Long term results of mitral valve repair: posterior papillary muscle repositioning versus chordal shortening

Gilles Dreyfus*, Naji Al AyleÂ, Claude Dubois, Philippe de Lentdecker

Cardiovascular Surgery Departement, Foch Hospital, 40 Rue Worth 92150 Suresnes Cedex, France

Received 26 January 1999; received in revised form 15 March 1999; accepted 23 March 1999

Abstract

Objective: Mitral valve repair is considered as the gold standard to treat mitral regurgitation. However anterior leaâtel prolapse in the posterior paramedial and paracommissural area remains a challenging problem. Indeed several elongated chordae may arise from a single posterior papillary muscle head which does not allow safe separate chordal shortening (CS). We therefore suggest use of papillary muscle repositioning in such cases. Methods: In a cohort of 180 mitral valve repair performed between 1989 and May 1998, we have retrospectively studied 100 consecutive patients who underwent anterior leaâtel repair in the posterior paramedial and paracommissural area. Group I (n = 60) had posterior papillary muscle repositioning (PPMR) and group II (n = 40) had CS. There was no statistical difference between the two groups concerning age, functional class and left ventricular function. Etiology was similar in both groups, degenerative process being predominant. At echocardiogram, regurgitation was graded 3.4/4 in both groups. There was no statistical difference concerning preoperative ejection fraction, end systolic and end diastolic left ventricular diameter. Results: There were no in-hospital deaths in group I and two deaths in group II not related to mitral valve repair. Mean follow up is 26 ± 24.2 months in group I and 46.1 ± 28.8 months in group II. No patient was lost to follow up. Severe mitral regurgitation was not observed. Mean regurgitation at follow up was 0.8 ± 0.7 in group I and 0.8 ± 0.8 in group II (P = n.s.); there was no statistical difference between the two groups concerning postoperative ejection fraction, end systolic and end diastolic left ventricular diameter. There was no late cardiac death in either group and there were no thromboembolic events. Actuarial survival rate is 100% and 94.4% in group I and 92% and 84.4% in group II at 2 and 6 years, respectively. Conclusion: This experience shows that PPMR provides as good longterm results as CS to repair anterior leaâtel prolapse in posterior paramedial and paracommissural area with lesser morbidity and mortality. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Mitral repair; Posterior papillary muscle repositioning; Chordal shortening

1. Introduction

Surgical treatment of mitral valve regurgitation is at best managed by mitral valve repair [1–5]. Carpentier and others, have already shown that mitral valve repair is the gold standard, as it is reproducible and durable with low incidence of complications and reoperations up to 16 years of follow-up [2,6–10]. Anterior leaâtel prolapse may still be a challenging problem. Many techniques have been used such as chordal shortening (CS), chordal transposition or chordal substitution. Chordal shortening was the first to be described by Carpentier [1] and has been used extensively for anterior leaâtel prolapse correction. It requires a learning curve as well as experience to achieve excellent results. Moreover, CS is an indirect shortening as opposed to many other techniques. However when anterior leaâtel prolapse occurs in the posterior paramedial and paracommissural area, with or without commissural prolapse, all previously described techniques may become difficult and ineffective. We therefore have used posterior papillary muscle repositioning (PPMR) as a surgical alternative to all other methods. The aim of this study is to compare CS with PPMR to demonstrate its feasibility in all instances and to show comparative results with a follow-up reaching 8 years.

2. Patients and methods

From October 1989 to May 1998, 100 consecutive patients with anterior leaâtel prolapse in the posterior paramedial and paracommissural area underwent valve repair. This cohort comprises 55% of all patients with mitral regurgitation treated in the same period with mitral repair. This series was divided in two groups: Group I (n = 60) had PPMR and group II (n = 40) had CS. Table 1 summarizes
the clinical profile of these patients. There was no statistical difference between the two groups concerning age, sex, atrial fibrillation and functional class (group I: 2.5 ± 0.7; group II: 2.5 ± 0.9). The majority of patients were either in class II or in class III of the NYHA classification. Etiology was similar in both groups with the degenerative (Barlow and dystrophic diseases) process being predominant, 86.6% and 80% in groups I and II, respectively.

