Outcomes of Minimally Invasive Mitral Valve Surgery in Patients With an Ejection Fraction of 35% or Less

Orlando Santana, MD, Javier Reyna, MD,* Andres M. Pineda, MD,* Christos G. Mihos, DO,* Lior U. Elkayam, MD,* Gervasio A. Lamas, MD,* and Joseph Lamelas, MD**

Objective: We evaluated the outcomes of minimally invasive mitral valve surgery via a right anterior thoracotomy approach in patients with isolated severe mitral regurgitation and severely reduced left ventricular systolic function.

Methods: We retrospectively reviewed all minimally invasive mitral valve surgeries for mitral regurgitation in patients with an ejection fraction of 35% or less performed at our institution between December 2008 and June 2011. The operative times, lengths of stay, postoperative complications, and mortality were analyzed.

Results: We identified a total of 71 patients with severe mitral regurgitation and an ejection fraction of 35% or less who underwent minimally invasive mitral valve surgery. The mean ± SD age was 67 ± 10 years, and 44 of the patients were men (62%). The mean ± SD left ventricular ejection fraction was 27% ± 6%, and 28 patients (39%) had previous heart surgery. The median aortic cross-clamp and cardiopulmonary bypass times were 62 [interquartile range (IQR), 50–80) and 98 minutes (IQR, 92–124), respectively. There was no mitral regurgitation noted in any patient on postoperative transesophageal echocardiogram. The median intensive care unit length of stay was 51 hours (IQR, 42–86), and the median postoperative length of stay was 6 days (IQR, 5–9).

Conclusions: Minimally invasive mitral valve surgery for severe functional mitral regurgitation in patients with severe left ventricular dysfunction can be performed with a low morbidity and mortality.

Key Words: Minimally invasive, Mitral regurgitation, Valve surgery.

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When compared with a standard median sternotomy approach, the reported benefits of minimally invasive valve surgery include a reduction in surgical trauma resulting in less bleeding, fewer reoperations for bleeding, shorter intensive care unit and hospital length of stay, less use of rehabilitation resources, a more rapid return to functional activity, and reduced cost.[1–8] The relative benefits of minimally invasive valve surgery seem to be most evident in higher-risk patient groups, such as the elderly, persons with obesity, and those undergoing reoperative valve surgery.[9–11] Notwithstanding, minimally invasive valve surgery is more technically demanding, typically requiring longer operative times, which could impact postoperative left ventricular function. Because of the potential for counterbalancing risks and benefits, we evaluated the outcomes of minimally invasive mitral surgery in patients with severe left ventricular dysfunction and severe mitral regurgitation.

METHODS

After obtaining approval from the institutional review board, we retrospectively reviewed 1008 minimally invasive heart operations performed at our institution between December 2008 and June 2011 to identify those patients with severe mitral regurgitation and an ejection fraction of 35% or less who underwent mitral valve surgery. Patients were excluded if they underwent concomitant coronary artery bypass grafting or surgery on the aortic valve or the aorta.

In all patients, valvular lesions were documented by diagnostic catheterization and echocardiography. Preoperative and postoperative transesophageal echocardiograms were reviewed, and transthoracic echocardiogram was performed before discharge. The grading of the mitral regurgitation was done in accordance with the American Society of Echocardiography guidelines.[12] The ejection fraction was measured from the apical four-chamber view according to the modified Simpson rule. Functional, or secondary, mitral regurgitation was defined by the presence of normal mitral leaflets and chordae. The patients were further classified by the cause of their myopathy. Ischemic cardiomyopathy was defined by a history of myocardial infarction and cardiac catheterization confirming coronary artery disease. In the absence of significant coronary artery disease, the patients were designated as idiopathic.

All preoperative data, in-hospital outcomes, and postdischarge outcomes were reviewed. The definitions and variables selected were based on The Society of Thoracic Surgeons (STS) database definitions. Operative variables, blood transfusion requirement, operative morbidity, length of intensive care unit and hospital stay, and 30-day mortality were analyzed in all patients. The postdischarge outcomes of all patients were analyzed

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From the *Division of Cardiac Surgery at Mount Sinai Heart Institute, Miami Beach, FL USA.

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Address correspondence and reprint requests to Orlando Santana, MD, Echocardiography Laboratory, Mount Sinai Heart Institute, 4300 Alton Rd, Miami Beach, FL 33140 USA. E-mail: osantana@msmc.com.

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30 days postoperatively on the basis of a follow-up visit to the operating surgeon.

