Mitral-valve repair without annuloplasty rings: results after repair of anterior leaflet versus posterior-leaflet defects using polytetrafluoroethylene sutures for chordal replacement

Lennart F. Duebener,a Olaf Wendler,a Niko Nikoloudakis,a Thomas Georg,b Roland Fries,c Hans-Joachim Schäfers,a,*

aDepartment of Thoracic and Cardiovascular Surgery, University Hospitals of Saarland, 66421 Homburg, Germany
bDepartment of Biometrics and Medical Informatics, University Hospitals of Saarland, 66421 Homburg, Germany
cDepartment of Cardiology, University Hospitals of Saarland, 66421 Homburg, Germany

Received 20 September 1999; received in revised form 14 January 2000; accepted 17 January 2000

Abstract

Objective: Defects of the anterior mitral leaflet (AML), including ruptured chordae, are often regarded as difficult or even impossible to repair. Chordal replacement may also be an option in extensive disease of the posterior mitral leaflet (PML). It has not yet been clearly defined whether the repair of either mitral leaflet using chordal-replacement techniques is as safe as the standard repair of the mitral valve (MV) including quadrangular resection and ring reduction alone.

Methods: Between October 1995 and June 1999, 160 patients underwent MV repair for mitral regurgitation (MR) in our institution. Chordal replacement with polytetrafluoroethylene (PTFE) sutures for elongated or ruptured chordae was performed in 72 (45%) patients. These patients were divided into two groups according to the location of the MV lesions: 48 patients with prolapse of the anterior or both leaflets (AML group) received an average of 2.2 ± 1.1 PTFE sutures for repair; in 24 patients with isolated PML defects (PML group), we used an average of 1.5 ± 0.8 PTFE sutures. No prosthetic annuloplasty rings were used.

Dilatation of the posterior mitral ring was corrected by PTFE suture annuloplasty. The remaining 88 patients underwent a standard mitral repair without chordal replacement. There were no statistically significant (NS) differences between the two groups (AML/PML) regarding age (59/62 years, \( P = 0.49 \)), left ventricular (LV) ejection fraction (64/66%, \( P = 0.6 \)) and preoperative NYHA class (2.9/2.9, \( P = 0.36 \)). Postoperatively, all patients were followed by serial transthoracic echocardiography at 1 week and after 3, 6, 12 and 24 months by the same investigator.

Results: In-hospital mortality was 4.2% (2/48) in the AML group and 0% (0/24) in the PML group (\( P = 0.55 \)). Three of the AML patients (6.3%) and one PML patient (4.2%) underwent reoperation for recurrent MR (\( P = 1.0 \)). The 1- and 2-year freedom from MV reoperation was 95.1 ± 3.4 and 92.6 ± 4.2% in the AML group versus 95.0 ± 4.9 and 95.0 ± 4.9% (\( P = 0.67 \)). The 1- and 2-year freedom from residual or recurrent MR grade 2 or higher was 97.6 ± 2.4 and 94.9 ± 3.5% (AML) versus 95.8 ± 4.0 and 95.8 ± 4.0% (PML) (\( P = 0.97 \)).

Conclusions: We were unable to find statistically significant differences concerning mortality, freedom from recurrent MR and MV reoperation between the AML and PML groups. Extensive prolapse or chordal pathology of the anterior and PML can be corrected by chordal replacement. Using these techniques, stable repair can be achieved in more than 90% of patients at mid-term follow-up. Long-term observations are necessary to confirm the durability of this type of MV repair. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Mitral valve; Mitral regurgitation; Mitral-valve repair; Chordal replacement; Polytetrafluoroethylene sutures; Suture annuloplasty

1. Introduction

Mitral-valve (MV) repair is superior to valve replacement with respect to valve-related complications and preservation of ventricular function [1,2]. Numerous studies have shown that MV repair is a form of treatment with excellent short- and long-term results [3]. Therefore, whenever feasible, MV repair is the surgical procedure of choice for symptomatic mitral regurgitation (MR) [4–7].

