Journal of Kerman University of Medical Sciences

JKMU

Journal of Kerman University of Medical Sciences, 2020; 27 (4): 294-303

The Impact of Cardiac Rehabilitation on Pulmonary Artery Systolic Pressure and Left Ventricular End-Diastolic Pressure in Patients after Coronary Artery Bypass Graft Surgery

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Received: 3 May, 2020 Accepted: 25 July, 2020

ARTICLE INFO

Article type:
Original Article

Keywords:
Cardiac Rehabilitation
Coronary Artery Bypass Graft
Left Ventricular End-diastolic Pressure
Pulmonary Artery Pressure
Blood Pressure

Abstract

Background: Cardiac rehabilitation program (CRP) is a useful method of modifying cardiovascular risk factors, improving life expectancy and quality of life in patients with ischemic heart disease (IHD). The present study was conducted to evaluate the effects of cardiac rehabilitation on the pulmonary artery systolic pressure (PASP) and left ventricular end-diastolic pressure (LVEDP).

Methods: This Quasi-experimental study with pretest-posttest design was conducted on 80 patients with IHD who had participated in CRP after undergoing coronary artery bypass graft (CABG) surgery. Echocardiography was performed before the beginning of CRP (the 1st session) and at the end of the rehabilitation sessions, and ventricular function indices (ejection fraction), PASP (using the tricuspid regurgitation velocity), and LVEDP (using Nagueh formula: 1.24×E/e´+1.9) were measured.

Results: Ejection fraction (EF) was changed from 49.3 ± 7.8 before rehabilitation to 50.7 ± 7.4 after rehabilitation, which was a statistically significant difference (P=0.003). The pulmonary artery systolic pressure altered from 30.3 ± 8.4 before rehabilitation to 27.3 ± 6.6 after rehabilitation. The left ventricular end-diastolic pressure (LVEDP) changed from 10.5 ± 3.7 before rehabilitation to 9.1 ± 2.9 after rehabilitation, which was a statistically significant difference (P= 0.000).

Conclusion: According to the results, LVEDP and PASP in patients with IHD who underwent CABGs decreased after cardiac rehabilitation.

Citation: Moazenzadeh M, Mohammadi KH, Sarafi Nejad A, Karimi Afshar F, Rashidinejad H.R. The Impact of Cardiac Rehabilitation on Pulmonary Artery Systolic Pressure and Left Ventricular End-Diastolic Pressure in Patients after Coronary Artery Bypass Graft Surgery. *Journal of Kerman University of Medical Sciences*, 2020; 27 (4): 294-303.

Introduction

There are various strategies to prevent cardiovascular complications in patients with coronary heart disease (CHD) and heart failure or those undergoing coronary revascularization, which includes medical treatments and non-pharmacological methods such as participation in cardiac rehabilitation programs (CRPs).

The main goals of CRPs include limiting the physical and psychological effects of cardiovascular diseases, reducing the risk of sudden death or further strokes, controlling cardiac symptoms, and improving the psychosocial status (1). According to the previous studies, cardiac rehabilitation is a clinically useful method for modifying cardiovascular risk factors including hypertension, hyperlipidemia, diabetes, obesity, and smoking, as well as anxiety and depression after heart surgery (2).

Cardiac rehabilitation program includes three phases: The first phase starts from patient admission and diagnosis and includes patient/family education and medical treatments. The second phase begins 2 to 4 weeks after discharge and includes a convalescence period and an outpatient exercise-training program while monitoring the patients. This phase lasts 2 to 3 months in order to recover patients' exercise capacity based on the health condition, modify lifestyle, satisfy the patients' psychological needs, and help them return to their activities and job opportunities. The third phase is usually self-centered care that focuses on maintaining cardiovascular stability and physical status for a long period (3,4).

Despite proven benefits of cardiac rehabilitation program in improving cardiac function, the relative frequency of patients who refer to rehabilitation centers is not prominent due to high costs and lack of widespread access to these centers, and only 30% of eligible patients refer to these centers (5,6). The main purpose of cardiac rehabilitation programs is to improve the physical performance indices as well as mental and psychological aspects of patients and to control cardiovascular risk factors in patients (6,7).

