Left ventricular performance in chronic mitral regurgitation: temporal response to valve repair and prognostic value of early postoperative echocardiographic parameters

Antonella Moreo, Veliano Gordini, Guglielma Rita Ciliberto, Marina Parolini, Claudio Russo, Alessandro Pellegrini

Department of Cardiology and Cardiac Surgery A. De Gasperis , Niguarda Hospital, Milan, Italy

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Mitral regurgitation; Mitral valve repair; Ventricular function.

Background. **The temporal response of the left ventricle due to the relief of volume loading after mitral valve repair, and the prognostic value of early changes in left ventricular size and function, are not fully documented. The purpose of this study was to analyze the evolution of left ventricular performance after surgery, and to evaluate how early postoperative echocardiographic parameters compare with late ventricular function.**

Methods. **We studied 58 patients with chronic degenerative mitral regurgitation using echocardiography, before, and 9 – 3 days and 38 – 6 months after mitral valve repair.**

Results. **Between the preoperative and early postoperative study, left ventricular end-diastolic and left atrial size, and ejection fraction decreased, whereas left ventricular end-systolic dimension did not change. Between the early and late postoperative study left ventricular end-systolic size decreased significantly, there was a further decrease in left ventricular end-diastolic dimension and a significant increase in ejection fraction; left atrial size did not change. Multivariate analysis showed that preoperative and early postoperative ejection fraction, and the early postoperative reduction in diastolic dimension were the best predictors of late left ventricular function.**

Conclusions. **In patients with chronic degenerative mitral regurgitation, the greatest reduction in end-diastolic dimension occurs within 2 weeks of the reversal of volume overload; a significant reduction in end-systolic dimension with an increase in ejection fraction occurs later. In our experience, early postoperative echocardiographic measurements of left ventricular size and function can provide important prognostic information.**

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Address:

Dr. Antonella Moreo

Via G. Da Sovico, 40
20050 Sovico (MI)
E-mail: amoreo@tin.it

Several studies have investigated the evolution of left ventricular function and the preoperative predictors of postoperative outcome in patients undergoing mitral valve surgery for mitral valve regurgitation. At the beginning they involved patients who underwent mitral valve replacement[1-8].

Valve repair is the preferred treatment for mitral valve regurgitation, because the preservation of the mitral apparatus leads to better preservation of left ventricular function[9-11] without any prosthesis-related complications.

Neither the temporal response of the left ventricle to volume unloading, nor the prognostic value of early postoperative echocardiographic parameters, has yet been fully documented.

The purpose of this study was to analyze the evolution of left ventricular performance both early and late after mitral valve repair, and to evaluate how early postoperative echocardiographic parameters compare with late postoperative results.

Methods

Patient population. Between January 1988 and December 1994, 134 consecutive patients with isolated, chronic, severe degenerative mitral regurgitation, without associated coronary artery disease, underwent mitral valve repair without concomitant cardiac procedures at our Institution. One patient died as a result of multiorgan failure 35 days after surgery; the remaining 133 discharged

patients were considered for inclusion in the study. Complete preoperative and early postoperative (within 14 days) echocardiographic studies were available only for 82 patients: 5 of them were considered ineligible because of the presence of residual moderate or severe mitral incompetence that required surgery in 2 cases. Of the 77 eligible patients, 15 were not recruited because they refused to undergo a further echocardiographic examination due to inconvenience as they lived a long distance from our Institution and 4 were lost at the follow-up.

The study group therefore consisted of 58 patients (31 men, 27 women) aged 16-74 years (mean age 58 ± 11 years). Forty patients were in NYHA functional class III-IV at the time of surgery. Nineteen (33%) were in atrial fibrillation. There were no statistically significant differences in the preoperative or operative characteristics of the study population and those of the other patients, not included in the study, who underwent mitral valve repair during the considered period (Table I).

