Mitral valve repair versus replacement for isolated non-ischemic mitral regurgitation in patients with preoperative left ventricular dysfunction. A long-term follow-up echocardiography study

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Abstract The aim of this study was to evaluate LV function, by means of echocardiography, after mitral valve repair (MVr) or mitral valve replacement (MVR) in patients (pts) with chronic degenerative mitral regurgitation (MR) and depressed LV systolic function during a 6-years follow-up (FU) period.

Patients and methods: Forty-five pts with moderately severe or severe MR and preoperative EF ≤ 50% were divided into 2 groups: MVr group (27 pts, 19 men–8 women, aged 62 ± 10 years) and MVR group (18 pts, 8 men–10 women, aged 60 ± 12 years). The cause of MR was myxomatous mitral valve disease (MVr/MVR: 16/8), endocarditis (0/4) and degenerative mitral valves with ruptured chordae tendineae (11/6). All pts underwent transthoracic echocardiography preoperatively, postoperatively and annually during the FU period (6 ± 3 years).

Results: In MVr group, 5 pts died, 5 were lost to FU and 2 pts underwent MVR due to MVr failure. In MVR group, 6 pts died, 3 were lost to FU and 1 was re-operated due to prosthetic valve endocarditis. Atrial fibrillation was similar between the 2 groups. MVr pts demonstrated significant LVEDD decrease postoperatively which was persistent during FU (p < 0.05). LVESD also decreased (p < 0.05), VTI improved (p < 0.05), while FS and EF showed a trend to improve. In MVR pts, LVEDD was decreased...
Mitral valve repair (MVR), when feasible, has become the procedure of choice for surgical treatment of chronic mitral regurgitation (MR) because it provides better postoperative clinical outcome than mitral valve replacement (MVR).¹⁻⁵ Poor preoperative left ventricular (LV) function has been associated with an adverse clinical outcome in patients with MR, while preoperative LV ejection fraction (EF) may be a powerful predictor of postoperative heart failure and death,⁶ regardless of the type of surgery used for correction of chronic MR. This is generally attributed to the postoperative increase in LV afterload and abolition of the "pop-off" valve effect of the regurgitant leak, further decreasing the EF and cardiac output.⁶ The better clinical outcome after MVR is directly related to the preservation of the subvalvular apparatus resulting in preservation of LV geometry. Patients with a significant degree of LV systolic dysfunction (EF < 50%) should undergo surgical correction of MR because: (a) surgical correction, compared to medical treatment, improves prognosis and (b) reduces the incidence of congestive heart failure.⁷,⁸

The purpose of this study was to evaluate the recovery of the preoperative LV function after mitral valve repair or replacement in patients with impaired systolic LV function due to chronic degenerative MR. We also tested the hypothesis that these patients may present a greater improvement of LV function after MVR than after MVR.

Patients and methods

Study population

The study group consisted of 45 patients with isolated moderately severe or severe MR and impaired LV function, without other significant associated valvular or coronary artery disease, documented by preoperative echocardiographic and cardiac catheterization studies. All patients had preoperative ejection fraction <50% (46 ± 5%, range 31–50%), determined by echocardiography. The selection of LVEF ≤ 50% as the cut-off point between normal and depressed LV function was based on Veterans Administration Co-operative Study on valvular heart disease.⁹ The underlying cause of MR was myxomatous mitral valve disease (floppy mitral valve) in 24 patients, endocarditis in 4 and degenerative valves with ruptured chordae tendineae in 17. Twenty-seven patients (19 men–8 women, aged 62 ± 10 years) (MVR group) underwent MVR (according to the Carpentier type reconstruction¹⁰,¹¹) and a rigid Carpentier annular ring was inserted in 16 of them (Table 2). Eighteen patients (8 men–10 women, aged 60 ± 12 years) (MVR group) underwent a conventional MVR without preservation of papillary muscles and a low profile mechanical disc valve was implanted in all of them (Bjork-Shiley in 15 patients and St. Jude in 3). Patients in the 2 groups had similar age and degree of preoperative MR assessed by echocardiography and cardiac catheterization (Table 1). The decision to replace or to repair the valve was made on the table by the surgeon based on the valve anatomy. All patients were operated at the same center (Hammersmith Hospital, London, UK) by the same group of surgeons.