Technique for Minimally Invasive Mitral Valve Surgery

The patients were placed in supine position and underwent anesthetic induction and intubation with a single-lumen endotracheal tube and a bronchial blocker. A transesophageal echocardiogram Doppler probe was placed intraoperatively to evaluate the valves and to assess the postoperative results. In all patients, a femoral platform was used to establish cardiopulmonary bypass. A 2- to 3-cm incision was made in the inguinal crease. The femoral artery was then cannulated with a 16F to 18F arterial cannula (Edwards, Irvine, CA USA), and the femoral vein was cannulated with a 25F venous cannula (Bio-medicus; Medtronic, Minneapolis, MN USA). With the aid of transesophageal echocardiography, the venous cannula was placed in the superior vena cava. If significant peripheral vascular disease had been suspected by history, by physical examination, or because of difficulty cannulating or if severe aortic atherosclerosis was evident by transesophageal echocardiography, then axillary artery cannulation would have been performed. We do not routinely perform preoperative computed tomographic angiography to check for the presence of peripheral vascular disease and/or aortic pathology.

A 5-cm skin incision was made in the right fourth to fifth intercostal space at the anterior axillary line. Using transesophageal echocardiography guidance, a retrograde coronary sinus catheter was directly inserted through the incision. One dose of antegrade cold blood cardioplegia was given to establish electromechanical arrest of the heart. Thereafter, retrograde cold blood cardioplegia was given throughout the procedure at 20- to 25-minute intervals. The mitral valve was accessed through the Waterson groove, and a left lateral atriotomy was performed to enter the left atrium. A specially designed atrial lift retractor and atrial exposure blade were used for visualization of the mitral valve. Mitral valve repair or replacement was carried out in the standard fashion. A 4-0 Prolene suture was used to close the left atrium. Carbon dioxide was infused into the operative field during the entire procedure.

The decision to repair versus replace the mitral valve was based on the results of the preoperative transesophageal echocardiogram. The anatomy of the mitral valve and its subvalvular apparatus were carefully studied. The distance between the mitral annular plane and the coaptation point of the mitral leaflets, or tenting height, was measured. Those patients with a tenting height of less than 10 mm underwent mitral valve repair, whereas those with a tenting height of greater than 10 mm underwent mitral valve replacement. For the mitral valve repairs, the size of the anterior leaflet was used to determine the size of the annuloplasty ring used. The annuloplasty ring used was a Profile 3D (Medtronic, Minneapolis, MN USA). Replacement of the mitral valve consisted of excision of the anterior leaflet with preservation of the posterior leaflet and chords. The prosthetic valves used were the Hancock II porcine (Medtronic, Minneapolis, MN USA), the Mosaic porcine (Medtronic, Minneapolis, MN USA), and the ATS Medical (Medtronic, Minneapolis, MN USA) heart valves.

In all cases, the pericardium was opened above the phrenic nerve and over the aorta to facilitate exposure. When performing tricuspid valve surgery, the same incision is used, and the superior and inferior vena cavae are snared with vessel loops. The long femoral venous cannula is retracted into the inferior vena cava, and this is snared along with the superior vena cava. The right atrium is immediately opened, and a sump suction is inserted into the superior vena cava, which provides adequate drainage. The pericardium was not closed at the completion of the operation to allow adequate drainage into the pleural space. In the patients with a history of heart surgery, we used moderate-to-deep hypothermia (24°C–26°C) and fibrillatory arrest. Cardioplegia was not delivered at all, very little dissection was performed, and removal of air was performed through a vent placed via the atriotomy through the mitral valve and into the left ventricle. With the heart empty, both atrial and ventricular pacing wires were placed. After discontinuing cardiopulmonary bypass and administering protamine, decannulation was performed. The purse-string sutures were tied, and the femoral artery was directly repaired using the 5-0 Prolene suture. A single chest tube was left in the pleural space. For pain relief, all patients had an On-Q pain relief system inserted (I-Flow Corporation, Lake Forest, CA USA). Two catheters were placed in the interspace to deliver 0.25% of bupivicaine for 72 hours. The thoracotomy incision was closed in the routine fashion.

Statistical Methods

All continuous variables were expressed as mean ± 1 SD. Nonparametric variables were expressed as median and interquartile range [IQR, 25%–75%]. A binomial test was used to compare the STS predicted risk scores as well as the actual measured morbidity and mortality. A P value of less than 0.05 was considered statistically significant. The statistical analyses were performed using the Statistical Package for the Social Sciences version 19 (Chicago, IL USA).

