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Original Article

Postmyocardial infarction left ventricular dysfunction – Assessment and follow up of patients undergoing surgical ventricular restoration by the endoventricular patchplasty

Margaret D'Mello [a,*], Abraham A. Kurudamannil [b], Degapudi J. Reddy [c], Penumatsa S. Raju [d]

[a] Dept. of Cardiology, St. Isabel Hospital, 49, Oliver Road, Luz, Mylapore, Chennai 600 004, Tamil Nadu, India
[b] Head of Department, Department of Cardiology, Fortis Malar Hospital, Chennai, India
[c] Chief Cardiothoracic Surgeon, Vijaya Heart Foundation, Chennai, India
[d] Chief of Anaesthesiology, Cardiac Anaesthesia, Vijaya Heart Foundation, Chennai, India

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ABSTRACT

Background: Surgical ventricular restoration with endoventricular patchplasty improves left ventricular function and restores left ventricular shape.
Method: The study included patients who presented with transmural anterior myocardial infarctions between June 2007 and May 2008. Briefly the technique included – coronary revascularization, resection of the endocardial scar, left ventricular reconstruction using an endoventricular synthetic patch. Left ventricular geometric parameters were studied preoperatively, early postoperatively, at 3 and 6 months and statistically analyzed by SPSS 14 software package.
Results: The ejection fraction increased from 33.5 ± 5.02 to 37.77 ± 7.17 immediate postoperatively. The preoperative left ventricular ejection fraction – a mean of 33.25% (±5.02%), increased by 10.3%–11% at the third and fourth follow up respectively after surgical ventricular restoration ($p \leq 0.001$). The left ventricular end systolic volume index improved from a mean of 48.84 ± 11.37 preoperatively to 24.66 ± 5.92 postoperatively ($p \leq 0.001$).
Conclusions: Surgical ventricular restoration in our study has clearly demonstrated a positive effect on LV geometry.

1. Introduction

In ischemic cardiomyopathy, surgical remodeling is often combined with revascularization, mitral valve repair, and cardiac resynchronization therapy, along with arrhythmia prevention and other pharmacologic regimens, to provide a comprehensive therapeutic strategy for patients with this infirmity.[1] Myocardial regional or global dysfunction can persist after successful early reperfusion leading to adverse remodeling and clinical heart failure in a consistent number

* *Corresponding author.* Tel.: +91 (44) 24991081/82/83, +91 (0) 9841072600; fax: +91 (44) 24984776.
E-mail address: drmarg20@gmail.com (M. D'Mello).
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of patients.[2] Surgical ventricular restoration (SVR), with endoventricular patchplasty (EVPP) is an emerging technique and a safe and effective surgical option for postinfarction myocardial dysfunction. It results in improvement of left ventricular (LV) geometry, reduction in wall tension, and improvement in pump function, functional status and survival.[3] Numerous investigations have demonstrated the value of LV volume measurement at a single time-point and over time in predicting clinical outcomes in patients with heart failure and in those after myocardial infarction.[4] Considering the ischemic cardiomyopathy, we undertook to study the clinical and hemodynamic benefits of surgical ventricular restoration by the endoventricular patchplasty in a sample of Indian subjects who had previous anterior myocardial infarction with left ventricular dysfunction.

2. Methods

2.1. *Study population and study design*

After due clearance from the Ethics Committee of the hospital, surgical ventricular restoration (SVR) using the endoventricular patch was performed in 59 consecutive patients (48 males) from June 2007 to May 2008,with previous transmural anterior myocardial infarction at a mean age of 56.3 (32–78) years. All the surgeries were done at our center – Vijaya Heart Foundation. Postinfarction LV dysfunction was present in most patients with a large akinetic or dyskinetic left ventricle in 20 and 32 patients, respectively. They were evaluated by history, detailed clinical examination, electrocardiogram, coronary angiography and echocardiographic documentation of the left ventricular geometric parameters.

