

Comparison of Valve Annuloplasty and Replacement for Ischemic Mitral Valve Incompetence

Slobodan Micovic, MD, Petar Milacic, MD, Petar Otasevic, MD, Nebojsa Tasic, MD, PhD, Srdjan Boskovic, MD, D. Nezic, MD, PhD, B. Djukanovic, MD, PhD

Cardiac Surgery Department and Echocardiography Cabinet, Cardiology Department, Cardiovascular Institute Dedinje, Belgrade, Serbia

ABSTRACT

Objective: Mitral incompetence is a chronic sequela of myocardial infarction. It is caused by apical displacement and tethering of the mitral valve leaflets after myocardial infarction, resulting in incomplete coaptation. The consensus is for mitral valve surgery in the presence of significant ischemic mitral regurgitation (IMR). Previously, the only option was mitral valve replacement (MVR) with a mechanical or tissue valve. The suboptimal results obtained prompted the development of several methods of mitral valve repair. Today, the most commonly used repair is undersized annuloplasty.

Methods: We conducted a retrospective nonrandomized study of all patients who underwent operation for coronary artery disease and IMR between 2000 and 2006. The surgeon chose the surgical method used for the mitral valve procedure. The most commonly used procedures were restrictive mitral valve annuloplasty (MVP) and MVR with a mechanical prosthesis. We collected all pertinent preoperative, intraoperative, and early-postoperative data. We followed up with phone interviews of the patients and their relatives and with complete clinical and echocardiography examinations.

Results: We carried out operations on 138 patients during the study period (MVR, 52 patients; MVP, 86 patients). The 2 groups had comparable demographic data and risk factors. The 2 groups were significantly different with respect to mean (\pm SD) New York Heart Association (NYHA) class (MVP, 2.72 ± 0.62 ; MVR, 2.48 ± 0.70 ; $P < .01$) and ejection fraction (MVP, $29.01\% \pm 11.00\%$; MVR, $35.87\% \pm 11.00\%$; $P \leq .01$). The 30-day mortality rates for the MVR and MVP groups were significantly different (9.61% and 5.81%, respectively; $P < .01$). Our follow-up included 83% of the patients

and continued for up to 84 months. The 2 groups showed no significant difference in mortality by the end of follow-up; however, the MVR patients had a better ejection fraction (37.79% versus 29.86%) and NYHA functional class (1.88 ± 0.498 versus 2.36 ± 0.564 ; $P < .01$).

Conclusion: Correcting chronic IMR with either repair or replacement produces a good mid-term survival rate (approximately 75%) for survivors in NYHA classes I and II. In our study, mortality rates for the MVP and MVR groups were similar, even though the repair group had a lower mean ejection fraction and a higher NYHA class before and after the operation. We therefore conclude that repair is superior to replacement in treating ischemic mitral insufficiency. A prospective randomized study is needed to better compare these 2 approaches.

INTRODUCTION

Ischemic mitral regurgitation (IMR), or regurgitation in the setting of structurally normal valve leaflets, is due to incomplete mitral leaflet coaptation in patients with left ventricular (LV) dysfunction and dilation (ischemic cardiomyopathy). IMR carries a poor prognosis, and many clinicians have investigated this disease. In patients with acute myocardial infarction, IMR occurs in approximately 15% of cases involving the anterior wall but is present in approximately 40% of patients with an inferior infarct [Tcheng 1992]. Chronic ischemic heart disease results in LV dilation and regional LV systolic wall-motion abnormalities, which can lead to papillary muscle malpositioning and MR. Mechanisms implicated in chronic IMR include simple annular dilation from LV enlargement, which causes incomplete mitral leaflet coaptation and is associated with normal leaflet motion (Carpentier type I), LV remodeling with papillary muscle displacement producing apical tethering (Carpentier type IIIb, restricted leaflet motion), or both [Gorman 2003]. Papillary muscle dysfunction in patients with coronary artery disease also may contribute to IMR. The papillary muscles are particularly susceptible to ischemia, with the posteromedial papillary muscle (posterior descending artery) being more vulnerable to ischemia than the anterolateral papillary muscle (left anterior descending and circumflex arteries) [Iung 2003; Miller 2004]. The posteromedial papillary muscle is perfused

The results of this study were presented at the Annual Conference of the European Society for Cardiovascular Surgery, Barcelona, Spain, April 24-27, 2008, and at the Annual Conference of the World Society for Cardiothoracic Surgery, Kos, Greece, April 29 to May 3, 2008.