Echocardiographic examination. All of the echocardiographic studies were performed using a commercially available cardiac ultrasound instrument (Vingmed CMF 700 and Vingmed CMF 750, Vingmed Sound, Horten, Norway), equipped with a 3 or 3.5 MHz annular phased-array transducer. All included parasternal long- and short-axis, as well as 4-chamber, 2-chamber and apical views, and most also included a subcostal view.

One echocardiographic examination was performed before surgery, the second 9 ± 3 days afterwards, and the third 38 ± 6 months after mitral valve repair.

The M-mode measurements of the left ventricle were obtained using guidance by two-dimensional echocardiography at end-systole and end-diastole, as recommended by the American Society of Echocardiography[12].

The left ventricular volumes and ejection fraction were determined from the apical 4-chamber view using the single plane area-length formula.

All of the studies were recorded on videotape for subsequent analysis and were blindly reviewed by two independent observers. Linear regression analysis showed a good correlation (r = 0.94) for interobserver variability in the measurement of left ventricular dimensions.

Table I. Comparisons of preoperative and operative characteristics between the study population and the patients who underwent mitral valve repair in the considered period not included in the study.

	Study population	Non-enrolled population	p
No. patients	58	76	NS
Age (years)	58 – 11	59 – 12	NS
NYHA class	2.8 – 0.8	2.8 – 0.7	NS
Cardiothoracic ratio	0.57 – 0.08	0.56 – 0.09	NS
LA (mm)	51 – 8	51 – 9	NS
EDD (mm)	63 – 7	62 – 7	NS
ESD (mm)	40 – 10	39 – 9	NS
FS (%)	38 – 8	39 – 7	NS
EDV (ml)	175 – 59	175 – 50	NS
ESV (ml)	63 – 33	60 – 22	NS
EF (%)	64 – 9	64 – 9	NS
Cardiopulmonary bypass (min)	78 – 24	72 – 27	NS
Aorta cross clamping (min)	56 – 19	54 – 23	NS

Data are expressed as mean – SD. EDD = end -diastolic diameter; EDV = end -diastolic volume; EF = ejection fraction; ESD = end -systolic diameter; ESV = end -systolic volume; FS = fractional shortening; LA

Surgical procedure. Cardiac surgery was performed by experienced cardiac surgeons at our Institution, using a standard cardiopulmonary bypass with moderate hypothermia, cold potassium cardioplegia, and topical cooling for myocardial protection.

The standard mitral valve repair techniques included posterior leaflet resection (46 patients), and, in prolapse of anterior leaflet, chordal shortening and transfer (12 patients). A Carpentier-Edwards ring was inserted in 18 patients (31%), and posterior annuloplasty using a Gore-Tex prosthesis was performed in 40 (69%).

The mean duration of the cardiopulmonary bypass and cross clamping of the aorta was respectively 78 ± 24 and 56 ± 19 min.

After surgery, electrocardiograms and cardiac enzyme determinations revealed no evidence of intraoperative myocardial infarction.

Postoperative medications were used at the discretion of the physician caring for the patient. ACE-inhibitors and/or diuretics were used preferentially in patients with poor postoperative left ventricular function.

Statistical analysis. The data are expressed as mean values ± SD. Student's t-test was used to assess the differences between mean values. A p value of < 0.05 was considered statistically significant.

Group comparisons were made using the unpaired Student's t-test or c^2 analysis as appropriate. The Student's t-test with the Bonferroni adjustment was used to compare the echocardiographic data before, and early and late after surgery.

The univariate and multivariate analyses were based on the Cox proportional-hazard model, with improvements in model fit based on likelihood ratio statistics. The software used was the Statistical Package for the Social Sciences Program (SPSS, SPSS Inc., Chicago, IL, USA) and the Biomedical Computer Program (BMDP Statistical Software Inc., Los Angeles, CA, USA).

Results

The preoperative and postoperative echocardiographic results are summarized in table II.

