A comparison of outcomes of mitral valve repair for degenerative disease with posterior, anterior, and bileaflet prolapse

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Objective: We sought to compare the clinical and echocardiographic outcomes of mitral valve repair for mitral regurgitation in patients with degenerative disease of the mitral valve with posterior, anterior, or bileaflet prolapse.

Methods: Patients underwent operations from 1981 through 2001: 359 had posterior (mean age, 60.4 years), 92 had anterior (mean age, 53.3 years), and 250 had bileaflet (mean age, 56.4 years) prolapse. Patients with anterior prolapse were younger ($P = .04$) and had more associated aortic valve disease ($P = .02$), particularly bicuspid aortic valve disease ($P < .001$). Anterior prolapse was corrected by using chordal replacement with Gore-Tex sutures in most patients, but early on in this series, leaflet resection, chordal shortening, and chordal transfer were also used. Echocardiograms were done annually, and clinical follow-up was complete at a mean of 6.9 ± 4.0 years (range, 0-23 years).

Results: The overall survival at 12 years was $75\% \pm 5\%$, with no difference among the posterior, anterior, and bileaflet prolapse groups ($P = .3$). The freedom from reoperation at 12 years was $96\% \pm 2\%$ for posterior, $88\% \pm 4\%$ for anterior, and $94\% \pm 2\%$ for bileaflet prolapse ($P = .019$). Anterior prolapse was the only independent predictor of reoperation. The freedom from moderate or severe mitral regurgitation at 12 years was $80\% \pm 4\%$ for posterior, $65\% \pm 8\%$ for anterior, and $67\% \pm 6\%$ for bileaflet prolapse ($P = .001$). Anterior and bileaflet prolapse, age, ejection fraction of less than 40%, and aortic valve disease were independent predictors of recurrent moderate or severe mitral regurgitation.

Conclusions: The pathophysiology of mitral regurgitation affects the durability of mitral valve repair for degenerative disease, and the results of posterior prolapse are better than those of anterior and bileaflet prolapse. This study indicates that rates of reoperation underscore the rates of failure of mitral valve repair.

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Mitral valve (MV) repair for mitral regurgitation (MR) caused by degenerative disease of the MV is feasible in more than 90% of patients.¹ Prolapse of the posterior leaflet (PL) is the most common cause of MR, valve repair is relatively simple, and the long-term results have been excellent.^{2,3} Prolapse of the anterior leaflet (AL) and bileaflet (BL) prolapse are more difficult to repair, and the long-term results are not as good as those for repair of prolapse of

Abbreviations and Acronyms

AF	= atrial fibrillation
AL	= anterior leaflet
BL	= bileaflet
MR	= mitral regurgitation
MV	= mitral valve
PL	= posterior leaflet

the PL.²⁻⁴ Although there are numerous studies on longitudinal outcomes of MV repair, few, if any, compared the outcomes on the basis of the prolapsed leaflet or assessed valve function by means of echocardiography.

This study examines the clinical outcomes and valve function after MV repair for MR caused by degenerative disease in patients with isolated PL prolapse, isolated AL prolapse, and BL prolapse.

Patients and Methods

From July 1981 through June 2001, 815 patients had operations for MR caused by leaflet prolapse as a result of degenerative disease of the MV. The predominant pathology was myxomatous degeneration, but cases of “fibroelastic deficiency”⁵ and dystrophic calcification of the mitral annulus were included. Patients with concomitant aortic valve-root and tricuspid valve disease were also included. The pathology of the MV was recorded prospectively at the end of each operation. The degree of myxomatous changes was recorded as mild, moderate, or severe depending on the thickness, volume, and interchordal hooding of the leaflets. Patients were divided into 3 groups according to the prolapsing leaflet: PL, AL, or BL prolapse. Patients with isolated prolapse of a commissure were classified as having BL prolapse. The operation performed was MV repair in 701 (86%) patients and MV replacement in 114 (14%) patients. The repair rates increased from 25% in 1982 to approximately 95% in 1990 and thereafter. The proportions of PL, AL, and BL prolapse were similar in patients who had repair or replacement ($P = .09$). Table 1 shows the clinical profile of the patients who had MV repair according to the prolapsed leaflet.

