Surgical Ventricular Restoration: Left Ventricular Shape Influence on Cardiac Function, Clinical Status, and Survival

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Background. **Myocardial infarction can result in a spectrum of left ventricular (LV) shape abnormalities. Surgical ventricular restoration (SVR) can be applied to any, but there are no data that relate its effectiveness to LV shape. Moreover, there is no consensus on the benefit of SVR in patients with a markedly dilated ventricle, without clear demarcation between scarred and normal tissue. This study describes postmyocardial infarction shape abnormalities and cardiac function, clinical status, and survival in patients undergoing SVR.**

Methods. **Echo studies of 178 patients were retrospectively reviewed. Three types of LV shape abnormalities were identified: type 1 (true aneurysm), type 2 (nonaneurysmal lesions defined as intermediate cardiomyopathy), and type 3 (ischemic dilated cardiomyopathy).**

Results. **SVR induced significant improvement in cardiac and clinical status in all patients, regardless LV shape types. Although not significant, mortality was higher in types 2 and 3.**

Conclusions. **Ischemic dilated cardiomyopathy and not just the true aneurysm can be successfully treated with SVR. Shape classification may be useful to improve patient selection and compare results from different institutions that are otherwise impossible to compare.**

(Ann Thorac Surg 2009;87:455–62)

Myocardial infarction (MI) can result in a spectrum of shape abnormalities related to the extent of myocardial damage, the site of infarction, "the border zone," the severity of the remodeling process, the nonischemic extension, and the presence of mitral regurgitation [1–7]. There is increasing interest in therapeutic strategies aiming to reshape the left ventricle (LV) to rebuild a more physiologic LV chamber and improve pump function.

Surgical ventricular restoration (SVR) as described by Dor and colleagues [8] was introduced to improve geometric reconstruction with respect to standard linear repair in LV aneurysm. Subsequently, Dor and colleagues [9, 10] described that the technique was applicable not only to the classic aneurysm but also to large akinetic ventricles. The Dor experience has changed the approach to ischemic failing ventricles, leading surgeons to address more and more dilated and dysfunctioning ventricles in patients who have sustained a MI.

However, patient selection and a clear definition of shape abnormalities of the ventricles that are treated with SVR are lacking in the reported series [11–13], and there are no data that relate effectiveness of SVR to baseline LV shape. Furthermore, there is no consensus on the benefit of this surgical procedure (with defined mortality) in patients with markedly dilated ventricle, where there is no clear demarcation between scarred and normal tissue and where there is associated mitral regurgitation. Many surgeons have been concerned that these patients have higher mortality and worse long-term survival.

Shape classification and its relative importance for outcome in terms of cardiac function, mortality, and survival after SVR, and is considered to be important in view of the numerous SVR patient cohorts presented in published reports in which there is a mixture of all types of morphology, ranging from the true, small postinfarction aneurysm to pure, globally dilated ischemic cardiomyopathy. It is therefore impossible to compare data among series. The objective of the present study is to describe LV shape abnormalities after MI and to assess their influence on clinical and cardiac status and survival in patients who undergo SVR.

Patients and Methods

Patients who undergo SVR in our center have a baseline echo examination. In-house echo studies are performed by the same experienced cardiologist. For the present study, we tried to find preoperative in-house echo tapes in our echo archive; 2 experienced cardiologists reviewed

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Accepted for publication Oct 16, 2008.

