Surgical Treatment of Patients with Ischemic Cardiomyopathy - A Novel Approach

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Summary

Nine patients with ischemic cardiomyopathy (ICM) underwent isolated coronary artery bypass grafting (CABG). Thirty-one patients with anterior-apical muscle fiber aneurysm of the heart underwent interventricular patch plasty of the left ventricle (LV) in combination with CABG. Both groups were randomized regarding their systolic function, end-systolic and end-diastolic dimensions, and volumes of the LV. It is remarkable that patients with ICM presented a more severe clinical picture of coronary artery disease ($p = 0.03$). Ventricular tachyarrhythmias were more frequent ($p = 0.006$), as well as atherosclerotic lesions in the circumflex artery ($p < 0.001$). It was shown that revascularization of the heart alone did not improve the systolic function, dimensions, and volumes of the LV. On the other hand, the aneurysm correction with interventricular patch plasty combined with CABG significantly improved the mechanical function of the LV in the postoperative period and during long-term follow-up. On the basis of our experience, 3 patients with ICM without apical aneurysm in the LV underwent the combined procedure of CABG and remodeling of the LV with an interventricular patch with good postoperative and long-term results. We conclude that combining CABG with the patch volume-reduction technique of the LV in patients with ICM could be an alternative to heart transplantation, cardiomyoplasty, and the Batista procedure.

Key Words

Left ventricle, heart aneurysm, ischemia, cardiomyopathy, coronary artery bypass

Introduction

Despite significant progress in anesthesiology, myocardial protection, as well as in the creation of new drugs which permit effective pre-treatment of the patients, isolated revascularization of the myocardium does not completely solve the problem of surgical treatment of patients with severe depression of the left ventricular function. This group of patients still exhibits a high rate of complications, higher mortality, and unsatisfying long-term results [1-5]. Controversial results of cardiomyoplasty and long waiting lists for heart transplantation justify the quest for new approaches to the treatment of these patients [6].

Recent successes in improving the clinical results with revascularization in patients with low ejection fractions are due to:

- selecting patients who have hibernating but still viable myocardium [7],
- using intraaortic balloon counterpulsation [8],
- improving the technique of antero-retrograde cardioplegia [9], and
- using arterial grafts [10].

The main goal of this study was to justify the option of left ventricular remodeling in patients with ischemic cardiomyopathy (ICM).

Materials and Methods

Group 1 consisted of 9 patients with ICM who had undergone isolated coronary artery bypass grafting (CABG). The control group (group 2) included 31 patients who had undergone patch plasty of an anterior-apical, akinetic aneurysm of the heart combined

Parameters	Preoperative state of ICM patients versus patients with LV aneurysms					
		ICM (Group 1)		LVA (Group 2)		
		n/N	%	n/N	%	p
Sex	Male	9/9	100	31/31	100	-
Unstable Angina Pectoris	Present	2/9	22.2	2/31	6.5	0.170
NYHA - Classification	1	0/9	0.0	2/31	6.5	0.430
	2	0/9	0.0	4/31	12.9	0.260
	3	4/9	44.4	20/31	64.5	0.280
	4	3/9	33.3	3/31	9.7	0.080
CHF grade	1	0/9	0.0	9/31	29.0	0.070
	2	9/9	100	22/31	71.0	0.070
Number of MI	1	5/9	55.6	20/31	61.5	0.630
	2	4/9	44.4	7/31	22.6	0.200
	3	0/9	0.0	4/31	12.9	0.260
VA	Present	6/9	66.7	6/31	19.5	0.006
CA lesions	LCA	1/9	11.1	2/31	6.5	0.640
	LAD pr	9/9	100	22/31	71.0	0.070
	LAD mid	0/9	0.0	13/31	41.9	0.020
	DB	0/9	0.0	6/31	19.4	0.150
	CB	2/9	22.2	8/31	25.8	0.830
	OMB	6/9	66.7	3/31	9.7	<0.001
	PLB	3/9	33.3	6/31	19.4	0.380
	RCA	6/9	66.7	15/31	48.4	0.330
LV diastolic dysfunction	Not impaired	2/5	40.0	5/16	31.2	0.720
	Impaired	3/5	60.0	11/16	68.8	0.720

Table 1. Preoperative state of ICM patients versus patients with LV aneurysms. CHF: congestive heart failure, MI: myocardial infarction, CA: coronary artery, VA: ventricular arrhythmia, LCA: left coronary artery, LAD: left anterior descending coronary artery, pr.: proximal, mid: middle, DB: diagonal branch, CB: circumflex branch, OMB: obtuse marginal branch, PLB: postero-lateral branch, RCA: right coronary artery, LVA: left ventricular aneurysm.

with CABG. All patients were males. The pre-operative state of the patients in the 2 groups is outlined in Tables 1 and 2.

