

Utility of stress echocardiography in selecting the optimal mitral valve procedure in patients with severe ischemic mitral regurgitation undergoing coronary artery bypass grafting

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KEY WORDS

mitral annuloplasty,
severe ischemic
mitral regurgitation,
stress
echocardiography

ABSTRACT

INTRODUCTION Severe functional ischemic mitral regurgitation (FIMR) considerably worsens the prognosis of patients after myocardial infarction. The complex pathomechanism of FIMR and its dynamic nature make it difficult to develop effective therapeutic methods.

OBJECTIVES The aim of the study was to prospectively assess a diagnostic strategy based on stress echocardiography in referring patients with severe FIMR for appropriate surgical procedure: coronary artery bypass grafting alone (CABGa) or CABG with mitral annuloplasty (CABGma) or replacement (CABGmr).

PATIENTS AND METHODS A prospective analysis included 42 patients (23 women, 19 men) aged 67 ± 12 years with severe FIMR after myocardial infarction, scheduled for CABG. In each patient, mitral valve morphology, left ventricular function, FIMR degree as assessed by the effective regurgitation orifice area (severe $\geq 20 \text{ mm}^2$), myocardial viability, and mitral deformation indexes were assessed prior to surgery. Based on clinical assessment and rest and stress echocardiography parameters, patients were referred for CABGa (group 1; $n = 6$), CABGma (group 2; $n = 27$), or CABGmr (group 3; $n = 9$).

RESULTS In all study groups, no differences in clinical and echocardiographic results were observed during a 12-month follow-up. A significant improvement was reported in the majority of patients regardless of the surgical procedure. Early (30-day) mortality in the whole study population was 11.9% ($n = 5$). Survival at 12 months was 100%, 81.5%, and 77.8% for groups 1, 2, and 3, respectively ($P = 0.3$). In all study groups, a statistically significant FIMR reduction was observed in a 12-month follow-up: small, moderate, and severe FIMR was observed in 29 (83%), 5 (14%), and 1 (3%) surviving patient, respectively. Reverse left ventricular remodeling was observed in 83% of the patients in group 1, 63.7% in group 2, and 100% in group 3 (statistically nonsignificant difference).

CONCLUSIONS The presented diagnostic strategy, based on stress echocardiography, may facilitate the process of choosing a suitable cardiac surgical procedure for patients with severe FIMR.

INTRODUCTION Severe functional ischemic mitral regurgitation (FIMR) considerably worsens the prognosis of patients after myocardial infarction, both in short- and long-term follow-up.¹⁻³ The complex pathomechanism of FIMR

makes it difficult to develop effective therapeutic methods.

Currently, the majority of authors recommend mitral valve surgery combined with coronary artery bypass grafting (CABG) for patients with

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Received: February 7, 2012.

Revision accepted: April 4, 2012.

Published online: April 11, 2012.

Conflict of interest: none declared.

Pol Arch Med Wewn. 2012;

122 (5): 217-225

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Kraków 2012

severe FIMR. Restrictive annuloplasty combined with CABG is the most common surgical procedure in this patient group. However, the sobering results of the current strategies create the need for better preoperative assessment of mitral valve and left ventricular (LV) geometry and function.^{4,5}

There are no straightforward clinical and echocardiographic criteria that would help effectively decide which procedure to choose – mitral valve surgery or CABG alone. A strict correlation between stress-induced changes of FIMR degrees, myocardial viability, mitral deformation indexes (MDI), and clinical symptoms and prognosis in patients should be taken into account when evaluating the eligibility of patients with severe FIMR for a particular surgical treatment.⁶⁻⁸ Such evaluation could help improve risk stratification and identification of patients who would likely benefit from different surgical strategies. In our opinion, the greater severity of stress-induced FIMR and MDI correlates with greater necessity to perform mitral valve intervention, and the progression from revascularization alone to revascularization with restrictive annuloplasty to revascularization with mitral valve replacement is predicated on the severity of stress-induced MDI and FIMR.

Based on exercise echocardiography (ExE) and dobutamine stress echocardiography (DBX), a diagnostic algorithm for precise determination of the range of surgical interventions has been developed.

The aim of the study was to prospectively assess the proposed diagnostic strategy based on stress echocardiography to determine the eligibility of patients with severe FIMR for an appropriate surgical procedure.

PATIENTS AND METHODS Study population

The study involved 42 patients with a history of myocardial infarction and eligible for CABG (23 women, 19 men; age 18–75 years). All patients had severe FIMR caused by restrictive systolic leaflet motion (Carpentier's type IIIb) with or without annular dilatation (Carpentier's type I) or both.