Nine LV geometric indices were measured in all patients preoperatively, at discharge, at 3 months and 6 months. Trends in selected variables at 3 time intervals following EVPP were studied- Left ventricular ejection fraction (LVEF), LV end-systolic dimension, LV end diastolic dimension (Fig. 1), LV end systolic volume, LV end diastolic volume, LV end systolic volume index, LV end diastolic volume index (Fig. 2), wall motion score index and the diastolic sphericity index.[5]

The above mentioned indices were measured on Philips 5500 Echocardiographic machine by a single operator and the study was not blinded. Mean follow up in operative survivors was six months. Lost to follow up and death excluded 7 patients from this analysis. Hence, 52 patients comprised the final study. All the patients were on optimal doses of the standard therapy with betablockers, Angiotensin converting enzyme inhibitors or Angiotensin receptor blockers, antiplatelet agents and diuretics with individual dosage adjustments according to clinical parameters and renal function status, preoperatively as well as postoperatively.

2.1.1. *Inclusion criteria*

1. Previous anterior myocardial infarction – by history, ECG, ECHO; 2. Significant ventricular dysfunction – LVEF $\leq$ 40% and LV end systolic dimension $\geq$ 40 mm; 3. Large akinetic or dyskinetic segments (more than 35% of LV mass); 4. LV dysfunction after myocardial infarction with symptoms of angina, congestive heart failure, or ventricular tachycardia.

2.1.2. *Exclusion criteria*

1. Patients with grossly elevated Pulmonary artery pressures (MAP $\geq$ 50 mmHg); 2. Patients with associated comorbidities – like end stage renal disease, liver disease, stroke with residual paralysis; 3. Lost to follow up and very early deaths (within 5 days of surgery).

2.1.3. *Definitions*

Dyskinetic LV segment: is defined as a segment displaying paradoxical motion without obvious protrusion from the LV outline; Akinetic LV segment: segment of the LV wall revealing loss of movement during systole, displaying 'nonparadoxical' motion; Anterior MI: All anterior, anterolateral and anteroapical myocardial infarctions with septal involvement; Preoperative assessment (Preop): preoperative status; Early postoperative: At discharge following surgery at day 7 or day

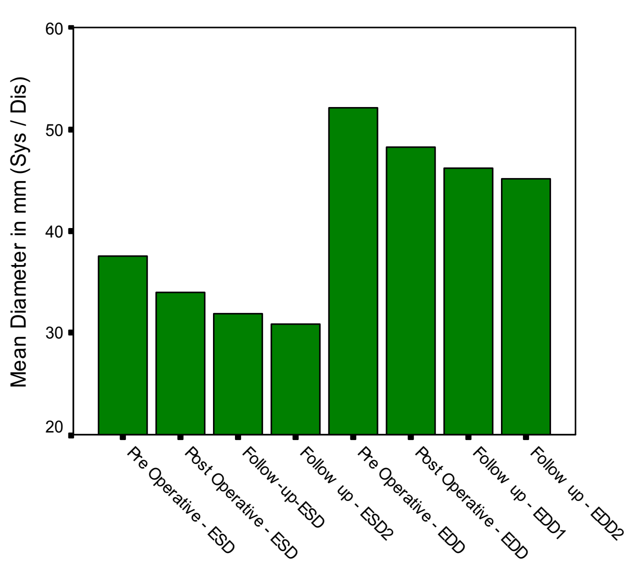

Fig. 1 – LV diameter (systolic/diastolic).

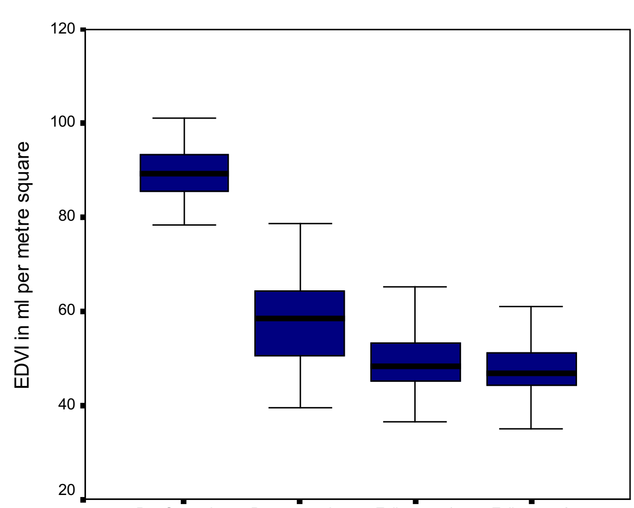

Fig. 2 – LV end diastolic volume index.