<table>
<thead>
<tr>
<th></th>
<th>Group A (MVR)</th>
<th>Group B (MVR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>27</td>
<td>18</td>
</tr>
<tr>
<td>Age (years)</td>
<td>62 ± 10</td>
<td>60 ± 12</td>
</tr>
<tr>
<td>Sex</td>
<td>women</td>
<td>19 men–8 women</td>
</tr>
<tr>
<td>MR severity(median)</td>
<td>3/4</td>
<td>3/4</td>
</tr>
<tr>
<td>Moderate 2/4</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Mod. severe 3/4</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Severe 4/4</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Underlying disease</td>
<td>Floppy MV</td>
<td>16</td>
</tr>
<tr>
<td>Flail MV</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>Endocarditis</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Leaflets involved</td>
<td>Posterior</td>
<td>21</td>
</tr>
<tr>
<td>Anterior</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Both</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>SR/AF/paced</td>
<td>16/10/1</td>
<td>11/7/0</td>
</tr>
</tbody>
</table>

MVR, mitral valve repair; MVR, mitral valve replacement; MR, mitral regurgitation; MV, mitral valve; SR, sinus rhythm; AF, atrial fibrillation.
Follow-up

The mean follow-up period was $6 \pm 3$ years in all patients and was divided in 3 consecutive time periods: 6–18 months after surgery (FU1), 18–36 months (FU2) and >36 months (FU3). All patients were evaluated at the outpatient clinic yearly.

Echocardiography

All patients were evaluated with transthoracic and transoesophageal echocardiography, within 5 months before surgery. Transthoracic echocardiography was repeated within 3 months after surgery and on an annual base during the follow-up (FU) period. Examinations were performed in the left lateral decubitus position. LV systolic function was estimated from LV end-diastolic and end-systolic diameters (LVEDD, LVESD), fractional shortening (FS), ejection fraction (EF) and velocity time integral of LV outflow track (VTI) with Pulse wave Doppler. EF was calculated using the modified Simpson’s method. The size of the left atrium (LA) was also measured and pulmonary artery systolic pressure (PASP) was estimated from tricuspid regurgitation. Mitral regurgitation was evaluated semi-quantitatively by color Doppler imaging at transthoracic and transoesophageal echocardiography and was graded as follows: 1 = mild, 2 = moderate, 3 = moderately severe, 4 = severe.

Statistics

Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) software. Results were expressed as mean values ± SD. Normal distribution of the echocardiographic indices was checked with Kolmogorov–Smirnov test. Due to the fact that some measured data were skewed, analysis of the overall differences between subgroups was performed using the non-parametric Mann–Whitney test or Kruskall–Wallis test for multiple comparisons. Paired analysis of each variable within the 2 groups was performed using the non-parametric Wilcoxon test or Friedman test for multiple comparisons. A $p$ value <0.05 was considered significant.

Results

Clinical characteristics of the study population

Patients’ clinical characteristics are presented in Table 1. No patient had any residual mitral regurgitation of any clinical significance at the first postoperative study.

In the MVr group, 5 patients were lost within the first year of FU and they were not included in the analysis of the data during FU period. In the MVR group, 2 patients died 2 and 3 months, respectively, following surgery and 3 other were lost within the first year of FU and so the data of all 5 patients in this group were not included in the analysis of the data during FU period. Thus, of the 45 patients studied pre- and immediately postoperatively, 35 patients completed the FU3 period (>36 months) (22 in the MVr group and 13 in the MVR group).

In-group analysis

Overall changes of the echocardiographic indices postoperatively and during FU are presented in Table 4.
Table 4  Changes of the echocardiographic indices postoperatively and during follow-up

<table>
<thead>
<tr>
<th></th>
<th>MVr Pre-op</th>
<th>MVr Post-op</th>
<th>MVr FU1</th>
<th>MVr FU2</th>
<th>MVr FU3</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVEDD (mm)</td>
<td>61 ± 6</td>
<td>53 ± 6*</td>
<td>52 ± 6</td>
<td>50 ± 7</td>
<td>51 ± 9</td>
</tr>
<tr>
<td>LVESD (mm)</td>
<td>43 ± 4</td>
<td>39 ± 5*</td>
<td>38 ± 7</td>
<td>35 ± 6</td>
<td>37 ± 8</td>
</tr>
<tr>
<td>FS (%)</td>
<td>28 ± 4</td>
<td>27 ± 5</td>
<td>29 ± 6</td>
<td>30 ± 5</td>
<td>29 ± 8</td>
</tr>
<tr>
<td>EF (%)</td>
<td>48 ± 6</td>
<td>46 ± 7</td>
<td>48 ± 10</td>
<td>50 ± 9</td>
<td>48 ± 13</td>
</tr>
<tr>
<td>VTI (cm)</td>
<td>13 ± 3</td>
<td>15 ± 2*</td>
<td>15 ± 2</td>
<td>15 ± 2</td>
<td>16 ± 2</td>
</tr>
<tr>
<td>LA (mm)</td>
<td>56 ± 10</td>
<td>50 ± 9*</td>
<td>49 ± 10</td>
<td>51 ± 9</td>
<td>52 ± 9</td>
</tr>
<tr>
<td>PASP (mmHg)</td>
<td>26 ± 5</td>
<td>26 ± 6</td>
<td>28 ± 7</td>
<td>28 ± 6</td>
<td>31 ± 10</td>
</tr>
</tbody>
</table>

