Original Article
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Assessment of the Left Ventricular Systolic Function of Patients with Acute Myocardial Infarction after Cardiac Rehabilitation by Using Two Dimensional Echocardiography

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Abstract

Objective: The aim of this study was to use two-dimensional speckle tracking echocardiography to evaluate the effect of cardiac rehabilitation (CR) on the left ventricular systolic function of patients with acute myocardial infarction (AMI) who had been revascularized by percutaneous coronary intervention (PCI).
Material and Methods: Forty-two patients with AMI and successful revascularization by PCI were enrolled in the study. Left ventricular global longitudinal, global circumferential, and mean radial systolic strain analyses were performed using two-dimensional speckle tracking echocardiography before and after CR. Left ventricular ejection fraction was measured using the biplane Simpson's method.
Results: There were significant differences in ejection fraction (EF) measurements before and after CR (49±8 vs. 53±8, respectively; p=0.039). The improvements in two-dimensional speckle tracking global longitudinal strain (p=0.031) and two-dimensional speckle tracking global circumferential strain (p=0.005) after CR were statistically significant. Despite these improvements, the difference between radial strain before and after CR was not statistically significant (p=0.109). Septal and lateral systolic motion measurements and myocardial performance index measured with tissue Doppler echocardiogram Improved with CR.
Conclusion: CR has beneficial effects on left ventricular global longitudinal and global circumferential strains, as well as EF, after AMI.
Keywords: Cardiac rehabilitation, left ventricular systolic function, ejection fraction, speckle tracking echocardiography

Introduction

Cardiovascular disease (CVD) is the leading cause of mortality and morbidity in the industrialized world despite advances in diagnosis and management. Exercise training is known to be effective in primary and secondary prevention of CVD (1). In the United States alone, over 14 million people suffer from CVD, and in Turkey, over 3.1 million people are sufferers, many of whom may be candidates for cardiac rehabilitation (CR) (2). The CR program aims to optimize cardiovascular risk reduction and improve functional capacity and psychological well-being for patients who have experienced acute myocardial infarction (AMI) and percutaneous coronary intervention (PCI) sometime within the previous year (3,4). Many clinical trials have demonstrated that CR results in a mortality benefit of approximately 20–25% over a median follow-up period of 12 months (5-7).

Improvement of ejection fraction (EF) by exercise training has been demonstrated in many clinical trials (8). If abnormal

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contracting segments exceed 15%, left ventricular pump function becomes depressed; consequently, cardiac output (CO), stroke volume, and EF may decline, and end-diastolic volume and pressure may increase. Speckle tracking two-dimensional strain is currently used as an echocardiographic tool for the quantitative assessment of cardiac function. The term "strain" is used in echocardiography to describe "deformation" of a given myocardial segment. During myocardial contraction, strain values are positive as the wall shortens and thickens, whereas negative values describe shortening related to the wall's original length. During the evaluation of contractile function, radial thickening describes a positive strain, whereas circumferential shortening and longitudinal shortening describe a negative strain. Strain rate (SR) is the rate by which deformation occurs (deformation or strain per time unit) (9,10). Some of the most important clinical indications for echocardiographic strain and SR measurements appear to be myocardial ischemia and the evaluation of myocardial revascularization efficiency. Strain and SR imaging have emerged during recent years as reliable and valuable methods for echocardiographic assessment of myocardial function.

In the present study, we aimed to compare the left ventricular systolic function before and after CR in patients with AMI and successful revascularization by PCI, with two-dimensional speckle tracking echocardiography strain and SR analyses.

Material and Methods

Study Design

Following AMI and revascularization by PCI, 42 lower-risk patients were enrolled this study. All patients were medicated according to the current guidelines. Patients with bundle-branch block on 12-lead electrocardiograms and those with devices such as pacemakers and defibrillators were excluded from the study. High-risk patients with severe residual angina, severe ischemia, poorly controlled hypertension, hypertensive or hypotensive systolic blood pressure response to exercise, or unstable concomitant medical problems (e.g., diabetes prone to hypoglycemia) were also excluded from the study.