10; Follow up 1 (FU 1): First follow up at 3 months after the operation; Follow up 2 (FU 2): Second follow up at 6 months after the operation.

2.1.4. *Operative technique*

Standard cardiopulmonary bypass with blood cardioplegia was obtained, continuous cardiac output monitoring carried out, with transesophageal echocardiaography when required. Distal coronary anastomosis and mitral valve repair or replacement when necessary was done through the left ventricle. LV restoration (EVPP) was done on beating heart in all cases, wherein the LV was opened with a curvilinear incision starting near the apex, a 0.6 mm Goretex patch was sutured with monofilament Goretex (CV-2; 91 cm × 26 mm size needle) to the septum and the patch anchored firmly to the septum and trimmed to appropriate shape. The Goretex patch was sutured to the lateral edge by the continuous mattress suture technique and the redundant sac was excised and sutured to the lateral wall, completing the LV restoration.

2.2. *Statistical analysis*

The clinical, echocardiographic, operative and outcome data were prospectively collected in a database and statistically analyzed using SPSS 14 software package. Statistical analysis were used to describe two scenarios:

2.2.1. *First scenario time course of geometric ventricular change*

Repeated measures ANOVA compared four time points in an analysis of variance with time of measurement as a within-subject factor. (Preoperative vs Early postoperative (at discharge) vs Follow up 1 (FU1) vs Follow up 2 (FU2). (Table 4).

2.2.2. *Second scenario: remodeling process of restored ventricles*

Given the substantial geometric modifications obtained by surgery and the intention to restore near normal left ventricular geometry, considering early postoperative status (at discharge) as a new starting point for ventricular remodeling, paired 't' test were used to compare early postoperative v/s FU2 (considered as the 6 months follow up control of the "new" ventricle in a within-subject model (Table 5).

Table 1A – Clinical characteristics.

No of patients	52
Age (years)	56 ± 24 (32–78)
Gender (M/F)	48/4
BSA/m^2 [a]	1.74 ± 0.14 (1.48–2.17)
Type 2 DM[b]	27 (46%)
Hypertension	9 (17%)
NYHA class[c]	3.56 ± 0.50
Time interval from MI (weeks/months)	3 weeks–12 months
EF%[d]	33.5% ± 5.02%
MR grade III–IV[e]	15.38%
Preoperative arrhythmias	10 (19.2%)
Prior angioplasty	5 (9.61%)
Thrombolyzed	17 (32.69%)

a Body surface area.
b Diabetes mellitus.
c New York Heart Association.
d Ejection fraction.
e Mitral regurgitation.

3. Results

The clinical and anatomical characteristics, the perioperative and postoperative data are provided in Table 1A and Table 1B, Table 2 and Table 3 respectively.

3.1. *First scenario: time course of geometric ventricular changes (repeated measures analysis)*

Pairwise comparisons showed: significant differences between preoperative and each follow up time in terms of diastolic and systolic lengths, absolute and indexed volumes, ejection fraction and wall motion score index. The diastolic sphericity index however increased at subsequent follow up. Global systolic function improved postoperatively. The EF, measured in 52 patients before discharge, increased from 33.5 ± 5.02 to 37.77 ± 7.17, postoperatively. The preoperative LVEF which had a mean of 33.5% (±5.02%), increased by 10.3%–11% at the third and fourth follow up respectively after SVR ($p \leq 0.001$) (Fig. 3). The left ventricular end systolic volume index improved from a mean of 48.84 ± 11.37 preoperatively to 24.66 ± 5.92 postoperatively ($p \leq 0.001$) (Fig. 4). All patients in this series showed a normalization of the ESVI. (Table 4).