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Published by Elsevier Inc

0003-4975/09/$36.00
doi:10.1016/j.athoracsur.2008.10.071

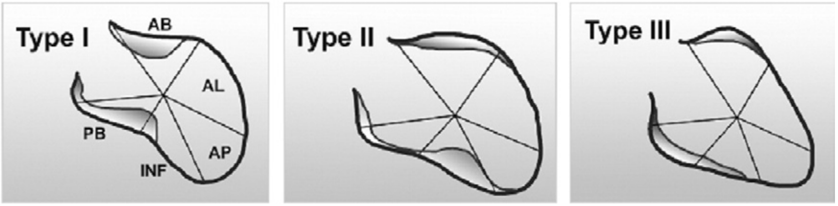


Fig 1. Left ventricular (LV) shape abnormalities after myocardial infarction, as evaluated in right anterior oblique (RAO) 30° LV angiography are shown. Type 1 (true aneurysm) is geometrically delimited by two systolic "borders" between thickening and nonthickening myocardium; the classic neck of the true aneurysm is evident. In type 2 (intermediate), the shape is characterized by only one border between thickening and nonthickening myocardium, instead of two borders as in type 1, and the term "intermediate" is used because type 2 is between type 1 (two borders) and type 3 (no borders). In type 3 (ischemic dilated cardiomyopathy), the LV systolic shape is without borders (ie the curvature is flattened along the overall perimeter of the LV).

nearly 270 tapes and selected only good quality and complete echo examinations with a good 2-chamber view that allowed off-line measurements. Satisfactory echo studies were found for 178 patients (160 men) who were a mean age of 63 ± 9 years. Those with unsatisfactory echo studies because critical views were missing were excluded.

This is a retrospective study based on the institutional database of the Istituto di Ricovero e Cura a Carattere Scientifico (IRCCS) Policlinico San Donato (July 2001 to date) for patients undergoing SVR. The study design was submitted to the local Ethics Committee, which waived the need for approval in consideration of the retrospective nature of the study. All the patients admitted to the study gave informed consent to the scientific analysis of their clinical data in an anonymous form.

Shape Analysis

LV shape assessment can be done using the Fourier or radius of curvature analysis [14], whereas wall motion asynergy (ie, akinesia/dyskinesia) is detected by evaluating shortening of regions, segments, or chords of the LV [10]. In a previous study we classified three types of shape abnormalities: type 1, 2, and 3 (Fig 1). The LV shape was evaluated in that study quantitatively by calculating the power spectrum and the regional curvatures of angiographic outlines as seen in the right oblique anterior projection. Regional curvatures (the reciprocal of internal radius, l/r) were calculated in the ventricular perimeter starting from the mitral corner and extending to the aortic corner. The power spectrum was calculated by means of Fourier analysis [15–17] (see description in Fig 2).

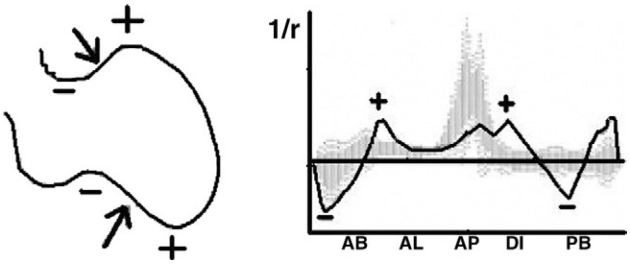


Fig 2. In the Mancini curvature analysis, the curvature values are on the ordinate (1/r) and ventricular regions are on the abscissa. AB = anterobasal; AL= anterolateral; AP = apical; DI = diaphragmatic; PB = posterobasal. The shadow area represents curvature values in healthy subjects and the black line represents 1 patient with type 1 aneurysm. Note the greatest value of wall curvature at apical level in healthy subjects and the flattening of the apical curvature in the patient. Note the abrupt variation of curvature in the patient (from negative to positive and positive to negative at the anterobasal and posterobasal regions, respectively).

For the present study, the baseline LV shape classification was obtained by an echo 2-chamber apical view that most resembled the right anterior oblique angiographic projection (Fig 3). LV shape was defined as follows:

- Type 1 (true aneurysm): Geometrically delimited by two systolic "borders" identified by an abrupt change in curvature from negative to positive and from positive to negative (Fig 2).
- Type 2 (intermediate): The shape is characterized by only one border between thickening and nonthickening myocardium, instead of two borders as in type 1. The term "intermediate" is used because type 2 is between type 1 (two borders) and type 3 (no borders).
- Type 3 (ischemic dilated cardiomyopathy): LV systolic shape is without borders; that is, the curvature is flattened along the overall perimeter of the ventricle (Fig 1).

