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Predictors of Positive Steps in the Five-Step Stress Echocardiography Protocol in Patients with Postinfarction Cardiosclerosis

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ABSTRACT

Aim. To study the frequency and predictors of positive steps in five-step stress echocardiography (SE) in patients with previous myocardial infarction (MI).

Materials and methods. The single-center study included 75 patients (61.6 ± 9.8 years, 84% men) with previous MI. The median duration of MI was 1,231.0 (381.5; 2,698.5) days. All patients underwent exercise SE according to the five-step protocol. At step A wall motion abnormalities (WMA) were detected, at step B – the sum of B-lines, at step C – contractile reserve (CR) of the left ventricle (LV), at step D – coronary reserve (CorR) in the left anterior descending artery, and at step E – heart rate reserve.

Results. The frequency of positive steps was 36.0% for step A, 18.7% for step B, 80.0% for step C, 53.3% for step D, and 50.7% for step E. Following the multivariate analysis, predictors of a positive step A (resting diastolic blood pressure (BP), $p = 0.030$, resting WMA index, $p = 0.007$), step B (taking β-blockers, $p = 0.035$; left ventricular (LV) mass index, $p = 0.005$), step C (increase in systolic BP (SBP), $p = 0.011$; increase in LV end-diastolic volume, $p = 0.019$; increase in LV ejection fraction, $p = 0.008$), and step D (taking angiotensin II receptor blockers, $p = 0.026$; increase in SBP, $p = 0.012$; increase in LV force, $p = 0.038$) were revealed.

Conclusion. Identification of predictors of WMA during exercise, subclinical pulmonary congestion, and a decrease in CR and CorR in patients with previous MI may be a target for therapeutic intervention in order to delay the development of adverse cardiovascular events.

Keywords: ABCDE stress echocardiography, myocardial infarction, contractile reserve, coronary reserve, chronotropic reserve

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Предикторы положительной пробы пятиступенчатого протокола стресс-эхокардиографии у пациентов с постинфарктным кардиосклерозом

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РЕЗЮМЕ

Цель. Изучить частоту и предикторы положительных шагов пятиступенчатой стресс-эхокардиографии (СЭ) у пациентов с перенесенным инфарктом миокарда (ИМ).

Материалы и методы. В одноцентровое исследование включены 75 пациентов (61,6 ± 9,8 лет, 84% – мужчины) с перенесенным ИМ. Медиана давности ИМ составила 1231,0 (381,5; 2698,5) сут. Всем пациентам была проведена СЭ с физической нагрузкой по пятишаговому протоколу. На шаге A выявляли нарушение локальной сократимости (НЛС), на шаге B – сумму B-линий, на шаге C – сократительный резерв (СР) левого желудочка (ЛЖ), на шаге D – коронарный резерв (КР) в левой передней нисходящей артерии, а также резерв частоты сердечных сокращений на шаге E.

Результаты. Частота положительных результатов составила 36,0% для шага A, 18,7% – для шага B, 80,0% – для шага C, 53,3% – для шага D и 50,7% – для шага E. В результате многофакторного анализа выявлены предикторы положительного шага A (диастолическое артериальное давление (АД) в покое, $p = 0,030$; индекс НЛС в покое, $p = 0,007$), шага B (прием β-блокаторов, $p = 0,035$; индексированная масса миокарда ЛЖ, $p = 0,005$), шага C (прирост систолического АД, $p = 0,011$; прирост конечно-диастолического объема ЛЖ, $p = 0,019$; прирост фракции ЛЖ, $p = 0,008$) и шага D (прием блокаторов рецепторов ангиотензина II, $p = 0,026$; прирост систолического АД, $p = 0,012$; прирост силы ЛЖ, $p = 0,038$).

Заключение. Выявление предикторов НЛС на нагрузке, субклинического легочного застоя, снижения СР и КР у пациентов с перенесенным ИМ может быть мишенью для терапевтического воздействия с целью отдаления развития неблагоприятных сердечно-сосудистых событий.