Received August 17, 2008; received in revised form October 5, 2008; accepted October 15, 2008.

Correspondence: Slobodan Micovic, MD, Cardiovascular Institute Dedinje, Milana Tepica 1, Belgrade, Serbia; 381-11-3670933 (e-mail: micko2006@yahoo.com).

by one major coronary artery in 60% of the cases, and on the other side, the anterior papillary muscle has 2-vessel perfusion in 71% of the population. Therefore, the posterior papillary muscle is more commonly involved in IMR pathophysiology [Carabello 2000; Kumanohoso 2003].

The indications for surgery in chronic IMR are not well defined. It is generally accepted that patients who have indications for coronary artery bypass grafting with moderate to severe IMR (3+ or 4+) should also undergo concomitant mitral valve (MV) surgery [Lam 2005]. The preferred surgical approach to IMR initially had been MV replacement (MVR) with a mechanical or tissue valve [Rumberger 1994; Miller 2000]. The negative effect of complete valvular excision on LV function explains the high mortality rates that were reported for the early IMR surgical series. The subvalvular apparatus can easily be preserved in IMR patients, improving the likelihood of preserving LV function. MVR is still a method of choice in many cases.

The suboptimal early results for MVR prompted surgeons to start performing MV repairs for IMR. The most common repair surgical procedure for chronic IMR is restricted mitral annuloplasty. Bolling and colleagues popularized this approach with the use of small annuloplasty rings [Bolling 1998]. The idea is that undersizing the mitral annulus will increase leaflet coaptation and decrease regurgitation. Although this procedure does not treat the ventricle, it is simple to perform and therefore has become widely accepted by cardiac surgeons. The type of ring that should be used for undersized annuloplasty is unclear, however, and an examination of the literature reveals no definite advantages or disadvantages for any particular ring type, with the exception of poor long-term results for pericardial bands. The initial results for undersized mitral annuloplasty seemed encouraging, with low perioperative mortality rates. The aim of this study was to investigate the differences in outcomes for repair and replacement in our group of patients.

MATERIALS AND METHODS

All patients who underwent surgery for IMR at our institution between January 1, 2000, and December 31, 2005, were included in the study. Patients who had undergone previous MV surgery or who presented with a floppy or rheumatic valve were excluded from the analysis. The patients were followed up via interviews and transthoracic echocardiography examinations performed by a cardiologist. We used both preoperative and operative records to identify the ischemic cause of the IMR. The primary end points were early postoperative survival (30 days) and mid-term survival (84 months). Secondary end points were hospital morbidity and freedom from reoperation. We compared the MV repair (MVP) and MVR groups with respect to ejection fraction (EF) and New York Heart Association (NYHA) class.

Statistical Methods

In this retrospective nonrandomized study, we used standard statistical methods to compare results for the 2 groups of patients. The Student *t* and chi-square tests were

used to compare different variables, and the Kaplan-Meier method was used to evaluate mortality rates.

RESULTS

Patients

Our database identified 138 patients (86 in the MVP group and 52 in the MVR group) who underwent operation for IMR during the study period. Of these patients, 83% of the survivors were included in the follow-up analysis. Table 1 summarizes the preoperative characteristics of these patients. All patients had symptomatic coronary artery disease, 9 patients had experienced a myocardial infarction within 30 days of the operation, and 81 patients had heart failure symptoms of NYHA class III or IV. Of note is that the 2 groups were significantly different only with respect to EF and NYHA class.

