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Comparative assessment of the diagnostic value of echocardiography and magnetic resonance imaging in determining myocardial viability

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Aim. To compare myocardial imaging methods in patients with complicated coronary artery disease with significantly decreased myocardial contractility.

Material and methods. This single-center retrospective study included 109 patients with complicated coronary artery disease who underwent surgical treatment between 2014 and 2020. All patients had indications for delayed contrast-enhanced cardiac magnetic resonance imaging (MRI) in order to determine myocardial viability due to a pronounced decrease in left ventricular contractility according to echocardiography (ejection fraction (EF) ≤30%).

Results. Impairment of local contractility according to MRI and echocardiography significantly correlates with depth of contrast accumulation (p=0,0000000018 and p=0,0000034, respectively). Delayed contrast-enhanced cardiac MRI with cine sequences allows to determine higher number of impaired contractility cases compared with echocardiography (p=0,000006).

Conclusion. MRI with cine sequence allowed to determine higher number of impaired contractility cases compared with echocardiography. Delayed contrast-enhanced MRI is a reliably more sensitive method than electrocardiography in detecting left ventricular scarring. The depth of contrast agent accumulation correlates with local contractility impairment detected by echocardiography and delayed contrast-enhanced cardiac MRI.

Keywords: cardiac MRI, coronary artery disease, myocardial viability, heart failure, ischemic cardiomyopathy, myocardial dysfunction.

Relationships and Activities: none.

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Assessment of a viable myocardium in patients with coronary artery disease (CAD) complications is an important aspect in considering a direct myocardial revascularization [1]. Evaluation of the hibernating myocardium in the system of involved arteries depends on the accuracy of diagnostic methods [2].

Randomized studies to assess myocardial viability and its effect on prognosis were performed only using positron emission tomography. Delayed-enhancement magnetic resonance imaging (DE-MRI) allows to determine not only the presence of myocardial damage, as isotopic techniques, but also provides information about the depth of involvement [3]. These data suggest the need for new studies in order to determine the effectiveness of DE-MRI in identifying viable myocardium, as well as to establish the MRI role in the algorithm for selecting patients for coronary artery bypass grafting and assessing the prognosis of patients after the intervention [4, 5].

The aim of the study was to compare myocardial imaging methods in patients with CAD complications with significantly decreased myocardial contractility.

Material and methods

The retrospective study included 109 patients with CAD complications, who in the period from 2014 to 2020 underwent echocardiography before direct myocardial revascularization at the Almazov National Medical Research Center and had indications (ejection fraction (EF) ⩽30%) for cardiac MRI to determine the proportion of viable myocardium. This study was performed in accordance with the Good Clinical Practice standards. All patients signed informed consent. There were following exclusion criteria: acute myocardial infarction (MI) <30 days old, LV aneurysm requiring surgical intervention, heart valve disease. The initial clinical state of the patients is shown in Table 1.

According to electrocardiography (ECG), 66 (60,5%) of the subjects had signs of prior anterior wall MI, 11 (10,1%) — LV lateral wall MI, 17 (15,8%) — inferior posterior wall MI, 15 (13,7%) — no ECG signs and a history of MI. Direct coronary angiography revealed an involvement of three arteries in 97 (88,9%) patients and two arteries in 12 (11,1%) patients. In 82 (75,2%) patients, left main coronary artery stenosis >50% was revealed.

All patients underwent 12-lead ECG at rest. Grade III-V premature ventricular contraction according to B. Lown, M. Wolf, modified by M. Ryan (1975) was found in 69 (63,3%) patients.

Echocardiography was performed before the operation, on the day of the operation, before and after the artificial circulation, on the 7th day after the intervention, as well as in the long-term follow-up period using the Vivid 9 system (General Electric Corp., USA). The echocardiography protocol included the assessment of cardiac sizes and volumes, ventricular contractility, as well as heart valves' function.

DE-MRI was performed on a MAGNETOM Trio system (Siemens, Germany) with a magnetic flux density of 3 Tesla. DE-MRI was performed twice as follows: before surgery and after coronary artery bypass grafting in the long-term follow-up. The contrast agent used was gadolinium-containing gadobutrol. The study protocol assessed the cardiac sizes and volumes, global and segmental LV contractility, and contrast accumulation depth in different LV segments. Delayed contrast enhancement was assessed by the depth of contrast accumulation: from 1 to 24% of the wall thickness; from 25 to 49%; from 50 to 74%; from 75 to 100% [3]. The localization of scarring and local contractility disorders was assessed using a standard 17-segment model adapted by M. D. Cerqueira, 2002 [6].