All patients were routinely examined by echocardiography. The ejection fraction (EF) (determined by the Simpson technique), the transversal and longitudinal dimensions of the heart, as well as the end-systolic and end-diastolic volumes of the heart were determined. To make the comparison of these two groups more accurate, we used indexes derived by normalization of all parameters to the square surface of the patient's body. The diastolic function of the left ventricle (LV) was evaluated by calculating the ratio between the velocities of the transmitral blood flow during the early filling of the LV and during atrial systole. Coronagraphy and ventriculography in the left oblique projection with evaluation of the akinetic left ventricular wall was routinely performed in all patients using the centerline method. To evaluate the degree of coronary vasculature lesions, an integral parameter -the coronary index- was measured.

All patients were operated under conditions of nor-

		ICM (Group 1) M ± SD	LVA (Group 2) M ± SD	p
Age	years	54.4 ± 6.7	47.4 ± 7.3	0.03
History	months	61.4 ± 54.2	31.2 ± 28.7	0.04
EDPLV	mm Hg	12.8 ± 5.2	13.3 ± 5.6	0.79
EF	%	34.0 ± 4.0	38.9 ± 10.8	0.19
Coronary index		21.9 ± 8.7	17.4 ± 8.4	0.22
Akinetic percentage	%	53.5 ± 8.1	48.0 ± 14.7	0.48
Mean quantity of grafts		3.0 ± 0.5	1.8 ± 1.1	0.004
Ischemic time	min	62.8 ± 37.1	72.6 ± 22.9	0.43
Perfusion time	min	122.9 ± 33.4	130.2 ± 44.9	0.85

Table 2. Preoperative state of ICM patients versus patients with LV aneurysms (quantitative parameters). EDPLV: end-diastolic pressure of the LV, EF: ejection fraction.

mothermic artificial circulation and antegrade warm-blood cardioplegia. The patients of the first group received the isolated CABG by using the left internal mammary artery as a conduit to the anterior descending branch of the left coronary artery. In patients of group 2, the routine CABG was complemented by an interventricular patch plasty with isolation of the scar tissues. The mean time of artificial circulation and the mean quantity of grafted coronary arteries in each group are presented in Table 2, along with other quantitative parameters of the pre-operative state.

The material was statistically processed by T-test and χ^2-tests. The mean values and standard deviations were calculated. A difference was considered significant if $p < 0.05$.

Results

Preoperatively, there were no differences in the severity of congenital heart failure and the frequency of previous myocardial infarction. However, patients with ICM were significantly older than those with left ventricular aneurysm ($p = 0.03$) and had a longer history of ischemic heart disease (Table 2).

The frequency of unstable angina pectoris was comparable in both groups, while the mean function class of stable angina was 3.4 ± 0.5 in patients with ICM, and 2.8 + 0.7 in the control group ($p = 0.03$).

Ventricular arrhythmia (primarily ventricular extrasystoles of high degrees) was significantly more frequent ($p = 0.006$) in the group of patients with ICM. The coronary index was comparable in both groups ($p = 0.22$); however, the quantity and localization of atherosclerotic lesions revealed the following particularities: 7 patients of group 1 revealed an occlusion of the proximal segment of the left anterior descending coronary artery (LAD), 2 patients exhibited 90% stenosis of this artery. In the control group, LAD lesions after the first diagonal branch were more frequent ($p = 0.02$). Furthermore, lesions of the circumflex artery branches were found more often in patients with ICM. The incidence of right coronary artery lesions was comparable in both groups.

The localization of myocardial scars was in complete correspondence to the coronary lesions. All patients in group 1 had pathologic QRS complexes in the precardial ECG leads. The localization of the scars was comparable in both groups.