Echocardiographic Variables

The following echocardiographic variables were measured:

- Diastolic and systolic internal diameters in the parasternal long-axis view (mm)
- End-diastolic and end-systolic volume (EDV and ESV) calculated by applying the Simpson method (mL); LV volumes were divided by body surface area (EDVI and ESVI) and expressed as mL/m^2
- Ejection fraction (EF) derived from volumes as EDV – ESV/EDV (%)
- Left atrium size in the long-axis view (mm)
- Mitral annulus size in parasternal long-axis view (mm)

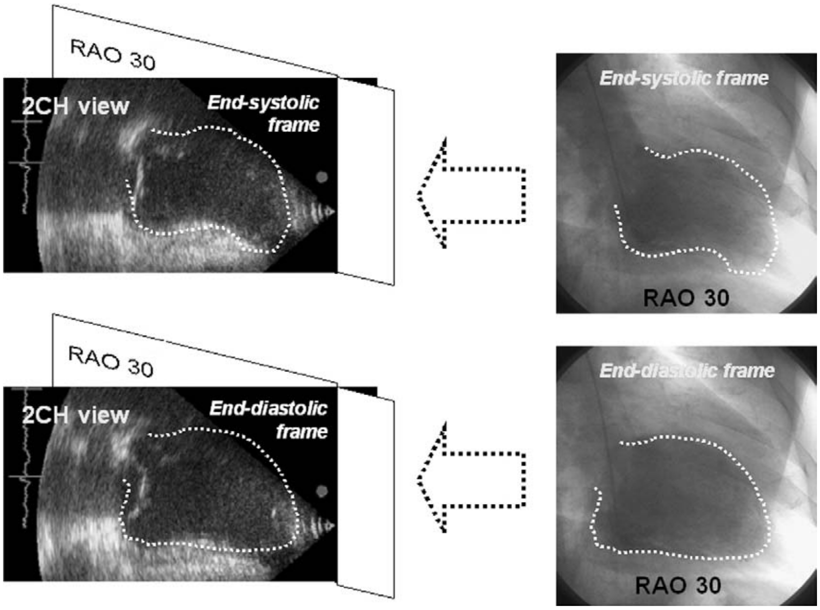


Fig 3. (Left) Echo 2-chamber view and (Right) right anterior oblique (RAO) 30° angiographic view. Imaging plane discrepancies and similarities are shown.

Table 1. Patient Demographics and Preoperative Variables[a]

	Type 1	Type 2	Type 3	ANOVA
Patients, No.	56	55	67	
Age, mean y	66 ± 9	63 ± 7	65 ± 9	0.121
Q MI	42 (76)	42 (77)	33 (50)	
Non-Q MI	14 (24)	13 (23)	34 (50)	0.02
Site of MI				
Anterior	53 (95)	55 (100)	51 (76)	
Posterior	3 (5)	0 (. . .)	16 (24)	0.02
Delay from MI, months	55 ± 90	55 ± 73	64 ± 82	0.962
NYHA class	2.8 ± 0.9	2.8 ± 0.8	2.8 ± 0.8	0.962
Diabetes	5 (10)	13 (24)	25 (37)	0.05
1-vessel disease	16 (28)	21 (39)	17 (26)	0.378
Multivessel disease	37 (66)	32 (58)	49 (73)	0.543
Hypertension	30 (54)	36 (65)	37 (55)	0.553
Dyslipidemia	22 (39)	29 (53)	31 (46)	0.693
Smoking	31 (55)	29 (53)	40 (60)	0.726
Renal insufficiency[b]	2 (4)	. . .	5 (7)	0.462
Stroke	2 (4)	3 (5)	5 (7)	0.520
Medications				
ACE inhibitors	49 (88)	48 (87)	60 (90)	0.891
Diuretics	44 (79)	38 (69)	61 (91)	0.03
β-Blockers	41 (73)	41 (75)	40 (60)	0.354
Statins	29 (52)	26 (47)	27 (40)	0.724
Aspirin	39 (70)	40 (73)	44 (66)	0.435

[a] Data are presented as number (%) or mean ± standard deviation. [b] Renal insufficiency defined as creatinine level > 1.5 mg/dL.

ACE = angiotensin-converting enzyme; ANOVA = analysis of variance; MI = myocardial infarction; NYHA = New York Heart Association.