The LV sizes, volumes and contractile function are presented according to echocardiography and cardiac MRI are presented in Table 2.

All patients with LV dilatation with a severe contractility decrease had indications for myocardial viability assessment. Stress tests for this group of patients are contraindicated due to absolute and relative contraindications: left main coronary artery stenosis, heart failure with a high functional class, high grade premature beats.

Statistical analysis of the data was carried out using the Statistica v. 10.0. (StatSoft Inc., USA). Results are presented as arithmetic mean and standard deviation (M±SD) for continuous variables. Categorical variables are presented as units and percentages (proportion). The significance

Table 1

Characteristics of the study group of patients

Parameters		Patients
Sex, n (%)	men women	98 (89,9%) 11 (10,1%)
Age, years		60,8±9,6
Angina FC, median [Q25;Q75]		3 [2;3]
HF FC (NYHA), median [Q25;Q75]		3 [3;3]

Note: data are presented as M±σ and median, 25th and 75th quartiles.

Abbreviations: HF — heart failure, FC — functional class, NYHA — New York Heart Association Functional Classification.

Table 2

Characteristics of LV function in the studied patients

	According to cardiac MRI	According to echocardiography	
		Simpson	Teicholz
EDV LV, ml	258,9±61,7	251,2±45,2	228,3±46,0
ESV LV, ml	180,7±62,6	181,3±43,8	149,5±41,6
LVEF, %	27,7±6,0	26,5±3,6	34,0±6,5

Note: data are presented as M±σ.

Abbreviations: EDV — end diastolic volume, ESV — end systolic volume, LV — left ventricle, MRI — magnetic resonance imaging, EF — ejection fraction.

Table 3

Distribution of patients depending on DE-MRI data

Contrast accumulation depth (%)	n, (%)
0	17 (15,6%)
<50%	30 (27,5%)
50-74%	40 (36,7%)
75-100%	22 (20,2%)

Table 4

The number of segments with impaired local contractility depending on diagnostic method used

Type of impaired local contractility	Diagnostic method		Discordance number	p
	Cardiac MRI[1]	Echocardiography[2]		
Moderate hypokinesis	142	321	179	$p^{1,2}$=0,000006
Severe hypokinesis	904	1108	204	
Akinesis	655	407	248	
Dyskinesis	45	8	37	

Note: p — Pearson χ^2 test.

Abbreviation: MRI — magnetic resonance imaging.

of differences between the groups was calculated using the chi-squared test (χ^2). Differences were considered significant at p<0,05.

Results

A detailed analysis of the ECG and DE-MRI data for LV fibrosis was carried out.

It was found that among patients who underwent Q-wave myocardial infarction according to ECG data, transmural scar was defined only in 20,2%. In 15,6% of cases, myocardial accumulation of contrast agent was not detected, and in 27,5% of patients, accumulation of contrast was found with a depth of up to 50% (Table 3).

MRI with cine sequence allowed to determine a higher number of impaired contractility cases compared with echocardiography (Table 4).

A significant relationship was established between the depth of myocardial damage and local contractility impairment according to echocardiography and MRI data (Tables 5, 6). With the accumulation of contrast by more than 50% of myocardial thickness, the number of hypokinetic segments decreases and the number of akinetic segments increases.

Pearson's χ^2 test discarded the hypothesis of the independence of local contractility disorders according to MRI and contrast accumulation depth according to MRI. Consequently, MRI local contractility abnormalities significantly depend on the MRI transmurality index (p=0,0000000018) (Table 5).

Pearson χ^2 test discarded the hypothesis of the independence of local contractility disorders according to echocardiography and contrast accumulation depth according to DE-MRI. Consequently, local contractility disorders according echocardiography significantly depend on the transmurality index according to MRI (p=0,0000034) (Table 6).

Pearson's χ^2 test discarded the hypothesis of the absence of difference between local contractility disorders according to echocardiography and MRI data, depending on the contrast accumulation depth according to MRI. Consequently, local contractility impairment according to echocardiography significantly depends on the transmurality index according to MRI (p<0,001) (Table 7).

Clinical case: Thirty-two-year-old male patient with a coronary artery disease, unstable (new-onset) angina pectoris (09.06.2016).