The degree of reduction in EF and the increase in end-diastolic pressure in the LV were the same in patients with ICM and those with an aneurysm of the LV. The centerline method revealed a comparable dimension of akinetic zones of the LV in both groups, which was 53.5 ± 8.1% and 48.0 ± 14.7%, respectively ($p = 0.48$). Impaired diastolic function of the LV occurred with the same frequency in both groups. However, in patients with ICM, the isovolumetric relaxation time was significantly longer ($p = 0.02$).

Echocardiography parameters, such as systolic function, end-systolic and end-diastolic dimensions, and volumes of the LV, were comparable in both groups (Table 3).

Preoperative functional state of LV		ICM (Group 1)	LVA (Group 2)	p
		M ± SD	M ± SD	
EF	%	36.7 ± 6.5	36.8 ± 7.8	0.47
iESDLV	mm/m^2	28.6 ± 2.5	25.2 ± 5.2	0.07
ESDLV	mm/m^2	35.0 ± 3.2	32.8 ± 5.9	0.31
iESDLV	ml/m^2	57.6 ± 19.0	64.1 ± 32.2	0.58
iEDVLV	ml/m^2	91.0 ± 27.5	101.0 ± 40.0	0.5
Stroke volume index	ml/m^2	33.2 ± 10.7	36.5 ± 12.6	0.44
D apic.	mm	49.7 ± 1.5	49.3 ± 7.5	0.92
D mid.	mm	57.0 ± 3.0	57.7 ± 6.7	0.85
L	mm	87.7 ± 4.6	89.4 ± 12.5	0.81
D apic. / D mid.	%	87.2 ± 3.1	85.5 ± 10.3	0.78
D mid. / L	%	65.0 ± 1.8	65.2 ± 7.5	0.97
E	m/s	0.52 ± 0.15	0.54 ± 0.18	0.82
A	m/s	0.59 ± 0.1	0.66 ± 0.14	0.27
E/A		0.93 ± 0.39	0.8 ± 0.24	0.43
IVRT	s	140.8 ± 26.9	86.8 ± 28.9	**0.002**

Table 3. Preoperative functional state of the LV. EF: ejection fraction, iESDLV: index of the end-systolic dimension of the LV, ESDLV: end-systolic dimension of the LV, iESVLV: index of the end-systolic volume of the LV, iEDVLV: index of the end-dia stolic volume of the LV, D: dimension, L: length, IVRT: interventricular relaxation time.

The duration of artificial circulation and placement of aortic clamps was the same in both groups. Patients with ICM received an isolated CABG of 3 to 4 coronary arteries. The mean quantity of grafted arteries in that group was 3.0 ± 0.5, and it was significantly higher than in the control group (mean = 1.8 ± 1.1) ($p = 0.004$).

Despite the complete revascularization in all patients of the group 1, we did not notice any postoperative improvement in parameters that characterize the functional state of the heart (Table 4). In contrast, the patients of the control group exhibited significant improvement of the systolic and diastolic function of the LV, as well as improvement of the left ventricular dimension following the surgery (Table 5).

Furthermore, 6 of 9 patients of the first group had significant acute heart failure postoperatively, while acute heart failure necessitating adrenergic medication was noted only in 3 of 31 patients of the control group ($p < 0.001$).

The long-term evaluation of functional parameters and dimensions of the LV also revealed the advantages of interventricular patch plasty compared with isolated myocardial revascularization in patients with big left ventricular dimensions (Table 6).

During long-term follow-up, patients with ICM showed either a complete absence or significant reduction of angina pectoris, but, at the same time, an increasing severity of congestive heart failure. These patients needed intensive heart therapy and frequent hospitalizations.

Discussion

Patients with dilated ICM, characterized by a transversal diastolic diameter of more than 70 mm, form the most complicated group for surgical treatment. With increasing life spans and improved odds of surviving a myocardial infarction, the quantity of such patients increases rapidly [11]. The main therapies used to correct dilated ICM are heart transplantation and cardiomyoplasty [12,13]. However, these procedures cannot be applied widely [6].

The recently introduced volume reduction (Batista procedure) in ICM is connected with a high mortality rate, and its long-term effectiveness has not yet been studied [14].

