Impact of Surgical Ventricular Restoration on Diastolic Function: Implications of Shape and Residual Ventricular Size

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Background. **Limited data are available on left ventricle (LV) diastolic function in patients with ischemic dilated cardiomyopathy submitted to surgical ventricular restoration (SVR). The purpose of this study was to assess postoperative diastolic function changes and identify potential predictors of its worsening.**

Methods. **One hundred and forty-six patients (65 ± 9 years) with previous anterior myocardial infarction were evaluated before and after SVR. Hemodynamic and geometric parameters including the sphericity index and conicity index were measured. Diastolic function was explored using the transmitral flow velocity pattern, and four classes were defined: normal, abnormal relaxation, pseudonormal, and restrictive pattern. Diastolic function was defined as unchanged (no difference in diastolic pattern), improved (at least one class less), or worsened (at least one class more or, in the case of preoperative restrictive pattern, an early transmitral flow velocity to atrial flow velocity [E/A] ratio increase of at least 20%).**

Results. **The filling pattern before SVR was normal in 7 patients (4.8%), abnormal relaxation in 99 (68%), pseudonormal in 28 (19%), and restrictive in 12 (8.2%). After SVR, the filling pattern was unchanged in 105 patients (72%), improved in 14 (9.6%), and worsened in 27 (18.4%). Based on the univariate analysis, the preoperative conicity index and the end-diastolic volume difference (the result of surgical volume reduction) were associated with a diastolic pattern worsening.**

Conclusions. **Diastolic function did not change or improve in the majority of patients. In the minority of patients who experienced worsening, this was associated with the preoperative LV shape and residual volume.**

(Ann Thorac Surg 2008;86:1849–55)

Surgical ventricular restoration (SVR) is a relatively new and continuously improving technique for restoring left ventricle (LV) shape, size, and function in patients with ischemic, dilated cardiomyopathy and heart failure. The technique, initially introduced by Dor and colleagues [1] and Jatene [2], has been refined over the last ten years in an effort to standardize the procedure and to optimize the results. So far, it has been well-established that SVR improves LV systolic function by reducing ventricular volumes and increasing the ejection fraction (EF) [3–6]. Moreover, the beneficial effects of SVR include an improvement in LV mechanical synchrony, resulting in a more efficient myocardial pump function [7].

To date, however, few data are available on LV diastolic function (DF) in patients submitted to SVR. It is well-known that ventricular remodeling after an acute myocardial infarction is accompanied by changes in the diastolic properties of the LV due to scar formation, which in turn increases chamber stiffness and compensatory hypertrophy of the remote zone, which is responsible for delayed relaxation [8]. The resulting increase in filling pressure within the ventricle may be responsible, in turn, for LV dilatation. Recently, our group demonstrated that severe diastolic dysfunction, when associated with mitral regurgitation and a high New York Heart Association functional class, is a risk factor for SVR outcome [6]. Experimental studies suggested an adverse effect on DF induced by surgical volume reduction [9, 10]. Tulner and colleagues [11] reported data obtained from pressure-volume loops analysis before and after SVR showing a leftward shift of the end-systolic and end-diastolic pressure-volume relationship with an increased slope of both, suggesting an improvement in systolic function and counteracting changes in diastolic properties as evidenced by an increased stiffness constant. However, the study was conducted under cardioplegia, which could be partially responsible for interstitial edema and increased diastolic chamber stiffness, as also suggested by Ratcliffe and Guy in their editorial [12]. Moreover, Gibson and Francis [13] had already pointed out as "the stiffness constant," derived by applying an exponential equation to a curvilinear relationship (as the relationship between pressure and volume is in fact) is not actually measuring stiffness but rather the extent by which stiffness varies with volume changes.

Accepted for publication Aug 4, 2008.