- Long axis measured in 4- and 2-chamber apical views as the distance between the apex and the mitral plane (mm)
- Short axis measured in 4- and 2-chamber apical views at the middle level of the long axis (mm)
- Sphericity index (SI) calculated as short/long axis ratio in diastole and systole
- Apical axis measured in 4- and 2-chamber apical views as the diameter of the sphere that best fits the apical curvature
- Conicity index (CI) calculated as apical/short-axis ratio both in diastole and in systole [18]

The degree of mitral regurgitation was assessed in a semi-quantitative way using the following scale: absent, 0; trivial, 1+; mild, 2+; moderate, 3+; and severe, 4+.

Surgical Technique

Details of the surgical technique have been previously reported [19]. The procedure is conducted on arrested heart with antegrade crystalloid or cold blood cardioplegia. Complete coronary artery bypass grafting is first performed, almost always with the left internal mammary artery on left anterior descending and sequential venous grafts on the right and circumflex arteries, when needed. After coronary grafting is completed, the LV is opened with an incision parallel to the left anterior descending artery, starting at the middle scarred region and ending at the apex. The ventricular cavity is inspected and thrombi are removed if they are present. Each papillary muscle head is identified, and the mitral valve leaflets and chords are evaluated.

SVR is performed using a mannequin (TRISVR, Chase Medical, Richardson, TX) filled at 50 to 60 mL/m^2 to optimize size and shape. Mitral repair is performed after

Table 2. Baseline Clinical and Hemodynamic Data by Left Ventricular Shape

Variable	Type 1 (n = 56)	Type 2 (n = 55)	Type 3 (n = 67)	ANOVA
EDV, mL	216 ± 77	219 ± 69	246 ± 67	0.04
ESV, mL	150 ± 63	157 ± 62	173 ± 65	0.01
EDVI, mL/m^2	120 ± 44	122 ± 38	137 ± 37	0.04
ESVI mL/m^2	83 ± 35	87 ± 34	96 ± 36	0.01
EF	0.32 ± 0.07	0.30 ± 0.09	0.27 ± 0.08	0.008
NYHA	2.8 ± 0.9	2.7 ± 0.8	28 ± 0.8	0.547
MR grade	0.5 ± 0.99	0.8 ± 1.0	1.5 ± 1.3	0.0003
MR, yes/no, No.	5/51	7/48	17/50	0.0255

Values are expressed as mean ± standard deviation, or numbers.

ANOVA = analysis of variance; EDV = end-diastolic volume; EF = ejection fraction; ESV = end-systolic volume; EDVI = end-diastolic volume index; ESVI = end-systolic volume index; MR = mitral regurgitation; NYHA = New York Heart Association functional class.

coronary grafting, if needed. Indication for mitral repair is moderate to severe mitral regurgitation (grade 3/4+) or mitral annulus dilatation (> 38 mm) if mitral regurgitation is mild (grade 2+).

The technique of mitral repair is posterior annulus suture through the ventricular opening in all cases. A double arm stitch running from trigone to trigone is tied on a 26-mm sizer, inserted through the mitral orifice, to undersize the mitral area [19].

Statistical Analysis

The continuous variables are expressed as mean values ± standard deviation. The two-tailed paired *t* test and the unpaired *t* test were used when appropriate. One-way analysis of variance was applied to compare groups. Pearson correlation and χ^2 test were also used. Variables resulting significant at univariate analysis were entered into multivariate regression analysis to assess mortality risk. Kaplan-Meyer actuarial survival was calculated for the three shape types, and differences between groups were assessed using the log-rank test. SPSS 9.0 software (SPSS Inc, Chicago, IL) was used for the analysis.

Table 3. Operative Findings and Mortality

Finding	Type 1	Type 2	Type 3	ANOVA
SVR, No. (%)	56 (100)	55 (100)	67 (100)	. . .
CABG, No. (%)	50 (90)	49 (90)	61 (91)	0.978
Anastomosis, mean ± SD, No.	2.5 ± 1.3	2.6 ± 1.0	3.0 ± 1.3	0.092
Patch, No. (%)	37 (67)[a]	21 (38)	35 (52)	0.227
Mitral repair, No. (%)	5 (9)	7 (13)	17 (25)	0.01
30-day mortality, No. (%)	3 (5.3)	7 (12.7)[b]	4 (5.9)	0.098

[a] ANOVA $p = 0.01$ vs type 2. [b] 3 of 7 with associated mitral repair.