The early postsurgical examination (9 ± 3 days after mitral valve repair) showed a marked decrease in left ventricular end-diastolic size in comparison with preoperative values, but no significant change in end-systolic size; this led to a significant decrease in ejection fraction (Table II). End-diastolic volume decreased from 175 ± 59 to 125 ± 48 ml ($p < 0.001$), and ejection fraction from 64 ± 9 to 51 ± 10% ($p < 0.001$).

At the late examination (38 ± 6 months), we observed a significant decrease in left ventricular end-systolic dimension and a further reduction in end-diastolic size. Between the early and late postoperative studies, ejection fraction significantly increased from 51 ± 10 to 57 ± 10% ($p < 0.001$).

The evolution of left ventricular function is shown in figure 1. An ejection fraction < 50% was reported preoperatively in 3 patients, early postoperatively in 21 and at the late examination in 10 (Fig. 1A). The end-diastolic volume was above the normal value in 37 patients preoperatively, in 16 early after surgery and in 10 at the late examination (Fig. 1B).

A mild mitral regurgitation was observed in 6 patients at early control and in 9 patients late postoperatively.

Predictors of late evolution of left ventricular function. At the late examination 48 patients had an ejection fraction □ 50%, 10 an ejection fraction < 50%. The latter group had larger preoperative left ventricular end-systolic dimensions (end-systolic diameter 48 ± 10 vs 37 ± 6 mm, $p < 0.001$; end-systolic volume 110 ± 39 vs 53 ± 20 ml, $p < 0.001$), larger early postoperative left ventricular end-diastolic and left atrial sizes (end-diastolic diameter 62 ± 10 vs 51 ± 5 mm, $p < 0.01$; end-diastolic volume 192 ± 65 vs 111 ± 28 ml, $p < 0.01$; left atrium 49 ± 6 vs 42 ± 6 mm, $p < 0.001$), and lower preoperative and early postoperative ejection fraction (preoperative 56 ± 11 vs 67 ± 6%, $p < 0.01$; early postoperative 41 ± 12 vs 53 ± 8%, $p < 0.001$).

The late ventricular function was analyzed in relation to early postoperative changes in diastolic size. The patients showing no or only minimal (< 15%) early reduction in diastolic size had, at the late examination, a significantly larger end-diastolic volume (176 ± 78 vs 100 ± 26 ml, $p = 0.013$), and a significant lower ejection fraction (47 ± 13 vs 60 ± 8%, $p = 0.013$) (Fig. 2).

Multivariate analysis of the echocardiographic vari-

Table II. Evolution of echocardiographic parameters before, early and late after valve repair for mitral incompetence.

	Preoperatively	p	9 – 3 days postoperatively	p	38 – 6 months postoperatively
LA (mm)	51 – 8	< 0.001	43 – 6	NS	42 – 9
EDD (mm)	63 – 7	< 0.001	54 – 7	< 0.01	50 – 8
ESD (mm)	40 – 10	NS	39 – 9	< 0.001	33 – 8
EDV (ml)	175 – 59	< 0.001	125 – 48	< 0.01	114 – 52
ESV (ml)	63 – 33	NS	62 – 39	< 0.01	52 – 41
EF (%)	64 – 9	< 0.001	51 – 10	< 0.001	57 – 10

Data are expressed as mean – SD. Abbreviations as in table I.