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Published by Elsevier Inc

0003-4975/08/$34.00
doi:10.1016/j.athoracsur.2008.08.010

Table 1. Echocardiographic Preoperative Data Within Groups

	Normal (n = 7)	Abnormal Relaxation (n = 99)	Pseudonormal (n = 28)	Restrictive (n = 12)	*p*
Age (years)	60 ± 12	66.9 ± 7.7	60.9 ± 9.3	63 ± 12.6	0.004
DD (mm)	63.3 ± 7.5	60.9 ± 9.3	65.1 ± 6.9	64.6 ± 9.6	n.s.
DS (mm)	50.8 ± 10.2	48 ± 11.1	52.1 ± 9.2	52.4 ± 11.3	n.s.
EDV (mL)	171 ± 65	191 ± 64	213 ± 73	229 ± 51	n.s.
ESV (mL)	112 ± 60	129 ± 59	145 ± 70	172 ± 48	n.s.
EF	0.37 ± 0.09	0.34 ± 0.09	0.34 ± 0.09	0.26 ± 0.06	0.015
SV (mL)	57.8 ± 12.6	61.9 ± 16.7	68.1 ± 15.4	62.5 ± 16.4	n.s.
LA (mm)	44.3 ± 6.4	41.6 ± 6.8	46.2 ± 7.4	46.8 ± 5.5	0.005
E/A	1.23 ± 0.38	0.68 ± 0.14	1.36 ± 0.25	2.46 ± 0.99	0.001
DT (msec)	196 ± 41	215 ± 62	180 ± 39	160 ± 33	0.004
sPAP (mmHg)	31 ± 5.6	30 ± 7.7	34.5 ± 8.8	39 ± 12.3	n.s.
SI (D)	0.62 ± 0.07	0.5 ± 0.09	0.55 ± 0.09	0.54 ± 0.16	n.s.
SI (S)	0.55 ± 0.07	0.41 ± 0.09	0.46 ± 0.1	0.49 ± 0.21	0.023
CI (D)	0.79 ± 0.13	0.89 ± 0.22	0.82 ± 0.1	0.93 ± 0.22	n.s.
CI (S)	0.84 ± 0.18	1.06 ± 0.32	0.95 ± 0.2	1.12 ± 0.46	n.s.

CI = conicity index; D = diastole; DD = LV diastolic diameter; DS = LV systolic diameter; DT = E wave deceleration time; E/A = early transmitral flow velocity to atrial flow velocity ratio; EDV = end diastolic volume; EF = ejection fraction; ESV = end systolic volume; LA = left atrium; LV = left ventricular; n.s. = not significant; S = systole; SI = sphericity index; sPAP = systolic pulmonary artery pressure; SV = stroke volume.

The SVR aims to resize and reshape the LV, raising the question of what is the ideal volume reduction and what are the geometric implications that may affect the prognosis of patients submitted to SVR. Standard Doppler echocardiography indices derived from mitral inflow have been widely used to assess diastolic dysfunction in the clinical setting, offering the opportunity to interpret different diastolic abnormalities in conjunction with information from M-mode and two-dimensional echocardiography such as LV size and shape.

The aim of the present study was to assess whether LV volumes and shape changes may induce changes in DF. Additional endpoint was to investigate the potential role of echocardiographic parameters in predicting a DF that has worsened after SVR.

Material and Methods

Study Design

This was a retrospective study based on the institutional database of the Istituto di Ricovero e Cura a Carattere Scientifico Policlinico San Donato 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 their informed consent for the scientific analysis of their clinical data in an anonymous form.

Patient

One hundred and forty-six patients (119 men, mean age 65 ± 9) with previous anterior myocardial infarction and secondary LV dilatation referred to our institution for SVR between July 2001 and October 2005 received a complete echocardiographic examination. Exclusion criteria were a posterior LV dilatation and the need for mitral valve repair or replacement. All but 6 patients received coronary artery bypass plus SVR. Indications for surgery were heart failure, angina, or a combination of the two.

Echocardiography

Complete M-mode, two-dimensional, and Doppler echocardiography were performed using a commercially available imaging system (Vivid 7; GE Medical System, Fairfield, CT) before SVR and at the time of hospital discharge. Hemodynamic and geometric parameters, including the long axis length (from the apex to the midpoint of the mitral valve plane in the 4-chamber view), the short axis length (as the axis that perpendicularly intersects the midpoint of the long axis in the same view), and the apical axis length (measured as the diameter of the sphere that best fits the apex in the 4-chamber view), were collected in all patients,. Diastolic and systolic measurements were obtained, and the sphericity index (SI, short to long axis ratio) and the conicity index (CI, apical to short axis ratio) were calculated.