Ключевые слова: ABCDE-стресс-эхокардиография, инфаркт миокарда, сократительный резерв, коронарный резерв, хронотропный резерв

Конфликт интересов. Авторы декларируют отсутствие явных и потенциальных конфликтов интересов, связанных с публикацией настоящей статьи.

Источник финансирования. Авторы заявляют об отсутствии финансирования при проведении исследования.

Соответствие принципам этики. Все лица подписали информированное согласие на участие в исследовании. Исследование одобрено комитетом по этике Медицинского института РУДН.

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INTRODUCTION

Cardiovascular diseases and primarily myocardial infarction (MI) are the most urgent problems of practical public health care due to high mortality and disability rate. Given wide introduction of reperfusion therapy methods into medical practice, the number of surviving patients after acute MI (AMI) is growing, and, accordingly, the prevalence of heart failure (HF) and mortality is increasing [1, 2]. The role of imaging techniques for risk stratification of distant complications after AMI is being actively studied. The modern protocol of stress echocardiography (SE) can provide the physician with important additional information. The procedure can help reveal induced myocardial ischemia, subclinical pulmonary congestion, and decreased contractile (CR) as well as coronary (CorR), and chronotropic reserves, which is currently regarded as the pathophysiological cascade in ischemic stroke and can be of fundamental importance in determining the patient management strategy to improve their prognosis [3–6].

Cardiac function testing with ABCDE-CE provides a comprehensive view of patient's risk factors using an extremely simple, low-cost test with minimal risk and zero radiation exposure. An exercise protocol is the most physiologic of all stress testing options. The main practical applications of ABCDE-SE include identification of functional mechanisms of disease and symptoms, long-term risk stratification for therapy adjustment or objective assessment of therapy efficacy, and evaluation of long-term prognosis in a broad group of patients.

There is evidence in the literature of the impact of each ABCDE-SE component on patient's prognosis in terms of the development of various adverse cardiovascular events [3–15].

Each step in the protocol defines a specific phenotype, a risk biomarker, and a potential selective target of personalized therapy [10]. Abnormal step A indicates the need for anti-ischemic therapy with beta-blockers, calcium channel blockers, or nitrates and, possibly, revascularization. Diuretic therapy is recommended in patients with pulmonary congestion, which is identified qualitatively and quantitatively in step B. Angiotensin-converting enzyme inhibitors are recommended in patients with asymptomatic left ventricular (LV) dysfunction after MI, which is identified by a decrease in CR in step C. Selectively abnormal step D implies the presence of coronary microvascular disease, and statins are recommended. Abnormal step E implies reduced cardiac sympathetic reserve, potentially amenable to treatment with various techniques that reduce overactive sympathetic nervous system by blockade of the β-adrenergic or renin–angiotensin–aldosterone systems or neuromodulation therapy aimed at restoring the autonomic balance by a sympathomodulatory intervention, such as, for example, renal denervation. All these parameters individually and combined may be important for the selection or adjustment of therapy to prevent adverse events [10, 15, 16].

Thus, the practical and prognostic value of revealing possible predictors of positive steps in the five-step protocol is beyond doubt, as it may help potentially identify possible additional variants of therapeutic intervention on various markers of stress-induced ischemia.

The aim of the study was to investigate the predictors of positive steps in five-step SE in patients with a history of MI.

MATERIALS AND METHODS

The single-center study included 75 patients with a history of MI receiving therapy according to current guidelines. The vast majority of patients in the experimental group were men (n = 63.84%), mean age 61.6 ± 9.8 years. Median time elapsed from MI was 1,231.0 (381.5; 2,698.5) days.

All patients underwent exercise testing on a Schiller treadmill (TM) ergometer MTM-1500 Med or a Schiller Ergosana ERG 911S/LS horizontal bicycle ergometer (BE) as part of a clinical examination [17]. Criteria for discontinuation of the test included new areas of wall motion abnormality (WMA), severe chest pain, diagnostic ST segment displacement, excessive blood pressure elevation (systolic blood pressure (SBP) ≥ 240 mm Hg, diastolic blood pressure (DBP) ≥ 120 mm Hg), exercise-limiting dyspnea, maximum predicted heart rate (HR), and significant arrhythmias. Antianginal medications were usually not discontinued before testing.

