Research Article
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Redistribution of Perfusion and Myocardial Function in Patients With Multivessel Disease and Myocardial Infarction With ST Segment Elevation After Recanalization of an Infarct-Associated Artery According to the Results of Single Photon Emission Computed Tomography, Synchronized With Electrocardiography

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BACKGROUND Numerous studies have shown that coronary reperfusion with primary percutaneous coronary intervention (PCI) improves outcomes in patients with ST-segment elevated myocardial infarction (STEMI). However, the question of the effect on the myocardium as a whole of an isolated intervention on an infarct-related artery in multivessel coronary disease remains incompletely studied.

AIM OF STUDY To study the features of perfusion redistribution and myocardial function using perfusion single photon emission computed tomography (SPECT) in patients with STEMI and multivessel coronary disease after isolated PCI on an infarct-related artery.

MATERIAL AND METHODS SPECT-ECG (electrocardiography) was performed in 32 patients (27 men and 5 women) with STEMI. According to the ECG results, the location of focal myocardial changes was regarded as “lower” MI in 19 (59%) patients, “anterior” in 13 patients (41%). Coronary angiography revealed a multivessel lesion of the coronary vessels in all of them. The patients were divided into groups according to the location of the infarction and the area of the lesion: group 1 — lower MI (stenting of the right coronary artery (RCA) and its branches) — 19 patients (mean age — 57.7±2.5; median — 55 [51.5; 63.5]), of which 8 with small-focal (1a) and 11 with large-focal infarction (1b); group 2 — anterior MI (stenting of the left coronary artery (LCA) and its branches) — 13 patients (mean age — 55.4±3.5; median — 54 [48.5; 62.5]), of which 5 with small-focal (2a) and 8 with large-focal infarction (2b). SPECT-ECG was performed 3 times: 1st — on days 2–3 after PCI of the infarct-related artery, 2nd — 6 days after PCI, and 3rd — 6 months after PCI.

RESULTS After RCA stenting in patients with lower MI and multivessel coronary disease, SPECT-ECG revealed a statistically significant decrease in local contractility of individual segments of the anterior septal and lateral walls (with sufficient revascularization of the RCA system) and worsening of perfusion and right ventricular (RV) volumes.
After stenting of the LCA branches in patients with anterior MI and multivessel coronary disease, a statistically significant decrease in local contractility in the basal segment of the diaphragmatic wall was observed, as well as impaired perfusion and an increase in the volume of the RV (with successful revascularization of the anterior interventricular branch). All these findings could be the result of partial steal of the blood supply to neighboring areas and myocardial remodeling after PCI in patients with multivessel coronary artery disease.

CONCLUSION 1. According to the data of single-photon emission computed tomography synchronized with electrocardiography in the early and late period of myocardial infarction after percutaneous coronary intervention in patients with multivessel coronary disease, there is a significant improvement in perfusion and function of the infarct-associated artery system.
2. Recanalization of only the left coronary artery with remaining stenoses in the right coronary artery in the long-term period can lead to an increase in the size of the cavity of the right ventricle of the heart and uneven distribution of perfusion in its myocardium. The revealed statistically significant disturbances in perfusion and local contractility of neighboring areas after percutaneous coronary intervention of an infarct-related artery may be the result of steal of the blood supply and early myocardial remodeling in multivessel disease.
3. Disturbances in perfusion and local contractility in neighboring myocardial blood supply pools after percutaneous coronary intervention of an infarct-related artery dictates the need to repeated single-photon emission computed tomography synchronized with electrocardiography as early as possible in patients with multivessel coronary disease in order to assess the redistribution of perfusion and myocardial remodeling for timely complete revascularization, preventing recurrent coronary incidents.

Keywords: myocardial infarction, multivessel coronary disease, perfusion and myocardial function, right ventricular dilatation, SPECT-ECG
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AK - aortic valve
AR - asynchronous reduction
OMB - obtuse marginal branch
DA - diagonal artery
WM - wall motion
WM_{LAD} - wall motion in individual segments of the LAD sys
WM_{RCA} - wall motion in individual segments of the RCA sys
CAD - coronary artery disease
CAG - coronary angiography
ED - end diastole
EDV - end diastolic volume
ESV - end systolic volume
LV - left ventricle
LCA - left coronary artery
MV - mitral valve
CA - circumflex artery
AMI - acute myocardial infarction
SPECT - single photon emission computed tomography
PD - perfusion in diastole
RV - right ventricle
RCA - right coronary artery
LAD - anterior interventricular branch
PS - perfusion in systole
ST - systolic thickening
TV - tricuspid valve
TBA - transluminal balloon angioplasty
EF - ejection fraction
PCI - percutaneous coronary intervention
ECG - electrocardiography
Echo-CG - echocardiography

INTRODUCTION

Numerous studies have shown that coronary reperfusion with primary percutaneous coronary intervention (PCI) improves outcomes in patients with ST-segment elevation acute myocardial infarction (AMI) [1–3]. However, the question of the effect on the entire myocardium as a whole, exerted by an isolated intervention on an infarct-related artery in multivessel coronary disease, remains not fully understood. Approximately 50% of STEMI patients have one or more obstructive coronary artery lesions remote from the infarct and not associated with infarction. Many patients with multivessel coronary lesions have foci of cardiosclerosis after previous infarctions [4–6].