TABLE 1. Clinical profile of patients with posterior, anterior, and bileaflet prolapse

	Posterior (%)	Anterior (%)	Bileaflet (%)	P value
No. of patients	359 (51)	92 (13)	250 (36)	.000
Age, y (mean $\pm$ SD)	60.4 $\pm$ 12.0	53.3 $\pm$ 15.6	56.4 $\pm$ 13.0	.04
Range, y	19-88	18-82	21-82	
Male sex	253 (70)	65 (71)	194 (78)	.13
Previous cardiac operation	5 (1)	8 (9)	3 (1)	.000
Healed infective endocarditis	30 (8)	11 (12)	27 (11)	.7
Active infective endocarditis	3 (1)	1 (1)	1	.8
Marfan syndrome	7 (2)	1 (1)	11 (4)	.02
NYHA class				
I	53 (15)	7 (8)	43 (17)	
II	120 (33)	26 (39)	84 (34)	
III	132 (37)	39 (42)	102 (41)	
IV	54 (15)	10 (11)	21 (8)	.08
Associated diseases				
Hypertension	107 (30)	29 (31)	44 (18)	.001
Diabetes mellitus	17 (5)	5 (5)	4 (2)	.08
Renal failure	0	1	3	.20
PVD disease	6	1	0	.12
COPD (FEV ₁ <1)	16 (5)	4 (4)	11 (4)	.75
Preoperative AF	78 (22)	26 (28)	58 (23)	.41
AV disease	18 (5)	14 (15)	20 (8)	.02
Bicuspid aortic valve	4 (1)	8 (9)	1	.000
Aortic root aneurysm	8 (2)	5 (5)	10 (4)	.3
TV regurgitation	11 (3)	3 (3)	10 (4)	.8
CAD	61 (17)	16 (14)	23 (9)	.016
LVEF				
>59%	211 (59)	34 (37)	136 (54)	
40%-59%	127 (36)	47 (51)	102 (41)	
20%-39%	20 (5)	9 (10)	12 (5)	
<20%	1	2	0	.001

Percentages greater than 1 are shown in parentheses. SD, Standard deviation; NYHA, New York Heart Association; PVD, peripheral vascular disease; COPD, chronic obstructive pulmonary disease; FEV₁, forced expiratory volume in 1 second; AF, atrial fibrillation; AV, aortic valve; TV, tricuspid valve; CAD, coronary artery disease; LVEF, left ventricular ejection fraction.

TABLE 2. Operative data and follow-up

	Posterior (%)	Anterior (%)	Bileaflet (%)	P value
MV repair				
Segmental resection of posterior leaflet	359 (100)	0	250 (100)	NA
Segmental resection of anterior leaflet	0	4 (4)	9 (4)	
Chordal shortening	0	11 (12)	28 (11)	
Chordal transfer	0	13 (14)	35 (14)	
Chordal replacement with PTFE sutures	42 (12)	68 (74)	186 (74)	
Reconstruction of mitral annulus	9 (3)	0	4 (1)	
Mitral annuloplasty				
None	33 (9)	0	0	.001
Carpentier ring	50 (14)	19 (21)	31 (12)	
Duran ring	72 (20)	35 (38)	59 (24)	
Cosgrove or other posterior band	204 (57)	38 (41)	160 (64)	
Maze procedure for AF	22 (6)	4 (4)	14 (6)	.7
AV repair or sparing	10 (3)	5 (5)	18 (7)	.1
AV replacement	9 (3)	14 (15)	4 (2)	.001
TV repair	11 (3)	3 (3)	10 (4)	.9
CAB	61 (17)	16 (14)	23 (9)	.017
Crossclamp time, min (mean $\pm$ SD)	60 $\pm$ 23	70 $\pm$ 24	73 $\pm$ 26	.001
CPB time, min (mean $\pm$ SD)	76 $\pm$ 27	87 $\pm$ 26	90 $\pm$ 29	.001
Duration of follow-up, y (mean $\pm$ SD)				
Clinical	6.9 $\pm$ 4.2	6.6 $\pm$ 4.8	6.3 $\pm$ 3.7	.2
Echocardiographic	6.7 $\pm$ 4.2	6.6 $\pm$ 5.0	5.9 $\pm$ 3.6	.1

