Minimally invasive mitral valve repair in Barlow's disease: Early and long-term results

Michael A. Borger, MD, PhD, Anna F. Kaeding, MD, Joerg Seeburger, MD, PhD, Serguei Melnitchouk, MD, Michael Hoebartner, MD, Michael Winkfein, MD, Martin Misfeld, MD, PhD, and Friedrich W. Mohr, MD, PhD

Objective: Barlow's disease remains a challenging surgical pathology in patients presenting with mitral regurgitation. We reviewed our early and long-term results for patients with Barlow's disease who underwent minimally invasive mitral valve surgery.

Methods: Between 1999 and 2010, 145 patients with Barlow's disease underwent minimally invasive mitral valve repair at Leipzig Heart Center. Preoperative echocardiography and intraoperative valve analysis confirmed annular dilatation, bileaflet prolapse, and excessive leaflet tissue in all cases. We retrospectively reviewed mitral valve repair techniques, early and late postoperative clinical outcomes, and follow-up echocardiographic data.

Results: Successful mitral valve repair was performed in 94.5% of patients (n = 137), initial mitral valve replacement was performed in 2.8% of patients (n = 4), and mitral valve replacement after unsuccessful mitral valve repair was performed in 2.8% of patients (n = 4). Mean aortic crossclamp time was 99 ± 33 minutes, cardiopulmonary bypass time was 153 ± 47 minutes, and total duration of surgery was 200 ± 44 minutes. Mitral valve repair techniques consisted of ring annuloplasty and a variety of other methods (not mutually exclusive): "loop" neochordae (72% of patients), posterior mitral leaflet resection (28%), Alfieri stitch (17%), commissural plication (9%), chordal transfer (9%), and anterior mitral leaflet resection (7%). Concomitant procedures consisted of cryoablation for atrial fibrillation (28%), tricuspid valve repair (6%), and closure of an atrial septal defect/patent foramen ovale (12%). Thirty-day mortality was 1.4% (n = 2), rethoracotomy for bleeding was required in 4.1% of patients (n = 6), and conversion to sternotomy was required in 1 patient (0.7%). Long-term clinical follow-up was obtained in 100% of patients, and long-term echocardiographic data were obtained in 93.3% of surviving patients. Long-term survival was $94.7\% \pm 2.2\%$ at 5 years and $88.3\% \pm 4.9\%$ at 10 years. Freedom from mitral valve reoperation was $96.8\% \pm 1.6\%$ at 5 years and $93.8\% \pm 2.6\%$ at 10 years. Freedom from greater than 2+ grade mitral regurgitation was $90.2\% \pm 3.4\%$ at 5 years and $88.4\% \pm 3.9\%$ at 10 years.

Conclusions: A wide variety of repair techniques can be used to perform successful minimally invasive mitral valve repair in the majority of patients with Barlow's disease, with good early and long-term results. (J Thorac Cardiovasc Surg 2014;148:1379-85)

As the second most common valve-related indication for cardiac surgery in the western world, mitral regurgitation (MR) is common among the general population and its prevalence increases with age.¹ Approximately two thirds of patients with MR who are referred for surgery in developed countries have degenerative mitral valve (MV) disease. In the spectrum of degenerative MV disease,

Barlow's syndrome is characterized by excessive myxomatous leaflet tissue, bileaflet prolapse or billowing, annular dilatation, and calcification of the leaflets or annulus.^{2,3} Barlow's pathology constitutes a clinical challenge for surgeons performing MV repair. Achieving a durable surgical result may be a formidable task in these frequently young and otherwise healthy patients.

Minimally invasive surgery (MIS) of the MV has proven to be feasible and technically acceptable for a wide range of mitral pathologies. Mounting data in the literature support the hypothesis that MIS can provide at least equivalent results for surgical correction of MR with several associated clinical benefits.⁴⁻⁶ Some have demonstrated that MIS techniques can be safely used for complex mitral pathologies, such as bileaflet prolapse and Barlow's valve.⁵⁻¹¹ The objective of our study was to describe the early and long-term results for MIS of the MV in a relatively large series of consecutive patients with Barlow's disease.

From the Department of Cardiac Surgery, Leipzig Heart Center, Leipzig, Germany. Disclosures: Authors have nothing to disclose with regard to commercial support. Drs Borger and Kaeding contributed equally to the article.

Presented at The American Association for Thoracic Surgery Mitral Conclave, New York, New York, May 2-3, 2013.

Received for publication July 15, 2013; revisions received Nov 12, 2013; accepted for publication Nov 20, 2013; available ahead of print Jan 13, 2014.

