Original Article

Effects of Cardiac Rehabilitation Program on Right Ventricular Function after Coronary Artery Bypass Graft Surgery

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Received 23 July 2011; Accepted 17 December 2011

Abstract

Background: *Cardiac rehabilitation has been recognized as one of the most effective strategies for managing cardiovascular indices as well as controlling the cardiovascular risk profile, in particular after coronary artery bypass graft surgery (CABG). However, the effect of this program on right ventricular function following CABG is unclear.The aim of this study was to evaluate the impact of cardiac rehabilitation on the right ventricular (RV) function in a cohort of patients who underwent CABG.*

Methods: *A total of 28 patients who underwent CABG and participated consecutively in an 8-week cardiac rehabilitation program at Tehran Heart Center were studied. The control group consisted of 39 patients who refused to attend cardiac rehabilitation and only received postoperative medical treatment after registration in the Cardiac Rehabilitation Clinic. Two-dimensional and Doppler echocardiography was performed to assess the RV function in both groups at the three time points of before surgery, at the end of surgery, and at the end of the rehabilitation program.*

Results: *Significant increase of RV function parameters were observed in both rehabilitation group (RG) and control group (CG) at the end of the rehabilitation program compared with post-CABG evaluation in terms of tricuspid annular plane systolic execution (RG: 12.50 mm to 14.18 mm; CG: 13.41 mm to 14.56 mm), tricuspid annular peak systolic velocity (RG: 8.55 cm/s to 9.14 cm/s; CG: 9.03 cm/s to 9.26 cm/s), and tricuspid annular late diastolic velocity (RG: 8.93 cm/s to 9.39 cm/s; CG: 9.26 cm/s to 9.60 cm/s).The parameters of the RV function did improve in both groups, but this improvement was not associated with participation in the complete cardiac rehabilitation program.*

Conclusion: *The RV function parameters gradually improved after CABG; this progress, however, was independent of the exercise-based cardiac rehabilitation program.*

J Teh Univ Heart Ctr 2012;7(1):25-29

This paper should be cited as: Zoroufian A, Taherian A, Hosseini SK, Sardari A, Sheikhvatan M. Effects of Cardiac Rehabilitation Program on Right Ventricular Function after Coronary Artery Bypass Surgery. J Teh Univ Heart Ctr2012;7(1):25-29.

Keywords: *Rehabilitation • Coronary artery bypass • Heart ventricles • Exercise*

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Introduction

Echocardiographic findings and magnetic resonance imaging studies through measuring tricuspid annular motion, tricuspid annular velocity, and analysis of the right ventricular (RV) strain have shown a depressed RV function following coronary artery bypass graft surgery (CABG) compared with preoperative measurements, which can persist for up to one year after surgery.[1-4] Some probable etiologies of RV dysfunction after this cardiac procedure have been identified as cardiopulmonary bypass, perioperative myocardial ischemia, intraoperative cardiac damage, cardioplegia, and pericardial disruption or adhesion.[5, 6] The RV function is a main determinant of cardiac surgery outcome and can be associated with high mortality and morbidity;[7]consequently, improving the RV function following cardiac procedures should be a final goal of postoperative supportive and curative strategies.

Cardiac rehabilitation has been recognized as one of the most effective strategies for managing cardiovascular indices as well as controlling the cardiovascular risk profile, in particular after CABG. This program can effectively augment the left ventricular (LV) function via increasing the ejection fraction and reducing the LV end-diastolic diameter.[8, 9] However, there is a dearth of information in the existing literature on the impact of this program on the parameters of the RV function.[10] A cardiac rehabilitation program should, therefore, be potentially focused on a persistent assessment of the RV function as well as enhancement of cardiovascular parameters following cardiac procedures, especially in those with evidence of the RV dysfunction.

In our center, a comprehensive cardiac rehabilitation program has been offered to all patients who undergo different cardiac procedures since 2006. The aim of this study was to evaluate the impact of this program on the RV function in a cohort of patients who underwent CABG.