RESULTS

We identified 71 consecutive patients with severe mitral regurgitation and an ejection fraction of 35% or less who underwent minimally invasive mitral valve surgery. The cohort consisted of 44 men (62%) and 27 women (38%), with a mean ± SD age of 67 ± 10 years. The mean ± SD ejection fraction was 27% ± 6%. There were 19 patients (27%) with a history of coronary artery bypass graft surgery and 9 patients (13%) with previous aortic valve surgery. In all patients, the mitral regurgitation was functional, with an ischemic etiology in 37 patients (52%) and a nonischemic origin in 34 patients (48%). All patients were in New York Heart Association functional class III or IV (Table 1).

There were 31 patients (44%) who underwent mitral valve repair and 40 patients (56%) who underwent mitral valve replacement. In the mitral valve repair group, the most common annuloplasty ring size used was 28 mm, with 26 mm being the second most common. Of the 40 patients who underwent mitral valve replacement, 39 had a bioprosthetic valve placed and 1 had a mechanical valve placed. The two most common sizes of prosthetic valve used were 29 and 31 mm. Of the 71 patients,

TABLE 1. Patient Baseline Characteristics

Variables	Minimally Invasive (N = 71)
Age, mean ± SD, y	67 ± 10
Men, n (%)	44 (62)
Hypertension, n (%)	67 (94)
Diabetes mellitus, n (%)	23 (32)
Dyslipidemia, n (%)	51 (72)
Ejection fraction, mean ± SD, %	27 ± 6
Previous coronary bypass graft surgery, n (%)	19 (27)
Previous aortic valve replacement, n (%)	9 (13)
History of cerebrovascular accident, n (%)	6 (9)
History of atrial fibrillation, n (%)	32 (45)
Chronic obstructive pulmonary disease, n (%)	24 (34)
Preoperative creatinine, mean ± SD, mg/dL	1.2 ± 0.5
Ischemic cardiomyopathy, n (%)	37 (52)
Nonischemic cardiomyopathy, n (%)	34 (48)
New York Heart Association functional class III or IV, n (%)	71 (100)

there were 4 (6%) who underwent concomitant tricuspid valve repair because of the presence of moderate to severe tricuspid regurgitation.

The aortic cross-clamp and cardiopulmonary bypass times were 62 (IQR, 50–80) and 98 minutes (IQR, 92–124), respectively. Adequate exposure of the surgical field was obtained in all operations, without the need for conversion to a median sternotomy in any of the patients. On the postoperative transesophageal echocardiogram, none of the patients had any discernable mitral regurgitation. The median number of units of packed red blood cells transfused was 2 (IQR, 0–3). The median intensive care unit length of stay was 65 hours (IQR, 44–88), and the median postoperative length of stay was 7 days (IQR, 5–9) (Table 2).

Postoperatively, 5 patients (7%) developed renal failure, 10 patients (14%) had prolonged intubation, and 5 patients (7%) required reintubation. None of the patients developed a deep wound infection, and one patient (1.4%) had a cerebrovascular accident. There were no vascular complications at the cannulation sites. The combined end point of morbidity and mortality was 13 (18.3%), which was lower than the 29.5% STS predicted score, $P < 0.0001$. There were two deaths in the first 30 days, with a 30-day mortality of 2.8 (Table 3).

TABLE 2. Types of Surgery and Operative Results

Variables	Minimally Invasive (N = 71)
Mitral valve repair, n (%)	31 (44)
Mitral valve replacement, n (%)	40 (56)
Mitral and tricuspid valve surgery, n (%)	4 (6)
Aortic cross-clamp time, median (IQR), min	62 (50–80)
Cardiopulmonary bypass time, median (IQR), min	98 (92–124)
Units of PRBC transfused, median (IQR)	2 (0–3)
Intra-aortic balloon pump use, n (%)	3 (4)
Total ventilator hours, median (IQR)	16 (12–20)
Intensive care unit length of stay, median (IQR), h	51 (42–86)
Hospital length of stay, median (IQR), d	6 (5–9)

IQR indicates interquartile range; PRBC, packed red blood cells.

DISCUSSION

Whether to perform mitral valve surgery in patients with severe mitral regurgitation and advanced heart failure is controversial. The functional, or secondary, mitral insufficiency noted in these cases is usually a result of annular dilatation, papillary muscle displacement, and chordal tethering, with the mitral leaflets being anatomically normal.[13] Because the main problem in these circumstances is dysfunction of the left ventricle rather than of the mitral valve itself, it is not clear what the optimal approach should be in correcting the mitral regurgitation. However, according to the 2008 focused update of the 2006 American College of Cardiology and American Heart Association guidelines, "mitral annuloplasty alone with an undersized annuloplasty ring is often effective in correcting the mitral regurgitation."[14] The purpose of this retrospective study was not to define the indications for surgery but rather to evaluate the results of a minimally invasive approach in these high-risk patients.