Address for reprints: Michael A. Borger, MD, PhD, Department of Cardiac Surgery, Leipzig Heart Center, Struempellstrasse 39, 04289 Leipzig, Germany (E-mail: michael.borger@med.uni-leipzig.de).

0022-5223/\$36.00

Copyright © 2014 by The American Association for Thoracic Surgery

<http://dx.doi.org/10.1016/j.jtcvs.2013.11.030>

Abbreviations and Acronyms

AML	= anterior mitral leaflet
CPB	= cardiopulmonary bypass
MIS	= minimally invasive surgery
MR	= mitral regurgitation
MV	= mitral valve
NYHA	= New York Heart Association
PML	= posterior mitral leaflet
SAM	= systolic anterior motion
TEE	= transesophageal echocardiography

PATIENTS AND METHODS**Study Population**

A total of 3502 patients underwent MIS of the MV at Leipzig Heart Center between 1999 and 2010. Of this cohort, 145 patients (4.1%) were identified as having Barlow's disease. The diagnosis was made during the intraoperative transesophageal echocardiography (TEE) examination and confirmed by the surgeon's direct assessment of the valve. All patients with Barlow's disease had excessive leaflet tissue, annular dilatation, and bileaflet prolapse or billowing. In more advanced stages, leaflet and annular calcification was present. Patients with isolated bileaflet prolapse without excessive leaflet tissue and patients with forme fruste Barlow's disease were not included. In addition, patients who required concomitant procedures that could not be performed through a MIS approach (eg, coronary bypass, ascending aorta, or aortic valve surgery) were excluded. All consecutive patients with documented Barlow's disease who underwent MIS at Leipzig Heart Center during this time period were included in the current study.

Operative Technique of Minimally Invasive Mitral Valve Repair

The standardized surgical approach for MV repair at Leipzig Heart Center is via a small (5-7 cm in length) anterolateral mini-thoracotomy and has been described in detail.^{4,5,12} Briefly, cardiopulmonary bypass (CPB) was instituted via femoral arterial and venous cannulation. An additional venous cannula was inserted in the right internal jugular vein in patients who required concomitant tricuspid valve repair or in patients weighing more than 75 kg. The aorta was crossclamped with a Chitwood clamp,¹³ and myocardial protection was achieved with mild hypothermia (34°C) and antegrade delivery of crystalloid Bretschneider cardioplegia (2 L). The left atrium was then opened posterior to the interatrial groove, and a left atrial retractor was used to expose the MV.

Our stepwise approach to Barlow's valve repair has been described.¹⁴ With the use of a combination of recently developed reparative methods and more established principles of MV repair,¹⁵ the following techniques were used: ring annuloplasty, the "loop technique" with premeasured polytetrafluoroethylene (Gore-Tex; WL Gore & Associates Inc, Flagstaff, Ariz) neochordae,^{7,12,16} leaflet resection with or without sliding annuloplasty, commissural plication, chordal transfer, and the edge-to-edge ("Alfieri") technique.¹⁷ MV replacement was performed in patients in whom satisfactory MV repair was not achieved or was evaluated as not technically possible during the initial assessment.

TEE was repeated post-CPB in all patients to assess the quality of the MV repair, and more than mild residual MR resulted in a repeat MV repair procedure or MV replacement. TEE examination also was used to confirm flow in the circumflex artery as it courses along the mitral annulus. Examination of the circumflex artery is routinely performed on all the MV cases at Leipzig Heart Center to rule out iatrogenic injury.¹⁸

Follow-up

Clinical long-term follow-up was 100% complete and consisted of New York Heart Association (NYHA) classification, reoperation on the MV or any other cardiac reoperation, and patient survival. It was ascertained by a mailed paper questionnaire or a phone call to the patient or family members, or by contact with the family physician. The follow-up was supplemented with late echocardiographic findings predominantly supplied by referring or institutional cardiologists. Late echocardiography follow-up was obtained in 93.3% of patients (n = 125), after excluding those who died perioperatively (n = 2) and those who underwent repeat MV surgery (n = 9). The degree of MR was classified as grade 0 (absent or trivial), 1+ (mild), 2+ (moderate), 3+ (moderate-to-severe), and 4+ (severe MR), according to published guidelines.¹⁹⁻²¹ In those cases in which NYHA class or MR grade was reported to be between 2 categories, it was rounded up (ie, to the worse grade). The mean length of time between surgery and clinical follow-up was 5.4 ± 3.0 years, whereas the mean echocardiographic follow-up time was 5.0 ± 2.9 years.