Surgical Procedure

The procedure chosen was based on the surgeon's preference. Four patients in the MVR group had undergone an MV repair attempt that had failed (according to an

Table 1. Patient Characteristics*

	Mitral Valve Repair	Mitral Valve Replacement	P
Patients, n	86	52	NS
Median age, y	60.7	61.7	NS
Female sex, % (n)	27.9 (24)	26.9 (14)	NS
Diabetes, % (n)	21 (18)	15.3 (8)	NS
Hypertension, % (n)	74.4 (64)	65.38 (34)	NS
Hyperlipidemia, % (n)	50 (43)	46.1 (24)	NS
Smoking, % (n)	61.6 (53)	69 (36)	NS
Heredity, % (n)	53.5 (46)	61.5 (32)	NS
PVD, % (n)	15.1 (13)	28.8 (15)	NS
Infarcts, % (n)	74.4 (64)	69 (36)	NS
Multiple infarcts	20.9 (18)	10 (5)	NS
NYHA class	2.72 ± 0.62	2.48 ± 0.70	≤.001
I, % (n)	0 (0)	7.7 (4)	.046
II, % (n)	36 (31)	42.3 (22)	NS
III, % (n)	52.3 (45)	48 (25)	NS
IV, % (n)	11.6 (10)	1.9 (1)	NS
LVEF, %	29.01 ± 11.00	35.87 ± 11.00	<.001
EF 15%-25%, % (n)	47.6 (41)	26.9 (14)	NS
Atrial fibrillation, % (n)	26.7 (23)	28.8 (15)	NS
Myocardial infarction, % (n)			
Within 30 d	8.1 (7)	3.8 (2)	<.01
Within 1 y	33.7 (29)	38.4 (20)	NS
>1 y	32.55 (28)	26.9 (14)	NS
Infarct territory, % (n)			
Diaphragmal	25.6 (22)	17.3 (9)	NS
Inferior	33.7 (29)	26.9 (14)	NS
Anteroseptal	29 (25)	26.9 (14)	NS
Lateral	9.3 (8)	9.6 (5)	NS

*NS indicates not statistically significant; PVD, peripheral vascular disease; NYHA, New York Heart Association; LVEF, left ventricular ejection fraction.

Table 2. Mitral Valve Replacement: Operative Procedure

	No. of Patients
Type of Mechanical Prosthesis	
Medtronic	5
CarboMedics	11
St. Jude Medical	17
On-X Life Technologies	19
Prosthesis size	
27	22
29	12
31	9
33	6

intraoperative transesophageal echocardiography [TEE] examination). All patients in the MVR group had a mechanical valve implanted, with a small-sized valve (no. 27) being the most frequently used. All or most of the posterior leaflet was preserved during the procedure, and the entire anterior leaflet was excised. This approach preserves LV shape and contractility. Unfortunately, none of surgeons tended to preserve the entire subvalvular apparatus during the study period. Table 2 summarizes the types and sizes of mechanical prostheses used in the MVR group, and Table 3 lists the concomitant procedures performed in the MVR group. The left internal mammary artery was the only arterial graft used (35 patients, 67.3%) and was anastomosed to the left anterior descending coronary artery in all cases. Saphenous vein grafts were used as the graft of first choice for all other territories.

The majority of the patients in the MVP group underwent restrictive annuloplasty, but the patients in 20 of the cases underwent different procedures, such as the Key or Alfieri technique. The various techniques of MV repair and types of MV prostheses used were described but were not included in the analysis because of inadequate power to evaluate their effects independently. Table 4 summarizes the types of repair procedures used in MVP group. The ring type used was based on the surgeon's preference and its availability at the time. The most commonly used annuloplasty ring was the Carpentier-Edwards Physio (Edwards Lifesciences, Irvine, CA, USA). All rings were undersized by at least 1 size to ameliorate coaptation between mitral leaflets. The median size of the annuloplasty ring used was 28 mm (range, 26-34 mm). During this period, we tended to undersize by 1 ring size, whereas today most surgeons undersize by 2 ring sizes. This is the reason for the absence of a ring size of 24 in our

Table 3. Mitral Valve Replacement: Concomitant Procedures

	No. of Patients
Tricuspid valve reconstruction (De Vega)	5
Coronary artery bypass grafting	52
Single	13
Double	20
Triple	16
Quadruple	3