PTFE, Polytetrafluoroethylene; AF, atrial fibrillation; AV, aortic valve; TV, tricuspid valve; NA, not applicable; SD, standard deviation; CAB, coronary artery bypass; CPB, cardiopulmonary bypass.

Operative Techniques

This series is the experience of one surgeon. The techniques of MV repair evolved over the years. Prolapse of the PL was corrected by means of quadrangular, rectangular, or triangular resection with or without sliding plasty in all patients except in cases of fibroelastic deficiency, in which the PL was not elongated and had minimal if any myxomatous changes. In this case the prolapse was corrected by using chordal replacement with Gore-Tex sutures (W. L. Gore & Associates, Flagstaff, Ariz). Prolapse of the AL was corrected by means of triangular resection of the prolapsing segment from 1981 through 1985, chordal shortening from 1981 through 1986, chordal transfer from 1986 through 1990, and chordal replacement with Gore-Tex sutures from 1985 to the present. The technique of chordal replacement with Gore-Tex sutures changed over the years, and details have been published elsewhere.^{6,7}

Patients with dystrophic calcification of the mitral annulus had mitral repair if the leaflets were pliable.⁸

Mitral annuloplasty was performed in all cases, except if the pathology was fibroelastic deficiency and the mitral annulus was not dilated. Table 2 lists the operative procedures in each group.

All patients were anticoagulated with warfarin sodium for 3 months and permanently if they had atrial fibrillation (AF).

Follow-up

Intraoperative Doppler echocardiography has been used routinely since 1985. All patients had an echocardiogram before hospital discharge and were instructed to have a study every year. Echocardiographic findings were entered prospectively into a database. Approximately one half of the patients had echocardiographic

studies in our institution, and the MR was recorded as none, trivial, mild, moderate, or severe (grades 0-4+, respectively). If the echocardiographic study was done at an outside institution and the report read "trace to mild MR," it was entered into our database as mild; if it read "mild to moderate MR," it was entered as moderate; and if it read "moderate to severe MR," it was entered as severe. The follow-up for this study was closed on December 31, 2004. No patient was lost to clinical follow-up, but 46 had not had an echocardiogram since discharge from the hospital. Table 1 shows the follow-up times for both clinical and echocardiographic evaluations.

Statistical Analysis

SAS 8.2 for Windows was used for all statistical analyses (SAS Institute Inc, Cary, NC). Continuous variables are reported as the mean $\pm$ 1 standard deviation; survival estimates are reported as the mean $\pm$ 1 standard error.

Continuous variables were evaluated with 1-way analysis of variance, with post-hoc comparisons between subgroups by using the Scheffe test. Where appropriate, categoric variables were compared with the χ^2 or Fisher exact tests. Late survival and freedom from adverse events were estimated by using the nonparametric Kaplan-Meier method. The log-rank test was used for statistical comparisons of the Kaplan-Meier curves.