This may make it difficult to understand the topography of an infarct-related lesion, and, therefore, complicate the decision on further management of the patient. Myocardial revascularization with recanalization of one coronary artery in the remaining stenotic "innocent" does not guarantee optimal blood supply to the viable myocardium [7, 8], especially when there is no reliable information about the viability of the myocardium in the territory of the recanalized infarct-associated artery (performed by PCI).

One method for visualizing viable myocardium is perfusion single photon emission computed tomography synchronized with electrocardiography (ECG) (SPECT-ECG). The European Heart Association's 2018 AMI Definition 4 states that the strength of the radionuclide method is that it is the only publicly available method for directly assessing viability, although the relatively low resolution limits the ability to detect the smallest areas of infarction. Nevertheless, SPECT-ECG provides a reliable assessment of myocardial motion, systolic thickening, and overall function [9-11].

Purpose of the study: to study the features of redistribution of perfusion and myocardial function using perfusion SPECT-ECG in patients with AMI with elevation ST and multivessel coronary disease after isolated PCI on an infarct-associated artery.

MATERIAL AND METHODS

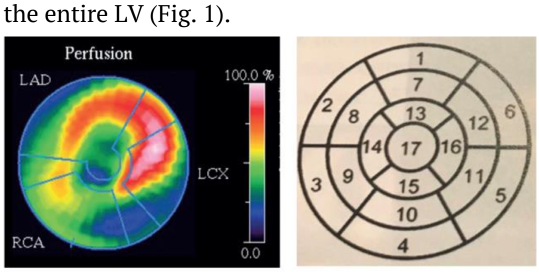
SPECT-ECG was performed in 32 patients (27 men and 5 women) with AMI with ST segment elevation.According to the ECG results, the localization of focal myocardial changes was regarded as "lower" AMI in 19 (59%) patients, "anterior" in 13 patients (41%). None of the patients had left bundle branch block with an increase in the duration of the QRS. The diagnosis was made on the basis of clinical, ECG, biochemical (determination of the activity of the MB-fraction of creatine phosphokinase in the blood, troponin level) data, taking into account the results of echocardiography (Echo-KG). ECG was performed before and after PCI, as well as 24 hours after the onset of MI, and analyzed at 5x magnification on the computer display after scanning. PCI was performed 2.5–10 hours after the onset of symptoms and/or ST changes on the ECG. Coronary angiography revealed a multivessel lesion of the coronary bed in all of them.

The patients were divided into groups according to the location of the infarction and the area of damage: group 1 — lower AMI (the right coronary artery (RCA) and its branches were stented) — 19 patients (mean age — 57.7±2.5; median — 55 [51.5; 63.5]), including 8 with small-focal infarction (1a) and 11 with large-focal infarction (1b); group 2 — anterior AMI (the left coronary artery (LCA) and its branches were stented) — 13 patients (mean age — 55.4±3.5; median — 54 [48.5; 62.5]), of which 5 with small-focal (2a) and 8 with large-focal infarction (2b).

SPECT-ECG was performed 3 times: on day 2-3 after PCI of the infarct-associated artery, 6 days after PCI and 6 months after PCI. SPECT was performed with emission tomographs Infinia II and Discovery 670 NM/CT (GE, USA) in synchronization with ECG during intravenous administration of a radiopharmaceutical ^{99m}Tc-technetrile (Diamed, Russia) at a dose of 800–900 MBq (radiation exposure 7.12–8.01 mSv).

The representative cycle consisted of 16 frames with a total collection time of 25 minutes. The use of SPECT using the domestic medical program "KARFI" made it possible to determine more than 50 parameters of perfusion and function of both the left (LV) and right ventricles (RV) of the heart, myocardial movement, its thickening in systole and general parameters of the function of both ventricles, as well as to evaluate according to the phase histogram intraventricular asynchrony in 17 LV segments both in degrees and in milliseconds (certificate of state registration No. 2014662434 dated November 24, 2014) [11].

In this study, the following indicators were analyzed: ejection fraction (EF%), end diastolic (EDV in ml) and end systolic (ESD in ml) volumes of the LV and RV. Another series of indicators reflecting changes in LV perfusion in systole (PS) and diastole (PD) in volumetric units (scores from 0 to 4) was calculated from 17 segments ("bull's eye") wall motion (WM) in mm and systolic thickening (ST) LV in percent. Additionally, the average values of WM and ST in the LAD and RCA systems was calculated, as well as the total perfusion value in points in these pools and in the entire LV (Fig. 1).



A B C

Нарушение перфузии	Баллы	Накопление %
Норма	0	80–100
Незначительное	1	65–80
Умеренное	2	50–65
Значительное	3	30–50
Отсутствие	4	менее 30

Fig. 1. Volumetric image of myocardial perfusion during single photon emission computed tomography: A — an example of inclusion of 99mTc-technetrile according to the main systems of the coronary blood supply, “bull's eye”; B — 17-segment bull's-eye model; C — scores and their correspondence to the accumulation of the radiopharmaceutical in %.