Statistical Analysis

Continuous variables are reported as mean $\pm$ standard deviation, and categoric variables are reported as percentages of group totals throughout the article. The Kaplan-Meier method was used to estimate survival rate, freedom from MV reoperation, and freedom from recurrent MR greater than 2+. Excel program (Microsoft Corp, Redmond, Wash) and Stata version XI (StataCorp, College Station, Tex) were used for statistical and survival analyses.

RESULTS

Baseline demographics and preoperative characteristics of the 145 patients are summarized in Table 1. Approximately two thirds of patients were male, and the mean age was 51.2 ± 12.6 years. Mean preoperative left ventricular ejection fraction was $63.2\% \pm 7.8\%$, and more than one quarter of the patients (26.9%) had preoperative atrial fibrillation. No symptoms were present in 22.1% of patients. One patient had undergone MV repair at another institution approximately 10 years previously.

Intraoperative data and selected MV repair techniques (not mutually exclusive) are listed in Table 2. Anterolateral mini-thoracotomy with femoral cannulation for CPB was the surgical approach in all 145 patients. Repair techniques consisted of neochordae formation with the loop technique in 71.7% of patients, which was applied approximately equally for the posterior mitral leaflet (PML) and anterior mitral leaflet (AML) (n = 87 and 90, respectively). Resection of the PML was performed in 28.3% of patients and the AML in 6.9% of patients. Chordal transfer and commissural plication were used in 9.0% of patients each. The Alfieri technique was applied in 25 patients (17.2%). A total of 77 patients (53.1%) received loop neochordae to both leaflets, 23 patients (15.9%) underwent resection of the PML in combination with loops to the AML, and 8 patients (5.5%) underwent resection of both leaflets. After excluding patients who underwent MV replacement (discussed later), all remaining patients but 1 received a complete (n = 123) or partial (n = 13) ring annuloplasty with a mean ring size of 35.7 ± 2.8 mm.

TABLE 1. Preoperative characteristics of patients who underwent minimally invasive mitral valve repair for Barlow's disease (n = 145)

Age, y (mean ± SD)	51.2 ± 12.6
Male/female	93/52
LVEF, % (mean ± SD)	63.2 ± 7.8
Preoperative logistic euroSCORE, % (mean ± SD)	2.5 ± 1.8
Preoperative atrial fibrillation	39 (26.9%)
NYHA class	
1	32 (22.1%)
2	50 (34.5%)
3	60 (41.4%)
4	2 (1.4%)
Previous operation on MV	1 (0.7%)

euroSCORE, European System for Cardiac Operative Risk Evaluation; LVEF, left ventricular ejection fraction; MV, mitral valve; NYHA, New York Heart Association; SD, standard deviation.

Initial MV replacement was necessary in 4 patients (2.8%). Conversion to MV replacement after an unsuccessful repair occurred in another 4 patients, with a final MV replacement rate of 5.5%. CPB time was 153 ± 47 minutes, aortic crossclamp time was 99 ± 33 minutes, and mean total length of surgery time was 200 ± 44 minutes. Concomitant procedures included cryoablation for atrial fibrillation in 41 patients (28.3%), atrial septal defect or patent foramen ovale closure in 17 patients (11.7%), and tricuspid valve repair in 8 patients (5.5%).

TABLE 2. Intraoperative data of 145 patients with Barlow's disease (repair techniques are not mutually exclusive)

Operative data	
Total duration of surgery, min (mean ± SD)	200 ± 44
CPB time, min (mean ± SD)	153 ± 47
Aortic crossclamp time, min (mean ± SD)	99 ± 33
Surgical techniques	
MV replacement	8 (5.5%)
MV repair	137 (94.5%)
Neochordae formation with the loop technique	104 (71.7%)
Neochordae AML	90 (62.1%)
Neochordae PML	87 (60.0%)
Resection PML	41 (28.3%)
Resection AML	10 (6.9%)
Sliding annuloplasty PML	12 (8.3%)
Alfieri technique	25 (17.2%)
Chordal transfer	13 (9.0%)
Commissural plication	13 (9.0%)
Cleft closure	7 (4.8%)
Complete annuloplasty ring	110 (75.9%)
Partial annuloplasty ring	26 (17.9%)
Mean ring size, mm	35.7 ± 2.8
Concomitant procedures	
Tricuspid valve repair	8 (5.5%)
Cryoablation	41 (28.3%)
ASD/PFO closure	17 (11.7%)

AML, Anterior mitral leaflet; ASD, atrial septum defect; CPB, cardiopulmonary bypass; MV, mitral valve; PFO, patent foramen ovale; PML, posterior mitral leaflet; SD, standard deviation.