Step A included an assessment of WMA. The WMA index (wall motion score index – WMSI) was calculated in each patient at baseline and at peak exercise. Step B evaluated B-lines using lung ultrasound and simplified scanning at four points: from the mid axillary to the mid clavicular line at the third intercostal space. Step C detected CR as a stress-to-rest ratio of force; LV force was calculated as the ratio of SBP to LV end-systolic volume (ESV). Coronary flow velocity reserve (step D) was assessed as the ratio of peak-to-rest left anterior descending artery (LAD) blood flow velocities. HR reserve (step E) was calculated as the ratio of peak-to-rest HR from ECG data. Criterion A was considered to be positive when new areas of WMA appeared or viable myocardium was identified. Subclinical pulmonary congestion was diagnosed when the sum of B-lines increased by 2 or more. A load-to-rest ratio ≤ 2.0 was taken as a decrease in CR. Step D was considered to be positive when the ratio of velocities in LAD at peak and at rest was ≤ 2.0. A decrease in chronotropic reserve was recognized as a decrease in HR by less than 1.8 times [10]. We calculated an increase in LV ejection fraction (EF) at loading compared to rest (Δ LV EF), LV end-diastolic volume (Δ LV EDV), LV force (Δ LV force), double product ((DP), SBP multiplied by HR at the peak of the load).

The sample size was calculated according to the method of K. A. Otdelnova (set power of the study 80%; significance level 0.05). SPSS software (version 22.0) was used for statistical data processing. Quantitative variables were described as the arithmetic mean and the standard deviation $M \pm SD$ (for normal distribution), or as the median and the interquartile range $Me \pm IQR$ (for non-normal distribution). The significance of differences between the studied distribution and normal distribution was assessed by the Lilliefors-corrected Kolmogorov – Smirnov test. The differences were statistically significant at $p < 0.05$. The direction and strength of the correlation between the parameters were evaluated using the Spearman's rank correlation coefficient. The dependence of binary parameters on quantitative and categorical ones was revealed by binary logistic regression (single- and multivariate analysis) with the determination of the odds ratio.

RESULTS

The most common comorbidities were hypertension (n = 70, 93.3%), dyslipidemia (n = 64, 85.3%), obesity or overweight (n = 33, 44.0% and n = 30, 40.0%, respectively), and NYHA class 1–2 chronic HF (n = 30, 40%). The median NTproBNP level was 50.3 (27.5; 118.9) pg/ml. Smoking history and/or current smoking was reported by 19 (25.3%) patients, alcohol abuse – by 4 (5.3%) patients. Chest pain bothered 48 (64.0%) patients (nonanginal – 4 (5.3%), atypical – 8 (10.7%), typical – 36 (48%)).

Coronary angiography data were known in 71 patients. Fifty-one patients (68.0%) had multivessel coronary lesions. The most frequent lesion site was the LAD (59 (78.7%) cases). Stenting was performed in 59 (78,7%) patients, coronary artery bypass grafting – in 1 (1.3%) individual. There was a stent in the LAD in 35 (46.7%) patients, in the right coronary artery – in 26 (34.7%) patients, in the circumflex branch – in 18 (24%) patients, in the trunk of the left coronary artery – in 5 (6.7%) patients. Sinus rhythm was registered in all patients at the time of the study, left bundle branch block was registered in 2 patients, and nonspecific ST depression was registered in 5 patients. The most frequent components of therapy were β-blockers (n = 54, 72.0%), statins (n = 62, 82.1%), and antiplatelet agents (n = 63, 84.0%).