These therapeutic limitations have led to the fact that

Parameter		LV functional state in ICM patients before and after surgery				
		Before	30 days after	12 months after	p 1 - 2	p 2 - 3
		M ± SD	M ± SD	M ± SD		
EF	%	36.7 ± 6.5	42.7 ± 9.6	37.8 ± 10.3	0.053	0.79
iESD	mm/m^2	28.6 ± 2.5	27.4 ± 4.6	30.6 ± 6.2	0.26	0.17
iEDD	mm/m^2	35.0 ± 3.2	33.3 ± 4.1	36.6 ± 2.2	0.16	0.31
iESV	ml/m^2	57.6 ± 19.0	48.5 ± 20.7	60.3 ± 19.6	0.058	0.79
iEDV	ml/m^2	91.0 ± 27.5	82.4 ± 20.9	94.8 ± 18.9	0.065	0.78
SV	ml/m^2	33.2 ± 10.7	33.7 ± 6.2	34.3 ± 9.7	0.96	0.85
D apic.	mm	49.7 ± 1.5	49.6 ± 6.2	51.6 ± 6.7	0.99	0.65
D mid.		57.0 ± 3.0	54.6 ± 5.2	56.8 ± 6.1	0.5	0.96
L	mm	87.7 ± 4.6	86.4 ± 5.3	87.0 ± 3.3	0.74	0.82
D apic./D mid.	%	87.2 ± 3.1	90.8 ± 6.1	91.7 ± 16.6	0.4	0.67
D mid./L	%	65.0 ± 1.8	63.5 ± 8.6	65.5 ± 9.1	0.77	0.93
E	m/s	0.52 ± 0.15	0.47 ± 0.15	0.53 ± 0.2	0.58	0.96
A	m/s	0.59 ± 0.1	0.66 ± 0.13	0.6 ± 0.13	0.39	0.84
E/A		0.93 ± 0.39	0.78 ± 0.43	0.93 ± 0.43	0.57	0.99
IVRT	ms	140.8 ± 26.9	93.6 ± 46.6	73.4 ± 37.7	0.08	0.01

Table 4. LV functional state in ICM patients before and after surgery. EF: ejection fraction, iESD: index of the end-systolic dimension, iEDD: index of the end-diastolic dimension, iESV: index of the end-systolic volume, iEDV: index of the end-dia stolic volume, SV: stroke volume, D: dimension, L: length, IVRT: interventricular relaxation time.

isolated revascularization of the myocardium has become the only alternative to heart transplantation in ICM patients [15]. The short- and long-term results of that approach are controversial [7-10,15-17]. In these patients, long-term results are routinely evaluated clinically by using the EF as an integral characteristic of the left ventricular function.

Comparing these data and the geometrical parameters of the LV in patients of group 1, we did not notice any significant changes either during short-term or during long-term observation. Patients did not exhibit a reduction in the degree of congestive heart failure. However, the functional class of angina pectoris improved significantly.

Isolated myocardial revascularization in patients with big akinetic muscle fiber scars or aneurysms was supposed to restitute the function of hibernated but still viable myocardium [18, 19], but, in practice, that was not the case [20].

Vincent Dor had shown that the interventricular patch technique may increase EF and reduce the dimensions of the heart (LV remodeling) in patients with big akinetic aneurysms. This was proven by good short- and long-term results in a statistically significant number of patients [21-23].

Our experience with Dor's technique in the surgical treatment of anterior-apical aneurysms of the LV also shows a significant improvement regarding dimensions, volume, and geometry of the LV in comparison to the group of ICM patients which had undergone the isolated CABG.

These primary results permitted us to speculate that the interventricular patch technique (LV remodeling) in combination with revascularization of the myocardium in patients with ICM will provide an opportunity to improve both clinical and functional results. We have performed 3 procedures of that type.

Case report

Patient X. Diagnosis: ischemic heart disease; stable angina pectoris of functional class 3; post-myocardial infarction cardiosclerosis; akinetic aneurysm of the LV; Lerish syndrome. The patient had survived 2 myocardial infarctions. The ECG revealed pathologic Q signals in leads 3 and avF, and pathologic QRS complexes in leads V1 to V5. The coronagraphy showed