The intraoperative course was uneventful in all cases, except for 1 patient in whom a conversion to a partial upper sternotomy was necessary to successfully control left atrial appendage bleeding that was noticed on removal of the aortic crossclamp.

Perioperative Outcomes/Major Adverse Events

Postoperative complications are summarized in Table 3. Rethoracotomy for bleeding was required in 6 patients (4.1%). Two patients sustained a postoperative cerebrovascular accident (1.4%). Postoperative atrial fibrillation occurred in 28.3% of patients, and respiratory failure (ventilation for >24 hours or reintubation) occurred in 2.1% of patients. Median hospital stay was 8 days (mean, 11.2 days; range, 2-258 days).

Predischarge transthoracic echocardiography revealed a mean left ventricular ejection fraction of 56.0% ± 8.0%, which was significantly reduced compared to preoperative ejection fraction (Table 4). No or trace residual MR was observed in 99 patients (70.7%), and mild MR was present in 35 patients (25%) on predischarge examination (Figure 1). One patient with postoperative MR 2+ underwent a re-repair, and 4 other patients with postoperative MR 2+ decided against a re-repair in the early postoperative period. Another patient showed MR grade 3+ on predischarge echocardiography and therefore underwent early MV replacement. Preoperative and predischarge MR data are presented in Figure 1.

Thirty-day mortality rate was 1.4% (2 patients). The first patient was a 76-year-old man who presented with severe MR, severe tricuspid regurgitation, and chronic atrial fibrillation. The patient underwent MV and tricuspid valve repair, as well as cryoablation. At the end of the case, he could not be weaned off CPB despite substantial inotropic support. An intra-aortic balloon pump and extracorporeal membrane oxygenator were implanted at the end of the case. Despite maximal support, the patient died of multiorgan failure secondary to low cardiac output on the third postoperative day. The second in-hospital death was a 51-year-old woman whose intraoperative and early postoperative courses were initially uneventful. However, the patient was found pulseless on the nursing ward on the second postoperative day. Despite immediate cardiopulmonary resuscitation, the patient did not regain signs of life. An autopsy was not performed.

Long-Term Outcomes

Most recent clinical follow-up showed that 67.5% of the patients were asymptomatic. Approximately one quarter of patients (23.6%) were classified as NYHA class II, and 8.9% of patients were classified as NYHA class III.

Freedom from MR grade greater than 2+, including those patients who underwent MV reoperation, was 90.2% ± 3.4% at 5 years and 88.4% ± 3.9% at 10 years (Figure 2). Altogether, 11 patients had to undergo cardiac

TABLE 3. Perioperative complications (n = 145)

	Patients (n)
Rethoracotomy for bleeding	6 (4.1%)
LCOS	2 (1.4%)
IABP	2 (1.4%)
ECMO	2 (1.4%)
Postoperative atrial fibrillation	41 (28.3%)
Respiratory failure	3 (2.1%)
CVA	2 (1.4%)
Sepsis	2 (1.4%)
Renal failure	1 (0.7%)
30-d mortality	1.4%

CVA, Cerebrovascular accident; ECMO, extracorporeal membrane oxygenation; IABP, intra-aortic balloon pump; LCOS, low cardiac output syndrome.

reoperation. Five patients underwent surgery within the first 30 days; 2 patients returned to the operating room because of an occluded circumflex artery, and 3 patients returned to the operating room because of recurrent MR. Later reoperations on the MV were due to acute endocarditis (n = 2) or recurrent MR (n = 4). Additional heart surgery after MV repair included 2 aortic valve replacements (1 for endocarditis and 1 for aortic regurgitation). Kaplan–Meier estimates for freedom from MV reoperation were $96.8\% \pm 1.6\%$ at 5 years and $93.8\% \pm 2.6\%$ at 10 years (Figure 3).

Apart from the aforementioned 2 in-hospital deaths, 8 late deaths occurred; 2 were cardiac related, 2 were noncardiac related, and 4 were of unknown cause. The Kaplan–Meier estimate for long-term survival was $94.7\% \pm 2.2\%$ at 5 years and $88.3\% \pm 4.9\%$ at 10 years (Figure 4).