3.2. *Second scenario: remodeling process of restored ventricles*

Considering postoperative follow up (at discharge) as a new starting point for the remodeling of the restored ventricles, we compared echocardiographic measurements at this point in time vs FU2 (follow up 2), representing a time interval of approximately 6 months. There was a significant correlation between EDV ($r^2 = 0.73$), EDVI ($r^2 = 0.84$), ESV ($r^2 = 0.61$) and ESVI ($r^2 = 0.68$), and paired *t* test showed a highly significant difference in all parameters. ($p < 0.001$). (Table 5). A

Table 1B – Anatomical details.

Single vessel disease	11 (21.15%)
Two vessel disease	23 (44.23%)
Triple vessel disease	18 (34.61%)
Coronary lesions	
LMCA[a]	4 (7.69%)
LAD[b]	50 (96.15%)
LCX[c]	28 (53.84%)
RCA[d]	31 (59.61%)
Mean grafts/patient	1.67
Akinetic segments	20 (38%)
Dyskinetic segments	32 (61%)

a Left main Coronary artery.
b Left anterior descending artery.
c Left circumflex.
d Right coronary artery.

Table 2 – Perioperative data.

	No.	Percentage
Type of surgery		
[a]CABG + [b]EVPP	43	82.69
[a]CABG + [b]EVPP + [c]MV repair	6	11.53
[a]CABG + [b]EVPP + [d]MVR	2	3.84
[b]EVPP only	2	3.84
Grafts		
[e]LIMA to [h]LAD/D1[f]	18	34.61
[g]LV thrombus	6	11.53

a Coronary artery bypass graft.
b Endoventricular patchplasty.
c Mitral valve.
d Mitral valve replacement.
e Left internal mammary artery.
f Diagonal.
g Left ventricular.
h Left anterior descending.

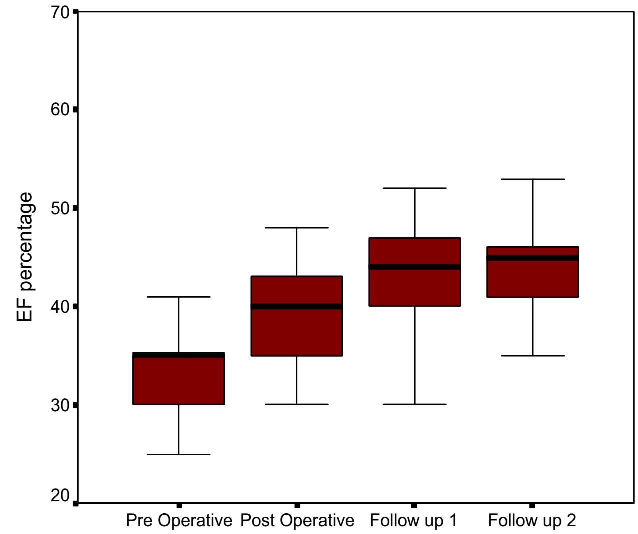

Fig. 3 – LV ejection fraction.

p value of ≤0.05 was considered as significant. Preoperatively, 49 patients (94%) were in symptom class III/IV, however, the functional class status at the last follow up (6 months) revealed 44 patients (84%) in NYHA class I and 4 patients (7.69%) patients in NYHA class II.