The study inclusion criterion was the presence of a significant area of viable myocardium observed during DBX (improvement in wall motion

of at least 4 dysfunctional segments). The exclusion criteria were as follows: recent myocardial infarction (<30 days), left bundle branch block, unstable angina, prosthetic heart valve, other valvular or congenital heart diseases, history of CABG, symptoms of severe heart failure (HF) (New York Heart Association [NYHA] class IV), atrial fibrillation or sinus rhythm with the heart rate at rest exceeding 100 beats/min, and the presence of restrictive filling pattern.

Preoperative and postoperative clinical status was determined according to the criteria of the NYHA and the Canadian Cardiovascular Society (CCS) functional class for HF and angina, respectively.

Forty-two consecutive patients were prospectively enrolled into the study. The time frame for the enrollment was 24 months. Patients were divided into groups according to the type of a scheduled procedure: group 1 – CABG alone (CABGa, n = 6); group 2 – CABG combined with mitral annuloplasty (CABGma, n = 27); and group 3 – CABG combined with mitral valve replacement (CABGmr, n = 9). The eligibility of patients for a particular therapeutic method was determined according to the echocardiographic criteria presented in [TABLE 1](#). Patients had to meet all criteria to be classified to a given group. Echocardiographic and clinical assessment was performed at discharge, at 1 month, and at 12 months. All patients provided written informed consent. The study was approved by the institutional review board of the Medical University of Warsaw, Poland.

Surgery CABG was performed in all patients using cardiopulmonary bypass in moderate hypothermia with crystalloid and blood cardioplegia. The main aim of the surgery was to perform complete coronary revascularization and, in the majority of patients, mitral valvuloplasty.

Ring size was determined after measurement of the height of the anterior leaflet and intertrigonal distance, and then downsizing by 2 sizes (undersizing annuloplasty).^{9,10}

The intraoperative criteria of successful surgery were as follows: leaflet coaptation height ≤ 0.6 cm, tenting area ≤ 1.2 cm², and FIMR ≤ 1 grade. Recurrent FIMR was defined as at least moderate insufficiency at follow-up visits in patients with no or small FIMR at discharge.

The echocardiographic criteria of the procedure efficacy during 12-month follow-up included the presence of left ventricular reverse remodeling (LVRR), no FIMR recurrence at follow-up, and no significant increase of FIMR during ExE (effective regurgitation orifice [Δ ERO] > 13 mm²).

Echocardiographic measurements and calculations

Transthoracic (TTE) and transesophageal (TEE) echocardiograms were performed within 2 to 3 days before surgery, and serial TTE examinations were performed at discharge and at follow-up visits.

TABLE 1 Eligibility criteria for an appropriate surgical treatment

	CABGa group 1	CABGma group 2	CABGmr group 3
ERO ExE	< 20 mm ²	≥ 20 mm ²	≥ 20 mm ²
CH DBX	≤ 6 mm	$6 \text{ mm} < \text{CH} \leq 10 \text{ mm}$	$> 10 \text{ mm}$
TA DBX	≤ 1.2 cm ²	$1.2 \text{ cm}^2 < \text{TA} \leq 2.5 \text{ cm}^2$	$> 2.5 \text{ cm}^2$
ERO DBX	< 10 mm ²	— ^a	— ^a

^a insignificant in qualification strategy

Abbreviations: CABGa – coronary artery bypass grafting alone, CABGma – CABG mitral annuloplasty, CABGmr – CABG mitral replacement, CH – coaptation height, DBX – dobutamine echocardiography, ERO – effective regurgitant orifice area, ExE – exercise echocardiography, TA – tenting area

Two-dimensional echocardiography All echocardiographic measurements were performed using the iE 33 system version 4.2–5.0 (Philips, United States), a broadband transducer for TTE of 2.5–3.5 MHz frequency and multiplane probe Omniplane II and III for TEE. The measurements were averaged over 3 cardiac cycles.

Severity of mitral regurgitation was quantified using the proximal isovelocity surface area method. Severe FIMR was defined as calculated ERO $\geq 20 \text{ mm}^2$ at rest.^{11,12} Wall motion abnormalities were evaluated in accordance with the recommendations of the American Society of Cardiology. The wall motion score index (WMSI) was calculated according to a 17-segment model.¹³ The LV volumes and ejection fraction (EF) were assessed by the biapical Simpson disk method. The mitral valve deformation was evaluated by measuring the tenting area (i.e., the area between mitral leaflets and the line of annular plane) and the coaptation height (i.e., the distance between leaflet coaptation and mitral annular plane from the parasternal long-axis view at mid-systole).¹⁴ According to Stellbrink et al.,¹⁵ a decrease in LV end-systolic

volume by less than 15% from the baseline value was considered as LVRR (at 12 months of follow-up compared with the baseline values).