Table 2. Diastolic Pattern Changes After the Operation

Unchanged (n)	Improved (n)	Worsened (n)	Total (n)
105	14	27	146

Diastolic Pattern Grading

Preoperative (mean ± standard deviation)	Postoperative (mean ± standard deviation)	t	*p*
1.27 ± 0.65	1.45 ± 0.7	2.2	0.031

t = Student t value for paired data.

Table 3. Echocardiographic Postoperative Data Within Groups

	Normal (n = 3)	Abnormal Relaxation (n = 90)	Pseudonormal (n = 39)	Restrictive (n = 14)	*p*
DD (mm)	61 ± 7.1	57.6 ± 7.3	59.5 ± 7.3	63.6 ± 5.5	n.s.
DS (mm)	47.5 ± 9.2	46.9 ± 8.3	48.7 ± 7.5	54.1 ± 8.4	n.s.
EDV (mL)	144 ± 9.2	126 ± 35	140 ± 39	164 ± 33	0.016
ESV (mL)	81 ± 10.6	76 ± 27	85 ± 31	98 ± 35	n.s.
EF	0.49 ± 0.19	0.40 ± 0.09	0.39 ± 0.09	0.41 ± 0.11	n.s.
SV (mL)	50 ± 13	49.6 ± 13.8	53.9 ± 13	66 ± 12.2	0.008
LA (mm)	36.5 ± 10.2	41.4 ± 7	45.3 ± 8.2	48.2 ± 4.7	0.012
E/A	1.13 ± 0.15	0.73 ± 0.16	1.31 ± 0.26	2.62 ± 0.95	0.001
DT (msec)	178 ± 32	183 ± 51	160 ± 40	131 ± 23	0.014
sPAP (mm Hg)	29 ± 4.1	28.2 ± 6.7	27.9 ± 6.5	41.5 ± 22	n.s.
SI (S)	0.65 ± 0.06	0.45 ± 0.09	0.55 ± 0.15	0.49 ± 0.11	0.027
SI (D)	0.65 ± 0.05	0.54 ± 0.07	0.61 ± 0.10	0.57 ± 0.12	0.035
CI (D)	0.68 ± 0.12	0.77 ± 0.12	0.73 ± 0.09	0.77 ± 0.12	n.s.
CI (S)	0.56 ± 0.18	0.83 ± 0.23	0.77 ± 0.15	0.78 ± 0.18	n.s.

CI = conicity index; D = diastole; DD = LV diastolic diameter; DS = LV systolic diameter; DT = E wave deceleration time; E/A = early transmitral flow velocity to atrial flow velocity ratio; EDV = end diastolic volume; EF = ejection fraction; ESV = end systolic volume; LA = left atrium; LV = left ventricular; n.s. = not significant; S = systole; SI = sphericity index; sPAP = systolic pulmonary artery pressure; SV = stroke volume.

The DF was explored using the transmitral flow velocity curve obtained by pulsed-Doppler imaging, positioning the sample volume between the tips of the mitral leaflets. According to the LV filling pattern, four progressive classes have been described: normal, abnormal relaxation, pseudonormal, and restrictive patterns [14]. After surgery, DF was defined as unchanged (no difference in diastolic pattern), improved (at least one class less), or worsened (at least one class more or, in case of a preoperative restrictive pattern, an early transmitral flow velocity to atrial flow velocity [E/A] ratio increase of at least 20%).