This study complied with the Declaration of Helsinki and was approved by the local ethical committee; each patient gave written consent before CR.

Cardiac Rehabilitation

After 2–6 weeks of recovery at home, each patient was ready to start phase II of his/her CR. The phase II CR program was initiated based on the results of exercise testing, and the exercise prescription was individualized. The CR program was administered to the participants by an integrated multidisciplinary team consisting of a cardiologist, an experienced nurse, and a physical therapy and rehabilitation specialist. The minimum frequency for exercising to improve cardiovascular fitness was five times per week during a six-week period. Patients allowed 30–60 min for each session, which included a warm-up for at least 10 min. The final 10 min were a cool-down period that involved muscular stretching. The intensity prescribed was in relation to the patients target heart rate. Aerobic conditioning was emphasized in the first few weeks of exercise, and strength training was introduced later. The Borg scale of rate of perceived exertion (RPE) was applied; patients exercised at RPE of 13–15. In addition to exercise, counseling and education regarding stress management, smoking cessation, nutrition, and weight loss were also incorporated into this phase.

Echocardiography

Standard two-dimensional echocardiographic exams were performed before and after phase II CR for all subjects who underwent CR and those in the control group. All patients were examined in the left lateral position and according to the recommendation of the American Society of Echocardiography (11) using a standard commercial ultrasound machine (Vivid 7; GE Vingmed, Horten, Norway) with a 2.5- or 3.5 MHz-multiphased array probe. Left ventricular volumes and left ventricular ejection fraction (LVEF) were evaluated using the biplane Simpson's method. CO was calculated as the product of heart rate and stroke volume. Color-coded tissue Doppler imaging (TDI) from the apical four-chamber view was used to determine the septal and lateral annular velocities, including systolic (S′), early (E′), and late (A′) diastolic velocities and myocardial performance index (MPI).

Two-Dimensional Speckle Tracking Echocardiography

Two-dimensional speckle tracking analyses were performed on three consecutive end-expiratory cardiac cycles using the high frame rate (69.8–147.7 frames/s) harmonic imaging of the left ventricle obtained in the apical four-chamber and short-axis mid-ventricular views. Acquired data for two-dimensional strains (radial, circumferential, and longitudinal), and SRs were subsequently analyzed offline using a developed two-dimensional speckle tracking software. The traces of the left ventricular regions for strain analysis were manually selected by marking the endocardial border at the end-systole to obtain peak systolic regional strain and SR measured prior to aortic valve closure in the longitudinal, radial, and circumferential planes. Global peak systolic strain and SRs were calculated by averaging the six regional values in the apical four-chamber and parasternal short-axis views at the mid-papillary level to measure the longitudinal, radial, and circumferential strains.

Statistical Analysis

Statistical analysis was performed using the Statistical Package for Social Sciences version 15.0 software for Windows (SPSS IBM., Armonk, New York, USA). Categorical data are expressed as frequencies. Continuous variables are presented as the mean ± standard deviation. The χ^2 test was applied to compare categorical variables. Continuous variables were analyzed using the Kolmogorov–Smirnov test for normal distribution. The variances between the groups were compared with paired-samples t tests. To assess intraobserver reproducibility, the two-dimensional speckle tracking strain data measurements were repeated after one week by the same echocardiographer. Intraobserver reproducibility was analyzed using Spearman's correlation analysis ($r=0.867$, $p<0.0001$). P values <0.05 were regarded as significant.