Stress echocardiography Low-dose DBX was used to differentiate akinetic viable segments from nonviable myocardial regions.¹⁶ If a significant area of viable LV myocardium was present, the patient was included in the further analysis. Additionally, during DBX the dynamics of MDI (increase or decrease) and FIMR changes were analyzed. DBX was performed in accordance with the current guidelines.¹⁷ The next step of the patient evaluation included ExE to assess the dynamics of FIMR changes and tricuspid regurgitation pressure gradient (TRPG) as the exponent of the right ventricular overload.

A symptom-limited grade ExE was performed according to the following protocol: the initial workload of 25 Watt (W) was maintained for 3 minutes, and then the workload was increased every 2 minutes by 25 W. Two-dimensional and Doppler echocardiographic recordings were available throughout the test. The exercise

TABLE 2 Baseline clinical characteristics of patients

	CABGa group 1 (n = 6)	CABGma group 2 (n = 27)	CABGmr group 3 (n = 9)	P for trend
age, y	68	67	61	0.17
women/men, %	50/50	62/58	33/67	0.4
EuroSCORE	10.3 $\pm$ 4.5	13.8 $\pm$ 8.3	11.4 $\pm$ 10.3	0.83
NYHA	1.83 $\pm$ 0.75	2.52 $\pm$ 0.64	2.33 $\pm$ 0.87	0.12
CCS	2.67 $\pm$ 0.52	2.18 $\pm$ 0.88	2.33 $\pm$ 0.87	0.2
hypertension, n (%)	5 (83)	17 (62)	6 (67)	0.59
diabetes, n (%)	1 (16.7)	14 (52)	2 (22)	0.93
chronic renal disease, n (%)	2 (33.3)	8 (29.6)	2 (22.2)	0.62
atrial fibrillation, n (%)	1 (16.7)	10 (37)	0 (0)	0.3
three-vessel disease, n (%)	6 (100)	16 (59.3)	5 (55.5)	0.1
history of MI, n (%)				
anterior / lateral	4 (66.7)	11 (41)	1 (11.2)	0.038
inferior / posterior	2 (33.3)	9 (33)	5 (55.5)	0.47
STEMI	3 (50)	14 (50)	5 (63)	0.61
NSTEMI	2 (33)	14 (50)	2 (25)	0.64
MI treatment, %				
PCI	2 (33)	8 (29)	4 (50)	0.45
thrombolysis	0 (0)	3 (11)	1 (13)	0.46
pharmacological treatment, %				
β -adrenergic blockers	100	89.29	100	0.88
ACEIs	100	75	100	0.81
calcium antagonists	50	3.57	12.5	0.063
loop diuretics	33.33	60.71	62.5	0.31
aldosterone antagonists	16.67	25	25	0.74
statins	100	89.29	87.5	0.46
ASA	83.33	82.14	87.5	0.81

Data are presented as mean $\pm$ standard deviation or number (percentage).

Abbreviations: ACEI – angiotensin-converting enzyme inhibitor, ASA – acetylsalicylic acid, CCS – Canadian Cardiovascular Society, MI – myocardial infarction, NSTEMI – non-ST-elevation MI, NYHA – New York Heart Association, PCI – percutaneous coronary intervention, STEMI – ST-elevation MI, others – see [TABLE 1](#)

