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ORIGINAL ARTICLE

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Left Ventricular Function after Revascularization in Patients with Chronical Coronary Syndromes

Sh. N. Doniyorov*, F. M. Bekmetova, R. Sh. Bekbulatova, Kh. G. Fozilov, M. G. Mukhamedova, N. A. Yuldashev, L. T. I'lkhomova, S. F. Arslonov, B. S. Karimov

Republican Specialized Scientific-Practical Medical Center of Cardiology
Tashkent, Uzbekistan

Abstract

The purpose of this study was to determine the dynamics of morpho-functional and myocardial deformation characteristics of the left ventricle after revascularization in patients with chronic coronary syndromes (CCS).

Methods and Results: The study included 136 CCS patients of both sexes with stable anginal symptoms [(i) clinical scenario] and asymptomatic coronary artery disease (CAD) at screening [(vi) clinical scenario]. Diagnosis of CCS was performed according to the 2019 ESC Guidelines for the diagnosis and management of chronic coronary syndromes. All patients underwent the following examinations: assessment of traditional risk factors, physical examination, general clinical and laboratory blood tests, 12-lead ECG, transthoracic echocardiography, two-dimensional speckle tracking echocardiography (STE), and coronary angiography (CAG). The SYNTAX score was calculated retrospectively according to the SYNTAX score algorithm. A total of 100 patients with CCS were enrolled in the main group (MG) and underwent revascularization by PCI with intracoronary stenting using drug-eluting stents. Among the main-group patients, one-vessel, two-vessel, and three-vessel CAD were detected in 36(26.5%), 34(25%), and 30(22.0%) cases, respectively. The comparison group (CG) included 36 CCS patients with hemodynamically non-significant coronary lesions.

LVEF values were within the normal range in all groups, with the highest value in the CG, followed by the one-, two- and three-vessel lesion groups. LVEF obtained by the area-length method and modified biplane Simpson's method did not differ. The assessment of the contractile function of the LV myocardium was also obtained by assessing the global longitudinal strain (GLS) and global longitudinal strain rate (GLSR). The comparative analysis of the LV myocardial deformation properties in the studied groups showed that less negative GLS and GLSR were found in the three-vessel CAD, followed by the two-vessel and one-vessel CAD groups, and CG. CG demonstrated more negative GLS and GLSR than all MG subgroups.

We found no statistically significant differences in the GLS before and 48 hours after revascularization in all studied MG subgroups and CG. Thirty days after revascularization, GLS significantly showed more negative values in all MG subgroups: -18.12±0.63 versus -17.9±0.4 in one-vessel CAD, -16.13±0.71 versus -15.9±0.4 in two-vessel CAD and -13.91±1.25 versus -13.1±1.1 in three-vessel CAD. In CG with medical treatment only, GLS did not change statistically significantly but had more negative values than in the studied MG subgroups. Analysis of changes in LVEF after revascularization in the MG of patients with one-, two- and three-vessel CAD and in the CG after medical treatment did not reveal statistically significant dynamics.

Conclusion: the results indicate the absence of statistically significant changes in myocardial deformation indicators and morpho-functional parameters of the left ventricle in CCS patients 48 hours after revascularization. Thirty days after revascularization, GLS significantly improves, while LVEF remains unchanged. GLS is superior to LVEF in visualizing improvement in LV function after revascularization in patients with CCS. **(International Journal of Biomedicine. 2023;13(4):240-245.)**

Keywords: coronary artery disease • speckle tracking echocardiography • global longitudinal strain

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Abbreviations

2D-STE, 2-dimensional speckle tracking echocardiography; **ASE**, American Society of Echocardiography; **ACS**, acute coronary syndromes; **CAD**, coronary artery disease; **CAG**, coronary angiography; **CCS**, chronic coronary syndromes; **CABG**, coronary artery bypass grafting; **GLS**, global longitudinal strain; **GLSR**, global longitudinal strain rate; **LVEDV**, left ventricular end-diastolic volume; **LVESV**, left ventricular end-systolic volume; **LV**, left ventricle; **LVEF**, left ventricular ejection fraction; **MI**, myocardial infarction; **PCI**, percutaneous coronary intervention; **SR**, strain rate.