Parameters		Groups ICM (Group 1) M ± SD	LVA (Group 2) M ± SD	p
EF	%	42.7 ± 9.6	45.8 ± 6.7	0.32
iESD	mm/m²	27.4 ± 4.6	21.8 ± 5.6	**0.01**
iEDD	mm/m²	33.3 ± 4.1	30.1 ± 6.8	0.16
iESV	ml/m²	48.5 ± 20.7	36.5 ± 11.9	**0.03**
iEDV	ml/m²	82.4 ± 20.9	65.3 ± 20.8	**0.03**
SV	ml/m²	33.7 ± 6.2	28.3 ± 9.8	0.16
D apic.	mm	49.6 ± 6.2	40.6 ± 4.9	**0.005**
D mid.		54.6 ± 5.2	50.9 ± 5.5	0.21
L	mm	86.4 ± 5.3	73.2 ± 3.9	**< 0.001**
Dapic/Dmid	%	90.8 ± 6.1	80.1 ± 9.3	**0.03**
Dmid/L	%	63.5 ± 8.6	69.7 ± 8.3	0.17
E	m/s	0.47 ± 0.15	0.63 ± 0.19	0.09
A	m/s	0.66 ± 0.13	0.59 ± 0.14	0.14
E/A		0.78 ± 0.43	1.16 ± 0.3	**0.03**
IVRT	ms	93.6 ± 46.6	67.2 ± 13.8	**0.04**

Table 5. LV functional state in ICM and LVA patients 30 days after surgery. EF: ejection fraction, iESD: index of the end-systolic dimension, iEDD: index of the end-diastolic dimension, iESV: index of the end-systolic volume, iEDV: index of the end-diastolic volume, SV: stroke volume, D: dimension, L: length, IVRT: interventricular relaxation time.

90% stenosis of the main left coronary artery, occlusion of the LAD in the middle third, 60% stenosis of the diagonal branch, 80% stenosis of the circumflex artery, and occlusion of the obtuse marginal branch and of the right coronary artery. The EF was 39%, the end-diastolic pressure of the LV (EDPLV) 18 mmHg. Ventriculography showed akinesia of the apical segment with an akinetic dimension of about 54%. The index of the end-systolic dimension of the LV (iESDLV) was 24.7 mm/m^2, that of the end-diastolic dimension of the LV (iEDDLV) 31.6 mm/m^2. The index of the end-systolic volume of the LV (iESVLV) was 66.8 ml/m^2, and that of the end-diastolic volume of the LV (iEDVLV) 108.8 ml/m^2. The transversal dimension of the apical segment of the LV was 49 mm, the dimension of the LV on the level base of the papillary muscles was 60 mm, the longitudinal dimension of the LV measured 95 mm. The diastolic function of the LV was significantly impaired (E/A = 0.62).The isovolumetric relaxation time of the LV (IVRT) was 144 ms.

The patient underwent surgery on November 12, 1998. The surgical procedure consisted of CABG to the LAD, the diagonal branch, the obtuse marginal branch, and the posterior descending artery. Exploration of the left ventricular apex did not reveal any aneurysms. The LV was transected through its apex. There was no endocardial scar. The apical endocardium exhibited a normal trabeculation.

The histological study of the apical myocardium showed a partial dystrophy of the cardiomyocytes (Figure 1). The majority of cardiomyocytes were in different stages of dystrophy and cell death. Areas of atrophied cardiomyocytes alternated with groups of hypertrophied ones.

In these regions, a great number of lymphatic histocytes were noted, as well as production of connective tissue (sclerosis).

Two small thrombi were removed from the left ventricular trabeculation. The large size of the LV necessitated its reduction. Two centimeters from the apex, an endocardial purse string was completed with a Prolen suture 2-0. The defect of the LV was narrowed to 2 cm, and an autopericardium patch was sewn on using the endocardial technique. The left ventricular incision was closed above the patch with autopericardial pled-

Parameters		Groups ICM (Group 1) M ± SD	LVA (Group 2) M ± SD	p
EF	%	37.8 ± 10.3	45.9 ± 7.3	**0.04**
iESD	mm/m²	30.6 ± 6.2	23.8 ± 5.7	**0.02**
iEDD	mm/m²	36.6 ± 2.2	32.1 ± 0.4	**0.048**
iESV	ml/m²	60.3 ± 19.6	43.4 ± 13.8	**0.03**
iEDV	ml/m²	94.8 ± 18.9	77.9 ± 15.4	**0.04**
SV	ml/m²	34.3 ± 9.7	34.9 ± 6.6	0.87
D apic.	mm	51.6 ± 6.7	0.62 ± 0.14	**0.03**
D mid.		56.8 ± 6.1	0.59 ± 0.11	**0.045**
L	mm	87.0 ± 3.3	1.08 ± 0.3	**0.007**
D apic / D mid	%	91.7 ± 16.6	78.2 ± 38.9	0.34
Dmid / L	%	65.5 ± 9.1	42.6 ± 6.8	0.76
E	m/s	0.53 ± 0.2	49.9 ± 5.5	0.31
A	m/s	0.6 ± 0.13	77.9 ± 5.8	0.85
E/A		0.93 ± 0.43	85.2 ± 9.2	0.44
IVRT	ms	73.4 ± 37.7	64.2 ± 7.2	0.83