Recently, the effects of exercise on cardiovascular and hemodynamic parameters have been widely evaluated and most of the studies have emphasized on the beneficial effects of exercise on the ventricular function indices and improvement of physical capacity in patients (8,9). In this regard, the relationship between exercise and improvement of ventricular volume and diameters and systemic pressure has been proved (10).

However, the effects of exercise on echocardiographic indices of ventricular diastolic function as well as the pulmonary artery pressure are still being debated (11,12).

As no comprehensive study has been conducted on the effects of cardiac rehabilitation program on pulmonary artery pressure (PAP) or left ventricular end-diastolic pressure (LVEDP), therefore, the present study was conducted to evaluate this issue, in which there was no change in the routine cardiac rehabilitation program.

Materials and Methods

This semi-experimental study with pretest-posttest design was conducted on 80 patients with ischemic heart disease (IHD) who underwent coronary artery bypass graft (CABG) surgery. The patients were recruited into the study using consecutive sampling. The sample size was calculated based on the formula for means comparison using Stata® at 95% confidence interval. The recruitment phase was performed between December 2015 and November 2016, and the patients

were discharged after undergoing CABGs and recommended to participate in the cardiac rehabilitation program.

All patients who referred to cardiac rehabilitation center of Shafa hospital in Kerman 8 weeks after CABGs, and did not suffer from heart valve or chronic lung diseases, did not received diuretic agents, did not have pulmonary arterial hypertension (PAH) and were not clinically unstable, and participated in all rehabilitation sessions, were entered into the research until the required sample size was achieved. Before the onset of the study, all the patients were informed about the study process and an informed consent form were obtained from them for participating in the study. Case group participated in a 45-minute training session before discharge, which its contents were related to cardiac rehabilitation program including explanation of the disease and its complications, cardiovascular risk factors and their modification methods, diet and medical education, instructions on how to do exercises such as walking and doing daily activities. Then, patients participated in the rehabilitation program according to rehabilitation protocol of Shafa hospital. The protocol consisted of cardiac rehabilitation sessions lasting about 2-3 months at intervals of 2 to 3 days. Each rehabilitation session lasted about 45 to 60 minutes and consisted of three phases: 1) Warm-up, 2) Aerobics (including a treadmill, arm ergometry, and bicycle ergometry) for 30 minutes, 3) Cool-down, while the Metabolic Equivalent of Task (MET) was added to activity level of persons weekly. Studied patients who had no significant symptom and no change in medication during the study, underwent echocardiography before the beginning of the rehabilitation program and at the end of the rehabilitation sessions (at the end of the 3rd month) by the same person and hemodynamic indices including pulmonary artery pressure (PAP) and left ventricular end-diastolic pressure (LVEDP) were measured using the tricuspid regurgitation velocity ($4\times TR\ velocity^2$) and Nagueh formula ($1.24\times E/e' + 1.9$), respectively.

Statistical analysis

Quantitative variables were expressed as mean and standard deviation (mean ± SD) and qualitative variables were reported as percentage (%). To compare the mean of LVEDP and PAP, before and after the rehabilitation period, paired sample t-test was used. Also, independent sample t-test was performed to compare and clarify the probable differences of the main variables (LVEDP and PAP) between genders before the onset of the rehabilitation period.

All the tests were performed using IBM® SPSS Statistics® v. 22 at 95% confidence level.

Results

In the present study, 80 patients aged 45-81 years (mean age of 60.4 ± 7.2 years) were enrolled. Among patients, 24 cases (30%) were female and 56 cases (70%) were male. There was a statistically significant difference between the mean age of men and women so that the mean age of women was 64.29 years with a standard deviation of 5.79 years while the mean age of men was 58.8 years with a standard deviation of 7.29 years (P=0.003). According to the significant difference between the mean age of men and women, Pearson correlation coefficient test was used to evaluate the effect of age on the studied variables and no significant relationship was observed between age and the variables before and after the intervention (P>0.1). Various variables such as history of diabetes, hypertension (HTN), hyperlipidemia (HLP), history of smoking and consumption of drugs including Aspirin (ASA),

STATINs, Angiotensin-converting enzyme inhibitors (ACEIs), Angiotensin II receptor blockers (ARBs), beta blockers (BB), and nitrate, were examined. Based on gender, the crude frequency and percentage of the variables are presented in Table 1.