All patients had preoperative Doppler echocardiography and severe (3-4/4) mitral regurgitation. Mean regurgitation was 3.3 ± 0.6 and 3.5 ± 0.5 (P = n.s.) for groups I and II, respectively. There was no statistical difference between the two groups concerning left ventricular end systolic diameter (LVESD) (group I: 39.1 ± 7.7 mm; group II: 38.5 ± 5.3 mm), left ventricular end diastolic diameter (LVEDD) (group I: 61.7 ± 7.5 mm; group II: 62.1 ± 8.9 mm) and left atrial size (group I: 46.1 ± 9.5 mm; group II: 48.9 ± 7.9 mm). Left ventricular ejection fraction (LVEF) was significantly higher in group II (group I: 64.8 ± 11.2%; group II: 69.5 ± 9.7%; P < 0.05) as well as systolic pulmonary artery pressure (PAPs) (group I: 38.1 ± 11.6 mm Hg; group II: 43.3 ± 11.5 mm Hg; P < 0.05).

Coronary angiography was performed in patients older than 40 years.

### 2.1. Anatomical considerations

Anterior papillary muscle shows two components: one anterior and one posterior. In contrast, posterior papillary muscle usually shows three components one anterior, one

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group I (PPMR)</th>
<th>Group II (CS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>57 ± 14</td>
<td>62 ± 12</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>39 (65)</td>
<td>25 (62.5)</td>
</tr>
<tr>
<td>Female</td>
<td>21 (35)</td>
<td>15 (37.5)</td>
</tr>
<tr>
<td>Electrocardiogram</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sinus rhythm</td>
<td>39 (65)</td>
<td>28 (70)</td>
</tr>
<tr>
<td>Atrial fibrillation</td>
<td>21 (35)</td>
<td>12 (30)</td>
</tr>
<tr>
<td>Functional class (NYHA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>5 (8.3)</td>
<td>6 (15)</td>
</tr>
<tr>
<td>II</td>
<td>25 (41.6)</td>
<td>12 (30)</td>
</tr>
<tr>
<td>III</td>
<td>25 (41.6)</td>
<td>15 (37.5)</td>
</tr>
<tr>
<td>IV</td>
<td>5 (8.3)</td>
<td>7 (17.5)</td>
</tr>
<tr>
<td>Etiology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Barlow disease</td>
<td>28 (46.6)</td>
<td>17 (42.5)</td>
</tr>
<tr>
<td>Dystrophic disease</td>
<td>24 (40)</td>
<td>15 (37.5)</td>
</tr>
<tr>
<td>Endocarditis</td>
<td>1 (1.6)</td>
<td>3 (7.5)</td>
</tr>
<tr>
<td>Rheumatic</td>
<td>5 (8.3)</td>
<td>3 (7.5)</td>
</tr>
<tr>
<td>Ischemic</td>
<td>2 (3.3)</td>
<td>2 (5)</td>
</tr>
</tbody>
</table>

Fig. 1. Anatomical view: the posterior papillary muscle has three heads, namely anterior, medial and posterior.

Fig. 2. Chordae arising from the anterior head are anchored to the anterior leaflet; chordae arising from the intermediate head are anchored to the commissural area and those arising from the posterior head to the posterior leaflet. Elongation of chordae arising from the anterior head is usually the reason for anterior leaflet prolapse.
intermediate and one posterior (Fig. 1). Chordae arising from the anterior head are anchored to the anterior leaflet; chordae arising from the intermediate head are anchored to the commissural area and those arising from the posterior head to the posterior leaflet (Fig. 2). Moreover the anterior head is always higher than the posterior one. The splitting of the anterior head from the intermediate one allows mobilization in any direction especially downwards into the ventricular cavity, as much as is needed. Therefore all elongated chordae arising from the anterior head can be repositioned with the papillary muscle thus correcting the prolapse (Fig. 3).

2.2. Surgical techniques

Operations were performed under cardiopulmonary bypass, in normothermia, and aortic cross-clamping during the entire repair of the valve. Myocardial protection was afforded with cold cristalloid cardioplegia until 1993 and cold blood with cristalloid (threethreevolumes onevolume) cardioplegia thereafter.

Table 2 summarizes the surgical lesions of mitral valve disease. All patients had anterior leaflet prolapse, and posterior leaflet prolapse was associated in 46 (76.7%) and 33 (82.5%) patients in groups I and II, respectively. Posterior commissural prolapse was associated in 6 (10%) patients in group I.

Repair of the mitral valve was performed by widely using Carpenter’s techniques [1]. Chordal shortening was performed by burying the excess length of the chordae into a trench created into the head of the papillary muscle. Two sutures were used: one showing a figure of eight which pulls down the elongated chordae into the trench; the second one reinforcing this burying by suturing both aspects of the split head head.