TABLE 3 Baseline echocardiographic characteristics of patients

	CABGa group 1 (n = 6)	CABGma group 2 (n = 27)	CABGmr group 3 (n = 9)	P
rest echocardiography				
LVDS, mm	41.5 ± 12.4	46 ± 8.3	42.1 ± 6.4	0.35
EDV, ml	142.5 ± 75.3	160.7 ± 46.3	141.8 ± 51	0.55
ESV, ml	96.3 ± 69	106.6 ± 37.8	89.2 ± 52.9	0.61
EF rest, %	38.2 ± 13.2	36.0 ± 8.9	40.0 ± 9.1	0.65
WMSI rest	1.78 ± 0.53	1.8 ± 0.3	1.72 ± 0.35	0.64
TRPG rest, mmHg	34.5 ± 8.5	34.5 ± 10.4	28 ± 8.2	0.16
ERO rest, cm ²	0.23 ± 0.03	0.3 ± 0.08	0.27 ± 0.03	0.15
CH rest, cm	0.82 ± 0.2	1.01 ± 0.3	1.23 ± 0.4	<0.001 for trend group 1 vs. 2; 2 vs. 3; 1 vs. 3 <0.05
TA rest, cm ²	2.06 ± 0.36	2.9 ± 0.6	3.06 ± 0.9	0.002 for trend group 1 vs. 2; 1 vs. 3 <0.05
SMA rest, cm ²	10.3 ± 1.42	11.2 ± 1.54	12 ± 1.7	0.13
exercise echocardiography				
Watt	63.3 ± 19.4	58.9 ± 21.6	61.3 ± 18.5	0.9
EF ExE, %	41.2 ± 13.9	35.1 ± 9.0	39.4 ± 3.9	0.25
TRPG ExE, mmHg	38.2 ± 6.8	49.3 ± 12.4	42.6 ± 17.7	0.066
ERO ExE, cm ²	0.17 ± 0.01	0.37 ± 0.12	0.34 ± 0.11	0.002 for trend group 1 vs. 2; 1 vs. 3 <0.05
dobutamine echocardiography				
EF DBX, %	48.7 ± 15.7	41.9 ± 10.8	48.13 ± 8.3	0.26
WMSI DBX	1.49 ± 0.44	1.62 ± 0.32	1.47 ± 0.19	0.39
ERO DBX, cm ²	0.07 ± 0.01	0.24 ± 0.06	0.22 ± 0.08	<0.001 for trend group 1 vs. 2; 1 vs. 3 <0.05
CH DBX, cm	0.47 ± 0.12	0.86 ± 0.08	1.1 ± 0.07	<0.0001 for trend group 1 vs. 2; 2 vs. 3 1 vs. 3 <0.001
TA DBX, cm ²	1.02 ± 0.16	2.52 ± 0.39	2.7 ± 0.59	<0.001 for trend group 1 vs. 2; 1 vs. 3 <0.05 2 vs. 3: NS (>0.05)
SMA DBX, cm ²	9.2 ± 1.22	10.2 ± 1.59	10.9 ± 1.89	0.16

Abbreviations: CH – coaptation height, DBX – dobutamine echocardiography, EDV – end-diastolic volume, EF – ejection fraction, ERO – effective regurgitant orifice area, exe – exercise echocardiography, ESV – end-systolic volume, LVDS – left ventricular end-systolic dimension, SMA – systolic area of the mitral annulus, TA – tenting area, TRPG – tricuspid regurgitation pressure gradient, WMSI – wall motion score index, others – see [TABLE 1](#)

was interrupted when ischemic electrocardiographic signs, fatigue, or intolerable dyspnea occurred.¹⁷

The follow-up ExE was repeated 12 months after surgery.

Clinical endpoints The proposed diagnostic algorithm was evaluated by comparing the results obtained during 12-month follow-up in 3 groups of patients. The results included the functional status (NYHA, CCS); dynamics of changes in selected LV function parameters at rest TTE (end-systolic

volume [ESV], EF, WMSI); dynamics of changes in selected echocardiographic variables during ExE (LV function, FIMR severity, systolic pressure in the pulmonary artery); analysis of the recurrence of at least moderate FIMR; presence of LVRR; early (30-day) and midterm (12-month) mortality, and hospitalization due to exacerbation of HF symptoms.

Statistical analysis Data are presented using standard descriptive statistical methods for the en-

TABLE 4 Perioperative and early postoperative data

Perioperative period	CABGa group 1 (n = 6)	CABGma group 2 (n = 27)	CABGmr group 3 (n = 9)	P
CCL, min	72 ± 5.2	95 ± 9.1	109 ± 3.7	<0.0001 for trend group 1 vs. 2; 1 vs. 3; 2 vs. 3; <0.001
CBP, min	104 ± 9.6	129 ± 9.1	142 ± 5.1	<0.0001 for trend group 1 vs. 2; 1 vs. 3; 2 vs. 3 <0.001
ICU stay, h	27 ± 4.5	46 ± 6.8	65 ± 11	<0.0001 for trend group 1 vs. 2; 1 vs. 3; 2 vs. 3 <0.01
use of LIMA/RIMA, mean	1 ± 0.6	0.9 ± 0.4	0.6 ± 0.5	0.25
use of saphenous grafts, mean	1.2 ± 1.0	1.2 ± 1.0	0.9 ± 0.6	0.71
AF, n (%)	2 (33)	13 (46)	0 (0)	0.13
cerebrovascular events (TIA/stroke)	0 (0)	1 (4)	1 (13)	0.9
IABP, n (%)	1 (17)	16 (57)	3 (38)	0.57
inotropes, n (%)	3 (50)	24 (86)	6 (75)	0.35

Abbreviations: AF – atrial fibrillation, CBP – cardiopulmonary bypass, CCL – cross-clamp time, IABP – intra-aortic balloon pump, ICU – intensive care unit, LIMA – left internal mammary artery, RIMA – right internal mammary artery, TIA – transient ischemic attack, others – see [TABLE 1](#)

tire study population and for all the subgroups according to the applied therapeutic procedure.