The exercise test was performed on a BE in 57 (76%) patients and on a TM in 18 (24%) patients. Reasons for discontinuation of the test were reaching the preset HR (n = 28, 37.3%), appearance of new WMA zones (n = 7, 9.3%), intolerable fatigue / dyspnea (n = 26, 34.7%), and increased arterial hypertension (n = 14, 18.7%). The achieved % of predicted HR was 94 (85; 100)%, and the % of predicted physical activity was 79 (68.5; 96.0)%. The mean DP was 252 ± 43. The most frequent complaints of patients were fatigue (n = 35, 46.7% of patients) and dyspnea (n = 21, 28.0%). Low exercise tolerance was demonstrated by 7 (9.3%) patients, moderate – by 17 (22.7%) patients, and high and very high – by 45 and 6 (68%) patients, respectively. A hypertensive response to exercise was registered in 33 (44%) patients.

LV contractility at rest was preserved in 55 patients (73.3%). Diastolic dysfunction was most often of grade 1 (E/e' 3.68 ± 1.08; left atrial volume index was 27.5±7.1 ml/m^2), concentric LV remodeling was registered in more than half of the patients (43 patients, 57.3%). The resting and load-dependent echocardiography parameters are presented in Table 1. The results of the SE are presented in Table 2.

Table 1

Quantitative Parameters of SE Stages

Parameter	Rest	Load
LV EF, %, $M \pm SD$	53.9 ± 7.5	57.0 ± 8.4
Δ LV EF, %, $M \pm SD$	3 ± 6	
LV EDV, mL, $Me \pm IQR$	93 ± 32	86 (70; 110)
ΔLV EDV, mL, $M \pm SD$	–1.0 (–8.0; 13.5)	
LV ESV, mL, $Me \pm IQR$	41 (30; 53)	36 (29; 49)
GLS, %, $M \pm SD$	–14.2 ± 3.2	–15.9 ± 3.4
WMSI, $Me \pm IQR$	1.10 (1.00; 1.43)	1.13 (1.00; 1.50)
B-lines, $Me \pm IQR$	0 (0;0)	0 (0;1)
SBP / DBP, mm Hg, $Me \pm IQR$	132 (120; 144)/80 (75; 85)	189 (175; 207)/97 (88; 100)
LV force, mm Hg/ml, $Me \pm IQR$	3.3 (2.5; 3.9)	5.1 (3.8; 6.8)

End of table 1

Parameter	Rest	Load
Δ LV force, mm Hg/ml, *Me ± IQR*	1.7 (0.6; 2.9)	
Contractile reserve, *Me ± IQR*	1.6 (1.2; 1.9)	
V_{LAD}, cm/s, *Me ± IQR*	23 (19; 26)	40 (31;50)
Coronary reserve, *M ± SD*	1.76 ± 0.40	
HR, beats/min, *M ± SD*	75 ± 12	132± 14
Chronotropic reserve, *Me ± IQR*	1.8 (1.6; 2.0)	

Note: EDV – end-diastolic volume, GLS – global longitudinal strain, V_{LAD} - velocity in the left anterior descending artery.

Table 2

Results of the Five-Stage SE

Parameter		Rest
Frequency of + step, *n* (%)	A	17 (22.7) – ischemia, 10 (13.3) –viable myocardium
	B	14 (18.7)
	C	60 (80.0)
	D	40 (53.3), not assessed in 9 (12.0)
	E	38 (50.7)
Sum of scores, n (%)	0	4 (5.3)
	1	12 (16.0)
	2	25 (33.3)
	3	22 (29.3)
	4	9 (12.0)
	5	3 (4.0)
Functional class of angina pectoris by double product, *n* (%)	1 (DP > 278)	22 (29.3)
	2 (DP 218-277)	38 (50.7)
	3 (DP 161–217)	14 (18.7)
	4 (DP < 150)	1 (1.3)

After identifying correlations of positive SE steps with clinical parameters, univariate and multivariate regression analysis was performed to determine their predictors.

The following parameters were found to have a significant effect on the probability of new WMA zones (Table 3).