PPMR was performed as follows. As a first step the anterior head was divided extensively from the intermediate one. In some instances some attachments with the left ventricular wall are also resected. A U stitch was then sutured to the upper extremity of the anterior head into its fibrous part. The appropriate shortening was than assessed by pulling the anterior head downwards. The stitch was anchored secondly to the fibrous tissue of the posterior head. The appropriate location was determined by the height of the prolapse (Fig. 3).

Association of several techniques were usually necessary in each patient.

In group I, PPMR was used in all 60 patients. In six patients (10%) shortening of chordae arising from posterior papillary muscle was associated to PPMR.

In group II, CS was used in all 40 patients.

Anterior papillary muscle repositioning was used in 4 (6.7%) and 2 (5%) patients of groups I and II, respectively. Table 3 summarizes the surgical techniques used in both groups.

Patients with coronary artery disease had the distal anastomosis as well as the proximal one’s performed after the valve was repaired. If an aortic or tricuspid valve correction was needed, it was performed after the mitral valve repair. Associated procedures were as follows: tricuspid valve repair was performed in 27 (45%) and 14 (35%) patients in groups I and II, respectively. Aortic valve was replaced in 4 (6.7%) and 3 (7.5%) patients, and seven (11.7%) and four (10%) patients underwent coronary artery bypass grafting in groups I and II, respectively.

Doppler echocardiography was used routinely intraoperatively, and before discharge. All patients underwent Doppler echocardiographic studies for this study.

Follow-up data were obtained through questionnaires and telephone contacts with patients, family physicians and cardiologists, with Doppler echocardiographic control performed for this study.

2.3. Statistical analysis

All results were expressed as mean ± SEM. Postoperative events such as death, thromboembolic complications,
infective endocarditis, and reoperations were characterized by actuarial statistics with the Kaplan–Meier method. The Student test is used to compare mean parameters, and \( x^2 \) test to compare repartition.

3. Results

There was no in-hospital death in group I and two deaths in group II (operative mortality 0% and 5% in groups I and II, respectively). The first death was in a woman aged 65 years who had coronary artery bypass. She suffered from persistent low cardiac output and died at the fifth postoperative day. The second one had postoperative septicemia and multi-organ failure and died at the 4th postoperative day.

Seven (11.7%) and nine (22.5%) patients experienced one or more perioperative complications in groups I and II, respectively: There was one (1.7%) and two (5%) low cardiac output, one (1.7%) and one (2.5%) reoperation for bleeding, one (1.7%) and one (2.5%) mediastinitis for groups I and II, respectively. Four patients (6.7%) in group I and 5 (12.5%) in group II had complete heart block necessitating a pace maker in two (3.3%) and one (2.5%) patient, respectively. Only one patient in group II required early reoperation for severe residual mitral regurgitation. He was reoperated on the 1st postoperative day and was successfully treated by prosthetic ring insertion. No systolic anterior motion (SAM) of the anterior leaflet occurred in any of the 100 patients of both groups.

3.1. Late results

Follow-up was complete for all 98 survivors and ranged from 1 to 89 months and 5 to 94 months with a mean of 26.4 and 46.1 months for groups I and II, respectively.

3.2. Patient survival

There was one late death in group I and two in group II. The causes of death were non-cardiac for all patients. The actuarial survival was 100% and 94.4% (74.2–99.0%) for group I and 92% (78.6–97.2%) and 84.4% (62.3–94.5%) for group II at 2 and 6 years, respectively (Fig. 4).

3.3. Reoperations

One patient in group II, who had received mitral valve repair with aortic valve replacement, required reoperation for hemolysis 11 months postoperatively. He had a mild mitral regurgitation. Both valves, aortic and mitral, were replaced. No patient in group I required reoperation (Fig. 5).

3.4. Anticoagulant-related hemorrhage

Fifteen patients in group I and eight in group II were

---

Table 3
Surgical techniques (data in parentheses are percentages).