DISCUSSION

MIS on the MV has slowly gained increasing acceptance within the cardiac surgery community and is experiencing a growing demand among patients and referring physicians. It facilitates earlier resumption of normal activities, is associated with improved cosmesis, and may reduce postoperative pain, blood loss, and hospital length of stay.^{6,8-11,22} As early as the late 1990s, the Leipzig Heart Center embraced a mini-thoracotomy with peripheral cannulation for CPB as the access of choice for patients undergoing isolated MV surgery. In one of the early reports from our center, we demonstrated good safety and efficacy in 1339 consecutive

patients with MR,⁵ with results that are at least as good as those achieved with conventional full sternotomy MV surgery. We herein describe our results for patients with Barlow's disease undergoing MV surgery via a MIS approach. We hypothesized that even in patients with complex MV pathology, good early and long-term results could be achieved with a MIS approach.

First described by John B. Barlow, pathognomonic findings of the Barlow's valve include leaflet thickening, excess tissue, chordal lengthening, bileaflet prolapse, annular dilatation, and, not infrequently, valvular tissue calcification.^{2,3} Also, as pointed out by Hutchins and colleagues,²³ Barlow's valve is frequently associated with disjunction of the mitral annulus fibrosis. The resultant atrial displacement of the mitral leaflet attachment may lead to leaflet hypermobility and subsequent excessive mucoid degeneration. Histologically, Barlow's valve is characterized by myxoid infiltration, which destroys the 3-layer leaflet architecture, and collagen alterations.²⁴

MV repair in Barlow's disease is particularly challenging because of extensive bileaflet billowing, which makes it difficult for the surgeon to find a normal "reference point" and thereby complicates valve analysis and repair planning. Nevertheless, a variety of surgical techniques have been described for successful repair of this challenging pathology.^{14,25,26} In the current study, neochordae formation with the Loop technique was used in 72% of the patients and was equally used for PML and AML reconstruction. We have previously published extensively on this technique and are satisfied with its easy handling, reproducibility, and good early and medium-term results.^{7,12,16} In addition, neochordal techniques decrease the risk of postoperative systolic anterior motion (SAM) of the AML, a particularly feared complication of patients with Barlow's pathology. As described by Mihaljevic and colleagues²² in a study of neochordal versus resectional techniques for robotic PML repair, postoperative SAM was observed only in the resectional group. Likewise, Lawrie and colleagues²⁵ found no occurrence of SAM and good early results in a series of 61 patients with Barlow's disease who underwent nonresectional MV repair.

In the current study, we observed no occurrence of SAM in 145 consecutive patients. The low incidence of observed SAM is probably related to our extensive use of the Loop

TABLE 4. Echocardiographic findings

	Preoperative TTE findings (n = 145)	Predischarge TTE findings (n = 143)	Long-term TTE findings (n = 125)	P value*
LVEF, %	63.2 $\pm$ 7.8	56.0 $\pm$ 8.0	58.7 $\pm$ 7.6	<.001
LVED _D , cm	5.8 $\pm$ 0.8	5.2 $\pm$ 0.7	5.0 $\pm$ 0.5	<.001
LVES _D , cm	3.6 $\pm$ 0.7	3.6 $\pm$ 0.7	3.5 $\pm$ 0.7	.8
LA _D , cm	4.7 $\pm$ 1.0	4.4 $\pm$ 0.9	4.2 $\pm$ 0.8	.002
MR grade	3.3 $\pm$ 0.5	0.1 $\pm$ 1.5	0.5 $\pm$ 0.6	<.001

Values are mean $\pm$ standard deviation. Long-term echocardiographic data exclude patients who died or underwent a redo MV procedure (93.3% complete). LA_D, Left atrial diameter; LVED_D, left ventricular end-diastolic diameter; LVEF, left ventricular ejection fraction; LVES_D, left ventricular end systolic diameter; MR, mitral regurgitation; TTE, transthoracic echocardiography. *Analysis of variance.

TABLE 5. Late clinical and echocardiographic findings of patients with Barlow’s disease

	Patient no. (%)
NYHA class (n = 123)	
1	83 (67.5)
2	29 (23.6)
3	11 (8.9)
4	0 (0)
MR grade (n = 125)	
0	65 (52.0)
1	48 (38.4)
2	10 (8.0)
3	1 (0.8)
4	0 (0.0)
Cardiac reoperation: aortic valve replacement	2 (1.4)
Reoperation on MV	11 (7.6)

Patients who died or underwent MV repeat surgery were excluded for NYHA and MR grading. NYHA, New York Heart Association; MR, mitral regurgitation; MV, mitral valve.

neochordae technique, application of the Alfieri technique in select patients, and implantation of a large annuloplasty ring (discussed later). In addition, we aggressively resected leaflet tissue in those patients in whom we opted to perform a leaflet resection technique. We recommend aggressive leaflet resection in patients with Barlow’s disease when the surgeon decides to use such a procedure, because the leaflets are usually very long (tall) in such patients.