Limited prolapse of the posterior leaflet can be safely treated by quadrangular-leaflet resection combined with a sliding plasty according to standard techniques by Carpentier [8]. There is, however, some uncertainty whether...
defects of the anterior leaflet or extensive defects of the posterior leaflet are suitable for repair with comparable results [9,10]. Therefore, the probability of MV replacement is often increased in symptomatic patients with defects of the anterior (or both) mitral leaflets.

Different techniques have been proposed to handle the challenge of repairing anterior leaflet prolapse. In patients with adequate chordal tissue, some groups have used chordal shortening or transfer techniques to correct chordal elongation. However, the experience with these technically difficult techniques is limited.

Where there is inadequate chordal tissue, the patients have to be managed differently. The artificial replacement of ruptured or thinned elongated chordae is an option of treatment in these patients. Polytetrafluoroethylene (PTFE) sutures, because of their mechanical properties, seem to be an excellent material for artificial chordal replacement and were introduced by David and Frater [11–13].

By adopting this technique, we have repaired more than 90% of regurgitant valves in patients with degenerative-valve disease, including anterior mitral leaflet (AML) prolapse due to elongated or ruptured chordae. Chordal replacement also appears suitable in the repair of extensive prolapse involving more than 50% of the posterior mitral leaflet (PML).

The goal of our study was to define whether the presence of defects of the AML or extensive posterior prolapse will adversely affect the results of MV repair compared to standard MV repair. Chordal replacement was used in all instances of anterior or extensive posterior mitral-leaflet prolapse. No prosthetic rings were implanted.

2. Patients and methods

2.1. Patients

From October 1995 to June 1999, 160 patients underwent MV repair for MR in our institution, i.e. 55% of all MV operations (290) during the study period. Patients with mitral stenosis or combined lesions were excluded from this study. Of the total number of patients (160) with mitral repair, 88 patients (55%) underwent standard posterior mitral-leaflet repair, including segmental posterior-leaflet resection and suture annuloplasty.

In the remaining 72 patients (45%), additional chordal replacement was performed. These patients were divided into two groups according to the location of MV lesions: there was an isolated defect of the posterior leaflet in 24 patients (PML group) not amenable to standard techniques alone. Isolated defects of the anterior or of both leaflets were found in 48 patients (AML group).

Baseline demographic characteristics were similar between the two groups (Table 1). The preoperative grade of MR and left ventricular (LV) ejection fraction was determined angiographically and by Doppler echocardiography.

The mean preoperative NYHA class was identical in both groups (AML 2.9 ± 0.4; PML 2.9 ± 0.4). In the AML group, 31% (15/48) of patients were in atrial fibrillation (AF) compared to 33% (8/24) in the PML group.

The etiology of MV disease was degenerative in 45 (94%) AML patients and 21 (88%) PML patients (P = 0.39). A congenital lesion was present in two (2.8%) AML patients and one (1.3%) PML patient (P = 1.0). Acute endocarditis was the cause of MR in one (2%) AML patient and three (13%) PML patients (P = 0.1).

2.2. Surgical technique

The chest was opened by a median sternotomy. The patient was placed on cardiopulmonary bypass with moderate hypothermia (35°C), using ascending aortic and right-atrial cannulation. Cardioplegic arrest was induced by antegrade administration of St. Thomas solution, and the left atrium opened through the interatrial groove.

Careful intraoperative examination of both mitral leaflets, the subvalvular apparatus and the mitral ring allowed classification of the patients into three types according to Carpentier (I, normal leaflet mobility; II, leaflet prolapse; III, restricted leaflet mobility). A combination of ring dilatation and leaflet prolapse was most prevalent in our patients. Table 2 lists the intraoperatively defined anatomical lesions.

MV repair was performed in the same order in all patients, starting with the repair of the posterior leaflet using quadrangular resection, and reconstitution of the leaflet incorporating a sliding plasty according to standard techniques described by Carpentier [8]. Leaflet perforations caused by endocarditis were treated by direct closure or pericardium-patch closure.

Chordal replacement was performed where there was a broad prolapse (more than 50% of the circumference of the posterior ring) after completion of the quadrangular resection of the prolapsed leaflet area. In eight cases (five AML (10%); three PML (12.5%)) with posterior-ring calcification, making a sliding technique dangerous, chordal replacement was also applied as the primary procedure.