Table 1. Patient demographics and clinical characteristics

Patients (n=42)	Cardiac rehabilitation group
Age, (years)	57.1±7
Gender	32 males (76%)
	10 females (24%)
Diabetes, (n)	17 (40%)
Hypertension, (n)	26 (61%)
Hyperlipidemia, (n)	20 (47%)
Smoking, (n)	16 (38%)
IRA, (n)	
• LAD	16 (38%)
• CX	11 (26%)
• RCA	15 (35%)

CR: cardiac rehabilitation; n: number; IRA: infarct-related artery; LAD: left anterior descending; CX: circumflex; RCA: right coronary artery

Table 2. The difference in echocardiographic parameters between the groups

Patients (n=42)	Before CR (mean±SD)	After CR (mean±SD)	p value
EF, (%)	49.6±8.3	53.9±8.2	0.039
LVEDV, (mL)	118.3±32.2	117.9±32.7	0.998
CO, (L/min)	6.0±0.91	5.9±0.79	0.627
MPI	0.42±0.05	0.38±0.03	0.006
Septal s' (cm/s)	8.1±1.9	9.6±2.1	0.003
Lateral s' (cm/s)	8.9±2.0	10.9±2.4	0.000
Global Long S, (cm/s)	15.1±2.1	16.5±3.1	0.031
Global Long SR, (cm/s)	0.97±0.21	1.12±0.26	0.010
Global Cx S, (cm/s)	13.1±2.8	15.2±3.5	0.005
Global Cx SR, (cm/s)	0.89±0.25	1.11±0.23	0.000
Mean Radial S, (cm/s)	28.9±9.6	33.1±9.0	0.109
Mean Radial SR, (cm/s)	1.2±0.38	1.3±0.30	0.905

EF: ejection fraction; n: number; CR: cardiac rehabilitation; LVEDV: left ventricle end diastolic volume; CO: cardiac output; L: liter; MPI: myocardial performance index; Cx: circumferential; s': systolic motion; S: strain; SR: strain rate; M: mean

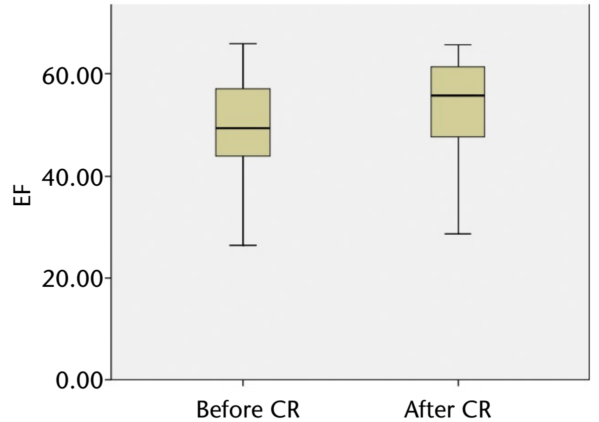

Figure 1. It shows the improvement in left ventricular EF with CR (p=0.039)

CR: cardiac rehabilitation

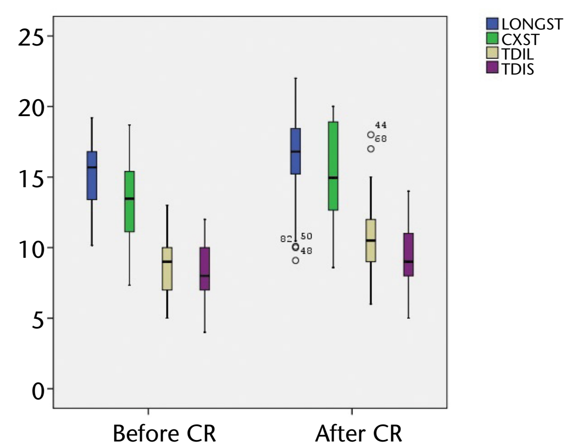

Figure 2. It shows the improvement in left ventricular longitudinal (LONGST) and circumferential strain (CXST) with two -dimensional speckle tracking echocardiography and lateral (TDIL) and septals' (TDIS) with TDI