Introduction

Coronary artery disease (CAD), also called coronary heart disease or ischemic heart disease, is the most common cause of death in developing and developed countries. CAD, characterized by the accumulation of atherosclerotic plaque in the epicardial arteries, with or without obstruction, can have long stable periods but can also become unstable due to an acute atherothrombotic event caused by plaque rupture or erosion.[1] The chronic course of the disease is most often progressive, even in clinically silent periods. The dynamic course of CAD leads to clinical conditions that can be divided into acute coronary syndromes (ACS) and chronic coronary syndromes (CCS).

In 2019, the European Society of Cardiology presented "Guidelines for the diagnosis and management of chronic coronary syndromes."[1] The Guidelines describe 6 clinical scenarios for CCS that carry different risks for future cardiovascular events [e.g., death or myocardial infarction]. This risk may be increased by poor control of cardiovascular risk factors, suboptimal drug therapy, or failed revascularization.

In CCS patients, optimal medical therapy reduces clinical symptoms and the progression of atherosclerosis, and prevents atherothrombotic events. In addition to medical therapy, myocardial revascularization via percutaneous coronary intervention (PCI) or coronary artery bypass grafting (coronary artery bypass grafting) effectively reduces angina symptoms and antianginal drug use, and improves exercise capacity and quality of life, compared with medical treatment alone.

The 5-year follow-up of the FAME 2 (Fractional Flow Reserve versus Angiography for Multivessel Evaluation 2) trial showed that in patients with stable angina and angiographically significant stenoses, fractional flow reserve (FFR [<0.80])-guided PCI plus medical therapy was associated with a significantly lower rate of the primary composite end point of death, myocardial infarction (MI), or urgent revascularization than medical therapy alone.[2] However, the individual risk-benefit ratio should be assessed, and revascularization should only be considered if the expected benefit outweighs the potential risk.[1]

In CCS patients, left ventricular ejection fraction (LVEF), evaluating left ventricular systolic function, is often normal.[3] Myocardial deformation analysis evaluates LV mechanics by quantifying strain and strain rate (SR). Global longitudinal strain (GLS), assessed by 2D-STE, is a sensitive method for assessing LV function.[4] GLS expresses the longitudinal shortening as a percentage (change in length as a proportion to baseline length). Reference values for normal longitudinal strain from a recent meta-analysis using transthoracic echocardiography are 19.7±0.4% (mean±SD).[5] GLS may be altered despite preserved LV function, as assessed by LVEF, in conditions predisposing to cardiovascular disease, including older age, hypertension, diabetes mellitus, stable angina, renal dysfunction, and obesity.[6-11] In addition, GLS has prognostic value in patients with cardiovascular diseases, including acute MI[12] and heart failure with reduced[13,14] and preserved LVEF.[15] In the general population, GLS provides independent and complementary prognostic information regarding the long-term risk of cardiovascular morbidity and mortality.[16] The speed of myocardial deformation is also important and is characterized by SR.[17,18] Average longitudinal systolic SR in subjects without cardiovascular disease measured by transthoracic echocardiography is -1.10±0.16 sec^{-1}.[19] It should be noted that GLS correlates with LVEF, and SR correlates with the rate of rise of LV pressure (dP/dt).[17]

The purpose of this study was to determine the dynamics of morpho-functional and myocardial deformation characteristics of the left ventricle after revascularization in patients with CCS.

Materials and Methods

The study included 136 CCS patients of both sexes with stable anginal symptoms [(i) clinical scenario] and asymptomatic CAD at screening [(vi) clinical scenario].

The study protocol was reviewed and approved by the Ethics Committee of the Republican Specialized Centre of Cardiology. All participants provided the written informed consent.