Table 6. LV functional state in ICM and LVA patients 12 months after surgery. EF: ejection fraction, iESD: index of the end-systolic dimension, iEDD: index of the end-diastolic dimension, iESV: index of the end-systolic volume, iEDV: index of the end-diastolic volume, SV: stroke volume, D: dimension, L: length, IVRT: interventricular relaxation time.

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No events pointing to heart insufficiency were observed during the postoperative period. The echocardiographic findings from two weeks after the operation showed an increase in the EF to 50%, a reduction of iESDLV to 20 mm/m², iEDDLV to 30 mm/m², iESVLV to 45.3 ml/m², and iEDVLV to 75 ml/m². The apical transversal dimension was reduced to 43 mm, the transversal dimension of the LV on the level base of the papillary muscles was reduced to 53 mm, and the longitudinal dimension of the LV to 78 mm. The diastolic function of the LV was normalized. The E/A ratio was increased to 1.22. The IVRT decreased to 80 ms.

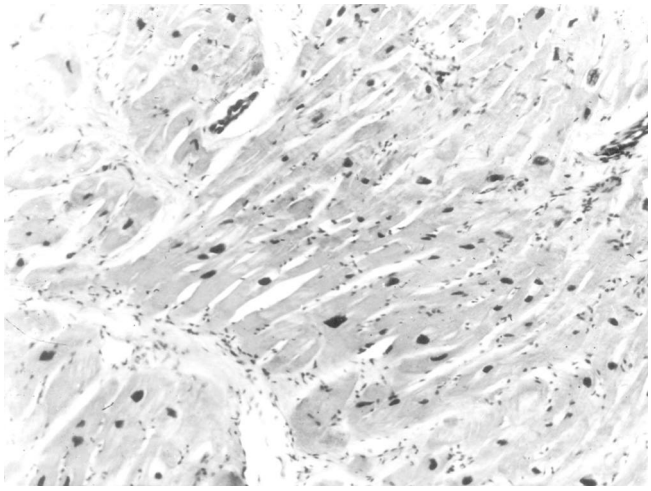

Figure 1. Ischemic myocardial zones with dystrophy and partial cell death of cardiomyocytes. Stain: hematoxilin eosin. Magnification factor x140.

The patient was discharged from the hospital without onsets of angina pectoris and congestive heart failure.

The patient underwent an echocardiographic examination 10 months after the procedure. It revealed that the parameters of systolic and diastolic function, as well as all dimensions and volumes of the heart had not changed any further.

The EF was 50%, the iESDLV was 20.5 mm/m², iEDDLV 29.5 mm/m2, iESVLV 40.5 ml/m², and iEDVLV 75 ml/m². The apical transversal dimension was 41 mm, the transversal dimension of the LV on the level base of the papillary muscles 53 mm, and the longitudinal dimension of the LV 78 mm. The diastolic

function of the LV was normal (E/A = 1.22), the IVRT remained at 80 ms.

Conclusion

Intensive treatment of acute myocardial infarction, including non-surgical rvascularization, has significantly changed the post-infarction morphology of the LV: the subepicardial layer of the LV remains in many cases unimpaired. Classical big diskinetic fibers aneurysms are now a rare case. At the same time, the quantity of patients with big akinetic scars and increased dimensions of the LV is increasing rapidly. In that group of patients, revascularization of the heart alone does not lead to reduction in the dimensions of the LV or to an improvement of the functional state of the LV, despite clinical improvements.

The use of a left ventricular reduction technique based on interventricular patch plasty in patients with ICM may be the real alternative to heart transplantation, cardiomyoplasty, and the Batista procedure.

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