Table 4. Mitral Valve Repair: Types of Procedures

	No. of Patients
Ring implantation only	66
P3 resection + ring	5
Alfieri stitch only	2
Alfieri + ring	11
Key	2

patient group. All patients underwent intraoperative TEE to confirm a satisfactory result. In addition, transthoracic echocardiography was performed at the time of discharge to exclude any deterioration in MR and the presence of significant pericardial effusion. Table 5 shows the different types of rings used for undersized annuloplasty, and Table 6 summarizes the concomitant procedures performed in the MVP group. The left internal mammary artery was used in 58 (67.4%) of the patients in the MVP group. The use of this artery increased significantly in the last few years of the study.

The intrahospital mortality rate for the MVR group was 9.61% (5 patients). Three of these patients died from the consequences of perioperative myocardial infarction within 30 days after surgery. The other 2 patients died from stroke and from sepsis more than 30 days after surgery. The mortality rate in the MVP group was 5.81% (5 patients). Two patients died with signs of perioperative myocardial infarction within 30 days of surgery. One patient died from stroke and coma, and the other 2 patients died from severe heart insufficiency. Of note is that the latter 2 patients had MR of grades 1 to 2 at the time of operation (TEE control), which the surgeon considered acceptable at that time. Table 7 summarizes the intrahospital morbidities for the 2 groups.

The transthoracic echocardiographic examinations performed 1 day before discharge in all of the patients revealed an absence of residual MR in 64% of the patients in the MVP group, 26.9% with grade 1 insufficiency, and 9.1% with grade 2 insufficiency. No moderate regurgitation was noted in this cohort of patients. Unfortunately, we found no data in the patient records regarding the coaptation area or any more specific information on echocardiographic variables.

The lengths of hospital stays were similar for the 2 groups. The mean length of stay was 16.5 days (range, 7-74 days) in the MVR group and 15.5 days (range, 7-53 days) in the MVP group. The mean follow-up duration in this study was 32 months (range, 15-70 months).

Table 8 compares the 2 groups with respect NYHA class and EF after 84 months. Follow-up was possible for 83% of

Table 5. Mitral Valve Repair: Ring Type

	No. of Patients
Duran	16
Carpentier-Edwards Physio	55
Carpentier classic	11

Table 6. Mitral Valve Repair: Concomitant Procedures*

	No. of Patients
Resection of LV aneurysm	3
ASD closure	1
Tricuspid valve reconstruction (De Vega)	14
Coronary artery bypass grafting	86
Single	8
Double	30
Triple	33
Quadruple	15

*LV indicates left ventricular; ASD, atrial septal defect.

the patients; 17% of the patients were lost during follow-up. This rate of loss to follow-up is acceptable, considering that many of the patients were from former Yugoslav republics and locating them was impossible. Transthoracic echocardiographic and clinical examinations were carried out in the entire cohort of patients. The 2 groups were examined separately. The end point of the study was to determine whether mortality and reoperation rates differed for the 2 groups. A statistical analysis showed that the preoperative relationships between the 2 groups with respect to NYHA class and EF were maintained in the follow-up evaluations; these 2 variables were the only ones that showed a significant statistical difference between the 2 groups. These results were comparable to those reported in the literature. The preoperative data for the 2 groups were similar. Preoperative NYHA class and EF were worse in the MVP group, and there were more patients with multiple infarcts in this group. Even though the MVP group was the higher-risk group, the initial (30-day) mortality rate was lower in this group (5.81%, 5 patients) than in the MVR group (9.61%,

Table 7. Intra-hospital Morbidity

	Mitral Valve Replacement, n	Mitral Valve Repair, n
Respiratory		
Prolonged intubation (>72 h)	4	7
Tracheostomy	1	3
Renal failure		
Acute renal failure	0	3
Dialysis	0	2
Rhythm disturbance		
Absolute arrhythmia	15 (28.8%)	25 (26.5%)
Ventricular arrhythmia	0	1
Permanent pacemaker	2	6
Infections		
Positive blood culture	5	2
Sternal	3	5
Vein harvest site	0	6
Urinary tract	2	3
Lungs	4	5
Pleural effusion	0	2
Resternotomy for bleeding	3 (5.76%)	4 (4.65%)