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Group I (PPMR) (n = 60)</th>
<th>Group II (CS) (n = 40)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior leaflet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posterior PMR</td>
<td>60 (100)</td>
<td>0</td>
</tr>
<tr>
<td>Anterior PMR</td>
<td>4 (6.7)</td>
<td>2 (5)</td>
</tr>
<tr>
<td>Posterior chordal shortening</td>
<td>6 (10)</td>
<td>40 (100)</td>
</tr>
<tr>
<td>Anterior chordal shortening</td>
<td>37 (61.7)</td>
<td>28 (70)</td>
</tr>
<tr>
<td>Chordal transposition</td>
<td>4 (6.7)</td>
<td>8 (20)</td>
</tr>
<tr>
<td>Chordal substitution (PTFE)</td>
<td>4 (6.7)</td>
<td>2 (5)</td>
</tr>
<tr>
<td>Commisural sliding</td>
<td>6 (10)</td>
<td>0</td>
</tr>
<tr>
<td>Posterior leaflet</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quadrangular resection</td>
<td>48 (80)</td>
<td>36 (90)</td>
</tr>
<tr>
<td>Sliding plasty</td>
<td>32 (53.3)</td>
<td>14 (35)</td>
</tr>
<tr>
<td>Ring annuloplasty</td>
<td>60 (100)</td>
<td>38 (95)</td>
</tr>
<tr>
<td>Annular decalcification</td>
<td>8 (13.3)</td>
<td>10 (25)</td>
</tr>
</tbody>
</table>

---

Fig. 4. Actuarial survival.
under anticoagulation therapy at the last follow-up, because of an atrial fibrillation or an aortic mechanical valve. There were no anticoagulant-related hemorrhage.

3.5. Thromboembolic complications and infective endocarditis

No thromboembolic episode occurred during follow-up, and there were no cases of infective endocarditis among all survivors.

3.6. Event-free survival

Event-free survival as assessed by the freedom from death, thromboembolism, reoperation, and anticoagulation-related hemorrhage at 2 and 6 years as 100% and 94.4% (74.2–99.0%) for group I and 86.7% (72–94%) and 79.5% (58.9–91.2%) for group II, respectively (Fig. 6).

3.7. Postoperative functional class

At the last follow-up, 45 (76.2%) and 25 (71.4%) patients were in NYHA functional class I, 10 (16.4%) and 7 (20%) were in class II, and four (6.8%) and three (8.6%) were in class III in groups I and II, respectively.

3.8. Doppler echocardiography

All patients but one in group I and two in group II were studied by Doppler echocardiography at the time of most recent follow-up. Residual MR was graded on a scale of 0 to 4+/4. Forty eight (82.7%) in group I and 27 (79.4%) in group II have no or minimal MR (0 to 1+/4). Nine (15.5%) patients in group I and six (17.6%) in group II have mild MR (2+/4). One patient in each group had important MR (3+/4). Mean regurgitation was 0.8 ± 0.7 and 0.8 ± 0.8 (P = n.s.) in groups I and II, respectively. There was no statistical difference between the two groups concerning LVESD (group I: 34.8 ± 7.2 mm; group II: 37.4 ± 9.7 mm), LVEDD (group I: 53.1 ± 7.5 mm; group II: 54.8 ± 8.5 mm), left atrial size (group I: 42.4 ± 9.1 mm; group II: 42.6 ± 8.8 mm), PAPs (group I: 26.8 ± 7.5 mm Hg; group II: 29.6 ± 7.5 mm Hg), and LV EF (group I: 65.4 ± 7.7%; group II: 62.9 ± 13.1%).

4. Comments

Mitral valve repair has been shown by Carpentier et al. to be the gold standard to treat surgically mitral regurgitation especially in degenerative lesions [1,2]. It is not only reproducible but durable and shows a low rate of valvular related events [1,2,7–10].

Posterior leaflet prolapse is treated uniformly by quadrangular resection. It is an easy and efficient operation. In contrast anterior leaflet prolapse may remain challenging in some instances such as Barlow disease, or posterior commissural prolapse. Anterior leaflet prolapse is not treated with one single method, but with a combination of different techniques such as CS, chordal transposition from the posterior leaflet to the anterior one, polytetrafluoroethylene (PTFE) substitute to replace ruptured chordae [1,11–14]. Most of these techniques have advantages and drawbacks. Carpentier et al. favor CS [1] and chordal transposition [11]; Smedira et al. [12] favors chordal transposition, and Zussa et al. [13] and David et al. [14] favor PTFE substitutes.

We have undergone this retrospective non-randomized study using a simple new method of PPMR because of its simplicity and to determine whether or not longterm results would be as good as those with classical techniques. Both techniques were used at the same time but CS were more frequent initially and PPMR became progressively the
method of choice. This report shows that with a follow-up period up to 8 years (mean 2.5 years) this method (PPMR) is durable. No patient was reoperated for recurrent mitral regurgitation in this subgroup. Our freedom from reoperation is 100% and event free survival is 94.4% (IC: 74–99%) at 6 years. Therefore this method compares favorably with all other methods used previously: Gillinov et al. [15] reports 10% reoperation at 5 years and Smédira et al. [12] had a freedom from reoperation of 74% at 5 years for CS and 96% for chordal transposition.