Table 4. Preoperative and Operative Factors Associated With Diastolic Function Worsening

Factors	Unchanged or Improved (n = 119)	Worsened (n = 27)	*p*
DD (mm)	62.2 ± 9.3	62.3 ± 7.2	n.s.
DS (mm)	49.3 ± 11	49.5 ± 9.8	n.s.
EDV (mL)	198 ± 68	193 ± 55	n.s.
ESV (mL)	135 ± 64	131 ± 49	n.s.
EF	0.34 ± 0.09	0.33 ± 0.08	n.s.
SV (mL)	62.7 ± 16.6	61.3 ± 15.4	n.s.
LA (mm)	42.7 ± 7.1	44.8 ± 7.1	n.s.
sPAP (mm Hg)	32.7 ± 9.3	28.9 ± 6.3	n.s.
SI (S)	0.44 ± 0.12	0.43 ± 0.1	n.s.
SI (D)	0.52 ± 0.11	0.52 ± 0.08	n.s.
CI (D)	0.9 ± 0.21	0.82 ± 0.17	n.s.
CI (S)	1.07 ± 0.34	0.93 ± 0.2	0.018
EDV difference (mL)	70.8 ± 60	47.3 ± 35	0.011
SI difference (S)	−0.04 ± 0.16	−0.056 ± 0.12	n.s.
CI difference (S)	0.22 ± 0.29	0.13 ± 0.22	n.s.

CI = conicity index; D = diastole; DD = LV diastolic diameter; DS = LV systolic diameter; EDV = end diastolic volume; EF = ejection fraction; ESV = end systolic volume; LA = left atrium; LV = left ventricular; n.s. = not significant; S = systole; SI = sphericity index; sPAP = systolic pulmonary artery pressure.

Surgical Technique

Details of the surgical technique have been previously reported [5, 6, 15]. Briefly, the procedure was conducted on an arrested heart with anterograde crystalloid or cold blood cardioplegia. Patients received crystalloid cardioplegia if the preoperative EF was 0.40 or greater (n = 36, 24%). Therefore, the great majority of the patients received cold blood cardioplegia. Complete coronary re-

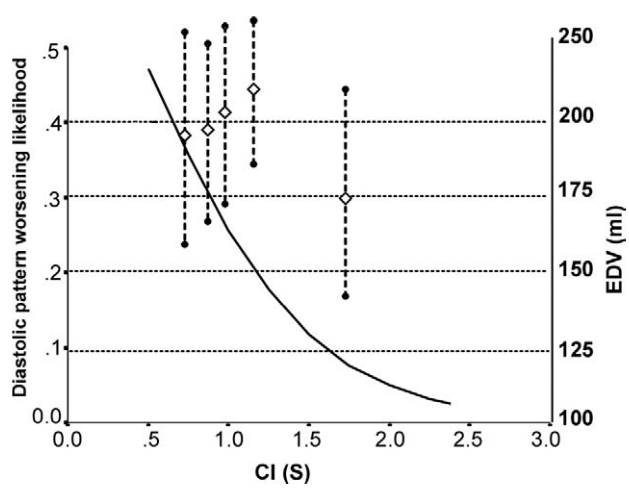

Fig 1. Diastolic function worsening likelihood as a function of preoperative systolic index – CI (S). Preoperative EDVs in each quintile of distribution of sCI are indicated (right axis) as diamonds (mean values and standard deviation). There is no significant difference between quintiles of volumes. (CI = conicity index; EDV = end diastolic volume.)

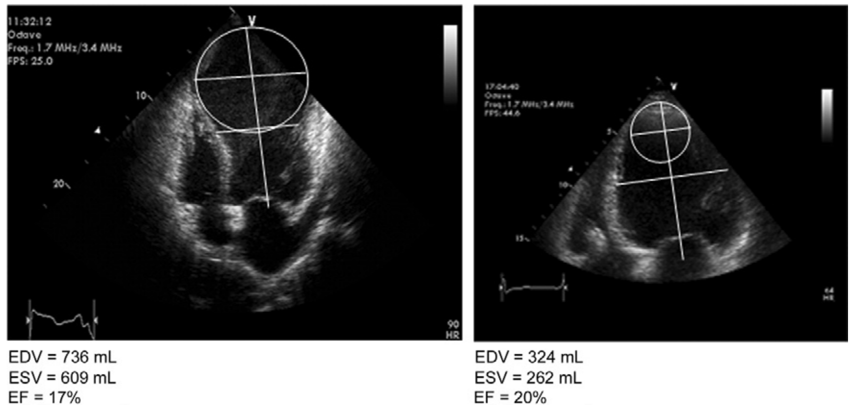

Fig 2. On the left is reported an example of classical aneurism showing an apical axis bigger than the short axis (systolic conicity index = 1.15); on the right is reported an example of ischemic dilated cardiomyopathy showing an apical axis smaller than the short axis (systolic conicity index = 0.72). (EDV = end diastolic volume; EF = ejection fraction; ESV = end systolic volume.)