Table 1. Frequency of different variables in patients based on gender

	Female		Male		Total	
	N	%	N	%	N	%
Total	24	100	56	100	80	100
DM	11	45.8	13	23.2	24	30
HTN	13	54.2	24	42.9	37	46.3
HLP	4	16.7	4	7.1	8	10
Smoking	0	0	9	16.1	9	11.3
ASA	24	100	53	94.6	77	96.3
Statin	24	100	46	82.1	70	87.5
ACEI/ARB	14	58.3	26	46.4	40	50
BB	21	87.5	49	87.5	70	87.5
Nitrate	20	83.3	33	58.9	53	66.3

DM: Diabetes mellitus, HTN: Hypertension, HLP: Hyperlipidemia, ASA: Acetylsalicylic acid,
ACEI: Angiotensin-converting enzyme inhibitor, ARB: Angiotensin II receptor blocker, BB: Beta blocker

Comparison of pulmonary artery systolic pressure (PASP) and LVEDP between females and males revealed a significant difference before and after rehabilitation. The PAP variable was reduced to 2.97 mmHg after rehabilitation and LVDEP variable decreased to 1.4 mmHg, which was statistically significant (P=0.000). The results are presented in Table 2. Comparison of EF variable with its crude frequency showed that the difference was 1.43% while determining the scale of 100, 3.9% increase after intervention was reported, which was statistically significant (P=0.003).

Table 2. Comparing PAP, LVEDP, and EF mean value in patients before and after rehabilitation

Variable	Before Rehabilitation	After Rehabilitation	P-value
Ejection fraction	49.3 ± 7.8	50.7 ± 7.4	0.003
Pulmonary artery systolic pressure	30.3 ± 8.4	27.3 ± 6.6	0.000
Left ventricular end-diastolic pressure	10.5 ± 3.7	9.1 ± 2.9	0.000

EF: Ejection fraction, LVEDP: Left ventricular end-diastolic pressure, PAP: Pulmonary artery pressure

Comparison of the changes in LVEDP in patients with normal or decreased EF before rehabilitation showed that LVEDP decreased in 83.8% of the patients with decreased EF while this ratio was 58.1% in patients with normal EF. Among

the patients with normal EF, there was an increase in LVEDP about 37.2% of cases while among patients with decreased EF this increase was 10.8% of cases reported 37.2% cases of increase in LVEPD while patients with decreased EF were 10.8% cases. The difference was statistically significant (P=0.024) (Table 3).

Table 3. Comparison of the changes in LVEDP in patients with normal and decreased EF

EF \ LVEDP	Unchanged	Decrease	Increase	Total
Total	4	56	20	80
Normal EF	2 (4.7%)	25 (58.1%)	16 (37.2%)	43
Decreased EF	2 (5.4%)	31 (83.8%)	4 (10.8%)	37

EF: Ejection fraction, LVEDP: Left ventricular end-diastolic pressure

Comparison of the changes in LVEDP in two groups with LVEDP lower or equal to 12 (normal) and higher than 12 (abnormal), showed that the mean value of LVEDP was decreased to 4.35 mmHg with standard deviation of 2.73 mmHg in the second group, while it was reported 1.46 mmHg with standard deviation of 1.21 mmHg in the first group, the difference was statistically significant (P=0.000).

The comparison of PAP changes in patients with normal and decreased EF indicated no significant difference between patients with normal and decreased EF (P>0.9) (Table 4).

Table 4. Comparison of changes in PAP in patients with normal and decreased EF

EF \ PAP	Unchanged	Decrease	Increase	Total
Total	13	49	18	80
EF normal	7 (16.3%)	26 (60.5%)	10 (23.3%)	43
Decreased EF	6 (16.2%)	23 (62.2%)	8 (21.6%)	37

PAP: Pulmonary artery pressure, EF: Ejection fraction

Discussion

The present study was conducted to investigate the effect of cardiac rehabilitation on various cardiac function indices in patients with ischemic heart disease (IHD) after undergoing coronary artery bypass graft (CABG) surgery and it was revealed that ejection fraction (EF) was significantly increased after cardiac rehabilitation but left ventricular end-diastolic pressure (LVEDP) and pulmonary artery systolic pressure (PASP) decreased. The findings were similar in both gender groups and patients' age had no effect on the outcomes of rehabilitation.