Increased leaflet mobility with extensive prolapse due to
chordal elongation and/or rupture and resulting regurgita-
tion was corrected in all patients by these techniques. A
variable number of PTFE sutures was required (AML
group, 2.2 ± 1.1 sutures/patient; PML group, 1.5 ± 0.8
sutures/patient).

For chordal replacement, double-armed PTFE sutures (5-
0) were placed through the fibrous head of the correspond-
ing papillary muscle and the free edge of the prolapsing
leaflet. The length of the PTFE suture was approximated
with a first knot. After filling the left ventricle with saline,
the optimal length of the artificial chorda was determined.
Once the length was adjusted, both arms of the suture were
tied with the knot on the ventricular side (Fig. 1). No chordal
shortening or transfer techniques were employed.

As a last step, a reduction of the posterior ring size was
performed using a suture annuloplasty. A modified Paneth
annuloplasty was employed. A double suture of 3-0 PTFE
(Gore-Tex) with a pledget of pericardium was sutured
circumferentially around the posterior annulus in 5-mm
steps, starting at the anterior commissure and ending at
the posterior commissure. It was then tied over a second
pledget of pericardium. No prosthetic annuloplasty rings
were used.

In case of remaining localized regurgitant jets, e.g. at
commissures, local plications of redundant mitral-leaflet
tissue were performed using a Prolene suture. Table 3
summarizes the operative details. Concomitant cardiac
procedures are listed in Table 4.

All patients underwent intraoperative transesophageal
ecocardiography for evaluation of the repaired MV after
discontinuation of cardiopulmonary bypass. In the majority
of patients (AML 97%; PML 98%) there was good leaflet
coaptation with only minimal residual MR (MR ≤ grade 1).
In one patient of the AML group, relevant MR was found
and an immediate operative revision carried out. The MV
was competent after placement of additional artificial chorda-
dae.

Postoperatively, patients were followed up at 1 week and
after 3, 6, 12 and 24 months by transthoracic Doppler echo-
cardiography (ATL HDI 3000). MV area and the left-
atrial diameter were determined. An assessment of the degree
of MR was performed according to the proximal isovelocity
surface area (PISA) method. This standard technique eval-
uates the zone of flow-acceleration proximal to a regurgitant
orifice using Doppler color-flow mapping. The hemispher-
oidal zone can be measured by assessing the radius of alias-
ing, allowing for quantitative estimation of the regurgitant
flow-rate.

All echocardiographic studies were carried out by the
same investigator. In addition, the clinical status (NYHA
class) and cardiac rhythm were evaluated.

Table 2
Intraoperatively-defined valvular pathology

<table>
<thead>
<tr>
<th></th>
<th>AML group</th>
<th>PML group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal leaflet mobility (type I)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ring dilatation</td>
<td>46 (96)</td>
<td>23 (96)</td>
</tr>
<tr>
<td>Leaflet perforation</td>
<td>0 (0)</td>
<td>1 (4.2)</td>
</tr>
<tr>
<td>Vegetation</td>
<td>1 (2.1)</td>
<td>2 (8.3)</td>
</tr>
<tr>
<td>Leaflet prolapse (type II)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isolated AML prolapse</td>
<td>48 (100)</td>
<td>–</td>
</tr>
<tr>
<td>Elongated chordae</td>
<td>36 (75)</td>
<td>–</td>
</tr>
<tr>
<td>Ruptured chordae</td>
<td>12 (25)</td>
<td>–</td>
</tr>
<tr>
<td>Additional PML prolapse</td>
<td>26 (54)</td>
<td>–</td>
</tr>
<tr>
<td>Elongated chordae</td>
<td>20 (42)</td>
<td>–</td>
</tr>
<tr>
<td>Ruptured chordae</td>
<td>6 (13)</td>
<td>–</td>
</tr>
<tr>
<td>Isolated PML prolapse</td>
<td>–</td>
<td>24 (100)</td>
</tr>
<tr>
<td>Elongated chordae</td>
<td>–</td>
<td>7 (29)</td>
</tr>
<tr>
<td>Ruptured chordae</td>
<td>–</td>
<td>17 (71)</td>
</tr>
</tbody>
</table>

| Restrictive leaflet mobility (type III) |          |           |
| Commissural fusion        | 2 (4.2)   | 1 (4.2)   |
| Chordal fusion            | 0         | 0         |

* Figures in parentheses represent % values.
Follow-up was 97% complete and ranged from 1 to 46 months (mean 27 months; total of 1944 patient-months).