Cox regression analysis with backwards selection was used to identify the multivariable and independent predictors of late outcomes. Variables submitted to the models included the following: age at the time of the operation in increments of 5 years, sex, left ventricular ejection fraction of less than 40%, New York Heart

TABLE 3. Cox regression analysis

	<i>P</i> value	HR	95% CI
Late mortality			
Age by increments of 5 y	.003	1.3	1.1-1.5
NYHA classes III and IV	.002	2.8	1.8-5.4
EF <40%	.004	2.4	1.3-4.5
Diabetes	.003	3.0	1.4-6.4
COPD	.014	2.4	1.2-4.7
Preoperative thromboembolism	.003	2.6	1.4-4.8
Valve-related mortality			
Age by increments of 5 y	<.001	2.1	1.5-3.0
Anterior leaflet prolapse	.013	4.0	1.3-12
CAD	.035	3.0	1.1-8.2
Hypertension	.036	2.9	1.1-8.0
Cardiac-related mortality			
Age by increments of 5 y	.002	1.4	1.1-1.7
Late AF			
Age by increments of 5 y	<.001	1.3	1.2-1.4
Preoperative AF	<.001	2.3	1.6-3.4
Male sex	.017	0.6	0.4-0.9
Thromboembolic complications			
Age by increments of 5 y	.022	1.1	1.0-1.3
Reoperation on the MV			
Anterior leaflet prolapse	.047	2.5	1.0-5.0
Recurrent moderate-severe MR			
Anterior and bileaflet prolapse	.001	2.1	1.3-3.3
Male sex	<.001	0.5	0.3-0.7
EF <40%	<.001	4.4	2.4-8.0
AV disease	.004	3.2	1.5-7.2

HR, Hazard ratio; CI, confidence interval; NYHA, New York Heart Association; EF, ejection fraction; COPD, chronic obstructive pulmonary disease; CAD, coronary artery disease; AF, atrial fibrillation; MV, mitral valve; MR, mitral regurgitation; AV, aortic valve.

Association functional class, associated diseases, previous cardiac surgery, surgical priority, coronary artery disease, congestive heart failure, preoperative AF, preoperative stroke or transient ischemic attack, concomitant aortic valve surgery, concomitant ascending aorta repair, concomitant maze procedure, degree of myxomatous changes, leaflet prolapse, type of repair, and type of mitral annuloplasty. Variable retention in the models was set at a *P* value of .05.

Results

Operative and Late Mortality

There were 5 operative and 98 late deaths (18 valve-related, 32 cardiac, and 48 noncardiac deaths). Overall survival at 12 years was $75\% \pm 3\%$, that for PL prolapse was $73\% \pm 4\%$, that for AL prolapse was $73\% \pm 6\%$, and that for BL prolapse was $78\% \pm 8\%$ ($P = .3$). Table 3 shows the independent predictors of death.

Thromboembolism

Thromboembolic complications occurred in 65 patients (40 strokes and 25 transient ischemic attacks). The freedom

Figure 1. Freedom from reoperation in all patients.

from thromboembolism at 12 years was $84\% \pm 2\%$ for all patients, $85\% \pm 5\%$ for patients with PL prolapse, $86\% \pm 4\%$ for patients with AL prolapse, and $79\% \pm 5\%$ for patients with BL prolapse ($P = .4$). The only independent predictor of thromboembolism was age (Table 3).

Anticoagulation-Related Hemorrhage

Eleven patients experienced major hemorrhage during anticoagulation therapy, and 7 died. The freedom from major bleeding caused by anticoagulation at 12 years was $94\% \pm 2\%$ overall, $93\% \pm 3\%$ for patients with PL prolapse, $95\% \pm 3\%$ for patients with AL prolapse, and $96\% \pm 2\%$ for patients with BL prolapse ($P = .9$).

Infective Endocarditis

Seven patients had infective endocarditis: 3 required surgical intervention (2 MV replacements and 1 reoperation), and 4 were treated with antibiotics alone; the infection was cured in all 7 patients. The freedom from infective endocarditis at 12 years was $99\% \pm 0.5\%$ for all patients, $99\% \pm 1\%$ for patients with PL prolapse, $94\% \pm 6\%$ for patients with AL prolapse, and 100% for patients with BL prolapse ($P = .02$).