We applied the Alfieri edge-to-edge technique in 25 patients in the current study (17.2%). One may argue that this technique is counterintuitive for a pathology characterized by elongation of both the subvalvular apparatus and the leaflet height. Nevertheless, a properly placed edge-to-edge stitch that encompasses a large amount of leaflet tissue can lead to marked shortening of the height of both leaflets and a lowering of the coaptation point to within the left ventricle. As described by Maisano and colleagues¹⁷ from Alfieri’s group, this double-orifice technique was used in their series

FIGURE 1. Preoperative and early postoperative echocardiographic grade of MR.

FIGURE 2. Kaplan–Meier estimate for freedom from MR more than grade 2+. Patients who were censored in survival were excluded in this graph, but patients who underwent MV reoperation were included. MR, Mitral regurgitation.

of 82 patients with Barlow’s disease and was associated with good midterm results. Freedom from reoperation was 86% ± 14% at 5 years, and the late echocardiographic follow-up showed freedom from moderate-to-severe MR in 71 patients.

All patients undergoing MV repair but 1 in the current study received a complete (n = 123) or partial (n = 13) ring annuloplasty with a mean ring size of 35.7 ± 2.8 mm. Ring selection in Barlow’s valve reconstruction is of particular importance because of the increased risk of SAM. As described by Adams and colleagues,²⁶ large ring sizes (up to 40 mm) are frequently necessary for successful repair of Barlow’s valves. These investigators even suggest that the definition of a true Barlow’s valve should be limited to those requiring a complete ring of size 36 or greater. However, Jouan and colleagues²⁸ used smaller rings in their recent series of 200 patients with Barlow’s disease, probably because of the inclusion of patients with forme fruste (ie, excess tissue localized onto several segments of the posterior leaflet and commissures) in their analysis.

FIGURE 3. Kaplan–Meier estimate for freedom from MV reoperation.

FIGURE 4. Kaplan-Meier survival estimate after MIS of the MV.

Because the MIS approach is the procedure of choice for isolated MV surgery (with or without associated tricuspid valve, atrial fibrillation, or atrial septal defect/patent foramen ovale surgery) at Leipzig Heart Center, we do not have a contemporary full sternotomy control group to compare outcomes. However, one can compare survival, freedom from reoperation, and echocardiographic follow-up data with conventional sternotomy series obtained from the literature. In this regard, Flameng and colleagues²⁹ reported a series of 348 patients who underwent MV repair for degenerative MR via a median sternotomy. In this series comprising patients with Barlow's disease and fibroelastic deficiency, 10-year survival was 80.1% and freedom from reoperation was 94.4%.²⁹ However, freedom from recurrent MR (>2+) was 82.2% at 5 years and 64.9% at 10 years for the entire group, with worse outcomes for patients with Barlow's disease.

David and associates³⁰ reviewed their results in 701 patients with posterior, anterior, and bileaflet prolapse and reported an overall survival at 12 years of $75\% \pm 5\%$ for the entire group and freedom from reoperation at 12 years of $96\% \pm 2\%$ for posterior prolapse, $88\% \pm 4\%$ for anterior prolapse, and $94\% \pm 2\%$ for bileaflet prolapse. The freedom from moderate or severe MR at 12 years was $80\% \pm 4\%$ for posterior prolapse, $65\% \pm 8\%$ for anterior prolapse, and $67\% \pm 6\%$ for bileaflet prolapse. In a more recent study, the same group examined 840 consecutive patients who underwent MV repair via a median sternotomy for MR due to degenerative disease. At 20 years, the probability of reoperation was 5.9%, freedom from recurrent severe MR was 90.7%, and freedom from moderate or severe MR was 69.2% for the entire group.³¹

A similar study recently published by Jouan and colleagues²⁸ described 200 patients with Barlow's disease who underwent MV surgery via a conventional sternotomy. In their series, repair was feasible in 94.7% of non-redo interventions (179/189). Operative mortality was 1.5%

($n = 3$), and the overall survival at 8 years was $88.6\% \pm 3.1\%$. The freedom from reintervention at 8 years was $95.3\% \pm 1.7\%$, and the freedom from late recurrent more than moderate MR (>2+ grade MR) was $90.2\% \pm 3.1\%$. The results of the study by Jouan and colleagues²⁸ are strikingly similar to our results, underlining the noninferiority of the mini-thoracotomy approach, even for patients with complex MV pathology.