2.3. Statistical methods

Data were analyzed using a statistical software program (SPSS 7.5 for Windows). Data in tables are expressed as mean ± standard deviation. For the comparison of nominal data, the Fisher’s exact test was used. The unpaired t-test was used for approximately normally-distributed data. Otherwise, the Mann–Whitney test was used. The Kaplan–Meier curves for statistical analysis of survival were computed. The test used for the comparison of survival curves was the log-rank test. A P-value of less than 0.05 was considered to be statistically significant.

3. Results

Isolated MV repair without concomitant procedures was performed in 29 patients (60%) of the AML group and 16 patients (67%) of the PML group (P = 0.80). The cardiopulmonary bypass time for isolated mitral repair was 64 ± 19 (AML) and 67 ± 20 min (PML) (P = 0.72). The ischemic time in this group of patients was 48 ± 19 (AML) and 43 ± 14 min (PML) (P = 0.60).

Two patients of the AML group (4.2%) died in hospital on postoperative days 17 and 23, respectively. The causes of death were low cardiac output syndrome and cerebral ischemia. Both patients had poor preoperative LV function (27 and 30%) and concomitant cardiac procedures (coronary artery bypass grafting). None of the PML patients died early after MV repair (P = 0.54). In both groups, there were no early deaths in patients with isolated MV repair. There were three late deaths (one AML patient and two PML patients). The causes of late death were pneumonia (AML), sudden unexplained death (PML) and congestive heart failure (PML). Survival at 1 and 2 years, including in-hospital mortality, was 95.8 ± 2.9 and 92.8 ± 4.1% (AML) versus 100 and 92.3 ± 7.4% (PML) (log rank P = 0.31).

Two AML patients (4.2%) in chronic AF experienced transient neurological problems postoperatively. One patient developed a seizure on postoperative day 2, while another experienced vision disturbances. There was no recurrence of either event and the visual problems were resolved spontaneously.

Three AML patients (6.3%) required reoperation for recurrent MR approximately 11 months after repair. One PML patient (4.2%) had to be reoperated on the MV for

![Fig. 2. Freedom from MV reoperation; y-axis truncated for graphical reasons.](image-url)
the same reason 9 months postoperatively. Intraoperatively ruptured native chordae were found in all cases. There was no recurrence of annular dilatation. Freedom from reoperation at 1 and 2 years was thus 95.1 ± 3.3 and 92.6 ± 4.2% (AML) versus 95.0 ± 4.9 and 95.0 ± 4.9% (PML) (Fig. 2). The differences were not statistically significant (log rank \( P = 0.67 \)). In all four patients the repaired MV was replaced with a mechanical valve without mortality.

At the last follow-up, Doppler echocardiographic evaluations demonstrated no or mild MR (MR grade 0 or 1) in 85% (AML) and 86% (PML) of patients (\( P = 0.9 \)). Mild to moderate MR (MRI grade 1–2) (\( P = 1.0 \)). In three patients (two AML and one PML), moderate to severe mitral insufficiency (MRI grade 2+) was documented (\( P = 1.0 \)). These patients have not undergone reoperation because of their stable clinical status. The freedom from MR grade 2 or higher at 1 and 2 years was 97.6 ± 2.3 and 94.9 ± 3.5% (AML) versus 95.8 ± 4.1 and 95.8 ± 4.1% (PML) (log rank \( P = 0.97 \); Fig. 3).