Intraventricular asynchrony in 17 segments of the left ventricle was calculated both in degrees and in milliseconds, estimating the mathematical expectation, standard deviation and range of asynchrony from the phase histogram.

Statistica software package was used to determine the statistical characteristics of the parameters (mean, median, standard deviation, error of the mean), the statistical significance of their differences according to the nonparametric Wilcoxon and Mann–Whitney tests.

RESULTS

SPECT-ECG studies performed on days 2–3, a week and 6 months after PCI showed that the parameters of EF, EDV, and ESV in both groups were within normal values [12].

In subgroup 1a (small-focal inferior AMI), a week after PCI, there was a tendency to improve perfusion in the territory of the infarct-associated artery, as well as in the LAD area. In 6 months, the parameters of perfusion and local contractility in patients of this subgroup did not change, remaining within the normal range (Table 1). Paradoxically, there was a statistically significant worsening of RV perfusion in RA with a trend towards an increase in its volumes in SP and WM compared with previous studies (myocardial remodeling?).

Table 1

Parameters of single-photon emission computed tomography synchronized with echocardiography at various times after percutaneous coronary intervention in the first group — lower myocardial infarction (n=19)

Indicators	Small focal infarction			Large focal infarction		
	2nd–3rd day	A week	6 months	2nd–3rd day	A week	6 months
Left ventricular ejection fraction, %	69.8±6.1	75.4±3.8	72.8±4.5	70.8±3.6	69.6±4.6	70.3±4.8
End diastolic volume of the left ventricle, ml	103.5±11.6	84.7±11.2	100.4±9.8	97.9±7.1	96.4±8.6	96.7±14.2
End systolic volume of the left ventricle, ml	34.9± 11.3	19.1± 2.8	27.8± 5.3	30.3± 5.2	31.5± 6.1	32.2± 9.8
Perfusion in diastole of the left ventricle, points	9.8±1.2	8.0±1.9	10.4±1.1	9.5±1.4	7.9±1.0	9.8±1.2
Perfusion in left ventricular systole, points	12.8±1.3	11.7±2.5	12.8±1.3	12.5±1.5	11.9±1.1	11.6±1.5
Asynchronous reduction, ms	97.1±15.4	106.1±16.1	81.2±13.8	61.1±6.8	63.3±10.6	80.1±12.9
Ejection fraction of the right ventricle, %	34.9±4.1	30.3±1.5	34.4±2.5	35.0±2.7	39.7±3.3	32.7±1.6
End diastolic volume of the right ventricle, ml	123.1±17.6*	107.9±13.0	153.6±27.5*	116.8±9.0	104.9±10.4	114.8±12.9
End systolic volume of the right ventricle, ml	81.0±12.8	75.3±8.8	106.2±18.0	75.7±6.9	62.7±6.2	76.3±7.7
Perfusion in diastole of the right ventricle, points	6.9±1.4	7.3±1.2	7.8±0.7	9.5±1.1	8.6±0.8	10.0±1.0
Perfusion in the systole of the right ventricle, points	5.3±0.9*	6.4±0.9	9.4±1.0*	10.1±1.0*	8.7±1.0*	11.3±1.0
Wall movement in individual segments of the LAD areal, mm	12.5±2.0	12.9±2.0	13.0±1.6	12.8±0.5	12.8±0.9	13.3±1.4
5th segment	16.8±2.1*			12.6±0.6 *		
6th segment	15.3±1.5*			12.0±1.2 *		
Wall movement in the RCA area, mm	9.6±1.7	9.2±1.3	11.0±1.8	9.5±1.0	10.0±1.3	11.2±2.0
10th segment				9.6±1.1		13.5±2.3
15th segment				10.0±1.3		12.6±2.2
Systolic thickening in the LAD area, %	49.6±6.3	51.7±6.0	52.0±4.5	55.4±2.4	54.6±2.9	53.9±2.6
1st segment				45.7±3.4*	42.1±2.4*	47.6±1.9
2nd segment				46.9±3.2	43.4±3.3	43.9±3.2
5th segment				44.7±1.7*	38.6±3.4*	42.4±5.6

8th segment				54.1±3.3	49.6±2.9	49.7±4.7
Systolic thickening in the RCA area, %	42.6±6.4	45.5±4.3	42.3±5.2	43.9±2.8	46.7±3.9	45.7±4.1
Perfusion in diastole in the LAD area, score	3.1±1.0*	1.9±1.1*	3.6±1.9	1.6±0.3	2.0±0.4	1.9±0.5
Perfusion in diastole in the RCA area, score	6.0±1.0	5.6±1.1	7.2±1.5	5.9±0.7	4.2±0.7	5.3±1.2

Notes: * - $p<0.05$, statistically significant difference between the indicators (2–3 days/week or 2–3 days/6 months or 1a and 1b)

In subgroup 1b (large-focal inferior AMI), a week after PCI, there was a statistically significant improvement in the perfusion of the lower LV wall in the WM and local contractility (ST) of the apical segment, and after 6 months — a statistically significant improvement in the local contractility of the lower wall (WM 10 and 15 -th segments).