ANOVA = analysis of variance; CABG = coronary artery bypass graft; SVR = surgical ventricular restoration.

Results

Type 1 LV shape was present 56 patients (31%), type 2 in 55 (31%), and type 3 in 67 (38%). Demographic and clinical characteristics are reported in Table 1. Posterior MI was more frequently associated with type 3 LV shape. Posterior MI is characterized by a flattening of the inferior wall curvature (loss of the physiologic inward bending) that is responsible for the higher incidence of mitral regurgitation compared with anterior MI.

A total of 105 patients (59%) were in New York Heart Association (NYHA) functional class III/IV. Table 2 reports other baseline clinical and hemodynamic data according to LV shape. Table 3 reports operative findings. Although not significant, 30-day mortality was higher in type 2 (12.7%) and type 3 (5.9%) than in type 1 (5.3%). Three of the 7 type 2 patients who died had associated mitral repair. Preoperative NYHA class was the only factor associated with 30-day mortality at univariate analysis.

All patients had SVR, 160 (90%) had associated coronary grafting, and 29 (16%) had associated mitral valve repair. Figure 4 shows systolic LV shape in the 2-chamber view in 3 patients. Shape is definitely different. Table 4 reports baseline geometric variables. There are progres-

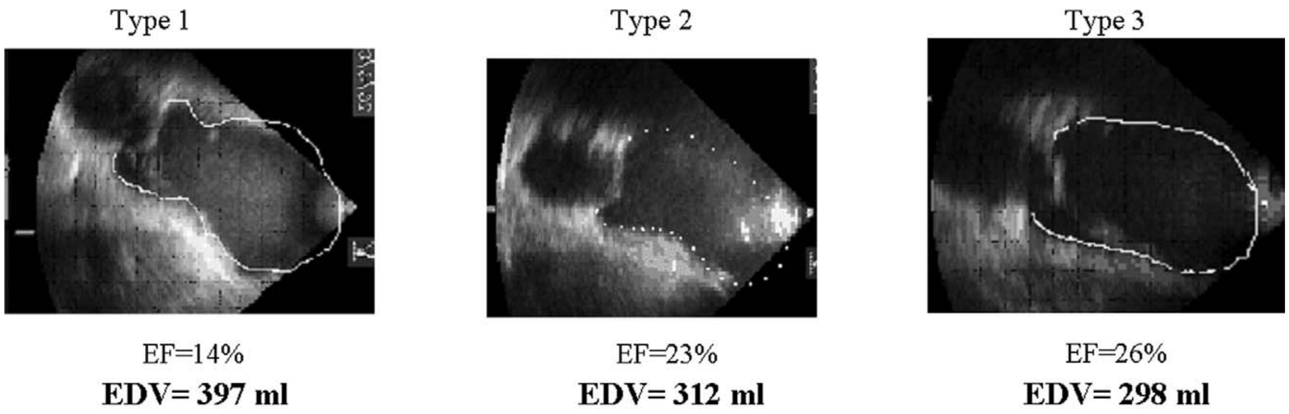


Fig 4. Images from three patients with type 1, 2, and 3 left ventricular shape abnormalities show that all three types have chamber dilatation and a markedly reduced ejection fraction, but the shape is definitely different.

Table 4. Baseline Geometric Variables

Variable	Type 1	Type 2	Type 3	ANOVA
DD, mm	57 ± 7	63 ± 6	69 ± 8	<0.001
SD, mm	44 ± 8	49 ± 8	57 ± 9	<0.001
Ejection fraction	0.32 ± 0.07	0.30 ± 0.09	0.27 ± 0.08	0.008
Left atrium, mm	41 ± 7	45 ± 8	46 ± 8	0.046
Short axis, cm	4.7 ± 0.9	5.1 ± .5	5.7 ± 1	0.008
SI, systole	.37 ± .09	.40 ± .06	.49 ± .10	0.003
CI, systole	1.3 ± .5	1.1 ± .2	0.91 ± .2	0.01
LVMI, g/m^2	147 ± 39	170 ± 40	194 ± 51	0.002

Data are presented with the standard deviation.

