO2 values were greater for the 3-EMP compared to the 4-EMP participants, with an absolute risk reduction of -1.7 kPa and -0.1 kPa, respectively, although the difference between the groups did not reach a statistically significant level (0.56).

The effects of group (p= 0.66), time (*p*=0.12), and the group and time interaction on the blood pH values were not statistically significant (*p*=0.21), indicating that interventions had no statistically significant effects on pH values. Analysing the results on pulmonary complications, only one participant in each intervention group (2.5%) developed pulmonary complications compared to 32.5% of participants in control group. The difference in pulmonary complications between the intervention groups and control was statistically significant (OR: 0.48, 95% CI 0.007 to 0.537, *p*<0.001) (Table 4). None of the study participants experienced other adverse effects from the interventions such as bradycardia, tachycardia, cardio-respiratory arrest, decreased arterial blood oxygen saturation, or the need for re-intubation.

Discussion

This study examined the effects of a three-phase and a four-phase early mobilization protocol on SpO2, PaO2, PaCO2, and blood pH values, as well as the incidence of pulmonary complications in patients following CABG surgery. Unfavorable SpO2 and arterial blood gas parameters were observed in the early phases after the surgery, which improved over time in all the groups, including the Control group, as participants began mobilizing. However, the improvements were more evident in the intervention groups than in Control. Comparing the results of the 3-EMP and the 4-EMP groups, there were trends towards greater improvements in SpO2, PaO2, and PaCO2 parameters in the 3-EMP, which emphasized on breathing exercises and chest physiotherapy as opposed to the 4-EMP emphasizing on early physical activity, including passive and active range of motion exercises in the bed. The results of our study also suggest that pulmonary complications decreased statistically significantly in both intervention groups compared to control; however, the difference in pulmonary complications between the 3-EMP and the 4-EMP was not statistically significant.

Comparing and contrasting the results of this study with the broader literature is difficult, as to our knowledge, this is the first study that compared the effects of the two early mobilization protocols on respiratory parameters and complications; one with emphasis on early range of motion exercises and upright positioning and mobilization and another on breathing exercises and chest physiotherapy followed by upright positioning and mobilization. The beneficiary effects of breathing exercises, incentive spirometry, exercises in the bed, and early mobilization on CABG patient outcomes, such as improved gas exchange, oxygen saturation, and reduced pulmonary complications, in particular, atelectasis, pneumonia, and pleural effusion, have been shown in several but isolated studies (Azarfarin et al., 2015; Cassina et al., 2016; Moradian et al., 2017; Tariq et al., 2017; Yazdannik et al., 2016).

We found that the early mobilization protocol technique consisting of early passive and active range of motion exercises and upright positioning and mobilization (the 4-EMP) improved respiratory parameters and complications compared to control. This finding aligns with the past research which used early physical activities. Azerfarin et al. found that in patients following an open heart surgery early mobilization consisting of changing position, sitting on the bed, legs dangling off the bed, sitting in the chair next to the bed, and walking commenced on day one post open heart surgery, had significantly positive effects on pulmonary function and arterial blood gases, and the early mobilization protocol improved inspiratory capacity and oxygen saturation compared to control (Azarfarin et al., 2015).

We also found that early mobilization with emphasis on chest physiotherapy and breathing exercise (the 3-EMP) improved respiratory parameters and reduced pulmonary complications compared to control. These findings are in line with the past research investigating the effects of chest physiotherapy in CABG patients. Tariq et al. (2017) found that in patients with cardiac surgery, early physical activity consisting of chest physiotherapy, sitting on the edge of the bed, moving out of bed, and sitting on a bedside chair had significant effects on reducing pulmonary complications through improvements in dyspnoea, respiratory rate, and oxygen saturation. The intervention also reduced the length of ICU stay (Tariq et al., 2017). Urell et al. compared the effects of 10 versus 30 breathing exercises early after CABG surgery on arterial blood gases and found that patients who performed 30 deep breaths the first two postoperative days experienced better improvements in SaO2 and PaO2 than the control group (Azarfarin et al., 2015). Yazdannik et al. found that using incentive spirometer significantly improved patients' SpO2, PaO2, and PaCO2 values. The intervention commenced one hour after extubation, and the patients were encouraged to perform ten times deep breathing using an incentive spirometer every 2 hours during the daytime for three postoperative days (Yazdannik et al., 2016). A study by Derakhtanjani et al. found that active cycle breathing exercises, including deep breathing exercises followed by huffing, were as effective as routine chest physiotherapy in CABG surgery patients (Derakhtanjani et al., 2019). However, whether or not deep breathing exercises are the essential parts of a chest physiotherapy program needs further investigation. At least one study has shown that eliminating deep breathing exercises from a routine postoperative physiotherapy program had no significant effect on oxygen saturation and pulmonary function (Yazdannik et al., 2016). It should be noted that routine physiotherapy in this study included supported coughing.

Our study results suggest that both the 4-EMP and the 3-EMP effectively improved pulmonary outcomes for patients after CABG. The 3-EMP may provide slightly greater benefits; although we did not find a statistically significant difference between the two protocols. Future research should compare these two early mobilization protocols using bigger sample sizes to confirm the results. Evidence from past research shows that within the first days after CABG surgery, patients' lung function decreases about 50% compared to their pre-operative values, increasing the risk of pulmonary complications such as atelectasis. This risk is notably higher in overweight and obese patients and those with pain (Urell et al., 2012). These findings indicate the necessity of early mobilization for CABG patients to help improve pulmonary function and prevent postoperative complications. The results of current study and previous studies suggest that early mobilization protocols that have applied either physical activities or chest physiotherapy are beneficial for patients following CABG surgery (Tariq et al., 2017; Urell et al., 2011; Yazdannik et al., 2016). Early physical activities, particularly upright positioning and upright mobilization, have been shown to improve functional recovery and reduce hospital stay [20]. A combination of early physical activities, including passive and active range of motion exercises along with chest physiotherapy and breathing exercises, may provide additional benefits and should be tested in future research. This combination may trigger different compensatory mechanisms and elicit a synergic effect to improve oxygenation, and prevent pulmonary complications.

Nurses should acknowledge that an early mobilization exercise is better than no early mobilization exercise. Until an optimum early mobilization protocol is identified for patients post CABG surgery, nurses follow an early mobilization protocol that best suit the patient's condition and is better tolerated by the patient. Regardless of the type of early mobilization protocol selected (either with emphasis on physical activities, or breathing exercises and chest physiotherapy), nurses should consider commencing mobilization exercises early after surgery, follow a progressive course of action depending on the patient's tolerance, and continue these exercises several days post-surgery.

The lack of an actual control group is the limitation of this study. Due to ethical reasons, it was impossible to deprive participants of early mobilization exercises in the control group.

Conclusion

This study showed early mobilization based on either early physical activities including passive and active range of motion exercises, upright positioning, and mobilization, or with emphasis on early chest physiotherapy and breathing exercises, upright positioning, and mobilization can improve respiratory parameters and decrease the incidence of pulmonary complications in patients following CABG surgery. The improvements were further evident in the later early mobilization protocol, although the differences between the groups did not reach statistically significant levels.

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