Diagnosis of CCS was performed according to the 2019 ESC Guidelines for the diagnosis and management of chronic coronary syndromes.[1] Exclusion criteria were ACS, history of myocardial infarction within previous 3 months, valvular heart disease, heart failure with reduced ejection fraction, cardiac arrhythmia, renal impairment, severe co-morbidities.

The research protocol consisted of 3 stages. In the first stage (outpatient setting), all patients were subjected to general clinical examination and complex instrumental diagnostics, including 12-lead ECG, echocardiography, 2D-STE, stress echocardiography, and laboratory tests. In the second stage (hospital setting), coronary angiography was performed, and patients were divided into 3 groups based on the extent of coronary artery damage. The third stage (30-day follow-up examinations) included standard echocardiography and 2D-STE.

Transthoracic echocardiography (TTE)

Conventional 2D echocardiography was carried out according to the recommendations of the American Society of Echocardiography and the European Association of Cardiovascular Imaging[20] in M- and B-modes using the Siemens Acuson x700 (Korea, 2016) ultrasound machine. The LV volumes (LVEDV, LVESV) and LVEF were calculated using 1) the area–length method (using the apical 4-chamber and apical 2-chamber views) and 2) the modified Simpson's method (biplane method of disks) by tracing the endocardial border of LV cavity in both the apical four-chamber and two-chamber views in end-systole and end-diastole.

LV diastolic function was analyzed by measuring peak early diastolic filling (E) and late diastolic filling (A) velocities, E/A ratio. All parameters were obtained as the average of 5 consecutive cardiac cycles.

The values of LVEF (modified Simpson's method) were as follows:

•Normal range: 52% to 72% for men; 54% to 74% for women
•Mildly abnormal range: 41% to 51 for men; 41 to 53% for women
•Moderately abnormal range: 30% to 40% for men and women
•Severely abnormal range: <30% for men and women

Two-dimensional speckle tracking echocardiography (STE)

A common standard for STE is provided by a consensus document of the EACVI/ASE/Industry Task Force.[21] Two-dimensional images of 4-chamber, 3-chamber and 2-chamber apical views, as well as an LV parasternal short-axis view (at the root of papillary muscle), were recorded with the same ultrasound machine. Three consecutive cardiac cycle loops were recorded at end expiration. To ensure acceptable image quality, the frame rate was between 50 and 80 frames per second. A well-defined cardiac cycle was acquired for each view and stored digitally for offline analysis. All images were stored digitally and analyzed with offline software (Syngo Dynamics 9.0 software, Siemens Medical Solutions). Speckle tracking for myocardial strain was performed using Velocity Vector Imaging (VVI) software (TomTec-Arena TTA2, Germany). GLS and SR were automatically calculated as the average of 6 myocardial segments from 3 echocardiographic views.

Coronary angiography

CAG was performed via the Judkins technique through the femoral or radial artery access using Phillip Allura CV20 (Phillips Medical Systems, The Netherlands). The angiographical severity of coronary stenosis was assessed in the position with the most luminal narrowing, and the percentage of luminal narrowing was recorded according to the American Heart Association reporting system.[22] The SYNTAX score, an anatomical scoring system to grade the complexity of CAD, was calculated for each patient accordingly. All coronary lesions resulting in luminal narrowing of ≥50% in diameter for vessels ≥1.5 mm in diameter were considered significant stenosis. The SYNTAX score was calculated retrospectively according to the SYNTAX score algorithm.[23]

Statistical analysis was performed using the statistical software STATISTICA (v.10.0, StatSoft, USA). Baseline characteristics were summarized as frequencies and percentages for categorical variables and as mean ± standard deviation (SD) for continuous variables. Multiple comparisons were performed with one-way ANOVA with Tukey's pairwise comparisons. Student's paired t-test was used to compare the differences between the paired samples. Group comparisons with respect to categorical variables were performed using chi-square tests. A probability value of $P<0.05$ was considered statistically significant.