For quantitative variables with close to normal distribution sample size, minimal and maximal values, arithmetical mean, and standard deviation (SD) are given. Continuous variables with distribution close to normal are presented as mean and SD while categorical variables as n/N (%). For qualitative variables, absolute and relative numbers are given for particular classes. The significance of the observed differences between the groups was examined using the *t* test, Wilcoxon test, Cochran–Mantel–Haenszel test, and χ^2 test. All analyses were performed using SAS 9.1 (SAS Institute, Cary, North Carolina, United States) and MedCalc 10.4 (Mariakerke, Belgium). Significance for hypothesis testing was set at the 2-tailed level of 0.05.

RESULTS Baseline characteristics The preoperative clinical and echocardiographic variables in 3 groups are shown in [TABLES 2](#) and [3](#). The mean logistic EuroSCORE was 12.9 ± 8.1 for all groups (*P* = 0.83). There were no significant differences in demographic and clinical characteristics between the groups. During rest echocardiography, no significant differences in basic parameters were observed. Compared with the CABGa group, significantly higher values of MDI were observed in the CABGma and CABGmr groups. During ExE, no significant differences in workload and exercise EF changes were reported in the subgroups of patients. The CABGa group showed a significant decrease in stress-induced FIMR (*P* = 0.019) and an insignificant increase in TRPG (*P* =

0.49). In the remaining groups, there was a significant increase in FIMR and TRPG during exercise ([TABLE 3](#)). During DBX, the normalization of MDI and a significant decrease in FIMR were observed in the CABGa group (*P* < 0.001); in the other groups, moderate/severe FIMR was maintained (*P* = nonsignificant for both groups). During DBX, in the CABGma and CABGmr groups no significant improvement in MDI was observed compared with the values at rest.

Operative results All patients underwent complete surgical revascularization. A biological valve was implanted in 2 patients, a mechanical valve in 7. Medtronic Hall 29 mm was implanted into mitral orifice with subvalvular apparatus preservation. Undersizing annuloplasty of the mitral annulus was performed in 27 patients. The following ring types were used: Carpentier-Edwards Physio in 19 patients and Duran Medtronic in 8 patients. Relevant surgical and early postoperative clinical data are presented in [TABLE 4](#).

Clinical endpoints and outcome Early (<30-day) mortality was 11.9% (n = 5). Four patients (14.8%) died in the CABGma group (low cardiac output in 2 patients and multiorgan failure in 2 patients). One patient (11.1%) died in the CABGmr group (multiple organ failure). Two patients died during follow-up. All patients in the CABGa group survived the perioperative period and 12-month follow-up. Survival rate at 12 months was 100%, 81.5%, and 77.8% in the CABGa, CABGma, and CABGmr groups, respectively (*P* = 0.3).

TABLE 5 Changes in the New York Heart Association and Canadian Cardiovascular Society classes at baseline and at 12 months after surgery in patient subgroups

	NYHA		P	CCS		P
	baseline	12 months		baseline	12 months	
CABGa (n = 6)	1.83 ± 0.75	1.33 ± 0.51	0.22	2.67 ± 0.52	1.33 ± 0.52	0.062
CABGma (n = 22)	2.52 ± 0.64	1.59 ± 0.67	0.0001	2.18 ± 0.88	1.14 ± 0.35	<0.0001
CABGmr (n = 7)	2.33 ± 0.87	1.14 ± 0.38	0.125	2.33 ± 0.87	1 ± 0.1	0.062

Abbreviations: see TABLES 1 and 2

In the whole study group, there were 5 hospitalizations (11.9%) due to HF exacerbation during follow-up (no hospitalizations in the CABGa group; 3 hospitalizations [11.1%] in the CABGma group, and 2 hospitalizations [22.2%] in the CABGmr group).

Postoperative functional status At baseline, the mean values of NYHA and CCS were not significantly different between the study groups (TABLE 2). At 12 months, an improvement in CCS and NYHA was noticed in all study groups, but a statistical significance was reported only in the CABGma group (TABLE 5). At the final follow-up visit, the majority of patients in all subgroups had NYHA class I and CCS class 1, and we observed no differences between the subgroups with respect to NYHA and CCS classes ($P = 0.36$ and $P = 0.32$, respectively).