Table 3

Characteristics of the Association of Predictors with the Probability of Positive Step A in the Five-Step SE Protocoll

Predictor	COR; 95% CI	*p*	AOR; 95% CI	*p*
DBP rest	0.934 (0.882; 0.989)	0.019	0.936 (0.882; 0.994)	0.030
LV EF rest	0.908 (0.845; 0.976)	0.009		
WMSI rest	10.0 (2.0; 49.4)	0.005	9.0 (1.8; 44.2)	0.007
WMSI load	33.0 (5.0; 217.7)	<0.001		
LV ESV load	1.03 (1.00; 1.05)	0.026		
DP	0.986 (0.974; 0.998)	0.019		
LV EF load	0.888 (0.826; 0.954)	0.001		

End of table 3

Note: COR – crude odds ratio (univariate analysis); AOR – adjusted odds ratio (multivariate analysis); 95% CI – 95%- confidence interval (here and in Tables 4–7). DP – double product.

Univariate and multivariate regression analysis was performed to identify predictors of subclinical pulmonary stasis as part of the SE protocol in patients with previous MI. Significant influence of the following parameters on the outcome was revealed (Table 4).

Table 4

Characteristics of the Association of Predictors with the Probability of Positive Step B in the Five-Step SE Protocol

Predictor	COR; 95% CI	*p*	AOR; 95% CI	*p*
Male gender	0.233 (0.061; 0.889)	0.034		
Taking β-blockers	0.232 (0.066; 0.811)	0.022	0.225 (0.056;0.902)	0.035
LVMI	0.941 (0.904; 0.981)	0.004	0.940 (0.900; 0.981)	0.005

Note: LVMI – left ventricular mass index.

Univariate and multivariate regression analysis was performed to identify predictors of CR reduction within the SE protocol in patients with previous MI. Significant influence of the following parameters on the outcome was revealed (Table 5).

Univariate and multivariate regression analysis was performed to identify predictors of decreased LV CorR within the SE protocol in patients with previous MI. Significant influence of the following parameters on the outcome was revealed (Table 6).

Statistically significant models have been developed for steps A, B, C, D to calculate the probability of an abnormal step given the identified predictors.

Univariate and multivariate regression analysis was performed to identify predictors of decreased chronotropic reserve as part of the SE protocol in patients with previous MI. The univariate analysis revealed significant influence of the following parameters on the outcome (Table 7).

We did not find any statistically significant effect of clinical, anamnestic, and echocardiography parameters on the scores resulting from the five-stage SE protocol in patients with previous MI.

Table 5

Characteristics of the Association of Predictors with the Probability Oo Positive Step C in the Five-Step SE Protocol				
Predictor	COR; 95% CI	*p*	AOR; 95% CI	*p*
SBP load	0.965 (0.939; 0.991)	0.010		
LV ESV load	1.058 (1.007; 1.111)	0.024		
DP	0.984 (0.968; 0.999)	0.039		
LV EF load	0.918 (0.848;0.993)	0.033		
LV peak force	0.767 (0.635; 0.926)	0.006		
Chronotropic reserve	0.105 (0.013; 0.887)	0.038		
Δ SBP	0.942 (0.910; 0.974)	0.001	0.851 (0.751; 0.964)	0.011
ΔLV EDV	1.120 (1.056; 1.189)	<0.001	1.422 (1.060; 1.909)	0.019
ΔLV EF	0.877 (0.789; 0.973)	0.014	0.561 (0.365; 0.861)	0.008
Δ LV force	0.419 (0.270; 0.652)	<0.001		
+E	3.596 (1.027; 12.591)	0.045		

Table 6

Characteristics of the Association of Predictors with the Probability of Positive Step D in the Five-Step SE Protocol				
Predictor	COR; 95% CI	*p*	AOR; 95% CI	*p*
Number of affected coronary vessels according to CAG data	3.0 (1.1; 7.9)	0.026	4.6 (1.2; 17.2)	0.024
% of BCA occlusion	1.045 (1.010; 1.081)	0.012		
Taking ARB	4.1 (1.2; 14.0)	0.026	23.3 (2.3; 240.7)	0.026
DP	0.987 (0.974; 0.999)	0.039		
LV peak force.	0.827 (0.689; 0.992)	0.041		
Contractile reserve	0.375 (0.145; 0.968)	0.043		
ΔSBP	0.974 (0.951; 0.998)	0.033	0.945 (0.904; 0.988)	0.012
Δ LV force	0.419 (0.270; 0.652)	<0.001	0.741 (0.558; 0.983)	0.038

Note: CAG – coronary angiography; BCA – brachiocephalic arteries; ARB – angiotensin II receptor blockers.