These changes indicated an improvement in myocardial function after endovascular intervention in the territory of the infarct-associated artery (Table 1). However, a statistically significant decrease in local contractility of individual segments of the anterior and lateral walls (ST in the 1st and 5th segments) and a trend towards a decrease in ST in the anterior septal region (segments 2 and 8) after a week attracted attention as a possible result of a partial steal in neighboring pools. Restoration of these parameters was noted during perfusion SPECT performed only 6 months after PCI.

When comparing the subgroups of the lower small-focal and large-focal infarcts (1a and 1b), 2-e-3rd day with small-focal AMI, there were statistically significantly better indicators of perfusion of the RV in the PS, as well as indicators of the movement of the lateral wall (WM in segments 5 and 6). Between other indicators of perfusion and function, with the exception of a decrease in local contractility in large-focal AMI in separate segments of the adjacent basin (LAD), no statistically significant difference was observed in the two subgroups.

In subgroup 2a (small-focal anterior MI), a week after PCI, there was a trend towards an increase in mean wall motion (WM) in the segments of the infarct-related artery with a statistically significant increase in the 6th segment and a trend towards an increase in ST in the 13th segment of the anterior wall, which reflects the positive dynamics in the LAD area as a result of PCI. However, there was a statistically significant decrease in RV perfusion in PD and local contractility (WM) in the basal segment of the RCA (segment 4), which can be explained by partial stealing of the blood supply after PCI of the neighboring pool in patients with multivessel coronary artery disease and remodeling of myocardial function (Table 2).

Table 2

Parameters of single-photon emission computed tomography synchronized with echocardiography at various times after percutaneous coronary intervention in the second group — anterior myocardial infarction (n=13)

Indicators	Small focal infarction			Large focal infarction		
	2nd–3rd day	A week	6 months	2nd–3rd day	A week	6 months
Left ventricular ejection fraction, %	73.2±5.4	75.54.8	77±4.8	61±2.2	68±3.8	68.6±5.1
End diastolic volume of the left ventricle, ml	96.2±21.1	103±12.8	96.2±12.8	106.8±3.6	106.3±11.1	107.1±12.4
End systolic volume of the left ventricle, ml	28.4±9.5	27.3±7.6	24.2±7.6	40.9±2.8	35.3±7.3	36.3±9.5
Perfusion in diastole of the left ventricle, score	**6.6±1.9***	**7.8±1.0**	**5.0±1.0***	**13.1±1.0***	11.2±1.4	**10.6±2.4***
Perfusion in left ventricular systole, score	11.6±2	12.0±1.9	9.0±1.9	14.8±1.4	10.7±2.6	12.6±2.5
Asynchronous reduction, ms	84.6±20.2	89±13.1	73.2±13.1	109.3±3.6	102.8±7.6	80.1±17.7
Ejection fraction of the right ventricle, %	37.8±1.7	36.5±2.5	34.6±2.5	34.7±1.6	33.0±2.8	32.3±2.7
End diastolic volume of the right ventricle, ml	**124.8±18.6***	119±14.5	**153.8±14.5***	**108.0±3.8***	121.3±24.8	**158.5±21***
End systolic volume of the right ventricle, ml	79.0±10.0	75.3±10.7	100.2±10.7	**71.8±3.3***	81.8±19.6	**110.4±18.7***
Perfusion in diastole of the right ventricle, score	**5.2±1.9***	**7.8±1.4***	**7.6±1.4***	**5.6±1.2***	4.7±0.7	**9.0±1.5***
Perfusion in the systole of the right ventricle, score	8.2±1.2	7.0±1.2	8.4±1.2	7.0±1.1	5.2±0.6	8.4±1.1

Wall movement in individual segments of the LAD area, mm	13.3±2.7	14±1.1	15.1±1.1	**8.3±1.0***	10.8±0.7	13.5±1.4 *
2nd segment	**11.2±1.3***			**7.5±0.8***		
6th segment	**11.4±0.9***	**14.3±1.0***	**16.2±1.0***			
7th segment	**12.8±1.8***		**15.6±1.7***	**9.6±1.3***	**15.2±0.9***	**15.7±1.8***
8th segment				**4.6±1.0***		**9.1±1.6***
12th segment	**13.2±1.7***		**16.8±0.8***			
14th segment	**12.2±3.1***			**5.0±1.2***		
Wall movement in the RCA area, mm	12.2±1.9	13.8±1.6	13.9±1.6	9.0±1.3	10.0±0.8	12.0±1.6
Systolic thickening in the LAD area, %	54.0±3.2	54.7±1.8	59.7±1.8	37.7±1.3	50.3±2.8	45.0±8.0
2nd segment				**29.9±1.9***	**46.2±3.7***	
7th segment	**51.2±5.2***		**61±2.4***	**37.5±1.6***	**58.0±4.3***	
8th segment				**35.3±1.7***	**49.5±5.0***	
11th segment				**51.6±2.7***	**61.7±3.7***	
12th segment				**42.0±1.6***	**56.0±4.6***	
13th segment	**57.0±3.7***			**36.1±1.8***		
14th segment				**40.1±1.4***	**53.0±5.4***	
16th segment				**44.0±2.2***	**56.8±4.4***	
17th segment	**66.6±3.1***			**44.1±1.7***		
Systolic thickening in the RCA area, %	54.1±3.5	49.7±3.8	54.3±3.8	42.1±1.9	48.7±5.1	43.1±4.2
3rd segment	**48.6±3.6***	**41.8±5.2***		**34.1±2.3***		
4th segment	**49.8±4.7***	**40.8±3.9***		**38.0±2.0***		
Perfusion in diastole in the LAD area, score	3.2±0.7	3.0±1.2	2.2±1.2	7.1±1.1	6.0±1.0	5.0±1.2
7th segment				**0.63±0.06***	**0.17±0.02***	
8th segment				**0.75±0.04***	**0.17±0.02***	