vascularization was first performed, almost always with the left internal mammary artery on the left anterior descending coronary artery and sequential venous grafts on the right and circumflex arteries, when needed. Since July 2001, we systematically introduced the use of a preshaped mannequin (TRISVR; Chase Medical, Richardson, TX) filled at 50 to 60 mL/m^2 to optimize the size and shape of the new ventricle. The technique is a refinement of the Dor technique and allows for standardization of the procedure.

Statistical Analysis

Statistical analysis included the analysis of variance with the Bonferroni correction for comparisons within group, or an independent variables Student *t* test for comparisons between the two groups. The association between DF worsening and the preoperative and operation-related changes were explored with a logistic regression analysis. For all the statistical tests, a *p* value less than 0.05 was considered to be significant. Data in the tables and in the text are reported as number (percentage) or mean (standard deviation of the mean). Statistical analyses were performed using a computerized statistical package (SPSS 11.0; SPSS, Chicago, IL).

Results

The preoperative diastolic profile is reported in Table 1. Seven (7) patients (4.8%) showed a normal pattern, 99 patients (68%) an abnormal relaxation pattern, 28 patients (19%) a pattern of pseudonormalization, and 12 patients (8.2%) a restrictive pattern. Factors associated with the degree of diastolic dysfunction were age (abnormal relaxation vs pseudonormalization, $p = 0.004$), EF (pseudonormalization vs restrictive pattern, $p = 0.015$), left atrium dimension (abnormal relaxation vs pseudonormalization, $p = 0.005$), and systolic sphericity index (normal vs abnormal relaxation, $p = 0.023$).

On average, the diastolic filling pattern showed a significant increase after the operation (from 1.27 $\pm$ 0.65 to 1.45 $\pm$ 0.7, $p = 0.031$) (Table 2). Within the groups, 105 patients (72%) did not change their diastolic pattern, 14 patients (9.6%) improved, and 27 patients (18.4%) worsened (Table 2). Postoperatively, the hemodynamic echo-derived profile as a function of diastolic pattern (Table 3) was significantly different for end diastolic volume (EDV) (abnormal relaxation vs restrictive pattern, $p = 0.016$), stroke volume (restrictive pattern vs the other groups, $p = 0.008$), left atrium diameter (abnormal relaxation vs restrictive pattern, $p = 0.012$), and systolic and diastolic sphericity index (normal vs restrictive pattern, $p = 0.027$ and $p = 0.035$, respectively).

Determinants of postoperative DF worsening were explored by comparing the worsened group (n = 27) to the unchanged or improved group (n = 119) (Table 4). In this analysis, we considered the preoperative diastolic pattern and the operation-induced changes as potential predictors. Only the preoperative systolic conicity index was associated with a diastolic pattern worsening; the only operation-related change associated with a diastolic pattern worsening was the EDV difference.

A univariate association between the above indices and the diastolic pattern worsening likelihood was explored with a logistic regression analysis. The CI and EDV differences (preoperative-postoperative) were independently and inversely associated with the likelihood of DF worsening (*p* values 0.038 and 0.036, respectively).

The risk of diastolic pattern worsening as a function of the preoperative systolic conicity index is reported in Figure 1. Patients with a low conicity index (greater conical apex) are more prone to DF worsening with respect to patients with a high conicity index (lesser conical apex). Figure 2 shows two different examples. To investigate the role of preoperative volumes associated with different shapes, the preoperative EDVs in the quintiles of distribution of the CI were calculated and reported (Fig 1). No differences in the preoperative EDV were observed for each CI quintile. Therefore, this shape-related predictor of DF worsening is independent of the preoperative EDV.