Methods

From a total of 126 candidates for cardiac rehabilitation referred to the cardiac Rehabilitation Clinic of Tehran Heart Center, 28 consecutive patients who underwent isolated CABG and participated in a complete 8-week cardiac rehabilitation program were included in the study. Participants entering cardiac rehabilitation following valvular surgeries or other cardiac interventions were all excluded, as were those participating in fewer than 24 cardiac rehabilitation sessions.

In the first session, the program was explained to the patients and informed consent was obtained. The control group was comprised of 39 patients who refused to attend cardiac rehabilitation and only received standard postoperative medical treatment after registration in the Cardiac Rehabilitation Clinic. The study was reviewed and approved by the Ethics Committee of Tehran University of Medical Sciences.

Demographic characteristics and medical history were collected using a questionnaire by face-to-face interviewing at the day of admission to the Cardiac Rehabilitation Clinic. Information on functional class and risk stratification was also completed by a cardiac rehabilitator or a general practitioner trained in cardiac rehabilitation, and echocardiographic parameters were measured by a cardiologist. Functional status was evaluated based on the New York Heart Association (NYHA) classification. Also, the patients were stratified into high, intermediate, and low-risk groups according to the risk stratification criteria of the American Association of Cardiovascular and Pulmonary Rehabilitation.[11]

The cardiac rehabilitation program consisted of 24 exercise sessions held three times a week for approximately 45 to 60 minutes. Each program was commenced with warm-up exercise, continued with 30 minutes of aerobic training, and ended with cool-down exercise. The program also included psychological and nutritional counseling within the first week of the program based on the recommendations of the American Heart Association.[12]

Echocardiography was performed to assess the RV function using a GE Vivid 3 device, equipped with a 3-MHz probe capable of performing two dimensional, M- mode, and Doppler as well as tissue Doppler studies. The parameters of the RV function in both study groups were measured at the three time points of before surgery, at the end of surgery, and after the rehabilitation program. The measurements of the RV function included in the analysis were tricuspid annular plane systolic excursion (TAPSE), tricuspid annular peak systolic velocity (TASV), tricuspid annular early diastolic velocity (TAEDV), and tricuspid annular late diastolic velocity (TALDV) on tissue Doppler imaging. The recording of each parameter was carried out according to the guidelines of the American Society of Echocardiography.[13] TAPSE was calculated in M mode in the apical four-chamber view: The cursor was placed at the junction between the tricuspid annulus and the lateral wall of the RV. TAPSE was defined as the systolic displacement of the mentioned point along the vertical axis with respect to the baseline situation, which represents the longitudinal shortening of the ventricular base with respect to the apex. Time from the onset of diastole to peak velocity (TDPV), TAEDV, and TALDV were also obtained in the apical four-chamber view and in pulsed tissue Doppler mode by placing the cursor at the junction between the base of the anterior cusp of the tricuspid valve and the lateral wall of the RV. For the measured parameters, the mean of three beats was taken.

The results are reported as mean ± standard deviation (SD) for the quantitative variables and percentages for the categorical variables.

The groups were compared using the Student t-test or

Mann-Whitney U test for the continuous variables and the chi-square test (or Fisher exact test if required) for the categorical variables. Within the groups, changes between the baseline and final sessions were tested with a paired t-test. The repeated-measure ANOVA test was employed to determine the differences in the RV parameters within the study period. Linear regression analysis was utilized to determine the effectiveness of cardiac rehabilitation on the RV parameters with the presence of cofounders, including the patients' age and gender and some risk profiles such as diabetes mellitus and systolic hypertension. P values ≤ 0.05 were considered statistically significant. All the statistical analyses were performed using SPSS version 16.0 (SPSS Inc., Chicago, IL, USA).

Results

The two study groups were similar in terms of baseline characteristics, medical history, primary physical function, and risk stratification (Table 1). The majority of the patients in both groups had an appropriate functional class to participate in the rehabilitation sessions. Eight patients who underwent rehabilitation, as opposed to none of the controls, were stratified in the high-risk group.

No significant differences were observed in all the study parameters of the RV function between the rehabilitation and control groups at baseline as well as at the end of surgery and also after the completion of the cardiac rehabilitation sessions. Also, the trend of changes in these parameters within the study period was not significant in both groups (Table 2).