Traditionally, mitral surgery has been performed via a median sternotomy approach, but, in the past decade, minimally invasive approaches have demonstrated improved outcomes. Although minimally invasive surgery seems to preferentially benefit higher-risk patients,[9–11] published series have focused on minimally invasive mitral surgery for younger patients with fewer comorbidities and preserved left ventricular function.[15,16] Therefore, data concerning minimally invasive valve surgery in patients with reduced left ventricular function are quite limited. Indeed, some centers consider poor left ventricular systolic function a contraindication to minimally invasive surgery.[17]

Previous published series of isolated mitral valve surgery performed via median sternotomy in patients with a mean ejection fraction of 30% or less have demonstrated a 30-day mortality[18–21] ranging from 1.6% to 6.1%. Using a minimally invasive approach, Walther and colleagues[22] performed mitral valve surgery in 79 patients with dilated cardiomyopathy and a mean ± SD ejection fraction of 21% ± 8%, demonstrating an overall mortality rate of 8.8%. Our data demonstrated a 30-day mortality of 2.8% and a low postoperative complication rate.

TABLE 3. Postoperative Complications

Variables	Minimal Invasive (N = 71)
Morbidity and mortality	13 (18.3)
30-d mortality	2 (2.8)
Reoperation for bleeding	0
Renal failure	5 (7)
Prolonged intubation	10 (14)
Reintubation	5 (7)
Sternal deep wound infection	0
Cerebrovascular accident	1 (1.4)
Atrial fibrillation	7 (10)

Values are presented as number (percentage).

Presently, the most common type of surgery performed for functional mitral regurgitation is an undersized mitral annuloplasty, which was popularized by Bolling and colleagues.[23] In this technique, a small (size, 24–26 mm) mitral annuloplasty ring is used, which causes a reduction in the anteroposterior (septolateral) diameter of the mitral valve, thus increasing the surface of coaptation. The drawback with the undersized annuloplasty technique is the high rate of failure. In a study of 585 patients who underwent undersized annuloplasty surgery during a 17-year period, the authors noted that moderate to severe mitral regurgitation developed in 28% of the patients by 6 months after operation.[24] It is believed that the reason for the recurrent mitral regurgitation is that the underlying process of left ventricular dilatation from negative left ventricular remodeling continues despite having "fixed" the mitral valve. Mitral valve replacement is also a reasonable option because of its reliability and reproducibility. It may be considered in patients with multiple comorbidities or severe tethering of both mitral valve leaflets. Because of high failure rates in patients with severe tethering of the mitral leaflets, Calafiore and colleagues[25] recommend mitral valve replacement when the distance between the coaptation point of the leaflets and the plane of the mitral annulus exceeds 10 mm. This is the approach that we used in the patients of this study.

In the present study, we also noted an incidence of postoperative atrial fibrillation of 10%, which is lower than expected. In a previous study, we evaluated the incidence of atrial fibrillation in patients undergoing minimally invasive valve surgery and noted a significant reduction in the development of postoperative atrial fibrillation.[26] We speculate that, because of the less surgical trauma associated with minimally invasive valve surgery, there is less inflammation and, subsequently, less atrial fibrillation.

Study Limitations

This was a single-center retrospective study. All operations were performed by a single surgeon (J.L.), who is the senior author. Thus, our findings can only be cautiously generalized. The follow-up period is limited to 30 days. Finally, this study does not address the clinical indications for mitral surgery in patients with severe left ventricular dysfunction and functional mitral insufficiency.

CONCLUSIONS

In conclusion, in patients with severe functional mitral regurgitation and severe left ventricular dysfunction, minimally invasive mitral valve surgery using the technique described herein can be performed with low morbidity and mortality and should be considered in these patients.

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CLINICAL PERSPECTIVE

This report describes a series of 71 patients with functional mitral regurgitation and an ejection fraction of 35% or less who underwent minimally invasive mitral valve repair or replacement through a right anterior thoracotomy. This was a high-risk cohort with a mean ejection fraction of only 27%. More than one third of the patients had had previous heart surgery. More than half of the patients had mitral valve replacement, and the rest had mitral valve repair with a reduction ring annuloplasty. Dr Santana and his group reported excellent outcomes in this high-risk group, with a 30-day mortality of 2.8% and acceptable morbidity, showing the feasibility of performing minimally invasive surgery in these sick patients at experienced centers. The limitation of this study is that it is a single-center retrospective series and is thus subject to selection bias. Moreover, all of the cases were performed by a single surgeon who is extremely experienced in these techniques. Bearing in mind these limitations, this impressive case series does suggest that, in experienced hands and with meticulous attention to surgical technique and myocardial protection, minimally invasive mitral valve surgery can yield excellent outcomes, even in very high-risk patients.