No patient had echocardiographic evidence of LV outflow tract obstruction. Mean MV area was 2.7 ± 0.3 (AML) and 2.9 ± 0.4 cm² (PML) (\( P = 0.71 \)) according to the pressure-halftime method. Mean mitral pressure gradients 2.9 ± 0.5 (AML) and 3.0 ± 0.6 mmHg (PML) (\( P = 0.92 \)). The differences were not statistically significant between the groups. No postoperative endocarditis occurred in either group.

Preoperatively, 84 (AML) and 82% (PML) of patients were in NYHA class III or IV (\( P = 0.89 \)). Postoperatively, at the last follow-up, 86 (AML) and 85% (PML) of patients were in NYHA functional class I or II (\( P = 0.93 \)).

4. Discussion

The disadvantages of MV replacement with biological or mechanical prostheses have stimulated an increased interest in the techniques of MV repair [4]. MV reconstruction has been proven to be an effective treatment of regurgitation with good long-term durability [3,12]. The rates of valve- and operation-related complications are low after standard MV surgery involving quadrangular resection of the posterior leaflet combined with prosthetic-ring annuloplasty [3,8,14]. The preservation of the subvalvular apparatus is associated with the preservation of LV function after MV repair, as shown in many experimental and clinical studies [1,2]. Numerous studies demonstrated a lower in-hospital mortality for mitral repair compared to replacement. Thus, it is increasingly accepted that there are many advantages of mitral repair over mitral replacement. Whenever feasible, MV reconstruction is the surgical treatment of choice for MR.

Many technical aspects of MV repair have been standardized. Most frequently, lesions of the PML are treated by quadrangular resection.

An innovative technical change introduced by Frater and David was the use of PTFE sutures for chordal replacement as part of MV repair in patients with extensive mitral pathology. Historically, the repair of an anterior-leaflet prolapse has been technically demanding and less predictable than the repair of a posterior-leaflet prolapse. The traditional approach for the repair of anterior-leaflet prolapse due to elongated chordae has been either chordal shortening or chordal transfer. Chordal-shortening techniques, especially, may have the disadvantage of impaired durability by recurrent mitral insufficiency in a significant number of patients, caused by the rupture of shortened chordae [3,15].

PTFE appears to be an ideal material for synthetic chordal replacement because of its biomechanical properties which ensure long-term durability and allow surface endothelialization [13]. No calcification has been found so far in PTFE sutures explanted at various time intervals after implantation [16].

Our strategy to correct anterior-leaflet defects and extensive pathology of the posterior leaflet has been to stabilize...
the leaflet using PTFE sutures [17] as part of mitral repair. We have also found the technique of chordal replacement very useful in patients with calcification of the mitral ring, making standard quadrangular resection difficult or even impossible. Adopting this technique using PTFE as substitute for elongated or ruptured mitral chords, valve repair has been feasible in more than 90% of patients with degenerative disease, including patients with anterior-leaflet prolapse [18].

At present, it is still uncertain whether the repair of prolapse of the anterior leaflet or extensive prolapse of the posterior leaflet using chordal-replacement techniques is as safe as the standard repair of the PML.

The aim of this study was to investigate whether the results of MV repair using chordal replacement at the anterior versus the posterior leaflet differ from each other and from the standard repair. We compared parameters such as in-hospital and late mortality, neurological complications, postoperative endocarditis, rate of reoperation, residual MR and postoperative NYHA class.

No statistically significant differences were found in early and late mortality between our patient groups. Neurological complications were seen more often in AML patients, but were transient in nature. None of the patients developed endocarditis postoperatively.

The number of reoperations (6.3%) for recurrent MR was highest in the group of AML patients and lowest (1/88; 1.1%) in our group of patients (comparable regarding preoperative status) who underwent a standard MV repair without chordal replacement. However, this difference did not reach statistical significance (P = 0.13).

The difference might be due to the severity of MV disease at the anterior leaflet in this highly-selected subgroup of patients. This is consistent with reports in the literature that the durability of MV repair is adversely affected by anterior leaflet prolapse [3].

The majority of patients in both groups experienced a marked improvement in clinical status. Thus, using artificial chordal replacement, conservative mitral surgery is feasible, with good mid-term results in the majority of patients independent of the location of the lesion.