Regarding changes in the RV functional indices during complete rehabilitation sessions, the parameters of TAPSE, TDPV, and TALDV had significantly increased at the end of the rehabilitation program compared with post-CABG evaluation time in both study groups (p values < 0.05 for all). However, there was no such increase in the TAEDV index. Multivariable linear regression analysis showed that there was a rise in the RV parameters in both rehabilitation and control groups, but participation in phase I of the complete cardiac rehabilitation program had no impact on this increase in the parameters of the RV function (Table 3).

Discussion

The current study is the first study of its kind to focus directly on the influence of a cardiac rehabilitation program on the parameters of the RV function in patients who undergo cardiac surgery. Our main finding was that participation in the complete cardiac rehabilitation program did not affect the trend of changes in the RV function, although the RV function in both rehabilitation and control groups enjoyed significant improvement at the end of this program. Another finding of note in the present study is that the decrease in the RVfunction in the wake of CABG could be enhanced through rehabilitation sessions.

Table 1. Baseline characteristics and clinical data in study patients undergoing cardiac rehabilitation*

Characteristics	Rehabilitation group (n=28)	Control group (n=39)	P value
Age (y)	58.05±6.83	58.42±10.08	0.875
Male gender	22 (78.6)	24 (61.5)	0.138
Diabetes mellitus	5 (17.9)	11 (28.2)	0.327
Hypertension	7 (25.0)	14 (35.9)	0.343
Function class			0.489
I	16 (57.1)	30 (76.9)	
II	12 (42.9)	9 (23.1)	
Risk stratification			0.457
Mild	16 (57.1)	29 (74.4)	
Intermediate	4 (14.3)	10 (25.0)	
Severe	8 (28.9)	0 (0.0)	

*Data are presented as mean±SD or n(%)

Table 2. Echocardiography in different time points in study patients undergoing cardiac rehabilitation*

Characteristics	Rehabilitation group (n=28)	Control group (n=39)	P value
TASV (cm/s)			
Pre-CABG	11.76±1.62	12.49±2.32	0.136
Post-CABG	8.55±1.45	9.03±1.59	0.203
Post-rehabilitation	9.14±1.50	9.26±1.61	0.781
TAEDV (cm/s)			
Pre-CABG	9.07±1.80	9.23±1.84	0.725
Post-CABG	6.21±1.40	6.85±1.89	0.120
Post-rehabilitation	6.46±1.40	6.84±2.12	0.456
TALDV (cm/s)			
Pre-CABG	13.82±2.74	13.87±2.94	0.943
Post-CABG	8.93±1.70	9.26±2.20	0.494
Post-rehabilitation	9.39±1.91	9.60±2.36	0.729
TAPSE (mm)			
Pre-CABG	21.26±2.84	21.57±3.20	0.680
Post-CABG	12.50±2.20	13.41±2.69	0.131
Post-rehabilitation	14.18±1.83	14.56±2.08	0.484

*Data are presented as mean±SD

TASV, Tricuspid annular peak systolic velocity; CABG, Coronary artery by-pass grafting; TAEDV, Tricuspid annular early diastolic velocity; TALDV, Tricuspid annular late diastolic velocity; TAPSE, Tricuspid annular plane systolic excursion

Table 3. Multivariable analysis of the role of cardiac rehabilitation to improve right ventricular function

	Beta	Standard Error	P value
Analysis for TASV			
Participation in CR	0.089	0.255	0.728
Male gender	0.337	0.289	0.251
Advanced age	-0.004	0.015	0.788
Diabetes mellitus	-0.174	0.280	0.539
Hypertension	-0.306	0.257	0.242
Analysis for TAEDV			
Participation in CR	0.266	0.294	0.372
Male gender	0.319	0.333	0.345
Advanced age	-0.010	0.018	0.595
Diabetes mellitus	-0.453	0.323	0.169
Hypertension	-0.217	0.296	0.469
Analysis for TALDV			
Participation in CR	0.162	0.271	0.553
Male gender	0.408	0.307	0.193
Advanced age	-0.003	0.016	0.849
Diabetes mellitus	-0.054	0.298	0.858
Hypertension	-0.143	0.273	0.605
Analysis for TAPSE			
Participation in CR	0.562	0.483	0.252
Male gender	0.901	0.546	0.108
Advanced age	-0.006	0.029	0.831
Diabetes mellitus	-0.205	0.530	0.702
Hypertension	-0.111	0.486	0.821