ANOVA = analysis of variance; CI = conicity index calculated as apical/short axis ratio; DD = diastolic internal diameter; EF = ejection fraction; LVMI = left ventricular mass index; SD = systolic internal diameter; SI = sphericity index calculated as short/long axis ratio.

sive geometry abnormalities from type 1 to type 3; diastolic and systolic diameters, left atrium size, and short axis are progressively greater, and ejection fraction is lower in type 3 vs type 2 and type 1. The SI is progressively greater from type 1 to 3, and the CI is progressively lower. SI and CI inversely correlated ($r = -0.54$, $p = 0.0002$ in diastole and $r = -0.59$ in systole $p = 0.0001$).

Table 5 summarizes the changes in clinical and cardiac function status induced by SVR. The degree of repaired mitral regurgitation improved at discharge from 3.6 ± 0.5 to 1.3 ± 0.9 ($p = 0.0001$). The improvement in clinical status at follow-up was not significantly different among groups.

Table 5. Preoperative and Postoperative Clinical and Cardiac Function Status

Variable[a]	Pre-op	Post-op	*p* Value
Type 1			
Diastolic diameter, mm	56 ± 8	51 ± 7	0.05
Systolic diameter, mm	45 ± 7	42 ± 9	0.395
Ejection fraction	0.32 ± 0.07	0.45 ± 0.10	0.0001
EDVI, mL/m^2	120 ± 44	63 ± 23	0.0001
ESVI, mL/m^2	83 ± 35	35 ± 16	0.0001
NYHA class	2.8 ± .0.9	1.6 ± .0.5[b]	0.0007
Type 2			
Diastolic diameter, mm	64 ± 5	56 ± 7	0.001
Systolic diameter, mm	48 ± 9	46 ± 10	0.079
Ejection fraction	0.30 ± 0.09	0.41 ± 0.10	0.0001
EDVI, mL/m^2	122 ± 38	64 ± 28	0.0001
ESVI, mL/m^2	87 ± 34	39 ± 18	0.0001
NYHA class	2.8 ± .0.8	1.5 ± .0.5[b]	0.0006
Type 3			
Diastolic diameter, mm	70 ± 8	65 ± 8	0.001
Systolic diameter, mm	57 ± 9	55 ± 9	0.1427
Ejection fraction (%)	0.27 ± 0.08	0.34 ± 0.07	0.0001
EDVI, mL/m^2	137 ± 37	85 ± 32	0.0001
ESVI, mL/m^2	96 ± 36	57 ± 25	0.0001
NYHA class	2.8 ± .0.8	1.6 ± .7[a]	0.0001

[a] Values are mean ± standard deviation. [b] 1 year after operation.

NYHA = New York Heart Association; EDVI = end-diastolic volume index; ESVI= end-systolic volume index.

Table 6. Preoperative and Postoperative Left Ventricular Shape Variables

Shape[a]	Pre-op	Post-op	*p* Value
Type 1			
SI diastolic	0.55 ± 0.05	0.48 ± 0.09	0.102
SI systolic	0.45 ± 0.1	0.39 ± 0.10	0.327
CI diastolic	1.02 ± 0.3	0.84 ± 0.07	0.050
CI systolic	1.29 ± 0.51	1.0 ± 0.19	0.050
Type 2			
SI diastolic	0.50 ± 0.06	0.58 ± 0.08	0.066
SI systolic	0.40 ± 0.06	0.51 ± 0.09	0.032
CI diastolic	0.84 ± 0.1	0.73 ± 0.09	0.026
CI systolic	1.04 ± 0.21	0.78 ± 0.13	0.006
Type 3			
SI diastolic	0.56 ± 0.10	0.64 ± 0.09	0.050
SI systolic	0.49 ± 0.11	0.58 ± 0.08	0.023
CI diastolic	0.84 ± 0.19	0.75 ± 0.12	0.050
CI systolic	0.91 ± 0.19	0.73 ± 0.14	0.022

[a] Data are presented as the mean ± standard deviation.