Note: * - $p<0.05$, significant difference between the indicators (2–3 days/week or 2–3 days/6 months or 2a and 2b)

After 6 months, patients in this subgroup showed a statistically significant increase in local myocardial contractility (WM and ST) in the area of the stented infarct-associated artery (6^{th}, 7^{th}, and 12^{th} segments) — a positive trend in general. The negative moment of the function was an increase in the diastolic volume of the pancreas (Table 2).

In subgroup 2b (large-focal anterior AMI), one week after PCI, there was a statistically significant improvement in perfusion in the end-diastole (ED) of the anterior septal region (7^{th}, 8^{th} segments) and myocardial function (WM and SU) in the pool of the stented infarct-associated artery (as in most segments - 2^{nd}, 5^{th}, 7^{th}, 8^{th}, 11^{th}, 14^{th}, 16^{th}, and on average in the LAD area), which reflects the restoration of perfusion and function after PCI in a week. After 6 months in this subgroup, a further improvement in perfusion and function in the LAD area was observed, but again a negative trend was noted in relation to RV function: a statistically significant increase in volumes (EDV and ESV) of the RV, as well as a deterioration in its perfusion in diastole (PD RV).

When comparing the subgroups of anterior small- focal and large-focal infarcts (2a and 2b), on the 2^{nd}–3^{rd} day with small-focal AMI, perfusion indicators (on average) and local contractility indicators (WM and ST) were statistically significantly better in most segments of the LAD area.

In small-focal AMI (both inferior and anterior), the recovery of perfusion and function as a result of PCI was more significant.

The following clinical example demonstrates the redistribution of perfusion and myocardial function after stenting of an infarct-related artery.

Clinical example

A 39-year-old male patient G. was admitted on Nov 27, 2021 with a diagnosis of coronary artery disease (CAD). Repeated large-focal AMI of the anterior wall, septum and apex of the left ventricle with ST segment elevation dated Nov 27, 2021. Postinfarction cardiosclerosis. Atherosclerosis of the aorta and coronary arteries. Hypertension III st., 2nd st., risk of cardiovascular complications 4. Circulatory failure 2A st. Concomitant diseases: Peptic ulcer of the stomach and duodenal ulcer. Obesity 2nd st. (body mass index 38.5).

ECG dated Nov 27, 2021: heart rate 78 bpm, sinus rhythm, deviation of the electrical axis of the heart to the left. Focal changes in the myocardium of the anterior septal region with ST segment elevation.

Coronary angiography (CAG) dated Nov 27, 2021: The right type of coronary circulation. The trunk of the LCA is developed, not changed. LAD (anterior interventricular branch): occlusion in the middle third; antegrade blood flow TIMI 0, no collateral replacement. Diagonal branch (DA) — uneven contours, without hemodynamically significant stenoses. The circumflex branch (CA) has uneven contours, 60% stenosis in the proximal third. Obtuse marginal branch (OMB) — rough contours, 75% stenosis in the proximal third, 75% stenosis at the mouth of the second order branch. RCA has uneven contours, occlusion in the middle third, the distal portion is filled along intra and intersystem collaterals. PCI on the infarct-associated artery: transluminal balloon angioplasty (TBA), LAD stenting (2 DES).

Echo-CG dated Nov 29, 2021: The chambers of the heart are not dilated. Global LV systolic function is preserved — EF 57% (according to Simpson). Hypokinesis of the anterior and anterior septal segments at the middle and apical levels. Moderate asymmetric LV myocardial hypertrophy. Atherosclerotic changes in the aorta, aortic valve (AV) and mitral valve (MV). MV regurgitation I st., Tricuspid valve (TC) 1.5 st., AV 0–1 st. LV diastolic function is not impaired. There are no signs of pulmonary hypertension (mean pulmonary artery pressure (MPAP) 30 mm). Pericardium without features.

On the 7th day (December 04, 21), the patient underwent perfusion myocardial SPECT (Fig. 2), which determined a diffusely uneven distribution of perfusion without significant focal changes.