Results

A total of 100 patients with CCS were enrolled in the main group (MG) and underwent revascularization by PCI with intracoronary stenting using drug-eluting stents. Among the main-group patients, one-vessel, two-vessel, and three-vessel CAD were detected in 36(26.5%), 34(25%), and 30(22.0%) cases, respectively. The comparison group (CG) included 36 CCS patients with hemodynamically non-significant coronary lesions (<50% stenosis).

Comparative analysis of standard echocardiographic parameters revealed significant differences between MG and CG. LVEF values were within the normal range in all groups, with the highest value in the CG, followed by the one-, two- and three-vessel lesion groups. LVEF obtained by the area-length method and modified biplane Simpson's method did not differ (Table 1).

The assessment of the contractile function of the LV myocardium was also obtained by assessing the GLS and GLSR (Table 2). The comparative analysis of the LV myocardial deformation properties in the studied groups showed that less negative GLS and GLSR were found in the three-vessel CAD, followed by the two-vessel and one-vessel CAD groups, and CG. CG demonstrated more negative GLS and GLSR than all MG subgroups.

We analyzed the effect of revascularization on the GLS and found no statistically significant differences before and 48 hours after revascularization in all studied MG subgroups and CG. Thirty days after revascularization, GLS significantly showed more negative values in all MG subgroups: -18.12±0.63 versus -17.9±0.4 in one-vessel CAD, -16.13±0.71 versus -15.9±0.4 in two-vessel CAD and -13.91±1.25 versus -13.1±1.1 in three-vessel CAD. In CG with medical treatment only, GLS did not change statistically significantly but had more negative values than in the studied MG subgroups (Table 3).

Analysis of changes in LVEF after revascularization in the MG of patients with one-, two- and three-vessel CAD and in the CG after medical treatment did not reveal statistically significant dynamics (Figure 1).

Discussion

Currently, several studies have shown the advantages of GLS compared to LVEF in evaluating LV function, especially for mild systolic dysfunction.[24,25] Some studies have indicated that the use of 2D-STE aids in predicting recovery of myocardial contractile function after revascularization in CAD patients. A meta-analysis performed by Ballo et al.[26] evaluated the performance of 2D-STE for predicting the improvement of segmental LV contractile function after revascularization. The authors found that longitudinal strain (LS) and circumferential strain (CS) during low-dose dobutamine (LDD) stress provided equally high sensitivity and specificity for identifying reversible myocardial dysfunction, whereas LS and CS at rest showed lower accuracy. Wang et al.[27] evaluated LV function by 2D-STE and conventional echocardiography in 43 patients with coronary chronic total occlusion (CTO) who underwent PCI. The authors found that the GLS assessed with 2D-STE was improved as early as 1 day after CTO-PCI, whereas LVEF tended to improve up to 3 and 6 months after CTO-PCI.

In conclusion, the results indicate the absence of statistically significant changes in myocardial deformation indicators and morpho-functional parameters of the left ventricle in CCS patients 48 hours after revascularization. Thirty days after revascularization, GLS significantly improves, while LVEF remains unchanged. GLS is superior to LVEF in visualizing improvement in LV function after revascularization in patients with CCS.

Table 1.
Left Ventricular Systolic Function in CCS Patients.