Values are expressed as mean ± SD. FU1: follow-up 6–18 months, FU2: 18–36 months, FU3: >36 months. LVEDD, left ventricular end-diastolic diameter; LVESD, left ventricular end-systolic diameter; FS, fractional shortening; EF, ejection fraction; VTI, velocity time integral at left ventricular outflow tract; LA, left atrium; PASP, pulmonary artery systolic pressure.

*p < 0.05 between pre- and postoperative values. *p < 0.02 between pre- and postoperative values and between post- and FU3 values. *p < 0.03 between pre- and postoperative values. *p < 0.05 between post- and FU2 and FU3 values. Values not indicated were NS (see text).

Patients in MVr group demonstrated a decrease of LVEDD from 61 ± 6 mm preoperatively to 53 ± 6 mm early postoperatively (p < 0.001), approaching normal values. The improvement of LVEDD remained unchanged throughout FU (Fig. 1). LVESD was also reduced from 43 ± 4 mm preoperatively to 39 ± 5 mm early postoperatively (p = 0.002), which was preserved during FU showing a trend for a further decrease (Fig. 2). FS and EF showed a mild deterioration from pre- to postoperative value (28 ± 4% → 27 ± 5%, p = 0.2; 48 ± 6% → 46 ± 7%, p = 0.25, respectively), but during FU, both indices showed a trend to improve (Fig. 3). Conversely, VTI showed an improvement from 13 ± 3 cm preoperatively to 15 ± 2 cm early postoperatively (p < 0.05), which was preserved during FU (Fig. 4). The LA size was reduced after surgery (56 ± 10 mm → 50 ± 9 mm, p = 0.001) and remained unchanged during FU. Finally, PASP was similar preoperatively, postoperatively and during FU (26 ± 5 mmHg → 26 ± 6 mmHg → 31 ± 10 mmHg, p = NS).

In the subgroup of MVr patients there were no differences in LV diameters and EF during FU between patients with or without an annular ring after surgical repair of the mitral valve. However, a borderline increase in FS and EF (p = 0.066 and p = 0.05, respectively) was noted at FU1, in patients without an annular ring, compared to those without.

Figure 1 Changes in left ventricular end-diastolic diameter from preoperative value through follow-up time. p1: difference between pre- and postoperative value in each group (in-group analysis), p2: difference between postoperative and FU3 value in group B (in-group analysis), p3: difference in FU2 and FU3 values between the 2 groups (between-groups analysis).

Figure 2 Changes in left ventricular end-systolic diameter from preoperative value through follow-up time. p1, p2: differences between pre- and postoperative value in MVr and MVR group, respectively (in-group analysis) p3: difference in FU2 and FU3 values between the 2 groups (between-groups analysis).
with an annular ring implanted, but this difference was not evident in FU2 and FU3.

In the MVR group, LVEDD showed an early postoperative decrease, compared to its preoperative value (59 ± 7 mm versus 55 ± 8 mm, p < 0.05). Conversely, LVEDD increased at 36 months of FU (post-op versus FU3 value: 55 ± 8 mm versus 59 ± 9 mm, p = 0.016, Fig. 1). LVESD remained high early postoperatively (Fig. 2), resulting in a significant decrease of FS and EF (pre-op/post-op value: 28 ± 4% → 25 ± 5%, p < 0.02, 47 ± 6% → 42 ± 9%, p < 0.03, respectively). The reduction in FS and EF further increased at 36 months of FU (Fig. 3). VTI and LA size remained practically unchanged. PASP did not change significantly after surgery (28 ± 7 mmHg → 30 ± 7 mmHg, p = NS), but at FU3 it increased from the postoperative value (30 ± 7 mmHg → 40 ± 10 mmHg, p = 0.005).