Reoperations

Twenty-seven patients required MV reoperation: 16 for recurrent severe MR (caused by recurrent leaflet prolapse), 4 for MR with hemolysis (caused by residual MR), 3 for mitral stenosis caused by pannus (5-8 years after the operation), 3 for infective endocarditis, and 1 for a left ventricular–coronary sinus fistula. In addition, 1 patient needed coronary artery bypass, and 1 patient had aortic root replacement but no MV reoperation. Figures 1 and 2 show the freedom from reoperation in all patients and in the various groups, respectively. Isolated prolapse of the AL was the only independent predictor of MV reoperation (Table 3).

Figure 2. Freedom from reoperation in patients with posterior (PL), anterior (AL), and bileaflet (BL) prolapse.

Figure 4. Freedom from recurrent moderate or severe mitral regurgitation (MR) in patients with posterior (PL), anterior (AL), and bileaflet (BL) prolapse.

Recurrent MR

Twenty-eight patients had severe MR and 61 had moderate MR during the follow-up. The remaining patients had mild, trace, or no MR. Figures 3 and 4 show the freedom from moderate or severe MR in all patients and in the various groups, respectively. The freedom from severe recurrent MR at 12 years was $89\% \pm 2\%$ for all patients, $92\% \pm 3\%$ for patients with PL prolapse, $86\% \pm 6\%$ for patients with AL prolapse, and $86\% \pm 4\%$ for patients with BL prolapse ($P = .13$). Predictors of recurrent moderate or severe MR are shown in Table 3. The degree of myxomatous changes in the MV, the type of repair used to correct the prolapse, and the type of mitral annuloplasty had no effect on recurrent MR in the entire group or in the AL and BL groups.

Atrial Fibrillation

AF was recorded in 134 patients during the follow-up. Since the introduction of the maze procedure in our practice, 40

patients with preoperative persistent AF had the maze procedure, and 11 (27%) were in AF at latest follow-up, whereas 31 patients with persistent AF preoperatively did not have the maze procedure, and 11 (35%) had AF.

Functional Status

At the latest follow-up, 571 patients were alive and free from reoperation, and 69% were in New York Heart Association functional class I, 20% were in class II, 10% were in class III, and 1% were in class IV, without differences among groups ($P = .3$).

Discussion

It is generally accepted that the long-term survival after MV repair is better than after MV replacement.² We have shown that survival after MV repair is identical to that of the general population when the operation is performed in asymptomatic patients, but it is lower when performed in patients in functional classes 3 and 4.¹ The present study identified AL prolapse as an independent predictor of valve-related mortality. It is noteworthy that patients with isolated AL prolapse were 7 years younger than those with PL prolapse and yet had the same 12-year survival. However, patients with AL prolapse had worse left ventricular function, more aortic valve disease, and the same incidence of coronary artery disease as patients with PL prolapse. Previous investigators found that the best clinical outcomes after MV repair are in patients with isolated prolapse of the PL.²⁻⁴

The overall freedom from reoperation was low in our patients: $94\% \pm 1\%$ at 12 years. However, the AL prolapse group did not fare as well as those with PL prolapse ($88\% \pm 4\%$ vs $96\% \pm 2\%$ at 12 years, $P = .019$). Mohty and associates² also found a higher rate of reoperation in patients with AL prolapse when compared with that seen in

Figure 3. Freedom from recurrent moderate or severe mitral regurgitation (MR) in all patients.

those with PL prolapse. Those investigators found that at 15 years, the reoperation rate was $28\% \pm 7\%$ for AL prolapse and $11\% \pm 3\%$ for PL prolapse.²

Sequential echocardiographic studies in this series suggested that MV repair did not arrest the progression of the degenerative changes in the MV. That was probably the reason patients with AL and BL prolapse had higher recurrence rates of moderate and severe MR at follow-up. Patients with isolated PL prolapse had the best results, and at 12 years, $80\% \pm 4\%$ were free from recurrent moderate or severe MR. Patients with AL or BL prolapse did not do as well, and the freedom from MR at 12 years was only $65\% \pm 8\%$ and $67\% \pm 5\%$, respectively. These findings suggest that reoperation rates underscore MV repair failure rates.