Table 7

Characteristics of the Association of Predictors with the Probability of Positive Step E in the Five-Step SE Protocol		
Predictor	COR; 95% CI	*p*
Diabetes mellitus	1.926 (1.088; 3.411)	0.025
Glycemic index	1.668 (1.071; 2.596)	0.023
BP rest	1.051 (1.014; 1.098)	0.006
DBP rest	1.090 (1.027; 1.155)	0.004
LVMI	1.027 (1.002; 1.052)	0.030
Type of LV remodeling	2.251 (1.128; 4.495)	0.021
Left atrial volume index, load	1.215 (1.004; 1.469)	0.045
ΔSBP	0.973 (0.952; 0.996)	0.019
+C	3.596 (1.027; 12.591)	0.045

DISCUSSION

In our study, one of the predictors of a positive step A among clinical, laboratory, anamnestic, and instrumental parameters was resting WMSI (AOR 9.0, p = 0.007). These results are consistent with the current knowledge about the pathophysiology, diagnosis, and prognostic value of coronary structural and functional disorders [7, 8, 16–18], as well as with the recommended management strategy in the detection of asynergy zones [16]. Another predictor in the multivariate analysis was resting DBP (AOR 0.936, p = 0.030, that is, an increase by 1 mm Hg leads to a 1.1-fold decrease in the chance of a positive step A).

Currently, there are little data on the correlation between the level of DBP and the risk of adverse events in patients. On the one hand, observational cohort studies report an increased incidence of CAD and a risk of AMI in individuals with very low DBP because the heart is perfused during diastole [19–21], which is consistent with our results. On the other hand, it is important to evaluate not only office measurements of DBP, because in this way it is possible to overlook patients receiving antihypertensive therapy with masked diastolic hypotension. Thus, the problem of diastolic arterial hypertension and hypotension in the light of SE may acquire new directions for study.

B-lines in lung ultrasound determine stasis at rest and, more often, during exercise in various cardiovascular diseases characterized by possible occurrence of increased pulmonary artery occlusion pressure and accumulation of extravascular fluid in the lungs [22]. We identified predictors of a positive step B: taking β-blockers (AOR 0.225; p = 0.035, that is taking drugs of this group decreases the chance of subclinical pulmonary congestion by 4.4 times) and LVMI (AOR 0.940; p = 0.005, that is an increase in LVMI per 1 g/m² decreases the chance of subclinical pulmonary congestion by 1.1 times). Taking β-blockers as a factor reducing the chance of subclinical pulmonary stasis can be explained by its pharmacologic actions, contributing to a decrease in pulmonary artery occlusion pressure (reduces the activity of blood plasma renin, decreases the increased total peripheral resistance). The increase in LVMI as a negative predictor of subclinical pulmonary stasis is probably explained by the fact that patients with higher LVMI in our study received more intensive antihypertensive therapy, including diuretics. However, these data require confirmation in larger studies.

Predictors of a decrease in LV CR in the multivariate analysis were an increase in SBP at the peak of load (AOR 0.851; p = 0.011, that is an increase in SBP by every 1 mm Hg decreases the chance of LV CR reduction by 1.2 times), an increase in LV EDV (AOR 1.422; p = 0.019, i.e. an increase in LV EDV at exercise by every 1 mL increases the chance of CR reduction by 1.4 times); an increase in LV EF (AOR 0.561; p = 0.008, that is a rise in LV EF by 1% decreases the chance of CR reduction by 1.8 times). The obtained results on the SBP increase as a negative predictor of reduced LV CR correlate with the results of the study conducted by Bouzas-Mosquera et al. – the frequency of adverse cardiovascular outcomes studied by them was significantly higher in patients with a normotonic response to stress ($p < 0.001$ for all comparisons), which is associated with increased LV CR [23].