On a technical standpoint CS is an indirect method to shorten elongated chordae because the effective shortening equals half of the length of the chordae buried into the trench of the papillary muscle [1]. Therefore it requires expertise in the field of mitral valve repair. On the contrary PPMR is a direct shortening, the repositioning down into the left ventricle is equal to the extent of the prolapse. Therefore it requires less experience. Moreover some authors such as Gillinov et al. [15] reported a failure of 22% in their valve repair due to CS, which increased up to 36% in the degenerative etiology. Chordal shortening requires not only experience but also some care to avoid the burying sutures to be in contact with the shortened chordae. This phenomenon might explain some high rate of reoperation required after CS [12]. In our own series in 180 consecutive mitral valve repair we have not found any case of reoperation for secondary rupture after CS. We have favored PPMR over CS especially in the posterior papillary muscle for technical reasons: in some instances, many chordae arise from the posterior papillary muscle to the free edge of the anterior leaflet. Chordal shortening thereafter becomes impossible because rarely more than two chordae can be buried in the same trench. In such instances PPMR offers a safe and elegant alternative. After splitting the anterior head from the medial and the posterior one, it is easy to shorten all the chordae with one single maneuver. In most cases the repositioning takes only one 4/0 monofilament suture which is tied into the fibrous area of the head of the papillary muscle. Our method appears to be simple, fast and reliable. We have never been unable to perform this PPMR when having the intention to do so.

If anterior leaflet prolapse can be difficult to treat, the most challenging lesion remains as posterior commissural prolapse. This lesion involves not only the anterior leaflet, but also the posterior commissure as well as the posterior leaflet. PPMR is then the only feasible method to treat such lesion. In our series we have found 10% in group I (PPMR) showing this type of lesion. When using PPMR, anterior leaflet chordae can be shortened to adequate length separately from the commissural chordae. Usually the posterior leaflet is resected, and a sliding plasty of the anterior leaflet as well as the posterior leaflet is then required. In such difficult lesions, we have never had to replace the valve, nor did we have to reoperate the patients.

In conclusion, we believe that all methods can achieve good results and probably many patients with degenerative lesions might require combined techniques. However myxomatous disease of the mitral valve still represents a challenge. In our series more than 40% of our patients had such an etiology. David et al. stated that ‘prolapse of multiple segments of both leaflets may be better served by valve replacement than by valve repair until newer reconstruction approaches such as shortening of the entire papillary muscle trunks are proved satisfactory’ [16]. We do believe that our series proves that PPMR is satisfactory as it shows it can be performed in all instances, it is durable with no reoperation for chordal rupture and it allows safe treatment of the most challenging lesions such as myxomatous disease and commissural prolapse. Obviously, as it is a direct shortening, the learning curve is short and it appears to be reproducible. We have also found this method efficient enough to treat anterior papillary muscle-dependant prolapse in a few
cases. PPMR is now our method of choice to treat anterior leaflet prolapse, as longterm results show an excellent survival rate, with no valve related reoperation and high incidence of event free survival.

References


Appendix A. Conference discussion

Dr N. DeVega (Malaga, Spain): It seems that we have now two easy and reproducible techniques for mitral incompetence due to anterior leaflet prolapse, the Alfieri technique and this new one. What are your feelings about the Alfieri technique, have you got any experience?

Dr Dreyfus: I think it is a very clever idea. We have been using it, especially in the Batista and in dilated hearts, or perhaps in ischemic heart disease especially for mitral regurgitation without prolapse. I do believe that when you have a prolapse, you can correct the prolapse centrally, but you do not correct the lesion. If you have Barlow disease, I don’t think you would treat it adequately with an Alfieri stitch, a real Barlow with prolapse of the anterior as well as posterior leaflet, and therefore I think it is an adjunct to some other techniques. And I do believe, especially in regard to the previous questions concerning whether or not to use a ring. I do think that if you have a dilated annulus, the Alfieri stitch should not avoid using a ring. If you have a non-dilated annulus, the Alfieri stitch is a very good option.

Dr DeVega: And so you think that in 100% of cases you have a dilated ring, a dilated annulus?

Dr Dreyfus: No. In ischemic heart disease as well as in endocarditis usually because of the acuteness of the illness you don’t have a dilated annulus, but in chronic regurgitation, you usually have a dilated ventricle as well as a dilated annulus.