4. Discussion

The results of left ventricular (LV) surgical restoration by endoventricular patchplasty observed in this prospective study show a steady geometrical improvement. The repeated measures ANOVA demonstrated that the morphologic and functional changes induced by restoration are maintained over time. The improvement in wall motion score index (WMSI) (Fig 5), ejection fraction, end systolic volume index (ESVI) and the absolute LV volumes like end diastolic volume (EDV) end systolic volume (ESV) as well indicate the gradual continuous positive remodeling of the new ventricle. In an echocardiographic substudy of the VALIANT (Valsartan in Acute Myocardial Infarction) study, Solomon et al[6] demonstrated that baseline LVEF, EDV, and ESV were each independent predictors of the primary combined end point of death or heart failure hospitalization. Lee et al.[7] found that LV end diastolic dimension index, measured with M-mode echocardiography, was an independent predictor of survival. The normalized LV volumes and geometry presumably lead to recruitment of neighbouring and remote segments of the LV. In previous studies by Marco Cirillo et al[8] this process has been studied for a period of 12 months time interval after surgery. In our series, we studied the LV indices for a period of six months. Inspite of the short follow up duration, steady geometric results were obtained.

Surgical restoration replaces the infarct scar with a smaller surgical scar and attempts to correct the distorted LV shape. Ventricular dilatation serves to maintain stroke volume early following the infarction. Eccentric hypertrophy caused by myocyte hypertrophy and elongation along with interstitial fibrosis, results in an increase in mass without concomitant increase in wall thickness.[9–11] Systolic torsion is adversely affected due to distortion of the normal fibre angle.[12] The structural anatomy of the myocardium cannot be reproduced

Table 3 – Postoperative data.

Death due to intractable VT[a]	1 patient
Death due to pump failure	1 patient
Late death due to CCF[b]	1 patient
Inotropic support (>10 μg/kg/min) for > 24 h	10 patients
Time to extubation (hours)	14 (4–148)
Stay in ICU (days)	2.1 (1–8)
IABP[c]	8 (15.38%) patients
Postop pneumonia	2 (3.84%) patients

a Ventricular tachycardia.
b Congestive cardiac failure.
c Intraaortic balloon pump.

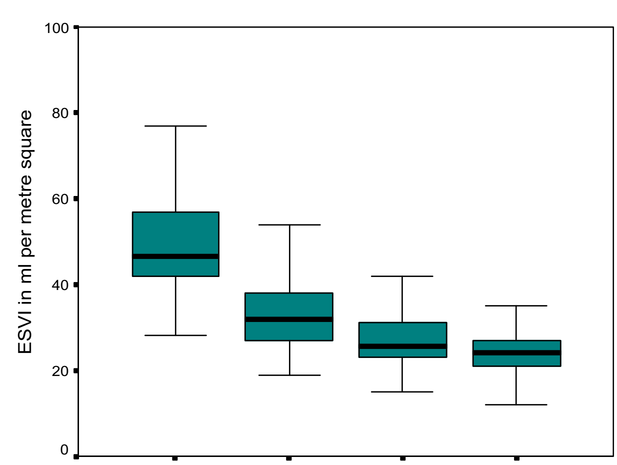

Fig. 4 – LV end systolic volume index.

Table 4 – Summary of hemodynamic improvement following SVR: comparison of preoperative and follow up geometric and functional echocardiographic parameters in patients as a whole.

Parameter	Preop	Early postop	FU1	FU2	*p* value
[b]EF%	33.5 ± 5.02	37.7 ± 7.17	43.32 ± 5.20	44.21 ± 5.58	≤0.001[a]
[c]ESVI ml/m^2	48.84 ± 11.37	33.34 ± 8.37	26.82 ± 7.25	24.66 ± 5.92	≤0.001[a]
[d]EDVI ml/m^2	89.78 ± 6.24	57.93 ± 9.66	49.98 ± 7.18	48.16 ± 6.42	≤0.001[a]
[e]ESV (ml)	84.67 ± 18.16	58.40 ± 12.84	45.21 ± 10.34	42.38 ± 9.44	≤0.001[a]
[f]EDV (ml)	151.30 ± 33.46	100.33 ± 15.93	86.00 ± 10.79	83.50 ± 9.81	≤0.001[a]
[g]WMSI	2.0 ± 0.3	1.7 ± 0.2	1.4 ± 0.3	1.3 ± 0.2	≤0.001[a]

a Denotes significance at 1% level.
b Ejection fraction.
c End systolic volume index.
d End diastolic volume index.
e End systolic volume.
f End diastolic volume.
g Wall motion score index.