Table 8. Follow-up*

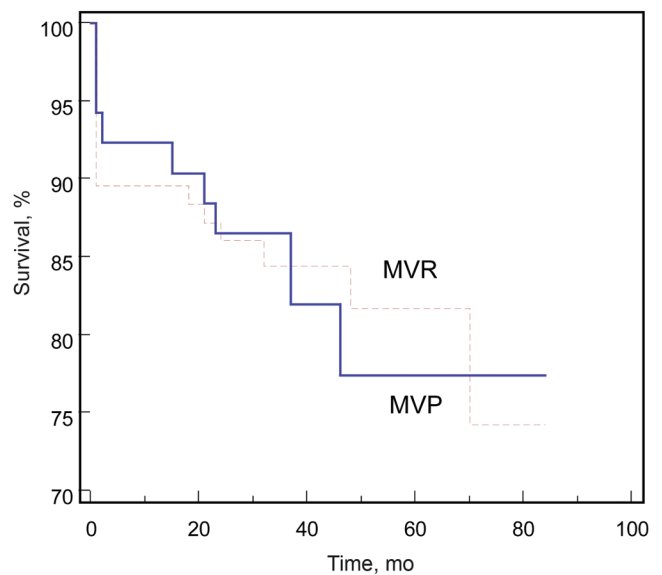
New York Heart Association class		
MV replacement	1.88 ± 0.498	<i>P</i> < .001
MV repair	2.36 ± 0.564	
Ejection fraction, %		
MV replacement	37.79 ± 11.00	<i>P</i> < .001
MV repair	29.86 ± 11.00	

*MV indicates mitral valve.

5 patients), and the difference was statistically significant (*P* < .01). Therefore, our follow-up database included 129 patients. Because we lost 17% of the patients to follow-up, 114 patients (or their spouse/parents) remained to be interviewed. All surviving patients underwent physical and transthoracic echocardiography examinations during visits to our hospital. Another 14 patients (14.4%) died during the follow-up, for a total of 24 patients. The total mortality rate was 17.39%, which is high but acceptable for such a patient cohort.

The 2 groups did not differ with respect to mortality but did differ significantly with regard to NYHA class and EF. We found no differences between the MVP and MVR groups with respect to recurrent angina, infarcts, symptoms of cardiac insufficiency, and other variables. The rate of freedom from reoperation was 100% in both groups. In the MVP group, 1 patient has a small paravalvular leak, and another has grade 2 regurgitation. Both are free of significant symptoms and continue to be followed.

The figure is a Kaplan-Meier survivorship analysis of the 2 groups of patients. The analysis shows no significant difference between the 2 groups of patients in our series. The survival rate at 84 months is approximately 75% for all patients. Table 9 summarizes the preoperative and postoperative results for NYHA class and EF in the MVR



Kaplan-Meier analysis of survival curve during follow-up.

Table 9. Comparison of the Pre- and Postoperative New York Heart Association (NYHA) Class and Ejection Fractions for the Mitral Valve Replacement (MVR) and Repair (MVP) Groups*

	NYHA Class			Ejection Fraction, %		
	Preoperative	Postoperative	P	Preoperative	Postoperative	P
MVR	2.48 ± 0.70	1.88 ± 0.498	<.001	35.87 ± 11.00	37.79 ± 11.00	NS
MVP	2.72 ± 0.62	2.36 ± 0.564	.01	29.01 ± 11.00	29.86 ± 11.00	NS

*NS indicates not statistically significant.

and MVP groups. The postoperative NYHA class was significantly lower than the preoperative NYHA class in both groups, with the difference in the MVP group just reaching statistical significance. The patients in both groups felt better after their operations, and the majority of patients were in NYHA class I or II postoperatively. This result speaks in favor of including MV repair/replacement when performing coronary artery bypass grafting in this class of patients. Analyses of the EFs showed no significant differences between the 2 groups of patients.

COMMENT

Our study indicates that MV repair is superior to replacement. The mortality rates for the 2 groups were similar (ie, not statistically different), even though the patients in the MVP group were much sicker before their operations. The EF and the NYHA class were still better in the MVR group at the mid-term follow-up. This result was expected and is comparable to the preoperative data.