Indicator	CG (n=36) [1]	One-vessel CAD (n=36) [2]	Two-vessel CAD (n=34) [3]	Three-vessel CAD (n=30) [4]	Statistics*
EDV, ml	91.3±14.7	112.7±22.7	110.8±24.4	104.6±22.3	F=7.3985 P=0.0001 P_{1-2}=0.0002 P_{1-3}=0.0011 P_{1-4}=0.0598 P_{2-3}=0.9821 P_{2-4}=0.4160 P_{3-4}=0.6504
ESV, ml	34.2±7.2	46.8±10.8	47.6±14.1	47.0±14.2	F=10.6695 P=0.0000 P_{1-2}=0.0001 P_{1-3}=0.0000 P_{1-4}=0.0001 P_{2-3}=0.9920 P_{2-4}=1.0000 P_{3-4}=0.9969
SV, ml	57.0±9.3	66.1±12.3	63.2±12.2	57.6±11.6	F=5.1933 P=0.0020 P_{1-2}=0.0051 P_{1-3}=0.1090 P_{1-4}=0.9965 P_{2-3}=0.7118 P_{2-4}=0.0160 P_{3-4}=0.2077
LVEF (area–ength), %	62.6±3.9	58.9±4.3	57.6±6.5	55.8±6.2	F=10.0022 P=0.0000 P_{1-2}=0.0184 P_{1-3}=0.0007 P_{1-4}=0.0000 P_{2-3}=0.7331 P_{2-4}=0.0875 P_{3-4}=0.5270
Biplane Simpson's LVEF (%)	63.9±3.7	57.8±5.6	57.3±8.1	55.0±8.7	F=10.9675 P=0.0000 P_{1-2}=0.0010 P_{1-3}=0.0004 P_{1-4}=0.0000 P_{2-3}=0.9895 P_{2-4}=0.3336 P_{3-4}=0.5209
Biplane Simpson's LVEDV, ml	98.6±17.3	115.3±30.4	111.8±31.7	101.8±27.3	F=2.9822 P=0.0337 P_{1-2}=0.0495 P_{1-3}=0.1823 P_{1-4}=0.9642 P_{2-3}=0.9495 P_{2-4}=0.1901 P_{3-4}=0.4596

**- one-way ANOVA with Tukey's pairwise comparisons.*

Table 2.
Assessment of LV myocardial function by 2D-STE in CCS patients.

Indicators	CG (n=36) [1]	One-vessel CAD (n=36) [2]	Two-vessel CAD (n=34) [3]	Three-vessel CAD (n=30) [4]	Statistics*
GLS, %	-21.0±0.7	-17.9±0.4	-15.9±0.4	-13.1±1.1	F=766.1250 P=0.0000 P_{1-2}=0.0000 P_{1-3}=0.0000 P_{1-4}=0.0000 P_{2-3}=0.0000 P_{2-4}=0.0000 P_{3-4}=0.0000
SR, c^{-1}	-2.1±0.1	-1.8±0.1	-1.5±0.2	-1.3±0.2	F=169.8468 P=0.0000 P_{1-2}=0.0000 P_{1-3}=0.0000 P_{1-4}=0.0000 P_{2-3}=0.0000 P_{2-4}=0.0000 P_{3-4}=0.0000

**- one-way ANOVA with Tukey's pairwise comparisons.*

Table 3.
The GLS changes in CCS patients after revascularization.

Group	Before PCI [1]	48 hours after PCI [2]	30 days after PCI [3]	*P*-value
CG	-21.0±0.70	-21.01±0.70	-21.03±0.71	NS
*One-vessel CAD	-17.9±0.4	-17.81±0.63	-18.12±0.63	0.015
*Two-vessel CAD	-15.9±0.4	-15.76±0.63	-16.13±0.71	0.024
*Three-vessel CAD	-13.1±1.1	-13.03±1.13	-13.91±1.25	0.014

**- statistically significant differences only between before and 30 days after revascularization.*

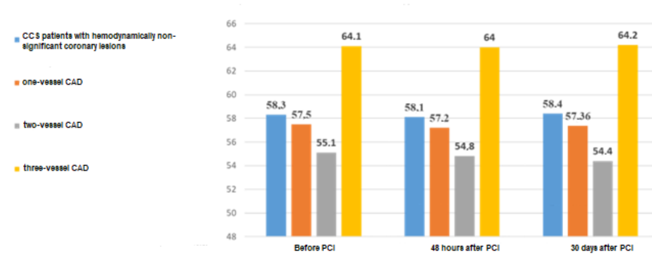

Fig. 2. *Changes in LVEF.*

Competing Interests

The authors declare that they have no competing interests.

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***Corresponding author**: Shukhratjon. N. Doniyorov. The Republican Specialized Center of Cardiology, Tashkent, Uzbekistan. E-mail: doctor.doniyorovsh.90@mail.ru*

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