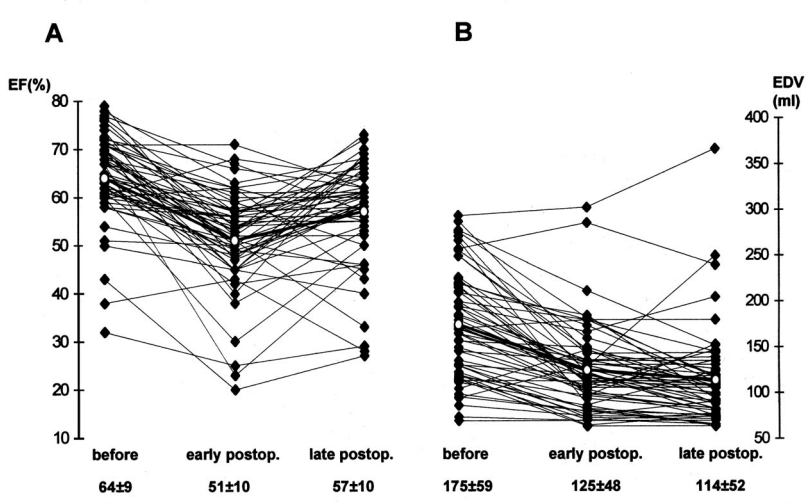

Figure 1. *Evolution of left ventricular function before, early and late after valve repair for mitral incompetence. Mean values are also shown* (open circles). A: *evolution of ejection fraction (EF).* B: *evolution of left ventricular end-diastolic volume (EDV).*

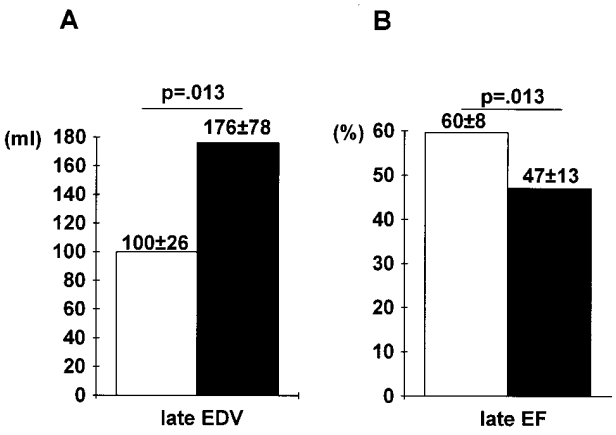

Figure 2. *Late evolution of ventricular function in relation to early postoperative changes in diastolic size. The patients with no or minimal (< 15%) early reduction in diastolic size* (solid bars) *compared with those with a reduction of > 15%* (open bars) *showed a significant greater end-diastolic volume* (A) *and lower ejection fraction* (B) *at the late examination. Abbreviations as in figure 1.*

ables showed that preoperative and early postoperative ejection fraction and the reduction in diastolic dimension early after surgery were the most reliable predictors of the late evolution of left ventricular function in response to valve repair (Table III). The absence of a reduction in diastolic size early after surgery increases the risk of late left ventricular dysfunction by more than 14 times.

Discussion

Table III. Multivariate analysis of the echocardiographic variables, predictors of late postoperative left ventricular dysfunction.

	β coefficient	RR	CI	p
Preoperative EF	-0.2129	0.81	0.64-1.02	0.004
Early postoperative EF	-0.2277	0.80	0.67-0.95	0.004
Lack of early reduction in diastolic size	2.6983	14.85	1.93-114.2	0.0001

CI = confidence interval; EF = ejection fraction; RR = relative risk.

Several studies[1-3,11,13-19] reported the effects of surgical procedures on left ventricular function in patients with chronic mitral regurgitation, but it is difficult to compare the results because of differences in patient selection and type of surgical correction. Furthermore, these studies not only used different methods for assessing systolic function, but also the time at which the measurements were made frequently varied.

Early postoperative results. Our data demonstrate that there is a substantial decrease in left ventricular end-diastolic size after mitral valve repair for chronic mitral regurgitation. The greatest reduction in this parameter developed within 14 days of the operation, representing approximately 82% of the overall decrease in end-diastolic volume observed during the postoperative follow-up. On the contrary, there was no significant change in end-systolic size, and this led to a significant early decrease in ejection fraction.

These findings are consistent with those of previously published studies designed to evaluate the results, during a comparable time period, both after mitral valve replacement[1,2] and after mitral valve repair[20].

An early significant decrease not only in end-diastolic but also in end-systolic dimensions with no change in ejection fraction was reported by other authors after mitral valve repair[13] or replacement with chordal preservation[16].

It is important to note that left ventricular end-diastolic volume decreases because of the elimination of volume overload, but changes in ejection fraction are caused by a more complex interaction of preload, afterload, contractility, geometry and chordal support.