ECG: Sinus rhythm. Postinfarction abnormalities were not found.

Echocardiography: end-diastolic volume — 186 ml, end-systolic volume — 131 ml. LV ejection fraction (Simpson's method) — 29,5%. Diffuse hypokinesia.

Table 5

Contingency table of the lesion depth (cardiac MRI) and local contractility impairments (cardiac MRI). An example of one of the segments

Type of impaired local contractility according to MRI	Depth of contrast agent accumulation			p
	0	<50%	>50%	p=0,0000000018
Moderate hypokinesis	207	25	13	
Severe hypokinesis	695	137	69	
Akinesis	113	145	417	
Dyskinesis	3	11	18	

Note: p — Pearson χ^2 test.
Abbreviation: MRI — magnetic resonance imaging.

Table 6

Contingency table of the lesion depth (cardiac MRI) and local contractility impairments (echocardiography). An example of one of the segments

Type of impaired local contractility according to echocardiography	Depth of contrast agent accumulation			p
	0	<50%	>50%	p=0,0000034
Moderate hypokinesis	79	13	30	
Severe hypokinesis	841	174	270	
Akinesis	90	134	213	
Dyskinesis	1	4	4	

Note: p — Pearson χ^2 test.

Table 7

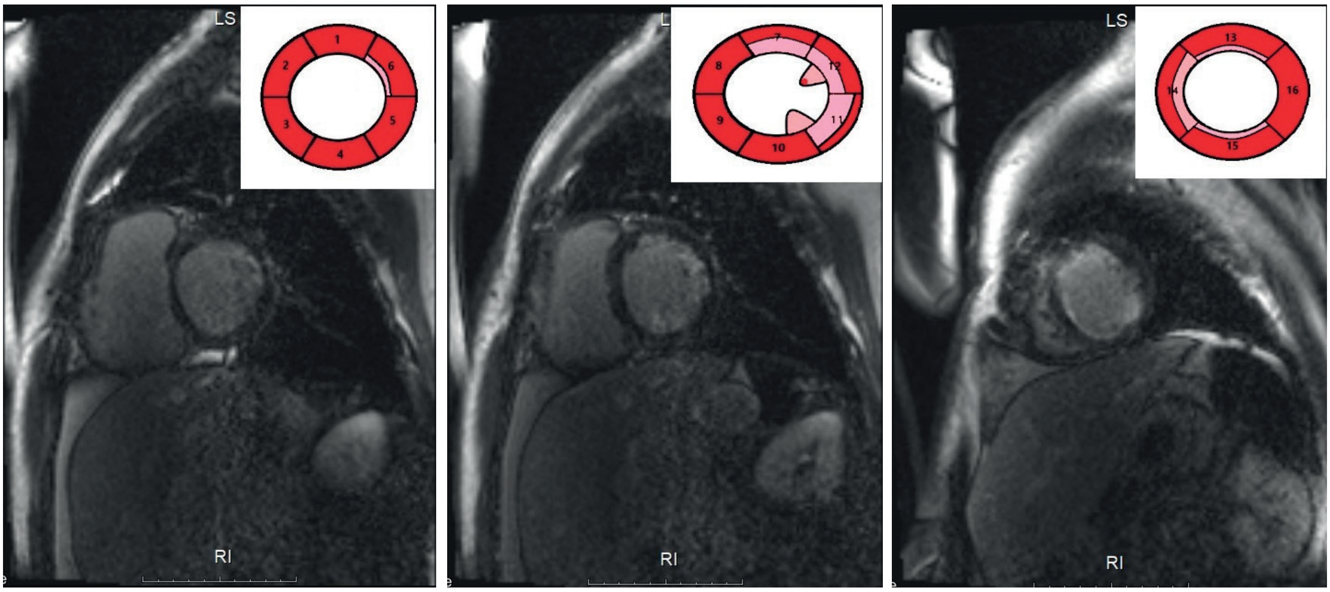
Contingency table of the lesion depth (cardiac MRI) and local contractility impairments according to cardiac MRI and echocardiography. An example of one of the segments

Summary Table: Expected Frequencies (Инд трасмурал и наруш сократимости отдельно
Marked cells have counts > 10
Pearson Chi-square: 327,535, df=28, p=0,00000