To date, no randomized trials have compared MV repair with replacement for chronic IMR, but there have been a number of retrospective studies. A recent article by Al-Radi et al [2005] confirmed lower perioperative mortality for MV repair in patients with chronic IMR. The survival advantage decreased over time and was not present after 5 years of follow-up. The 2 largest studies are those of Gillinov et al [2001] and Grossi et al [2001], which showed that both MV repair and MV replacement are effective at eliminating MR in the early postoperative period but that MV repair was associated with a lower perioperative mortality. For those with chronic IMR and multiple comorbidities, complex regurgitant jets, or severe tethering of both MV leaflets, replacement is the treatment of choice. Calafiore et al have recommended replacement when the distance between the coaptation point of the leaflets and the plane of the mitral annulus exceeds 10 mm [Calafiore 2001, 2004; Jamieson 2004]; however, patients at the highest risk with the most severe MR did just as well, and maybe better, with MV replacement. Regardless of which surgical technique was employed, the 5-year survival rates (approximately 50%) were disappointing. Today, there is opinion among cardiac surgeons that MV repair produces lower perioperative mortality than replacement and therefore should be performed whenever possible [Hendren 1991; Bishay 2000]. Many studies at many different centers, however, have revealed that a significant number of patients develop recurrent MR during follow-up [Hausmann 1997;

Hung 2004]. A recent study from the Cleveland Clinic examined 585 patients who underwent undersized annuloplasty surgery over a 17-year period. Moderate or greater MR developed 6 months postoperatively in 28% of the patients, an incidence similar to that described by other investigators [Carpentier 1980; McGee 2004]. MR recurrence tends to occur early in the postoperative period, with relatively low recurrence rates thereafter [Carpentier 1980; Liel-Cohen 1997].

The results of our study are encouraging. The rate of freedom from reoperation was 100% for both groups. We are continuing to follow up these patients to determine whether repairs fail later. Morbidity and mortality rate were relatively low in the mid term, even though many of the patients were very sick. The MVP group was much sicker preoperatively with lower EFs and a higher NYHA class, but the similar mortalities of the 2 groups at the mid-term follow-up have led us to conclude that MV repair was superior to replacement in our study. The EF and the NYHA class were better in the MVR group during follow-up, but this result was expected and was comparable to the preoperative data.

Study Limitations

Any conclusion of this study can be criticized because of its retrospective and nonrandomized nature; however, no prospective randomized study has yet been published. We can identify a few minor limitations. First, the number of patients is relatively small. Second, 10 surgeons performed operations in our institution during the period of the surgeries, and each surgeon was free to choose how to treat MV disease. In the replacement procedures carried out during the period, only the posterior leaflet of the subvalvular apparatus was preserved. The strongest limitation is that 20 of the patients underwent other procedures for valvular plasty (Alfieri and Key techniques and others).

CONCLUSION

We conclude that restrictive annuloplasty is the preferred surgical treatment for this group of very sick patients. Although the patients in the MVP group were sicker preoperatively, the morbidity and mortality rates for the 2 groups were almost equivalent by the end of our study, and both groups were free of reoperation during the middle period of the follow-up. The slightly higher NYHA class in the repair group corresponded to the preoperative data for the 2 groups and should not be related to the type of

procedure performed. Long-term follow-up is necessary to draw further conclusions, and follow-up will continue at our institution. Many promising new techniques are being developed, and some will become standard for treating MV disease.