The risk of diastolic pattern worsening as a function of the EDV difference induced by SVR is reported in Figure 3; preoperative EDVs were calculated for the quintiles of distribution of the EDV difference. In this case, there is a significant difference in the volumes; patients with a large preoperative EDV receiving a wide LV size reduction have a minimal risk for DF worsening, whereas patients with a relatively small preoperative LV (receiv-

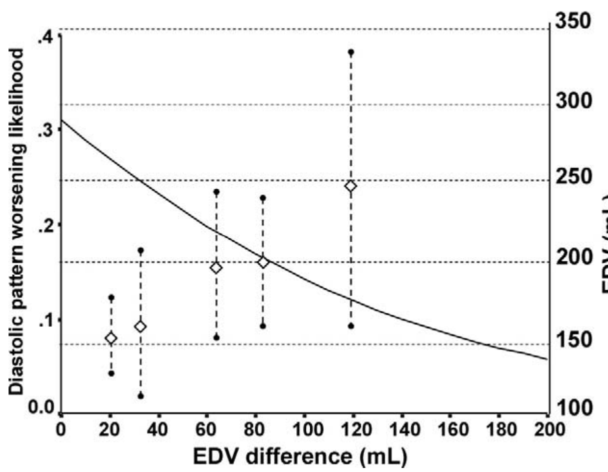

Fig 3. Diastolic function worsening likelihood as a function of operative changes in end diastolic volume (EDV). Preoperative EDVs in each quintile of distribution of EDV difference are indicated (right axis) as diamonds (mean values and standard deviation). There is a significant difference between quintiles in volumes.

ing a limited LV size reduction) are more prone to DF worsening.

Comment

The major findings of this study include the following; (1) Diastolic dysfunction occurs in the majority of patients affected by ischemic dilated cardiomyopathy and heart failure suitable for SVR; (2) after surgery, the average DF is impaired even if a worsening of the diastolic pattern occurs in a minority of the patients; (3) the preoperative shape, irrespective of the volumes, is a predictor of DF worsening; and (4) a limited surgical volume reduction associated with a relatively small preoperative EDV is a predictor of DF worsening.

Diastolic dysfunction occurs in 95% of the population in this study before the operation, and this confirms that diastolic dysfunction is an integral part of systolic heart failure [16]. After the operation, only 27 patients (18%) showed a worsening of the DF, defined as at least one grade more or, in the case of preoperative restrictive pattern, an E/A ratio increased by at least 20% with respect to the preoperative value.

Diastolic Function and LV Volumes

Although SVR is increasingly performed and large series of data are now available in the literature [3, 6, 17, 18], results are sometimes difficult to interpret either because the surgical technique is not standardized yet or because of the lack of clear indications for which ventricles should be treated. In particular, this applies to the problem of the preoperative volumes and shapes and to the concept of the "ideal residual volume" that should be associated with the greater improvement of the overall cardiac function. It is well known that SVR induces a significant reduction in LV end-diastolic and end-systolic volumes and a significant improvement in the EF, indicating an improvement in systolic function [3, 6]. However, the observation coming from this study that DF is impaired after SVR, even if in a minority of patients (18%), raises the question on the possible role of the preoperative EDV and the related changes induced by resizing the LV cavity. To verify this hypothesis, we analyzed the risk for diastolic pattern worsening as a function of the EDV difference induced by SVR, with respect to the preoperative EDV (Fig 3). We showed that the likelihood for DF worsening is higher when the surgical volume reduction, in terms of the EDV difference, is lower, which in turn is directly related to the preoperative EDV. It is reasonable to suspect that a relatively small ventricle (EDV < 160 mL), which necessarily will have a smaller surgical reduction, should not be treated with SVR to avoid a deterioration in DF.