Late postoperative results. Our data demonstrate that, late after surgery, there is not only a further reduction in end-diastolic size, but also a decrease in end-systolic size. The percent decrease in end-systolic dimension (approximately 16%) was more marked than that in end-diastolic dimension (approximately 8%), and thus led to a significant increase in ejection fraction that normalized in all but 10 patients.

The previously published results are conflicting. Some authors[1,2] have observed no significant change in ejection fraction between an early and late (1-2 years after surgery) postoperative study, whereas others[8,13,21] found a substantial improvement in ejection fraction similar to that we observed.

Irreversible preoperative left ventricular dysfunction due to myocardial degenerative changes may account for a lack of normalization in cardiac performance, despite a technically successful reversal of volume overload and conservation of the architecture of the mitral apparatus. In three subgroups of patients, Starling et al.[21] observed temporally different left ventricular sizes and ejection fraction responses to mitral surgery: a persistent decrease in ejection fraction at 3 months and 1 year was only reported in the group of patients with preoperatively impaired contractile function.

Predictors of postoperative left ventricular function. Preoperative left ventricular function is an important prognostic factor in patients undergoing surgery because of mitral valve incompetence.

Previous studies have concentrated on the difficulty of assessing left ventricular function in mitral regurgitation because of the altered loading conditions, and suggested preoperative angiographic, nuclear or echocar-

diographic indexes.

The studied preoperative variables, markers of ventricular function and possible predictors of outcome, include ejection fraction[5,14], end-systolic diameter and end-systolic volume index[3,7,22], end-systolic wall stress[3], the end-systolic wall stress/end-systolic volume index ratio[4,23], the systolic diameter/wall thickness ratio[6], the slope of the end-systolic pressure-volume relationship (E max)[21], the tension-volume ejection fraction index[4], the rate of change in left ventricular pressure over time[24], end-systolic stress-strain[25], and left atrial size[6].

However, we believe that, in the clinical setting, it is essential to determine the ability of simple and routinely obtained parameters, applicable to a large number of patients, to predict postoperative results and to improve the clinical decision-making process.

In our experience, the preoperative ejection fraction was the most powerful independent preoperative predictor of postoperative left ventricular function.

This result is consistent with previous studies[5,13]. Other authors reported the prognostic value of preoperative left ventricular dimensions[3,7,14,25].

Few data are available regarding how early postoperative left ventricular size and function compare with the late postoperative results.

In our series, early postoperative ejection fraction, and an early postoperative change in diastolic size were the best predictors of the late evolution of left ventricular function in response to valve repair. The patients with no reduction in left ventricular end-diastolic size had a significant greater end-diastolic volume and a significant lower ejection fraction on long-term follow-up.

Our experience is confirmed by the results of Lee et al.[26], who demonstrated that early postoperative left ventricular function (3-10 days) was a useful prognostic indicator of late postoperative left ventricular dysfunction. The patients with an early postoperative left ventricular ejection fraction of < 40% had a high incidence of postoperative asymptomatic or overt left ventricular dysfunction.

Limitations of the study. Our study group may not be representative of the total population of patients operated on for mitral regurgitation during the considered period, even though there were no significant differences between the enrolled and not enrolled patients.

Furthermore, the requirement of a late echocardiographic study obviously biased the population toward those surviving, and the duration of the observation (38 ± 6 months) may be misleading in terms of true long-term outcome.

Finally, no consideration is given to other variables, which may be independent predictors of postoperative ventricular function.

Clinical implications. The analysis of preoperative predictors of late results allows a better selection of patients with chronic mitral regurgitation for surgery by providing data useful for optimizing the timing of surgery. The echocardiographic studies performed before hospital discharge also provide data relevant to long-term prognosis: ejection fraction and the absence of a reduction in left ventricular end-diastolic size early after surgery define a population of patients who may require closer follow-up and who may benefit from early pharmacological intervention.

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