CI = conicity index calculated as apical/short axis ratio; SI = sphericity index calculated as short/long axis ratio.

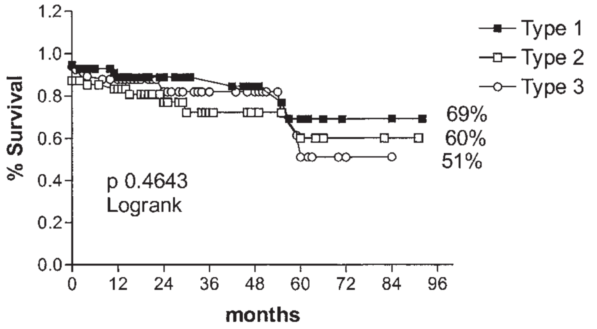
Table 6 reports changes in geometry after SVR. All patients showed a more conical shape after the procedure (apical reconstruction); types 2 and 3 had a significant increase in SI (more spherical shape). The postoperative increase in SI is due to the surgical reduction of the long axis, which always exceeds the reduction of the short axis.

Follow-up was 100% complete (mean 30 ± 21 months; range, 4 to 92 months). Twenty deaths from any cause occurred during follow-up. We assessed overall mortality risk (30-day plus mortality at follow-up), testing several variables including comorbidities (hypertension, diabetes, renal insufficiency), medications, hemodynamic and geometric variables. Preoperative NYHA and mitral regurgitation, but not LV shape were significantly associated to mortality. At multivariate analysis, NYHA class was the only significant predictor of overall mortality ($\beta = 2.453$; 95% confidence interval, 1.395 to 4.312; $p = 0.01$).

Figure 5 shows Kaplan-Meyer survival curve by baseline LV shape. A trend towards a higher mortality rate in type 2 and 3 is observed; however, survival rate is not significantly different.

Comment

The present study addresses postinfarction LV shape classification and aims to find a relationship, if any, between preoperative LV shape and the effectiveness of SVR. Our results demonstrate that shape definition allows cardiac function and geometric stratification and



	Months							
	0	12	24	36	48	60	72	84
Subjects at risk								
Type 1	56	38	24	20	15	4	2	1
Type 2	55	34	14	10	8	3	1	1
Type 3	67	38	16	11	8	2	1	1

Fig 5. Kaplan-Mayer survival curve in type 1 (black squares), 2 (white squares), and 3 (white circles) are reported. All-cause mortality is reported, and operative mortality is included.

that SVR improves clinical and cardiac status regardless of LV shape; that is, SVR is effective also in nonaneurysmal ischemic LV dilatation. Types 2 and 3 have higher mortality compared with type 1; however, the difference is not significant. Survival rate is satisfactory if we consider the expected survival in postinfarction ischemic dilated cardiomyopathy with frequently associated mitral regurgitation and high functional class.

Survival of patients undergoing SVR reported by the Reconstructive Endoventricular Surgery Returning Torsion Original Radius Elliptical (RESTORE) group [11] evidenced that patients with akinesia had significantly lower survival in respect to dyskinesia. Akinesia and dyskinesia in that study referred to visually inspected regional wall motion abnormalities; in the present study, we did not stratify patients on regional wall motion but on LV shape, and we may have had akinesia or dyskinesia in any LV shape. In a previous article, we demonstrated that SVR outcome is related to the extent of asynergy and not to the type of asynergy (ie, akinesia or dyskinesia) [10]. In the present study, shape classification was easily obtained by an echo 2-chamber view in a qualitative way (Fig 3), avoiding more complex and time-consuming Fourier analysis [14].

Regional or Global LV Shape Changes

We think that a clear definition of LV shape is important to compare results after SVR in different series; otherwise, results are impossible to compare because the published reports contain a mixture of all types of morphology, ranging from true, small postinfarction aneurysms to pure, globally dilated ischemic cardiomyopathies.