Echocardiographic results The analysis of selected echocardiographic variables at 12 months showed most beneficial changes in the CABGma group (TABLE 6). The comparison of the mean values of

WMSI, EF, and ESV during subsequent follow-up visits did not reveal significant differences between the analyzed study groups. TABLE 7 presents a pooled analysis of the changes in FIMR value during follow-up.

During preoperative assessment, the mean workload value was of 60 ± 20.3 W. No significant differences between the study groups were observed (CABGa vs. CABGma vs. CABGmr: 63.3 ± 19.4 vs. 58.9 ± 21.6 vs. 61.3 ± 18.5 W; $P = 0.9$, respectively). At 12 months, an increase in the workload value during ExE was observed in all groups, but only in the CABGma group the difference was statistically significant ($P < 0.001$; TABLE 6). At 12 months, no significant increase in FIMR was observed in any of the subgroups during ExE.

Reverse remodeling At 12 months, LVRR was observed in 83% of the patients in the CABGa group, 63.7% in the CABGma group, and 100% in the CABGmr group. There were no differences between the patient groups ($P > 0.05$). In 2 patients in the CABGma group, the ESV value was significantly increased when compared with

TABLE 6 Changes in selected echocardiographic parameters at 12 months after surgery

	CABGa (group 1)			CABGma (group 2)			CABGmr (group 3)		
	baseline	12 months	P	baseline	12 months	P	baseline	12 months	P
Watt	63.3 ± 19.4	79.2 ± 29.4	0.19	58.9 ± 21.6	81.7 ± 22.3	<0.001	61.3 ± 18.5	84.2 ± 19.3	0.054
ERO rest, cm ²	0.23 ± 0.03	0.12 ± 0.06	0.024	0.3 ± 0.08	0.06 ± 0.05	<0.001	0.27 ± 0.03	0.05 ± 0.03	<0.001
ERO ExE, cm ²	0.17 ± 0.01	0.13 ± 0.06	0.12	0.37 ± 0.12	0.07 ± 0.06	0.003	0.34 ± 0.11	0.05 ± 0.02	<0.001
TRPG rest, mmHg	34.5 ± 8.5	21.7 ± 11.5	0.066	34.5 ± 10.4	29.6 ± 9.2	0.033	28 ± 8.2	19.3 ± 12.3	0.4
TRPG ExE, mmHg	38.2 ± 6.8	33.8 ± 5.7	0.22	49.3 ± 12.4	33.0 ± 11.1	<0.001	42.6 ± 17.7	28.3 ± 5.7	0.098
EF rest, %	38.2 ± 13.2	45.3 ± 9	0.11	36.0 ± 8.9	39.4 ± 10.7	0.12	40.0 ± 9.1	45.3 ± 7.9	0.062
EF ExE, %	41.2 ± 13.9	47.3 ± 9.9	0.06	35.1 ± 9.0	42 ± 11.3	0.0003	39.4 ± 3.9	46.5 ± 6.7	0.066
ESV, ml	96.3 ± 69	71.3 ± 43.4	0.183	106.6 ± 37.8	86.1 ± 37.7	0.0003	89.2 ± 52.9	67.5 ± 38.5	0.027
WMSI	1.78 ± 0.53	1.36 ± 0.24	0.069	1.8 ± 0.3	1.58 ± 0.28	0.042	1.72 ± 0.35	1.46 ± 0.25	<0.001

Abbreviations: see TABLES 1 and 3

TABLE 7 Degrees of functional ischemic mitral regurgitation – intraoperative, at discharge, at 6 months, and at 12 months after surgery

FIMR grade	Intraoperative			2–7 days			6 months			12 months		
	mild	moderate	severe	mild	moderate	severe	mild	moderate	severe	mild	moderate	severe
CABGa, n	6	0	0	4	2	0	3	3	0	3	3	0
CABGma, n	23	0	0	22	1	0	20	2	1	19	2	1
CABGmr, n	8	0	0	8 ^a	0	0	7 ^a	0	0	7 ^a	0	0

^a constructional regurgitation

Abbreviations: FIMR – functional ischemic mitral regurgitation, others – see TABLE 1