НЛС МРТ без 0 15	НЛС ЭХО 15	НЛС без 0 15 1	НЛС без 0 15 2	НЛС без 0 15 3	Row Totals
1	0	0,015487	0,15680	0,03872	0,2110
1	1	0,108408	1,09763	0,27102	1,4771
1	2	1,254440	12,70120	3,13610	17,0917
1	3	0,309738	3,13610	0,77435	4,2202
Total		1,688073	17,09174	4,22018	23,0000
2	0	0,035687	0,36133	0,08922	0,4862
2	1	0,249811	2,52933	0,62453	3,4037
2	2	2,890666	29,26799	7,22666	39,3853
2	3	0,713745	7,22666	1,78436	9,7248
Total		3,889908	39,38532	9,72477	53,0000
3	0	0,022220	0,22498	0,05555	0,3028
3	1	0,155542	1,57487	0,38886	2,1193
3	2	1,799848	18,22347	4,49962	24,5229
3	3	0,444407	4,49962	1,11102	6,0550
Total		2,422018	24,52294	6,05505	33,0000
Column Total		8,000000	81,00000	20,00000	109,0000

Note: p — Pearson χ^2 test.

Coronary angiography: left main coronary artery — 70% stenosis. Left anterior descending artery — subocclusion in the proximal third. Circumflex artery — stenosis before subocclusion in the middle third after the marginal branching. Right coronary artery — posterior interventricular artery stenosis (90%).



A **B** **C**

Figure 1. Delayed-enhancement MRI along the short LV axis with a lesion pattern by segments.
Notes: A — at the level of basal segments, the area of contrast accumulation in S6 is visualized up to 25% of segment thickness; **B** — at the level of median segments, the areas of contrast accumulation are visualized in S7 and S12 up to 50% of segment thickness, and S12 up to 50% of segment thickness, as well as in the papillary muscles; **C** — at the level of apical segments, areas of contrast accumulation are visualized in S13 and S15 up to 25% of segment thickness.
On the diagrams, LV segments are marked with numbers; the viable myocardium is indicated in red, the scarring — in pink.

Delayed-enhancement MRI: end-diastolic volume — 218 ml, end-systolic volume — 154 ml. LV ejection fraction (Simpson's method) — 29,3%. Akinesia in S15 with diffuse hypokinesia of the remaining LV segments. Delayed accumulation of contrast agent along the LV short axis with a lesion pattern by segments (Figure 1).

Discussion

ECG, echocardiography and coronary angiography are the main research methods in patients with CAD. However, in the case of diagnosing a pronounced LV contractility decrease and extensive areas of local contractility disorders, the state of dysfunctional myocardium should be assessed. The listed research methods do not make it possible to judge the size of the viable myocardium.

The presented study analyzed the results of myocardial imaging in patients after MI, complicated by a decrease in the global contractile function.

The MRI data made it possible to conduct a correlation analysis of the depth and prevalence of postinfarction cardiac fibrosis with impaired LV local contractility. It also made it possible to compare the data of cardiac MRI with echocardiography and ECG, once again proving the advantage of MRI in assessing local myocardial contractility decrease and in determining the postinfarction cardiac fibrosis.

The severity of postinfarction cardiac fibrosis in patients with CAD complications is an objective criterion for predicting the effectiveness of myocardial revascularization [7, 8]. When selecting treatment strategy, the volume of viable myocardium is taken into account, which makes it possible to obtain information on the number of myocardial segments [9], which, after revascularization, will restore their function, thereby improving the patient's condition.

All of the above emphasizes the fact that the verification of a viable myocardium should be carried out using the most modern diagnostic methods with high resolution, sensitivity and specificity. To confirm the myocardial ischemia in patients with CAD and heart failure, cardiac MRI is recommended by the European Society of Cardiology (2014 and 2018 guidelines) [2]. Given the data obtained, it is necessary to supplement the current guidelines. Also, this article relates to the fact that the current guidelines do not sufficiently describe the issue of diagnosing viable myocardium in patients who have contraindications to stress tests due to the high risk of complications [10-12].

Conclusion

1) MRI allows to determine a significantly higher number of segments with impaired local contractility

in comparison with echocardiography, and DE-MRI is a more sensitive method in detecting LV myocardial scarring than ECG.

2) The depth of contrast agent accumulation according to MRI correlates with the type of local contractility disorder: the higher the transmurality index, the higher the number of akinetic segments and the lower — hypokinetic segments.

3) DE-MRI makes it possible to assess the viable myocardium, which determines further treatment strategy, the effectiveness of revascularization and further prognosis.

Relationships and Activities: none.

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