Numerous technical improvements have been made in MV repair, and because this report covers a 20-year experience, it is possible that the results described here exaggerated the problems of recurrent MR associated with AL and BL prolapse. Indeed, most failures of AL and BL prolapse occurred in the first decade of our experience, when triangular resection of the AL, chordal shortening, and fewer Gore-Tex sutures were used to correct the prolapse. Since we increased the number of synthetic chords during repair of AL prolapse, we have not had a single case of recurrent severe MR, although a few patients had moderate MR. However, because there were only a few cases of severe MR, the differences between operative techniques did not reach statistical significance. Mohty and associates² also observed this improvement in outcomes in AL prolapse with increased experience. They found a reduction in the rates of reoperation at 10 years from $24\% \pm 6\%$ to $10\% \pm 2\%$ from the 1980s to 1990s in patients with AL prolapse.

There are several techniques to correct prolapse of the AL: triangular resection,⁹ chordal shortening,⁹ chordal transfer,^{10,11} chordal replacement with Gore-Tex,^{6,7} posterior papillary muscle repositioning,¹² and edge-to-edge repair.¹³ Carpentier⁹ was the first to describe triangular resection of the AL to correct prolapse. Some surgeons still use this technique routinely for segmental prolapse of the AL.¹⁴ We reserve it for the occasional patient with an excessively large AL with localized myxomatous aneurysm or infected leaflet. Chordal shortening has been shown by several surgeons to be inferior to chordal transfer¹⁵ or chordal replacement.¹⁶ However, others believe that chordal shortening is a good procedure in patients with elongated chordae tendineae.¹² There are, however, simpler alternatives to chordal shortening or chordal transfer, and that appears to be the practice of most surgeons.^{12,17,18} The edge-to-edge repair, commonly known as the “Alfieri stitch,” is probably the simplest method to repair localized prolapse of the AL. We do not believe it works in cases of extensive AL or BL prolapse with advanced myxomatous disease and massive

dilation of the mitral annulus. Alfieri and colleagues⁹ recently reported on the results of edge-to-edge technique in a series of 150 patients with isolated AL prolapse caused by a variety of pathologies, but degenerative disease was present in 111 patients. The freedom from reoperation at 9 years was 92%, and only 4 patients had severe recurrent MR. These results are indeed impressive considering the complexity of the MV pathology and the simplicity of the operation. Many surgeons have adopted this technique of repair, and recently, it was shown to be useful to treat systolic anterior motion of the AL of the MV after MV repair for MR.¹⁸

During the past 15 years, we have used almost exclusively chordal replacement with 5-0 and 6-0 polytetrafluoroethylene sutures (Gore-Tex sutures, W. L. Gore & Associates, Inc, Flagstaff, Ariz) to correct prolapse of the AL and of commissural areas. We find the technique extremely useful, and it was the single most important factor in making MV repair feasible in most patients with MR caused by degenerative disease of the MV in our practice. We also use Gore-Tex chords to correct prolapse of the PL in patients with fibroelastic deficiency with small PLs. In patients with myxomatous disease and voluminous PLs, we believe that resection with sliding plasty is the appropriate treatment.

In our series of 701 cases of MV repair, isolated PL prolapse was present in 51% of all patients, isolated AL prolapse was present in 13%, and BL prolapse was present in 37%. This relative incidence of PL, AL, and BL prolapse probably represents the occurrence of the various types of leaflet prolapse in patients with MR caused by degenerative disease who are referred for surgical intervention because approximately 95% of all patients in our practice had MV repair.¹ Thus at least one half of all patients with MR caused by degenerative disease can have a relatively simple and lasting repair. The results of repair in patients with AL and BL prolapse are also satisfactory and probably better than described in this study because of newer methods of repair. Finally, patients with isolated prolapse of the AL in this series were different from the other 2 subgroups in several aspects: they were younger; had more aortic valve disease, particularly bicuspid aortic valve; had worse left ventricular ejection fraction; and had more coronary artery disease than patients with isolated PL prolapse.