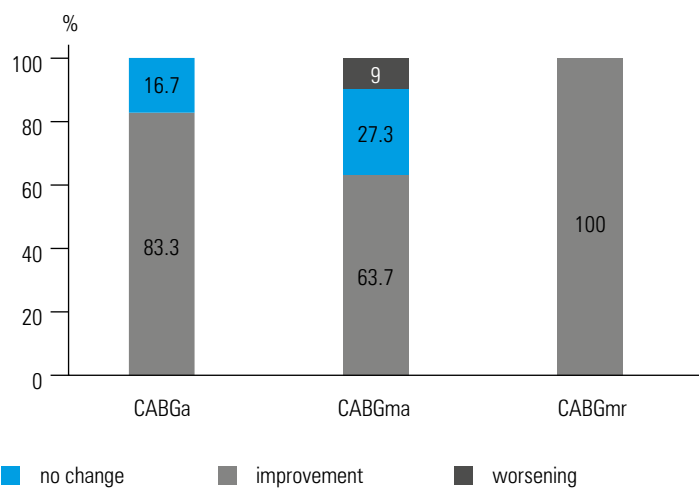


FIGURE Reverse remodeling in the subgroups of patients during 12-month follow-up
Abbreviations: see **TABLE 1**

the baseline value (in both patients recurrence of moderate FIMR was observed; **FIGURE**).

DISCUSSION Currently, restrictive mitral valve annuloplasty is the most widely accepted surgical technique in the management of patients with severe FIMR. The results of this procedure are disappointing due to high rates of persistent and recurrent FIMR at follow-up, which are associated with poor prognosis.¹⁸ The results of current strategies create the need for a better understanding and preoperative assessment of the mitral valve and LV geometry and function.

Selection of patients for CABGa was based on strict echocardiographic criteria (**TABLE 1**), the crucial component of which was to reveal the myocardial viability of the LV segments whose dysfunction during rest examination generated severe FIMR. A cumulative analysis of the ExE and DBX results allowed us to make final therapeutic decisions. Simultaneously, it was a prerequisite to obtain complete normalization of MDI and a decrease in FIMR degree during DBX by at least 2 classes. The above criteria allowed us to schedule only 6 patients for this type of treatment. Postoperative results confirmed that our therapeutic decisions were appropriate. Only in this group of patients, there were no deaths or exacerbations of HF or angina symptoms during 12-month follow-up. Additionally, LVRR and only moderate FIMR were observed in the majority of patients in the CABGa group.

In our study, early mortality in the entire study population was 11.9% (n = 5), which is in line with the rates reported in the previous studies in similar high-risk populations.^{19,20} The operative mortality was lower in patients who underwent CABGa (0%) than in those who underwent CABGma (14.8%; n = 4) or CABGmr (11.1%; n = 1). During follow-up, only 2 patients died but mortality in the CABGa group was 0%.

The analysis of the functional status and exercise capacity in the follow-up ExE was an important component of the overall assessment of the surgical procedure and its efficacy. At 12 months, the functional status and physical capacity improved in all patients, and no

differences in the NYHA and CCS classes were observed between the groups. Our results are in agreement with those reported by Kim et al.,²¹ who observed a similar improvement in the NYHA class at 2-year follow-up in the CABG and repair groups.²¹

During follow-up, we observed a statistically significant reduction in FIMR in all study groups (**TABLE 6**). Small, moderate, and severe FIMR was observed in 29 (83%), 5 (14%), and 1 (3%) surviving patient, respectively (**TABLE 7**). Complete revascularization performance resulted in a significant improvement in LV geometry and function, particularly in the CABGma group. Kang et al.²² reported that patients who demonstrated an improvement in LV function and a reduction in LV size after CABG also had a reduction in FIMR degree at 1 year.²² In our study, we observed a similar reduction in FIMR in the CABGa group (**TABLE 6**). The progress of LV remodeling and, secondarily, the posterior mitral valve leaflet restriction are the mechanisms responsible for the lack of improvement or increase in FIMR degree after surgery.²³ In our study, independently of the type of surgery, we observed LVRR in most patients and favorable echocardiography results were reflected in their clinical status.

To our knowledge, this is the first and the largest analysis of the criteria for the selection of patients for surgical treatment based on all the essential components of mitral complex functioning in echocardiography examination at rest and during exercise. However, it was an observational, nonblinded, single-center, prospective case series study, and the application of our results is limited. The main limitation is a relatively low number of patients. Thus, the statistical power of correlations is low. It has to be stressed, however, that severe FIMR in patients treated with CABG is observed only in a small number of patients. Considering the innovative character of this study, our group of patients is one of the most numerous groups presented in the literature, and it is the first study that used such a complex methodology in the selection of patients for surgical procedure.

Another limitation of the study is the lack of randomization, which may result in potential selection bias, possibly leading to incorrect conclusions. It has to be stressed that we used deterministic criteria in the selection of patients for a suitable type of treatment. Lack of randomization resulted in uneven classification of patients to the CABGa, CABGma, or CABGmr groups.