and hence it becomes imperative to restore the LV shape and volume to as normal as possible at least to regain the LV physiological function.[13,14] This ensures elimination of the neurohormonal trigger of LV remodeling.[15] Surgical ventricular restoration (SVR) decreases wall tension by reducing chamber size (Laplace's law). Di Donato et al and Dor have clearly demonstrated that volume reduction by infarct exclusion enhances regional systolic function in the myocardium remote from the anterior scar.[16] Additionally, shape alteration leads to realigned muscle fibre orientation to allow optimal ejection.[17] In patients with impaired LV function after myocardial infarction, LV end systolic volume is a better predictor of long term survival.[18] We have known that the LVEF is less helpful than LVESV in the assessment of long term mortality.[19]

The normalization of LVESVI documented in the present study is a good reference for positive remodeling over time. Our findings showed that 88% of the ventricles with a surgically normalized ESVI remained unchanged at subsequent follow up. The improvement in LVESVI was independent of mitral valve procedure.

As documented here, the sphericity index (diastolic) showed a gradual increase, however NYHA class as well as the indices of LV function were not affected. Two factors could explain the above: 1. The procedure causes an increased diastolic sphericity, however, during each cardiac cycle the systolic shape is more elliptical relative to its diastolic component.[20] 2. The Apical conicity index (ACI)-probably would be a superior marker of normalized LV shape since sphericity index studies the global LV dimension unlike the ACI which is more precisely a marker of LV apical geometry.

Another important indicator of post surgical left ventricular positive remodeling is the wall motion score index (WMSI). In the present series the WMSI revealed a constant improvement (Fig. 5), possibly due to the recruitment of neighbouring and remote segments of the LV wall, which regains its normal physiology as a result of normalized LV volumes. These findings compare with the previous studies by Dr. Cirillo et al.[21]

The restoration of the natural left ventricular geometry accounts for the improved myocardial performance.[22] The near normalization of the LV geometry, reduces the paradoxical contractile forces. Myocardial oxygen demand is reduced due to a reduction in LVEDV. In an overwhelming majority of subjects we noticed an increase in the EF. The change in clinical status in NYHA classification was as reported in previous similar studies reported from abroad.[23] Preoperatively the majority of patients (94%) were in NYHA

Table 5 – *P* values of paired samples correlations and *t*' test considering early postop as baseline and follow up 2 as six months follow up.

Parameters	Correlations	Paired 't' tests
End diastolic diameter	0.75	≤0.001[a]
End systolic diameter	0.70	≤0.001[a]
End systolic volume	0.61	≤0.001[a]
End diastolic volume	0.73	≤0.001[a]
End diastolic volume index	0.84	≤0.001[a]
End systolic volume index	0.68	≤0.001[a]
Ejection fraction	0.32	≤0.001[a]
Wall motion score index	0.54	≤0.001[a]
Sphericity index (diastolic)	0.87	0.005

a Denotes significance at 1% level.

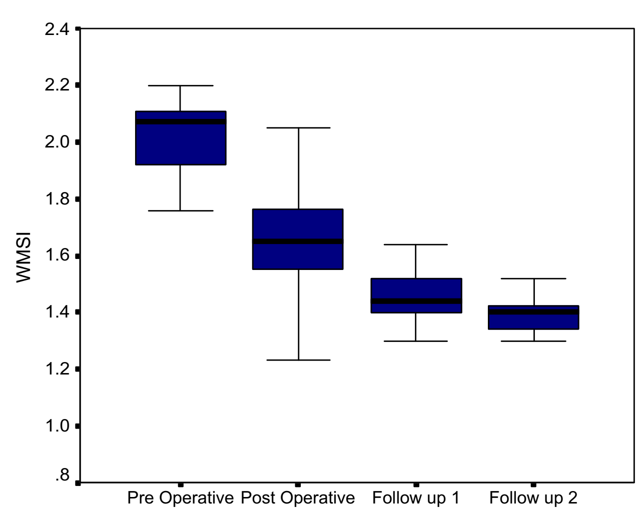

Fig. 5 – LV wall motion score index.

functional class III to IV. On follow up at six months, 84% patients were found to be in NYHA class I and 7.6% patients were found to be in NYHA II (Fig. 6).