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Discussion

Dr Friedrich-Wilhelm Mohr (Leipzig, Germany). First, I would like to congratulate our President for these excellent results and this study with follow-up up to 100%. This article analyzes the clinical and echocardiographic outcomes of 701 patients undergoing MV repair during a time period of 20 years performed by a single surgeon. Different repair techniques have been applied during this time period, especially to correct for anterior leaflet prolapse, such as chordal shortening and replacement and transfer for the anterior leaflet, and most often for the posterior leaflet, resection techniques as described by Carpentier.

As in many other series, isolated posterior leaflet prolapse was most frequent in 51% of all patients, isolated prolapse of the anterior leaflet in 13% only, and bileaflet prolapse in 37%. The excellent results being reported support the high success rate of 95% repair, even in complex cases.

Looking into long-term durability and success rate, overall survival was 75%, with no difference among the groups. Looking into both recurrence of MR and freedom of reoperation, isolated posterior leaflet prolapse repair significantly was superior to ante-

rior and bileaflet repair techniques, which confirms earlier reports by Carpentier and many others.

The most interesting aspect of this study seems to me that a single surgeon's experience during a 20-year time period is reviewed, and several repair techniques, especially for anterior leaflet prolapse, were applied. This leads to my first question. Was there any significant difference when applying chordal replacement instead of shortening and transfer techniques for anterior leaflet repair? It has not been addressed in your slides.

Question two. The article did not address the use of specific annuloplasty rings, such as complete rings or semicircular bands. Can you comment on your selection criteria for annuloplasty rings and whether this might have had an effect on patients with either anterior leaflet or bileaflet prolapses because these patients often present with a more pronounced ring dilatation at the time of the operation?

Question three. The improved imaging technology, like intraoperative transesophageal echocardiography, allows for better preoperative assessment and intraoperative quality control. Did this technology specifically influence your intraoperative decision making and postoperative outcome?

Dr David. Thank you, Dr Mohr. You asked some important questions. There was no difference in outcomes among patients who had leaflet resection, chordal shortening, chordal transfer, or chordal replacement with Gore-Tex sutures. I have to admit, however, that early in my experience, we had very few leaflet resections, and these were in highly selected patients, all of whom did well. From 1983 through 1986, I used chordal transfer and chordal shortening, and soon after the introduction of Gore-Tex sutures to replace chordae tendineae in 1985, we just about abandoned the other techniques. In other words, the sample size of a leaflet resection, chordal shortening, and chordal transfer were too small in comparison with chordal replacement, and this might explain the similar failure rates.

The type of annuloplasty ring had no effect on the outcomes either. Actually, a few patients had no annuloplasty ring, and their outcomes were also similar, and that is perhaps because of Professor Carpentier's influence on our views of degenerative disease of the MV. Thus in patients with myxomatous degeneration of the MV, the entire apparatus is involved by the degenerative process. The annulus is almost invariably dilated, and an annuloplasty is an important part of the repair, but in patients with what Professor Carpentier refers to as "fibroelastic deficiency," the annulus is usually normal, the leaflets are relatively small, and in some of these patients, I repair the prolapse and do not perform an annuloplasty. Patients with fibroelastic deficiency are often older and have more localized disease caused by ruptured chordae, usually P2. Approximately 100 patients had a Carpentier ring, 166 had a Duran ring, and 402 had a posterior band of Dacron, mostly the Cosgrove band. There was no difference in outcomes whether it was a band, a ring, or no ring.