Our results indicate that the use of an elaborate diagnostic strategy based on stress echocardiography may improve decision-making process in the selection of patients with severe FIMR for a suitable surgical procedure, which helps achieve satisfactory clinical results (in the early postoperative period and at 12 months after surgery). Based on such a selection, CABGa may reduce FIMR and lead to functional and structural improvement without an increase in the operative and

long-term mortality rates in a selected group of patients. Because this novel clinical decision-making tool was applied only in 42 patients, the results should be considered as hypothetical. This must be clearly stated, as should the need to study a larger group of patients before the approach is widely accepted and broadly implemented. Certainly, further validation and randomized studies on a larger patient group and with longer follow-up are needed.

Acknowledgments The study was supported by the grant of the Ministry of Science and Higher Education (No. 2 P 05B 080 29).

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Przydatność echokardiografii obciążeniowej w wyborze optymalnej interwencji kardiochirurgicznej u pacjentów z niedokrwienią niedomykalnością mitralną dużego stopnia zakwalifikowanych do pomostowania aortalno-wieńcowego

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SŁOWA KLUCZOWE

annuloplastyka
mitralna,
echokardiografia
obciążeniowa,
niedokrwienność
niedomykalność
mitralna dużego
stopnia

STRESZCZENIE

WPROWADZENIE Niedokrwienność niedomykalność zastawki mitralnej (NNM) dużego stopnia znacząco pogarsza rokowanie chorych po przebytym zawale mięśnia sercowego. Złożony patomechanizm powstawania NNM oraz jej dynamiczny charakter utrudniają opracowanie skutecznych metod terapii.

CELE Celem badania była prospektywna ocena strategii diagnostycznej uwzględniającej echokardiografię czynnościową w kwalifikacji chorych z NNM dużego stopnia do odpowiedniego leczenia operacyjnego: jedynie pomostowanie aortalno-wieńcowe (*coronary artery bypass grafting alone* – CABGa) lub CABG w połączeniu z annuloplastyką mitralną (CABG *mitral annuloplasty* – CABGma) lub wymianą zastawki (CABG *mitral replacement* – CABGmr).

PACJENCI I METODY Prospektywnej analizie poddano 42 pacjentów (23 kobiety, 19 mężczyzn) w wieku 67 ± 12 lat z pozawałową NNM dużego stopnia, zakwalifikowanych do CABG. U każdego pacjenta przed CABG wykonano szczegółową analizę morfologii aparatu mitralnego, czynności lewej komory, stopnia NNM na podstawie oceny pola powierzchni ujścia fali zwrotnej (duża $\geq 0,2$ cm²), żywotności mięśnia sercowego oraz wskaźników deformacji zastawki mitralnej. Na podstawie oceny klinicznej oraz parametrów echokardiografii spoczynkowej i czynnościowej, chorych zakwalifikowano do następujących sposobów terapii: CABGa (grupa 1, n = 6), CABGmp (grupa 2, n = 27) i CABGmr (grupa 3, n = 9).

WYNIKI We wszystkich grupach uzyskano porównywalne wyniki analizy klinicznej i echokardiograficznej w 12-miesięcznej obserwacji. Istotną poprawę odnotowano u większości pacjentów, niezależnie od rodzaju operacji. W całej analizowanej grupie wczesna (30-dniowa) śmiertelność wyniosła 11,9% (n = 5). Przeżywalność 12-miesięczna w grupach 1, 2 oraz 3 wyniosła odpowiednio 100%, 81,5% i 77,8% (p = 0,3). We wszystkich grupach odnotowano znamiennej redukcję wielkości NNM po 12 miesiącach od zabiegu: NNM małego, umiarkowanego i dużego stopnia wystąpiła odpowiednio u 29 (83%), 5 (14%) i 1 (3%) chorego. Odwrotny remodeling lewej komory stwierdzono w grupie 1 u 83% pacjentów, w grupie 2 u 63,7%, a w grupie 3 u 100% (różnica nieistotna statystycznie).

WNIOSKI Przedstawiona strategia diagnostyczna oparta na echokardiografii czynnościowej może pozwolić na precyzyjną kwalifikację chorych z NNM dużego stopnia do odpowiedniego rodzaju zabiegu kardiochirurgicznego.

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Praca wpłynęła: 07.02.2012.
Przyjęta do druku: 04.04.2012.
Publikacja online: 11.04.2012.
Nie zgłoszono sprzeczności
interesów.
Pol Arch Med Wewn. 2012;
122 (5): 217-225
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