REFERENCES

- Al-Radi OO, Austin PC, Tu JV, David TE, Yau TM. 2005. Mitral repair versus replacement for ischemic mitral regurgitation. *Ann Thorac Surg* 79:1260-7.
- Bishay ES, McCarthy PM, Cosgrove PM, et al. 2000. Mitral valve surgery in patients with severe left ventricular dysfunction. *Eur J Cardiothorac Surg* 17:213-21.
- Bolling SF, Pagani FD, Deeb GM, Bach DS. 1998. Intermediate-term outcome of mitral reconstruction in cardiomyopathy. *J Thorac Cardiovasc Surg* 115:381-8.
- Calafiore AM, Di Mauro M, Gallina S, et al. 2004. Mitral valve surgery for chronic ischemic mitral regurgitation. *Ann Thorac Surg* 77:1989-97.
- Calafiore AM, Gallina S, Di Mauro M, et al. 2001. Mitral valve procedure in dilated cardiomyopathy: repair or replacement? *Ann Thorac Surg* 71:1146-53.
- Carabello B. 2000. The pathophysiology of mitral regurgitation. *J Heart Valve Dis* 9:600-8.
- Carpentier A, Chauvaud S, Fabiani JN, et al. 1980. Reconstructive surgery of mitral valve incompetence. *J Thorac Cardiovasc Surg* 79:338-48.
- Gillinov AM, Wierup PN, Blackstone EH, et al. 2001. Is repair preferable for ischemic mitral regurgitation? *J Thorac Cardiovasc Surg* 122:1125-41.
- Gorman RC, Gorman JH III, Edmunds LH Jr. 2003. Ischemic mitral regurgitation. In: Cohn LH, Edmunds LH Jr, eds. *Cardiac surgery in the adult*. New York, NY: McGraw-Hill. p 751-69.
- Grossi EA, Goldberg JD, LaPietra A, et al. 2001. Ischemic mitral valve reconstruction and replacement comparison of long-term survival and complications. *J Thorac Cardiovasc Surg* 122:1107-24.
- Hausmann H, Siniawski H, Hotz H, et al. 1997. Mitral reconstruction and mitral valve replacement for ischemic mitral insufficiency. *J Card Surg* 12:8-14.
- Hendren WG, Nemecek JJ, Lytle BW, et al. 1991. Mitral valve repair for ischemic mitral insufficiency. *Ann Thorac Surg* 52:1246-52.
- Hung J, Papakostas L, Tahta SA, et al. 2004. Mechanism of recurrent ischemic mitral regurgitation after annuloplasty: continued LV remodeling as a moving target. *Circulation* 110(suppl 1):II85-90.
- Iung B. 2003. Management of ischaemic mitral regurgitation. *Heart* 89:459-64.
- Jamieson WRE, Cartier PC, Allard M, et al. 2004. Canadian Cardiovascular Consensus 2004: surgical management of valvular heart disease. *Can J Cardiol* 20(suppl E):33E-49E.
- Kumanohoso T, Otsuji Y, Yoshifuku S, et al. 2003. Mechanism of higher incidence of ischemic mitral regurgitation in patients with inferior myocardial infarction quantitative analysis of left ventricular and mitral valve geometry in 103 patients with prior myocardial infarction. *J Thorac Cardiovasc Surg* 125:135-43.
- Lam BK, Gillinov AM, Blackstone EH, et al. 2005. Importance of moderate ischemic mitral regurgitation. *Ann Thorac Surg* 79:462-70.
- Liel-Cohen N, Otsuji Y, Vlahakes GJ. 1997. Functional ischemic mitral regurgitation can persist despite ring annuloplasty: mechanistic insights. *Circulation* 96(suppl):I540.
- McGee EC, Gillinov AM, Blackstone EH, et al. 2004. Recurrent mitral regurgitation after annuloplasty for functional ischemic mitral regurgitation. *J Thorac Cardiovasc Surg* 128:916-24.
- Miller DC. 2004. The three-dimensional geometry of the mitral valve: implications for surgical therapy. In: *Proceedings of the 84th Annual Meeting of the American Association for Thoracic Surgery*, Toronto, Ontario, Canada.
- Miller DC. Ischemic mitral regurgitation redux: to repair or to replace? 2000. *J Thorac Cardiovasc Surg* 122:159-62.
- Rumberger JA. 1994. Ventricular dilatation and remodeling after myocardial infarction. *Mayo Clin Proc* 64:664-74.
- Tcheng JE, Jackman JD Jr, Nelson CL, et al. 1992. Outcome of patients sustaining acute ischemic mitral regurgitation during myocardial infarction. *Ann Intern Med* 117:18-24.