CR: cardiac rehabilitation

Results

The baseline demographics and characteristics of the 42 AMI patients included in our study are listed in Table 1. The infarct-related artery (IRA) was the left anterior descending artery in 38% of the individuals. Successful coronary patency was achieved in each case. There were significant differences in EF measurements before and after CR (49±8 vs. 53±8, respectively; p=0.039, Figure 1). However, there was no significant difference in CO or left ventricular end-diastolic volume measurements before and after CR (p=0.636 and p=0.998, respectively). There were significant improvements in the two-dimensional speckle tracking global longitudinal strain (p=0.031) and SR (p=0.010) with CR. Additionally, the two-dimensional speckle tracking global circumferential strain (p=0.005) and SR (p=0.000) improved after training (Figure 2). Although there were significant differences in the two-dimensional longitudinal and circumferential speckle tracking echocardiography measurements after CR, the radial strain and SR measurements before and after CR were not statistically different (p=0.109 and p=0.905, respectively). Septal and lateral systolic motion and MPI, measured with tissue Doppler echocardiograms, improved with CR (Table 2). When patients were analyzed according to their IRA, there were no significant differences in the EF measurements (p=0.502).

Discussion

The present study showed that EF and speckle tracking two-dimensional strain measurements, which demonstrate the improvement in left ventricular systolic function, improved with CR. As a clinical index of myocardial contractility, left ventricular EF is a well-established independent predictor of mortality and long-term prognosis in AMI (12). Echocardiographic measurements of the strain and SR have the potential to provide valuable information about regional and global left ventricular systolic function (13). It is believed that strain and SR data in normal human ventricles are less load-dependent than other regional or global indices of ventricular function (14). Tagged magnetic resonance imaging, the gold standard technique for deformation analysis, correlates well with non-Doppler two-dimensional strain measurements, both in normal myocardial segments and infarcted areas (15). Leitman et al. (16) demonstrated that speckle tracking-based two-dimensional strain imaging could adequately recognize 80.3% of infarcted segments and 97.8% of normal segments in a study of 30 patients. In this study, increases in global left ventricular EF, MPI, and myocardial contractility were observed, and this result was supported by increases in the circumferential and global longitudinal strains and SR values measured by speckle tracking two-dimensional strain echocardiography, which is highly sensitive and specific for the diagnosis of myocardial performance.

Septal and lateral systolic motion and MPI, as measured with tissue Doppler echocardiograms, improved with CR, and this may support the improvement in left ventricular systolic function. In this follow-up, CO, left ventricular end diastolic volume, and radial movement of myofibrils did not change significantly. Long-term analysis may be needed to further evaluate these parameters. Many studies have previously demonstrated improved EF with CR, but to the best of our knowledge this is the first study to not only show an improvement in EF but also support this finding by demonstrating the improvement segmently via two-dimensional speckle tracking echocardiography.

Despite the wealth of evidence supporting the proven benefits of CR to eligible patients, only 14–35% of heart attack survivors and 31% of patients subjected to coronary artery bypass surgery participate in CR programs (17,18). In our center, 5.553 PCI, 1.170 CABG, and 692 heart valve surgeries were performed last year, but only 678 of these patients participated in CR (unpublished data). Similar to the current data (19), participation rates of women, the elderly, and patients with low socioeconomic status were low in our center (unpublished data).

Cardiac rehabilitation is one of the most clinically effective therapeutic interventions in CVD management (20-23). It is probably the best-kept secret in cardiovascular medicine that has been absolutely proven to decrease mortality. Although there is now an increasing awareness of CR programs with insurance coverage in Turkey, they are still underutilized for those patients who are eligible for similar programs worldwide. Despite established evidence that CR lowers morbidity and mortality, referral rates to CR programs remain inadequate. The present study demonstrates CR-related improvements in the left ventricular EF of patients with AMI who have been revascularized by PCI, and these effects were measured with conventional echocardiography, TDI, and two-dimensional speckle tracking echocardiography.

This study has several limitations. First, this is a short-term follow-up study. Second, the mean LVEF of the subjects was favored and high-risk patients were not included in the study. Third, the majority of our subjects were men.

Conclusion

Cardiac rehabilitation improves the two-dimensional speckle tracking of the left ventricular global longitudinal and global circumferential strains, as well as LVEF, of patients with AMI and successful revascularization by PCI.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Kartal Koşuyolu Yüksek İhtisas Training and Research Hospital.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

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Conflict of Interest: No conflict of interest was declared by the authors.

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