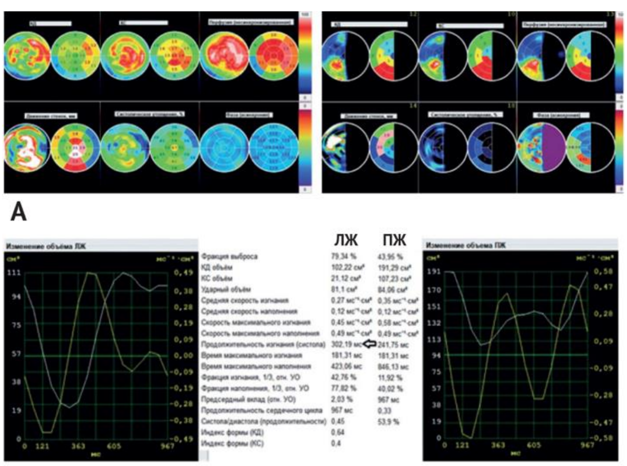


Fig. 2. Results of single-photon emission computed tomography synchronized with echocardiography after placement of 2 stents in the anterior interventricular branch: A - bull's-eye with changes in perfusion, wall motion, and systolic thickening by segments; B - flow-volume curves with quantitative parameters of the function of the left and right ventricles

LV EF is normal. Foci of hypokinesis in the lateral, anterior septal areas and interventricular septum. diastolic dysfunction. Severe intraventricular asynchrony up to 500 ms on 9 segments. Enlarged RV with RV EF 44%.

The patient was discharged from the hospital in a satisfactory condition. Despite taking medications (efient, cardiomagnyl, verospiron, bisoprolol, prestarium, rosuvastatin), chest pains persisted on Dec 23, 2021, and he was hospitalized with a diagnosis of acute coronary syndrome. CAG on December 23, 21 revealed 75% stenosis in the distal third of the RCA. Previously placed stents without signs of thrombosis and restenosis. The other branches were unchanged compared to Nov 27, 2021. PC, TBA and stenting of the coronary arteries: the distal third of the RCA, the proximal third of the OMB, the distal third of the LAD (total 3 stents).

The ECG dated Dec 24, 2021 showed no changes compared to the ECG dated Nov 27, 2021 (Fig. 3).

Fig. 3. The result of electrocardiography dated Dec 24, 2021

Echo-CG dated 23 Dec, 2021. EF 63% (according to Simpson). Local systolic function is not disturbed. Slight asymmetric hypertrophy of the LV myocardium. Atherosclerotic changes in the aorta, AV and MV. MV regurgitation I st., TV 1 st. LV diastolic function is not impaired. There are no signs of pulmonary hypertension (SPPA - 25 mm). Pericardium without features.

According to the data of myocardial perfusion SPECT dated December 25, 2021 (Fig. 4), compared with the results dated December 4, 2021, there was a clear restoration of the function of the lateral and posterolateral walls of the LV, an improvement in the diastolic function of both ventricles and an increase in their size in diastole. LV EF=67%. EF RV=21%. Interventricular asynchrony 120 ms. Expressed positive dynamics.

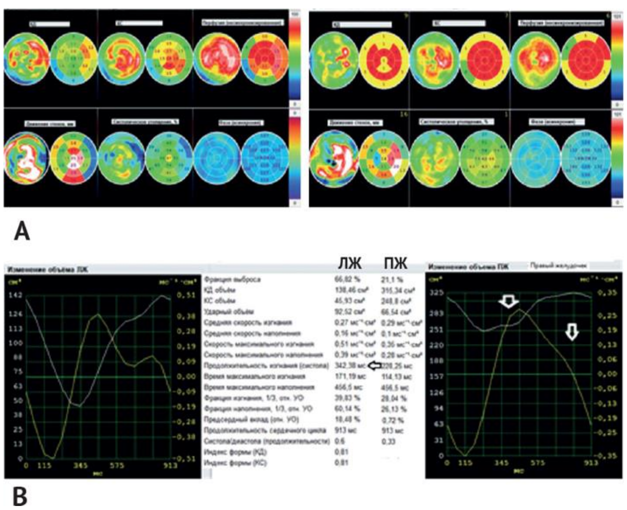


Fig. 4. Results of single-photon emission computed tomography synchronized with electrocardiography after installation of 3 stents (right coronary artery, obtuse marginal branch, and anterior interventricular branch): A — bull's-eye with changes in perfusion, wall motion, and systolic thickening by segments; B — flow-volume curves with quantitative parameters of the function of the left and right ventricles

On March 23, 2022, against the background of complete well-being, the patient underwent outpatient myocardial perfusion SPECT, synchronized with ECG, with a stress test (veloergometry) (Fig. 5), in which, at the peak of threshold physical activity, the non-enlarged LV myocardium was visualized with a uniform distribution of perfusion, a zone of hypokinesis in basal sections of the anterior septal wall and diastolic dysfunction by the type of restriction. LV EF=74% (normal). The RV is not enlarged, foci of intraventricular pathological asynchrony up to 496 ms in 9 segments, diastolic dysfunction as a violation of elasticity, RV EF=46%. Interventricular asynchrony 54 ms.