Diastolic Function and LV Shape

The remodeling process after an anterior myocardial infarction includes a sequence of structural changes, which alter the size and the shape of the LV. Previous efforts to assess LV shape have been making use the sphericity index (SI) as a short to long axis ratio [19, 20]. More recently, our group [21] demonstrated that a new parameter named the conicity index (CI), which is calculated as the apical to short axis ratio, is more accurate in detecting regional shape abnormalities originating from the apex, which is primarily involved in anterior myocardial infarction. The results obtained in the present study confirm the superiority of the CI with respect to the SI in predicting the likelihood of DF worsening after SVR. This indicates that, irrespective of the preoperative EDV, globally dilated LV cavities (CI < 1) are more likely to worsen the DF compared with LV cavities equally dilated but mainly at the apical level (CI > 1) for the presence of a dyskinetic scar. A CI greater than 1 can reflect a relatively more compliant tissue, and its resection or exclusion does not affect a DF that eventually may improve, in agreement with the theoretic considerations expressed by Artrip and colleagues [22].

Study Limitations

This study has a few potential limitations. First, the number of patients with a worsening of the DF is small. However, this is the first time, to the best of our knowledge, that detailed changes in diastolic filling pattern are reported in patients who underwent SVR. Second, we utilized echo-Doppler measurements of the mitral inflow to assess DF and tissue Doppler imaging might have been more indicative; however, Tissue Doppler imaging is still not routinely available in the clinical setting. Third, DF assessment through either Doppler flow or tissue Doppler does not allow examination of passive ventricular properties. Fourth, we recognize that early changes in diastolic function may not be completely conclusive; we are currently assessing late postoperative data that will be the subject of a future paper.

ADULT CARDIAC

Conclusions

Before surgery, diastolic dysfunction is often detectable in patients affected by postanterior myocardial infarction dilated cardiomyopathy and depressed systolic function. After surgery, DF remains unchanged or improved in the great majority of patients while it worsens in a minority of cases.

Our study suggests that Doppler echocardiographic assessment, in conjunction with a careful evaluation of geometric and hemodynamic parameters, may provide additional prognostic information and may be used to select patients who will benefit from SVR the most. Moreover, the data reported in this study were collected during a period in which we believed the surgical procedure had been sufficiently standardized, as previously mentioned, leaving the patient selection as a matter of debate. The role of the preoperative shape and of the surgical residual LV volume in predicting DF outcome after SVR is a major finding that has never been reported in the clinical setting.