Finally, a modest correlation was found in both groups, between preoperative and postoperative LVEF (r = 0.40).

**Between-groups analysis**

Patients in the 2 groups did not show any difference in any echocardiographic parameter preoperatively, as well as postoperatively. During FU1, no difference was found in any parameter, but at FU2 patients in MVR group compared to patients in MVR group demonstrated lower LVEDD (50 ± 7 mm versus 59 ± 8 mm, p < 0.05), lower LVESD (35 ± 6 mm versus 43 ± 9 mm, p < 0.05), higher FS (30 ± 5 mm versus 25 ± 6 mm, p = 0.07) and EF (50 ± 9 mm versus 42 ± 11 mm, p = 0.07), smaller LA (51 ± 9 mm versus 61 ± 11 mm, p < 0.05), lower PASP (28 ± 6 mmHg versus 35 ± 9 mmHg, p < 0.05) and similar VTI (15 ± 2 mm versus 13 ± 4 mm, p = 0.3). Finally, similar differences were observed between patients in the MVr and patients in the MVR group during FU3 (Figs. 1–4).

**Follow-up**

In MVr group, five patients died at 5 ± 1 years after surgery. All patients who died had completed the FU3 period, so their data were included in the analysis. Two other patients underwent MVR due to MVr failure (1 and 2 years after surgery, respectively). Two more patients demonstrated a progressive increase of mitral regurgitation during the FU period, not requiring surgical intervention. In the remaining 18 patients with MVr, the mild residual MR observed early postoperatively, remained unchanged throughout FU period. Three patients developed atrial fibrillation (AF) during FU. None of the patients developed clinical or echocardiographic signs suggestive of coronary artery disease (akinesis or scar). Also, no perioperative myocardial infarction was found in the MVr group.

In the MVR group, 2 patients died during early postoperative period (<3 months) and their data were not included in the analysis. Four other patients died at 7 ± 4 years having completed the FU3 period, so their data were analyzed. Additionally, 1 patient was re-operated due to prosthetic valve endocarditis and four patients...
developed AF (2 permanent, 2 paroxysmal) (Group A versus Group B \( p = \text{NS}, \) Table 3). Occurrence of AF did not differ between the 2 groups. Furthermore, in the MVR group the mitral prosthesis remained well functioning with the pressure half time remaining unchanged throughout the FU period (PHT post-op: 94 ± 35 ms, FU1: 105 ± 30 ms, FU2: 88 ± 32 ms, FU3: 82 ± 27 ms, \( p = \text{NS})\). Finally, only 1 patient demonstrated increase of MR during FU period, not requiring surgical intervention, while in the rest of MVR patients the mild residual MR remained unchanged. Thus, there was no significant difference between the 2 groups in the number of patients with deterioration of MR during FU (Table 3).

Discussion

Degenerative mitral valve disease is currently the most common cause of mitral regurgitation in Europe. Mitral regurgitation leads to chronic volume overload of the left ventricle, progressively leading to LV dysfunction. The regurgitant volume, ejected into the low-resistance left atrial chamber during systole, increases the total stroke volume and the EF. Since the LVEF, in the presence of severe MR, is often supranormal, the slightest reduction in EF is synonymous to significant LV dysfunction. Myocardial failure is also an important postoperative complication and it is responsible for the majority of postoperative cardiac related mortality and morbidity.

Many reports have shown that MVr is superior to MVR, as far as preservation of LV function is concerned. To our knowledge, there have been no reports on the effects of mitral valve replacement versus repair on an already impaired LV function prior to valve surgery for isolated MR.