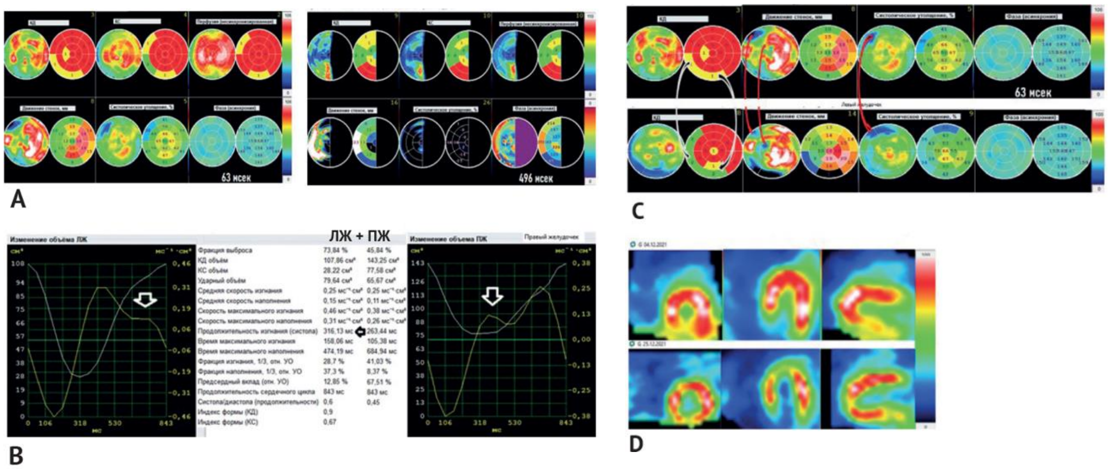


Fig. 5. Results of single-photon emission computed tomography synchronized with electrocardiography with a stress test 3 months after the installation of five stents (right coronary artery, obtuse marginal branch and anterior interventricular branch): A — bull's eye with changes in perfusion, wall motion and systolic thickening by segments; B — flow-volume curves with quantitative parameters of left and right ventricular function; C — comparison of changes in perfusion and left ventricular function at rest and at the peak of physical activity; D — comparison of myocardial sections in 3 planes dated Dec 4, 2021 and Dec 25, 2021 with significant improvement in perfusion of the lower wall of the left ventricle

Conclusion. There were no significant focal changes in the myocardium at the peak of threshold physical activity. The movement of the lateral wall of the pancreas compared to 25 Dec, 2021 has improved significantly. Reducing the size of the cavity of the LV and RV, the growth of EF of the LV and RV. Reducing interventricular asynchrony. Signs of diffuse changes in the coronary bed (in the LAD area). There were no indications for CAG.

The given clinical example clearly showed a pronounced positive effect on perfusion and myocardial function of both ventricles after stenting of several branches of the coronary arteries in case of multivessel lesion, registered using the radionuclide method. It can be assumed that the installation of stents in a short time after a heart attack made it possible to avoid further undesirable coronary events in this patient.

THE DISCUSSION OF THE RESULTS

Literature evidence suggests that in patients with ST-segment elevation MI (STEMI), PCI on an infarct-related artery reduces the risk of CV death. Emergency revascularization for AMI, especially in patients with cardiogenic shock, should be simple and short in time. Studies have shown that among patients with coronary artery disease and STEMI, complete revascularization after PCI occurs when one "guilty" vessel is damaged with the intact state of neighboring branches, which is reflected in a reduced risk of AMI and cardiovascular death [2, 3]. In recent European guidelines [1], indications for multivessel PCI have been reduced to class III. However, in a number of literary sources (S.R. Mehta et al., 2019, Ch-Ho Lee et al., 2020) noted that single-vessel PCI in multivessel myocardial disease does not lead to complete myocardial revascularization, and the risk of cardiovascular death increases. Obviously, in case of multivessel coronary disease and recanalization of only the infarct-associated artery in patients with AMI with ST- segment elevation, it is important to know how regional perfusion and myocardial function can be redistributed after stenting.

In our study, after RCA stenting in patients with inferior AMI and multivessel coronary disease, according to SPECT-ECG data, a statistically significant decrease in local contractility of individual segments of the anterior septal and lateral walls (with sufficient revascularization of the RCA area) and deterioration in perfusion and prostate volumes were revealed. After stenting of LCA branches in patients with anterior AMI and multivessel coronary disease, a statistically significant decrease in local contractility in the basal segment of the diaphragmatic wall was noted, as well as impaired perfusion and an increase in RV volumes (with successful LAD revascularization). All these findings could be the result of partial stealing of the blood supply to neighboring areas and myocardial remodeling after PCI in patients with multivessel coronary artery disease.