TASV, Tricuspid annular peak systolic velocity; CR, Cardiac rehabilitation; TAEDV, Tricuspid annular early diastolic velocity; TALDV, Tricuspid annular late diastolic velocity; TAPSE, tricuspid annular plane systolic excursion

Regarding our first result, some similar studies have reported no association between the RV function and exercise capacity based on tissue Doppler analysis. In a study by Rubis et al. on heart failure patients, the RV systolic pressure correlated weakly with peak oxygen uptake. In a multivariable prognostic model for assessing the relationship between exercise capacity and ventricular parameters, only the LV parameters evaluated at peak stress were the independent predictors of exercise capacity, whereas all the RV variables were seen to be excluded from the model.[14] Similarly, Clark and his colleagues[15] were not able to demonstrate a strong association between the RV ejection fraction and exercise capacity. Baker et al.[16] and Di Salvo[17]reported a significant correlation between the RV function and exercise capacity and posited that exercise capacity might be the main predictor of mortality and that it appeared to be more closely related to the RV function than the LV function.

We were not able to demonstrate any beneficial effects of cardiac rehabilitation on the RV function, but numerous studies have demonstrated the prognostic value of the RV function in coronary artery disease, particularly following reduction in exercise tolerance. Indeed, increased risk of death, arrhythmia, and shock has been demonstrated in patients with RV myocardial dysfunction.[18] In addition, decreased exercise tolerance is believed to represent one of the most important prognostic factors for these events in patients with RV failure associated with pulmonary hypertension or congestive heart failure.[19, 20] These findings highlight the multi-factorial nature of the changes in the RV function during exercise programs, not least cardiac rehabilitation.

As regards the changes in the LV function after surgery, we showed that despite a reduction in the RV function immediately after surgery, exercise performance three months after CABG was augmented in both study groups, which chimes in with the findings of the Hedmanet al.1 study. Some other studies have been able to demonstrate that the RV function might remain depressed for as long as one year after CABG.2These changes are mainly allied with the decrement in some parameters such as tricuspid annular motion, tricuspid annular velocity, or RV strain. Some probable causes have been suggested for this phenomenon such as cardiopulmonary bypass, perioperative ischemia, cardioplegia, and pericardial disruption.[5, 6] Nonetheless, the relationship between preoperative risk profile, revascularization of the right coronary artery, pump time, or the number of grafts with RV dysfunction after CABG has not been proved yet.

In the present study, the RV function, initially reduced following CABG, enjoyed a gradual improvement; this progress, however, was independent of exercise. It is also deserving of note that long-term RV function is not adversely affected by CABG.3 Most of our patients had appropriate functional class, even after CABG, which underscores the predictability of recovery in the RV parameters in the long term after CABG.

Although our findings did not demonstrate the beneficial effects of phase I cardiac rehabilitation on the RV function, the influence of the inpatient phase of this program cannot justify the ineffective role of cardiac rehabilitation on the RV function and thus the impact of long-term phases of rehabilitation (phases II to IV) should be assessed in further studies.

Conclusion

CABG might beget a reduction in the RV function. Our patients enjoyed improvement in their RV function following cardiac rehabilitation; they, however, did not obtain baseline optimal RV function following this program. Furthermore, participation in the complete cardiac rehabilitation program could not potentially compensate for the depressed RV function in those who underwent CABG. Hence, participation in phase II of outpatient cardiac rehabilitation or in prolonged sessions might have more beneficial effects on the RV function; this should be evaluated in further studies with longer follow-up durations.

Acknowledgements

This study was supported by Tehran University of Medical Sciences. We thank the University authorities, who offered critical administrative support and managerial services in carrying out the study. Many thanks are also due to all the researchers for their help and support.

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