In some series, improved clinical and hemodynamic parameters were documented after mitral valve procedure which were sustained.[24–26] We had a small number of patients who underwent mitral valve procedures, and who were not analyzed separately – however, we noticed that the functional status and ejection fraction improved in all patients consistently among those who underwent and those who did not undergo the mitral valve procedure. More number of patients will have to be studied to probe this finding.

It is vital that this technique for improving left ventricular function is accompanied by interruption of pathways for arrhythmia propagation. In our series, 13% (7/52) of patients presented with arrhythmias which were eliminated post-operatively following a nonguided endocardiectomy, conjecturally by interruption of re-entrant pathways. Immediate control of the ventricular tachycardia seems attributable to the same as reported by Sosa et al.[27] We found an early mortality of 5.75% which is as reported in other similar studies.[28]

Our results are comparable to those reported in larger series from the Cardiothoracic Center of Monaco, series reported by Lorenzo Menicanti and Marisa Di Donato of Milan, Italy and the RESTORE team. Dor described 100 patients (51 akinetic/49 dyskinetic) on whom he performed the endoventricular patchplasty (EVPP). Myocardial revascularization was performed in 98%, with 10% concomitant mitral valve surgery. The EF improved in both groups (23–42%), ESVI decreased from 188 ml/m^2 to 70 ml/m^2 in the akinetic group and from 160 ml/m^2 to 48 ml/m^2 in the dyskinetic group. The surgical outcome in a large series of patients treated with SVR is linked to the extent of asynergy, rather than the type of asynergy.[29] Migrino et al. demonstrated a continuous relationship between ESVI and both mortality and the development of heart failure symptoms.[30] Although the number reported in the present study is comparably smaller, the concordant results show sustained improvement in LV function parameters, in NYHA functional class and an endocardial resection that provides freedom from the ventricular arrhythmias.

This study provides useful data for SVR following post-myocardial LV dysfunction which showed improved functional status in our patients, contrary to the finding reported in STICH trial.[31] Although a quarter of Cardiothoracic Surgical centers are performing SVR, most have limited experience and perioperative events are somewhat higher than prior selected series. Further studies of SVR are needed to improve patient selection and procedural performance. To translate the success from centers of expertise seen in the RESTORE registry, it is important to periodically examine the characteristics and outcomes of SVR in other settings. Identifying differences in use or outcomes may guide success with the real-world application of a new procedure by studying unselected patients and centers.

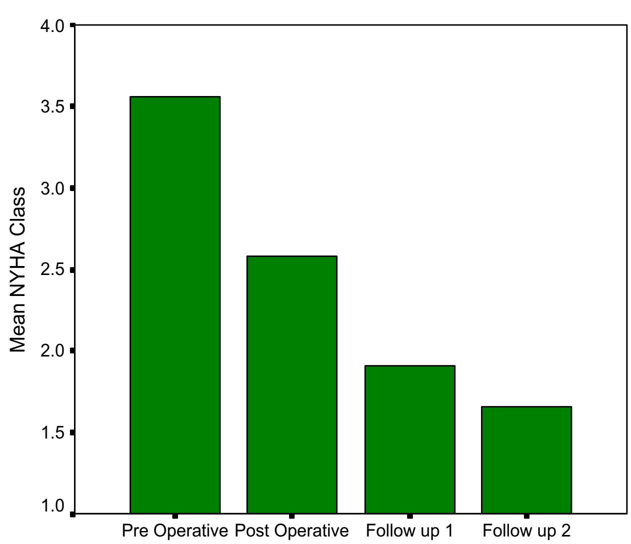

Fig. 6 – NYHA functional class.

Disclaimer

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Conflicts of interest

All authors have none to declare.

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