The calculation of CI helped to characterize regional apical abnormalities. In healthy subjects, CI was 0.60 ± 0.09 in diastole and 0.52 ± 0.10 in systole; significantly lower than in post-MI patients [18]. In the present study, the apical CI was significantly greater in types 1 and 2 compared with type 3, whereas SI (an index of global shape) was greater in type 3. The short axis is significantly greater in type 3, which has the higher rate of associated mitral regurgitation, confirming that the septum-lateral dimension is one of the major determinants of mitral regurgitation [20, 21].

It is commonly reported that the aim of SVR is to rebuild a more elliptical shape, but no studies have demonstrated that the LV is less spherical (ie, more elliptical) postoperatively. Preoperatively, the LV is not more spherical in respect to normal (unless mitral regurgitation is present), because after anterior MI, the elongation of the ventricle is proportional to the increase in width and the ratio does not change [18]. SI in healthy individuals is 0.52 ± 0.06 in diastole and 0.45 ± 0.06 in systole [18]. After SVR, the LV is not more elliptical because the surgical reduction in length always exceeds the reduction in width, despite the use of the conical device to reshape the ventricle.

A recent study by Cirillo and colleagues [22] shows that the eccentricity index (the opposite of the SI) significantly decreases after SVR. The intraventricular conical device allows one to avoid the amputation of the apex, and it is useful to place the new apex in the correct position allowing the alignment with aortic flow tract. Moreover, the device allows one to maintain the long axis of the ventricle in a more physiologic range (7.5/8.5 cm).

The introduction of the CI may help in identifying LV regional shape changes after MI and surgical reshaping procedures. CI reflects apical regional abnormalities, and the increase observed in post-MI patients focuses on a less conical shape. The conical endoventricular device allows apical reconstruction and induces a more conical apical shape in all patients with a significant decrease in CI, whereas the SI does not change or even increases (Table 6). Despite postoperative LV shape being more spherical, all three patient groups do about the same in terms of mortality, cardiac function, and clinical status; this finding suggests that the reduction of LV size and the improvement of apical conicity play the major role on outcome.

Limitations

The number of patients in each category is relatively small in respect to our overall series [23] because we found preoperatively satisfactory in-house echo examinations in only 178 patients, and this may account for bias selection. We do not have cardiac function variables other than ejection fraction, and that is not a good measure of function after SVR because of the marked reduction of EDV induced by the procedure.

Another limitation due to the limited number of patients with few events is that we cannot exclude that having more patients and more events. Type 3 patients might have lower survival rate than the other two groups. Finally, this is an uncontrolled study and the effects of coronary artery bypass grafting and mitral repair on outcome cannot be excluded.

Conclusions

Shape classification stratifies patients with progressively severe cardiac dysfunction and geometric abnormalities. The results show that SVR is effective also in patients with nonaneurysmal shape abnormalities. The postsurgical shape has a more conical apex but tends to be more spherical in types 2 and 3.

We believe that a clear definition of LV shape abnormalities allows the evaluation of SVR outcome and a comparison with other series that otherwise would be impossible. This study does not show a prognostic value of shape classification, but as mentioned in Limitations, it may depend on the limited number of patients and by the few events. We think that time has arrived to redefine the LV aneurysm.

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INVITED COMMENTARY

Heart failure progression is characterized by left ventricular remodeling, including dilatation and thinning of the ventricular wall combined with worsening of cardiac function. Left ventricular dilatation is a strong predictor of poor outcome in heart failure patients, and various surgical options have therefore been developed to prevent or reverse the remodeling process through ventricular reconstruction surgery. A wide spectrum of left ventricular shape abnormalities develop in patients with ischemic dilated cardiomyopathy, ranging from true aneurysm to global dilatation. All are amendable to ventricular restoration surgery.

In this retrospective study [1], the outcome of a very large cohort of patients who underwent ventricular restoration procedures has been reviewed according to the extent of postinfarction left ventricular shape abnormalities, divided into "true aneurysm," "intermediate" and "dilated cardiomyopathy." Although coronary artery bypass grafting and mitral valve procedures were performed when needed, the common denominator for all patients was ventricular restoration surgery. The authors clearly demonstrate that all types of ventricular shape differences can be operated on with remodeling surgery, with similarly good results.

Published by Elsevier Inc

0003-4975/09/$36.00
doi:10.1016/j.athoracsur.2008.10.080