Since none of our patients underwent prosthetic ring implantation, we cannot compare the results to a control group with annuloplasty rings. However, our results of mitral repair, using standard approaches without chordal replacement, are not significantly different from the results of many centers using prosthetic rings [3]. In addition, ring size remained stable in all patients undergoing reoperation. Recurrent MR in these patients was due to the rupture of further native chordae. Thus, the use of suture annuloplasty (instead of the well-established annuloplasty rings) does not seem to adversely affect the results of mitral repair in our experience.

The use of PTFE suture annuloplasty and avoidance of annuloplasty rings might decrease the risk of postoperative endocarditis and embolic events. Furthermore, in small patients with small MV orifice areas there is the risk of creating a relevant gradient.

In our experience, even AML prolapse and extensive posterior prolapse are feasible for repair when artificial chordae are used for stabilization of the leaflet edge. The mitral pathology in this highly-selected group is not amenable to quadrangular resection and ring reduction alone. The risk of reoperation is increased in the first year in this patient group with the most severely diseased MVs including the anterior leaflet. Nevertheless, using this technique, MVs can be successfully conserved in more than 90% of patients that would otherwise be replaced by prostheses. Long-term follow-up is necessary to evaluate the durability of this form of MV repair.

References


Appendix A. Conference discussion

**Dr J. Reveulta (Santander, Spain):** Just to start, I want to say that I see that one third of your patients with isolated posterior-leaflet prolapse had been repaired with a PTFE suture. We know by experience that most of the PMLs can be repaired easily with a Carpentier technique. Do you have any reason to replace so many cases with PML prolapse with a PTFE? Can you comment on the indications you have for that?

**Dr Duebener:** There were patients who had a normal valve area, or calcifications of the posterior ring, and so the sliding plasty would be quite dangerous, and that was the reason why we preferred to perform PTFE suture replacement.

**Dr Reveulta:** In 24 patients?

**Dr Duebener:** In all patients.

**Dr A. Carpentier (Paris, France):** Each time someone claims that he can avoid the use of ring, I am interested, and for the last 25 years, every 2 or 3 years, I have heard mid-term results like the one you presented. I also have a few questions. The one which has been raised by Dr Revuelta was one I wanted to raise to you. Again, as you were surprised, I am surprised by the fact that you were obliged to use a PTFE suture in posterior-leaflet prolapse. Does this mean that you don’t perform a quadrangular resection, an extensive quadrangular resection, and that part of the leaflet remains and needs to be supported? Is that what you mean?

**Dr Duebener:** No.

**Dr Carpentier:** If you do a quadrangular resection, we don’t understand why you need to have, in addition, chordal suturing, chordal support. Will you tell us that?

**Dr Duebener:** The quadrangular resection was performed first, and in about 45% of cases, and if there was residual MR, the leaflet was stabilized by PTFE sutures. Therefore, it was an additional technique to the segmental resection and to the sliding plasty.

**Dr Carpentier:** The other question I have is, could you tell us about the etiology of your diseases, whether some of them were rheumatic, some others were Barlow or degenerative valvular disease, or a type of degenerative valvular disease, because we all know that depending upon the etiology, the postoperative course is different. Could you tell us about the etiology of your diseases?

**Dr Duebener:** The vast majority of patients had degenerative MV disease.

**Dr Carpentier:** Of which type, Barlow or fibroelastic deficiency?

**Dr Duebener:** Of Barlow type.

**Dr Carpentier:** Thank you.

**Dr Schäfers:** As the senior author, I can perhaps address the question regarding the reasoning for the use of PTFE for the posterior leaflet. The philosophy we have is that whenever possible to primarily apply the standard techniques of quadrangular resection and repair, and perhaps we are not quite as extensive in resecting the leaflet tissue as Professor Carpentier, but still, I personally would call it relatively extensive. The question arises, what to do when there are calcifications in the ring, as Dr Duebener already addressed, or once quadrangular resection has been done, and close to the commissures there is additional prolapse of the posterior leaflet, resulting in residual MR, and it was those two instances in which we chose to use additional PTFE sutures on the posterior leaflet.