The current study confirms the safety, feasibility, and durability of MIS of the MV for Barlow's disease in a large-volume MIS center. Our low rates of perioperative morbidity and mortality, in addition to the good long-term results, are comparable to those observed from large series of Barlow's valve surgery performed via conventional median sternotomy. However, one should keep in mind that MIS is associated with a definite learning curve and that a relatively large number of operations is required to achieve optimal results.³² Patients with Barlow's disease and other complex MV pathologies who want to undergo a MIS technique probably should be referred to surgeons with the appropriate expertise.

Study Limitations

Our study is retrospective in nature and therefore subject to the inherent weaknesses of a retrospective analysis. As mentioned earlier, we were also unable to make comparisons with a control group of patients who underwent operation via median sternotomy, because the MIS approach has been our procedure of choice since the late 1990s. Another limitation is the late postoperative echocardiographic follow-up studies, which in the majority of cases were obtained as reports from outside institutions. Therefore, we were unable to analyze more quantitative aspects of MR severity, such as effective regurgitant orifice area, vena contracta, regurgitant volume, and regurgitant fraction.

CONCLUSIONS

MIS of the MV can be performed with good results in the majority of patients with Barlow's disease. The operation is associated with low rates of morbidity and mortality, as well as good durability in early and long-term follow-ups. Despite the clinical challenge presented by patients with Barlow's disease, a MIS approach can be successfully implemented in selected high-volume centers.

References

1. Singh JP, Evans JC, Levy D, Larson MG, Freed LA, Fuller DL, et al. Prevalence and clinical determinants of mitral, tricuspid, and aortic regurgitation (the Framingham Heart Study). *Am J Cardiol.* 1999;83:897-902.
2. Barlow JB, Bosman CK. Aneurysmal protrusion of the posterior leaflet of the mitral valve. An auscultatory-electrocardiographic syndrome. *Am Heart J.* 1966;71:166-78.
3. Barlow JB, Bosman CK, Pocock WA, Marchand P. Late systolic murmurs and non-ejection ("mid-late") systolic clicks. An analysis of 90 patients. *Br Heart J.* 1968;30:203-18.