Finally, I have been fortunate to have had transesophageal echocardiography in the operating room well before most of you because one of the cardiologists I worked with in the 1980s was an investigator for a transesophageal probe, but even before that, he used to come to the operating room and get transepical echocardiograms to assess MV function after repair. Echocardiography has been the single most important diagnostic tool to select pa-

tients for mv repair, particularly if they are asymptomatic, and also in assisting us in assessing valve function in the operating room. We have learned not to accept more than mild MR and no residual prolapse at all after repair. I believe that the anatomy of the MV is very important in predicting long-term outcomes after repair. Mild MR without any prolapse remains mild, but the same is not true if a prolapsing segment is left unattended.

Dr Alain Carpentier (*Paris, France*). Of course I enjoyed very much this presentation, and I have a lot of questions, but I am going to restrict it. Number one, an important question. You pointed out that it is very difficult to describe and to analyze the results according to the physiopathology, and you are right, but we found that it is also important to analyze the results according to the disease itself. And as you know, there are several types of degenerative valvular diseases, particularly, excluding Marfan, the so-called Barlow with excess tissue and fibroelastic deficiency with no excess tissue. Usually when you have excess tissue you have a higher risk of recurrence according to Laplace's law. This is because the larger the tissue, the larger the stress and the higher the risk of recurrence. Therefore my first question is whether you were able to analyze the cause or to separate the groups and whether you found a differences depending on whether it is a fibroelastic deficiency or Barlow?

Dr David. That is an important question. Ninety-two patients had what you classify as fibroelastic deficiency. Of the 92, most of them, I do not recall the precise number, had prolapse of the posterior leaflet. There were some patients in this group who had bileaflet prolapse caused by ruptured chordae tendineae. In our series, however, most patients had myxomatous degeneration of the MV and dilation of the mitral annulus. I believe patients with fibroelastic deficiency do better in the long term than those with generalized myxomatous degeneration of the entire MV, but we could not prove this in our study. I think it is noteworthy that patients with fibroelastic deficiency were much older than those with advanced myxomatous changes. Thus although recurrent MR might be less common, the overall survival might be shorter because of their age.

Dr Carpentier. Were able to analyze the results depending on the cause of prolapse being chordal rupture plus elongation or only elongation?

Dr David. It made no difference, to be quite honest.

Dr Carpentier. You did not analyze that?

Dr David. It made no difference if the prolapse was due to chordal elongation or rupture.

Dr Carpentier. What about annulus calcification, associated annulus calcification?

Dr David. Only 13 patients in this series had reconstruction of the mitral annulus.

Dr Carpentier. You did decalcify the annulus?

Dr David. We removed the entire calcium bar. Unlike you, we cover the area with fresh autologous pericardium, reattach the posterior leaflet, and then put the ring in. In those patients, believe it or not, there was just one failure over our 20-year experience. This is a good repair as well. But they were selected patients, and I did not repair all of them.

Dr Carpentier. I believe it. It is just more complicated to do it this way than to just resect the valve and to reconstruct the annulus, but next time you are going to do it.

You did not mention systolic anterior motion of the anterior leaflet of the mitral valve (SAM).

Dr David. It has been just about abolished in our practice since we learned what causes SAM in the operating room. Particularly in patients who have a hyperdynamic ventricle before the operation and a large posterior leaflet, we really shorten the height of the posterior leaflet, and by doing this, we just about abolished SAM. Only 2 patients in the past 10 years required a second pump run for SAM. It is something of the past, I believe.

Dr Carpentier. Therefore in other words you pay attention to prevent SAM, and—this is for the audience—you take the precaution of reducing the height to, what, 15 mm, as we suggested?

Dr David. My cutoff is a centimeter. I make the height of the posterior leaflet 1 cm or less, depending on the height of the anterior leaflet. If the posterior is 1.5 cm but the anterior is 4 cm, it probably is going to be all right. I believe the height of the posterior leaflet should be less than one third of the height of the anterior leaflet. By using this rule, we can prevent SAM in almost all patients. Mind you, if the heart is very hyperdynamic, I still worry about SAM, and I tend to detach the entire posterior leaflet and shorten it.