References

1. Dor V, Saab M, Coste P, Kornaszewska M, Montiglio F. Left ventricular aneurysm: a new surgical approach. Thorac Cardiovasc Surg 1989;37:11–9.
2. Jatene AD. Left ventricular aneurysmectomy: resection or reconstruction. J Thorac Cardiovasc Surg 1985;89:321–31.
3. Athanasuleas CL, Buckberg GD, Stanley AWH, et al. Surgical ventricular restoration in the treatment of congestive heart failure due to post-infarction ventricular dilation. J Am Coll Cardiol 2004;44:1439–45.
4. Di Donato M, Sabatier M, Dor V, Toso A, Maioli M, Fantini F. Akinetic versus dyskinetic postinfarction scar: relation to surgical outcome in patients undergoing endoventricular circular patch plasty repair. J Am Coll Cardiol 1997;29:1569–75.
5. Menicanti L, Di Donato M. The Dor procedure: what has changed after fifteen years of clinical practice? J Thorac Cardiovasc Surg 2002;124:886–90.
6. Menicanti L, Castelvecchio S, Ranucci M, et al. Surgical therapy for ischemic heart failure: single-center experience with surgical anterior ventricular restoration. J Thorac Cardiovasc Surg 2007;134:433–41.
7. Di Donato M, Toso A, Dor V, et al. Surgical ventricular restoration improves mechanical intraventricular dyssynchrony in ischemic cardiomyopathy. Circulation 2004;109:2536–43.
8. Raya T, Gay R, Lancaster L, Aguirre M, Moffett C, Goldman S. Serial changes in left ventricular relaxation and chamber stiffness after large myocardial infarction in rats. Circulation 1988;77:1424–31.
9. Dickstein ML, Spotnitz HM, Rose EA, Burkhoff D. Heart reduction surgery: an analysis of the impact on cardiac function. J Thorac Cardiovasc Surg 1997;113:1032–40.
10. Ratcliffe MB, Wallace AW, Salahieh A, Hong J, Ruch S, Hall TS. Ventricular volume, chamber stiffness, and function after anteroapical aneurysm plication in the sheep. J Thorac Cardiovasc Surg 2000;119:115–24.
11. Tulner SAF, Steendijk P, Klautz RJM, et al. Surgical ventricular restoration in patients with ischemic dilated cardiomyopathy: evaluation of systolic and diastolic ventricular function, wall stress, dyssynchrony, and mechanical efficiency by pressure-volume loops. J Thorac Cardiovasc Surg 2006;132:610–20.
12. Ratcliffe MB, Guy TS. The effect of preoperative diastolic dysfunction on outcome after surgical ventricular remodeling. J Thorac Cardiovasc Surg 2007;134:280–3.
13. Gibson DG, Francis DP. Clinical assessment of left ventricular diastolic function. Heart 2003;89:231–8.
14. Nishimura R, Tajik A. Evaluation of diastolic filling of left ventricle in health and disease: Doppler echocardiography is the clinician's Rosetta Stone. J Am Coll Cardiol 1997;30:8–18.
15. Dor V, Sabatier M, Montiglio F, Coste P, Di Donato M. Endoventricular patch reconstruction in large ischemic wall-motion abnormalities. J Card Surg 1999;14:46–52.
16. Sanderson JE. Diastolic heart failure: fact or fiction? Heart 2003;89:1281–2.
17. Dor V, Di Donato M, Sabatier M, Montiglio F, Civaia F; RESTORE Group. Left ventricular reconstruction by endoventricular circular patch plasty repair: a 17-year experience. Semin Thorac Cardiovasc Surg 2001;13:435–47.
18. Mikleborough LL, Merchant N, Ivanov J, Rao V, Carson S. Left ventricular reconstruction: early and late results. J Thorac Cardiovasc Surg 2004;128:27–37.
19. Dor V, Montiglio F, Sabatier M, et al. Left ventricular shape changes induced by aneurysmectomy with endoventricular circular patch plasty reconstruction. Eur Heart J 1994;15:1063–9.
20. DiDonato M, Sabatier M, Dor V, et al. Effects of the Dor procedure on left ventricular dmension and shape and geometric correlates of mitral regurgitation one year after surgery. J Thorac Cardiovasc Surg 2001;121:91–6.
21. Di Donato M, Dabic P, Castelvecchio S, et al. Left ventricular geometry in normal and post-anterior myocardial infarction patients: sphericity index and "new" conicity index comparisons. Eur J Cardiothorac Surg 2006;29(suppl 1):S225–30.
22. Artrip JH, Oz MC, Burkhoff D. Left ventricular volume reduction surgery for heart failure: A physiologic perspective. J Thorac Cardiovasc Surg 2001;122:775–82.

INVITED COMMENTARY

To achieve symptomatic and survival benefit in the surgical management of heart failure in appropriate patients, each of the three "Vs" must be addressed: (1) vascularization, (2) valvular competence, and (3) volume restoration of the left ventricle. Standardized management strategies and selection criteria exist for coronary and valvular reconstructions, but there remains quite significant surgeon and institutional variability with regard to selection and technique of surgical ventricular restoration (SVR). In past publications, Menicanti and colleagues [1] have provided us with techniques to help standardize the technique of the procedure, but the Achilles' heel of SVR has been patient selection. Here Castelvecchio and colleagues [2] have provided us with a preliminary, but insightful and objective technique to consider in case selection.

Abnormal diastolic function (DF) is the component of heart failure, which produces symptoms and as such relates directly to functional class and quality of life after surgical correction. The goal of surgery is to improve DF. Using objective echocardiographic measurements (sphericity and conicity indices) Castelvecchio and colleagues [2] have suggested to us which types of adversely remodeled left ventricles are most likely and which are least likely to demonstrate improvement in postoperative DF. These data,

Published by Elsevier Inc
0003-4975/08/$34.00
doi:10.1016/j.athoracsur.2008.09.038