4. Mohr FW, Onnasch JF, Falk V, Walther T, Diegeler A, Krakor R, et al. The evolution of minimally invasive mitral valve surgery—2 year experience. *Eur J Cardiothorac Surg.* 1999;15:233-9.
5. Seeburger J, Borger MA, Falk V, Kuntze T, Czesla M, Walther T, et al. Minimal invasive mitral valve repair for mitral regurgitation: results of 1339 consecutive patients. *Eur J Cardiothorac Surg.* 2008;34:760-5.
6. Goldstone AB, Atluri P, Szeto WY, Trubelja A, Howard JL, MacArthur JW Jr, et al. Minimally invasive approach provides at least equivalent results for surgical correction of mitral regurgitation: a propensity-matched comparison. *J Thorac Cardiovasc Surg.* 2013;145:748-56.
7. Kuntze T, Borger MA, Falk V, Seeburger J, Girdauskas E, Doll N, et al. Early and mid-term results of mitral valve repair using premeasured Gore-Tex loops ('loop technique'). *Eur J Cardiothorac Surg.* 2008;33:566-72.
8. Suri RM, Burkhart HM, Rehfeldt KH, Enriquez-Sarano M, Daly RC, Williamson EE, et al. Robotic mitral valve repair for all categories of leaflet prolapse: improving patient appeal and advancing standard of care. *Mayo Clinic Proc.* 2011;86:838-44.
9. McClure RS, Cohn LH, Wiegand E, Couper GS, Aranki SF, Bolman RM 3rd, et al. Early and late outcomes in minimally invasive mitral valve repair: an eleven-year experience in 707 patients. *J Thorac Cardiovasc Surg.* 2009;137:70-5.
10. Rodriguez E, Nifong LW, Chu MWA, Wood W, Vos PW, Chitwood WR. Robotic mitral valve repair for anterior leaflet and bileaflet prolapse. *Ann Thorac Surg.* 2008;85:438-44.
11. Casselman FP, Slycke SV, Dom H, Lambrechts DL, Vermeulen Y, Vanermen H. Endoscopic mitral valve repair: feasible, reproducible, and durable. *J Thorac Cardiovasc Surg.* 2003;125:273-82.
12. von Oppel UO, Mohr FW. Chordal replacement for both minimally invasive and conventional mitral valve surgery using premeasured Gore-Tex loops. *Ann Thorac Surg.* 2000;70:2166-8.
13. Chitwood RW, Elbeery JR, Moran JF. Minimally invasive mitral valve repair using transthoracic aortic occlusion. *Ann Thorac Surg.* 1997;63:1477-9.
14. Borger MA, Mohr FW. Repair of bileaflet prolapse in Barlow syndrome. *Semin Thorac Cardiovasc Surg.* 2010;22:174-8.
15. Carpentier A. Cardiac valve surgery—the "French correction" *J Thorac Cardiovasc Surg.* 1983;86:323-37.
16. Seeburger J, Kuntze T, Mohr FW. Gore-Tex chordoplasty in degenerative mitral valve repair. *Semin Thorac Cardiovasc Surg.* 2007;19:111-5.
17. Maisano F, Schreuder JJ, Oppizzi M, Fiorani B, Fino C, Alfieri O. The double-orifice technique as a standardized approach to treat mitral regurgitation due to severe myxomatous disease: surgical technique. *Eur J Cardiothorac Surg.* 2000;17:201-5.
18. Ender J, Selbach M, Borger MA, Krohmer E, Falk V, Kaisers UX, et al. Echocardiographic identification of iatrogenic injury of the circumflex artery during minimally invasive mitral valve repair. *Ann Thorac Surg.* 2010;89:1866-72.
19. Enriquez-Sarano M, Akins C, Vahanian A. Mitral regurgitation. *Lancet.* 2009;373:1382-94.
20. Enriquez-Sarano M, Avierinos JF, Messika-Zeitoun D, Detaint D, Capps M, Nkomo V, et al. Quantitative determinants of the outcome of asymptomatic mitral regurgitation. *N Engl J Med.* 2005;352:875-83.
21. Bonow RO, Carabello BA, Chatterjee K, de Leon AC, Faxon DP, Freed MD, et al. ACC/AHA 2006 guidelines for the management of patients with valvular heart disease. *J Am Coll Cardiol.* 2006;48:e1-148.
22. Mihaljevic T, Pattakos G, Gillinov AM, Bajwa G, Planinc M, Williams SJ, et al. Robotic posterior mitral leaflet repair: neochordal versus resectional techniques. *Ann Thorac Surg.* 2013;95:787-94.
23. Hutchins GM, Moore WG, Skoog DK. The association of floppy mitral valve with disjunction of the mitral annulus fibrosus. *N Engl J Med.* 1986;314:535-40.
24. Fornes P, Heudes D, Fuzellier JF, Tixier D, Bruneval P, Carpentier A. Correlation between clinical and histologic patterns of degenerative mitral valve insufficiency: a histomorphometric study of 130 excised segments. *Cardiovasc Pathol.* 1999;8:81-92.
25. Lawrie GM, Earle EA, Earle NR. Nonresectional repair of the Barlow mitral valve: importance of dynamic annular evaluation. *Ann Thorac Surg.* 2009;88:1191-6.
26. Adams DH, Anyanwu AC, Rahmanian PB, Abascal V, Salzberg SP, Filsoufi F. Large annuloplasty rings facilitate mitral valve repair in Barlow's disease. *Ann Thorac Surg.* 2006;82:2096-101.
27. Adams DH, Anyanwu AC. Seeking a higher standard for degenerative mitral valve repair: begin with etiology. *J Thorac Cardiovasc Surg.* 2008;136:551-6.
28. Jouan J, Berrebi A, Chauvaud S, Menasché P, Carpentier A, Fabiani J-N. Mitral valve reconstruction in Barlow disease: long-term echographic results and implications for surgical management. *J Thorac Cardiovasc Surg.* 2012;143:S17-20.
29. Flameng W, Meuris B, Herijgers P, Herregods M-C. Durability of mitral valve repair in Barlow disease versus fibroelastic deficiency. *J Thorac Cardiovasc Surg.* 2008;135:274-82.
30. David TE, Ivanov J, Armstrong S, Christie D, Rakowski H. A comparison of outcomes of mitral valve repair for degenerative disease with posterior, anterior, and bileaflet prolapse. *J Thorac Cardiovasc Surg.* 2005;130:1242-9.
31. David TE, Armstrong S, McCrindle BW, Manlhiot C. Late outcomes of mitral valve repair for mitral regurgitation due to degenerative disease. *Circulation.* 2013;127:1485-92.
32. Holzhey DM, Seeburger J, Misfeld M, Borger MA, Mohr FW. Learning minimally invasive mitral valve surgery: a cumulative sum sequential probability analysis of 3895 operations from a single high-volume center. *Circulation.* 2013;128:483-91.