The correlation of LV EDV at stress and CR was also studied by Bombardini et al. They evaluated the effect of decreased LV CR, chronotropic reserve, and increased LV EDV on the decrease in cardiac index using the data of 1,344 patients. The binary logistic regression analysis revealed that reduced preload reserve (increase in LV EDV at SE) (OR 5.610), chronotropic incompetence (OR: 3.923), and abnormal LV CR (OR: 1.579) were independently associated with the lowest tercile of cardiac index reserve at peak exercise [5]. Thus, ABCDE-SE plays an important role in identifying the causes of decreased functional cardiac output reserve, which may be underlying separate but not mutually exclusive mechanisms (decreased chronotropic or contractile reserve) [24]. Finally, the increase in LV EF upon exercise as a negative predictor of reduced CR is explained by the methods of calculation of these values: at the same EDV, LV EF increases due to the decrease in ESV and LV CR, although the CR value is also affected by the increase in SBP. Thus, this result may be one of the examples of integration of LV EF (as a key factor for clinical classification, risk stratification, and therapeutic decision making) with other indices of LV function and may improve the characterization, in particular, of the hypercontractile phenotype [25].

Finally, independent predictors of LV CorR reduction in our group of patients were the number of affected coronary vessels according to CAG (AOR 4.6; p = 0.024, an increase in the number of affected vessels by 1 raises the chance of LV CorR reduction by 4.6 times), ARB intake (AOR 23.3; p = 0.026); increase in SBP (AOR 0.945; p = 0.012, an increase in SBP by 1 mm Hg decreases the chance of LV CorR reduction by 1.1 times), a rise in LV force (AOR 0.741; p = 0.038, an increase in LV force by 1 mm Hg / ml decreases the chance of LV CorR reduction by 1.3 times). The SBP increase as a negative predictor of reduced LV CorR correlates with the data in the study by Rimoldi et al. It was revealed according to positron emission tomography data that in patients with stage 1–2 hypertension and LV hypertrophy, LV CorR is reduced due to a lack of a proper stress response, which is inversely proportional to SBP ($p < 0.001$ for epicardial CorR; p = 0.003 for endocardial CorR). In patients, the degree of impairment of epicardial (R = 0.52, p = 0.003) and endocardial CorR (R = 0.51, p = 0.004) was inversely proportional to SBP [26].

The use of ARB as a positive predictor of reduced LV CorR is probably explained by frequent prescription of these drugs to patients with hypertension and previous MI to reduce the risk of associated cardiovascular morbidity and renal protection (in patients with type 2 diabetes mellitus), as part of the combined therapy of chronic HF.

Changes in force and, consequently, in LV CR can be caused by microvascular and/or epicardial disease of coronary arteries, as well as by myocardial scar, necrosis and/or disease of the subepicardial layer, and reduced LV CorR [27]. The heart responds to inotropic stimuli by increasing its contractile function, which is accompanied by an increase in coronary blood flow [28]. Thus, in our study, LV force increment acted as a negative predictor of LV CorR reduction.

CONCLUSION

Identification of predictors of WMA at exercise, subclinical pulmonary congestion, and decreased CR and CorR as functional mechanisms of disease and symptoms in patients with MI may be a target for therapeutic intervention to delay the development of endpoints.

LIMITATIONS OF THE STUDY

The results relate to a limited number of patients with previous MI of different duration, with different intensity of coronary lesions, different degrees of comorbidity, initial symptomatology, and different therapy regimens. Not all patients had available CAG results within six months from the date of SE, and the diagnostic power was calculated with the actual number of studies per index hospitalization and anamnestic data in the remaining patients, and the conclusions were applied to the whole group. There is a clear need for a large randomized clinical trial to study the relationship between SE steps and the detection of significant coronary lesions, as well as their prognostic significance with respect to the functional status and prognosis in patients with previous MI.

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