In our study, LVEDD was significantly reduced in both groups postoperatively. This was an expected finding, since the cause of LV volume overload was eliminated. During FU however, while in MVr patients LVEDD remained within normal limits, in the MVR group it increased again, 3 years after surgery, reaching the preoperative values, without any significant residual MR. This finding could be explained by the fact that in MVr without chordal preservation, LV remodeling alters the shape of the left ventricle toward a spherical geometry (decreased eccentricity index), whether in MVr the LV shape is not affected. Previous reports support this finding, although FU period was shorter. It should be also noted that during FU, no perioperative acute myocardial infarction, which develops more frequently during MVr, was found in our MVr group. Consequently, at 6 years FU, patients with MVr demonstrated a lower FS and EF than patients with MVR, compared to the early postoperative study. A possible explanation for these alterations is based upon the aforementioned changes in LV geometry. It has been proposed that, despite expected increase in LV afterload caused by the competent mitral valve, in MVr as well as in MVR with chordal preservation, LV afterload decreases after mitral surgery. Preservation of the subvalvular apparatus in these techniques maintains LV geometry and allows a reduction of LV radius, leading to a reduction in wall stress (LV afterload), according to the Laplace equation. This LV afterload reduction is even more beneficial in patients with preoperatively reduced LV contractility. Conversely, end-systolic wall stress is increased after MVr without chordal preservation due to the loss of chordal support and LV end-systolic volume fails to decrease. Ren and colleagues suggest that preservation of LVEF in MVr and in MVR with chordal preservation is not caused by a decrease in end-systolic volume; the decrease in end-systolic volume is the result of a preserved EF (due to the maintenance of the functional components of the subvalvular apparatus), even though there is a decrease in end-diastolic volume. Our results are in agreement with other reports that showed preservation (not improvement) of LVEF after MVr and deterioration after MVR and this preservation is maintained during a long period of time postoperatively after MVr, while it further deteriorates after MVR. The decrease in FS and EF that was noted in both groups at the early postoperative period, is consistent with the reports of Enriquez-Sarano et al., who reported this finding almost 10 years ago, in patients with preoperatively normal systolic function. The weak correlation that was also found in both groups, between preoperative and postoperative LVEF \((r = 0.40)\), is consistent with previous reports. The data of this cohort demonstrate that patients with MR, who have developed LV dysfunction because they were not operated early enough during the natural history of their valve disease, can benefit from valve reconstruction. However, neither with MVr nor with MVR a normalization of LVEF with mean values > 55% could be obtained.

Incidence of atrial fibrillation

Incidence of AF did not differ between the 2 groups neither preoperatively, nor postoperatively or during FU. Because of the small number of patients, we could not demonstrate whether AF played any role in LV remodeling, although such
a role seems inexplicit to influence the results of one surgical technique over the other. This is supported by Lim et al.,\textsuperscript{20} who suggested that AF did not affect early outcome of MVR.

**Ring versus no ring**

Patients who underwent MVR with concomitant annular ring insertion did not show any significant difference in postoperative LV function, compared to those without ring implantation. The decision whether a ring should be inserted was based upon the surgeon’s choice for best anatomical correction of the responsible leaflet, since the 2 subgroups with and without ring were identical, concerning the affected leaflet and the degree of MR preoperatively. The use of annular ring during MVR is controversial and not all surgeons do recommend its implantation, since it improves the results of MVR but, on the other hand, it increases the frequency of systolic anterior motion (SAM).\textsuperscript{21} Moreover, the effects of rigid or flexible rings on LV function are also controversial. David et al.\textsuperscript{22} reported better LV function after insertion of flexible ring, while Castro et al. did not show any significant difference between the 2 rings.\textsuperscript{23}

**Study limitations**

It is possible that due to the relatively small number of patients involved, some of our results might have been affected, particularly in the subgroup analysis. The patient’s surgical procedure was not randomized preoperatively and was determined by the surgeon at the time of the operation. However, since a randomized trial will probably never be performed, the only acceptable method of comparison of the 2 surgical procedures is to adjust the baseline preoperative parameters.

We reported a significant increase of LVEDD in MVR group during 6 years FU. However, subclinical coronary artery disease may not be excluded, as coronary angiography was not performed in any patient postoperatively.

The paradoxic septal motion associated with cardiac surgery might raise concern about the use of echocardiography for postoperative assessment of LVEF. This, however, has been attributed to a translational movement rather than a regional wall motion abnormality and it does not impair the ability to assess LV function by echocardiography.\textsuperscript{24} Finally, we did not perform any formal quantitation of MR due to the absence of any standardized criteria at the time of the study.

**Conclusion**

In this study we report that during a 6-year follow-up, patients with chronic degenerative MR and LV dysfunction show further deterioration of LV function after MVR. Conversely, MVR appear to better preserve the overall LV function. Mitral valve repair should therefore be the surgical procedure of choice, not only for the lower mortality during the operation itself, but also for the better preservation of LV function in the long term and the level of ejection fraction should not be a reason for denying the benefits of repair to patients with MR. Nevertheless, although MVR seems to preserve LV function, it rarely achieves complete normalization of LVEF and therefore early surgery should be performed before these patients develop LV dysfunction.

**References**