Similar studies have reported positive effect of physical activities in the form of cardiac rehabilitation on the cardiac function indices in patients after heart attack (13-15) and these activities have been recommended in most of the articles published in this field (16-20). In the present study, EF was

significantly increased after cardiac rehabilitation, which is consistent with the results of a study by Basati et al. (15), which examined the patients suffering from myocardial infarction (MI) after 8 weeks of participation in cardiac rehabilitation program. Improvement of cardiac systolic function in the patients examined in the present study may be due to stunning myocardial improvements originated from CABGs (21). In addition, exercise reduces afterload and increases stroke volume, and consequently, increases EF (15,22). Besides, a recent study by Abtahi et al. (2017) has shown that cardiac rehabilitation improves myocardial global longitudinal strain (23). Many studies have shown that left ventricular diastolic dysfunction exists in a large number of patients with IHD, which represents worse prognosis in comparison to normal diastolic function (13,24-26). Measurement of LVEDP is a useful way of predicting cardiac diastolic function (34), therefore, the Nagueh formula (1.24×E/e´+1.9) was used in this study to calculate LVEDP which has an appropriate relationship with left ventricular filling pressure (27-30). Increased LVEDP causes symptoms such as shortness of breath, orthopnea and paroxysmal nocturnal dyspnea (PND) by pulmonary congestion (42). It was observed that LVEDP was significantly decreased after rehabilitation and this decrease was significant in those patients with LVEDP higher than 12 before rehabilitation compared to other groups, which is consistent with the results of studies by Wuthiwaropas and YU et al. (13,14). In the study by Yu et al. (14), the prevalence of impaired left ventricular diastolic function was reported 65% in patients who underwent cardiac rehabilitation and 88% in patients who did not participate in the rehabilitation program, and the amount and speed of improving left ventricular diastolic function indices in rehabilitation group was significantly higher than those in control group. Wuthiwaropas et al. (2013) also demonstrated that cardiac diastolic function, E/e' ratio, and end-diastolic pressure (EDP) were significantly improved in patients undergoing cardiac rehabilitation. The mechanism of improving diastolic function may be due to reduced LV stress and improved LV filling (13). Giallauria et al. (2006) showed that LV stress and NT-proBNP levels decreased after three months of rehabilitation (31). Reduction of LV stiffness may be another factor of improving diastolic function. Experimental studies showed that exercise training after MI can reduce fibrosis (32). In addition, Malftto et al. (2009) claimed that physical training improves left ventricular compliance and its stiffness (33). Rehabilitation also reduces resting heart rate (34), which leads to an increase in relaxation time and improves cardiac diastolic function (22). Also, increased EF reduces LVEDP (42).

Left heart diseases (LHDs) are the most common causes of increased PAP in response to an increase in the left atrium or left ventricular filling pressure. In the past, rheumatic heart diseases were the most common causes of pulmonary hypertension (PH) in the left heart diseases, but today, they are more common causes of IHD and HTN (35). Several studies have reported the beneficial effects of cardiac rehabilitation and exercise training in patients with PH and some have reported a reduction in PAP (36-41). But, few studies have been conducted on the effect of cardiac rehabilitation in patients with IHD. The present study also revealed that PASP was significantly reduced in patients with IHD after participation in the rehabilitation program but it did not differ in patients with normal or reduced EF.

As mentioned above, the elevated PAP in patients with IHD is due to the increase of LVEDP, cardiac rehabilitation program improves left ventricular systolic function indices (like EF) and LVEDP, and subsequently, decreases PAP. However, various studies have reported the role of exercise in reducing PAP with endothelial mechanism and improving endothelial function (22,42), which is apparently not true for the patients examined in the present study because these changes require more time.

Conclusion

The present study was conducted on patients with ischemic heart disease and it was revealed that left ventricular end-diastolic pressure and pulmonary artery systolic pressure were significantly decreased in the patients after cardiac rehabilitation. Furthermore, EF index was significantly improved in the patients.

Acknowledgments

The authors would like to appreciate all those who assisted them in preparing and writing this report.

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