Thus, the results of our study showed that in the case of isolated stenting of the infarct-related artery in patients with multivessel coronary disease in the early and late periods after AMI, perfusion and functions of neighboring areas of the LV and RV myocardium are redistributed to one degree or another. This dictates the need for additional performance of perfusion SPECT synchronized with ECG for timely endovascular interventions and prevention of possible coronary events in the pool of stenotic, but not associated with AMI, branches of the coronary arteries in the immediate post-infarction period (1.5–2 months after AMI), without waiting for the next coronal events.

CONCLUSIONS

1. According to the data of single-photon emission computed tomography synchronized with electrocardiography, in the early and late period of acute myocardial infarction after percutaneous coronary intervention in patients with multivessel coronary disease, there is a statistically significant improvement in perfusion and function of the infarct-associated artery basin.

2. Recanalization of only the left coronary artery with remaining stenoses in the right coronary artery in the long-term period can lead to an increase in the size of the cavity of the right ventricle of the heart and an uneven distribution of perfusion in its myocardium. The revealed statistically significant disturbances in perfusion and local contractility of neighboring areas after percutaneous coronary intervention of an infarct-related artery may be the result of stealing of the blood supply and early myocardial remodeling in multivessel disease.

3. Disturbances in perfusion and local contractility in neighboring myocardial blood supply pools after percutaneous coronary intervention of an infarct-related artery dictate the need to repeat, as early as possible, single-photon emission computed tomography synchronized with electrocardiography in patients with multivessel coronary disease in order to assess the redistribution perfusion and myocardial remodeling for timely complete revascularization, preventing recurrent coronary incidents.

REFERENCES

1. Neumann F-J, Sousa-Uva M, Ahlsson A, Alfonso F, Banning AP, Benedetto U, et al. 2018 ESC/EACTS Guidelines on myocardial revascularization. Eur Heart J. 2019;40(2):87–165. PMID: 30165437 https://doi.org/10.1093/eurheartj/ehy394
2. Thiele H, Akin I, Sandri M, Fuernau G, de Waha S, Meyer-Saraei R, et al. PCI strategies in patients with acute myocardial infarction and cardiogenic shock. N Engl J Med. 2017;377(25):2419–2432. PMID: 29083953 https://doi.org/10.1056/NEJMoa1710261
3. Adriaenssens T, Van de Werf F. Is Culprit-Lesion-Only PCI in Cardiogenic Shock Still Better at 1 Year? N Engl J Med. 2018;379(18):1775–1776. PMID: 30380397 https://doi.org/10.1056/NEJMe1810971
4. Weil BR, Canty JM. Coronary Blood Flow and Myocardial Ischemia. In: Rosendorff C. (ed.) Essential Cardiology. 3rd ed. New York, NY: Springer; 2013. Ch.34:387–403. https://doi.org/10.1007/978-1-4614-6705-2
5. Johnson NP, Kirkeeide RL, Gould KL. Coronary Steal: Mechanisms of a Misnomer. J Am Heart Assoc. 2021;10(13):e021000. PMID: 34187172 https://doi.org/10.1161/JAHA.121.021000
6. Gould KL, Gewirtz H, Narula J. Coronary blood flow and myocardial ischemia. In: Fuster V, Harrington RA, Narula J, Eapen ZJ. (eds.) Hurst's the heart. 14th ed. New York: McGraw Hill; 2017:893–922.
7. Mehta SR, Wood DA, Storey RF, Mehran R, Bainey KR, Nguyen H, et al. Complete Revascularization with Multivessel PCI for Myocardial Infarction. N Engl J Med. 2019;38(15):1411–1421. https://doi.org/10.1056/NEJMoa1907775
8. Lee C, Chong S, Hsueh S, Chung W-J, Cheng C-I. Residual Right Coronary Artery Stenosis after Left Main Coronary Artery Intervention Increased the 30-Day Cardiovascular Death and 3-Year Right Coronary Artery Revascularization Rate. J Interv Cardiol. 2020; 2020:1–8. https://doi.org/10.1155/2020/4587414
9. Hamalainen H, Corovai A, Laitinen J, Laitinen TM, Hedman M, Hedman A, et al. Myocardial ischemia and previous infarction contribute to left ventricular dyssynchrony in patients with coronary artery disease. J Nucl Cardiol. 2021;28(6):3010–3020. PMID: 32869165 https://doi.org/10.1007/s12350-020-02316-9
10. Thygesen K, Alpert JS, Jaffe AS, Chaitman BR, Bax JJ, Morrow DA, et al. Fourth Universal Definition of Myocardial Infarction. J Am Coll Cardiol. 2018;72(18):2231–2264. PMID: 30153967 https://doi.org/10.1016/j.jacc.2018.08.1038
11. Kotina E, Ostroumov E, Ploskikh V. Left and Right Ventricular Phase Analysis of Gated SPECT Myocardial Perfusion. Eur J Nucl Med Mol Imaging. 2012;39(Suppl 2):S213. https://doi.org/10.1007/s00259-012-2221-x
12. Lishmanov YuB, Chernov VI (eds.). National'noe leadership po radionuclide diagnostics.In 2 vol. Vol 2. Tomsk: STT Publ.; 2010. (In Russ.)

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