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Five Years of Less Invasive Mitral Valve Surgery: From Experimental to Routine Approach

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ABSTRACT

Background: In the last five years, mitral valve surgery has changed fundamentally. This study reviews our experience in less invasive mitral valve surgery (LIMS) during that time.

Methods: LIMS was performed in 449 patients (age 59 ± 14 years, 237 female) via a right lateral minithoracotomy. The operations included 42 "redo" procedures. After initially experiencing a high number of complications, we have modified and simplified the procedure. After using the Port-Access™ Technique (PAT) in the earlier stages of our series, in the last 226 patients the aorta was clamped directly using the transthoracic clamping (Chitwood) technique (TTC). In our most recent cases, PAT was only employed in redo procedures. In 336 patients, the procedure was completed with robotic assistance, and in 23 of these we used the da Vinci telemanipulation system.

Results: The mitral valve was repaired in 327 patients and replaced in 122 patients. In 100 patients, additional surgical procedures (TVR n = 13, ASD closure n = 16, left atrial ablation n = 65, left atrial reduction plasty n = 6) were performed. Bypass and clamp time, including times for both additional and redo procedures, were 124 ± 44 min. and 65 ± 29 min. in the overall series. Complications, which were mainly neurological, were fewer in the TTC group than in the PAT group (n = 4 vs. n = 17; p <0.04). Hospital mortality was 3.1% and 5.2%, respectively, for the two groups. There were no additional costs associated with using the TTC technique compared to conventional procedures. Mean survival rate was 96.3% at a mean follow-up of 727 ± 451 days (95% CI, 677 to 779).

Conclusions: Less invasive mitral valve surgery enables the patient to avoid the surgical trauma associated with sternotomy. It has developed into a reliable technique with reproducible results for primary, redo, and additional procedures. LIMS has become the standard approach for mitral valve operations at our institution.

INTRODUCTION

Less invasive techniques for heart valve surgery have greatly evolved over the past five years [Carpentier 1996, Arom 1997, Benetti 1997, Cosgrove 1998, Gulielmos 1998, Loulmet 1998]. We have previously shown that surgical and technological improvements in less invasive mitral valve surgery (LIMS) have enhanced the possibility of achieve the same quality standards as conventional mitral valve surgery with less surgical trauma, decreased pain and recovery time, and better cosmesis, resulting in improved patient satisfaction [Mohr 1999]. In the beginning there were some limitations. The procedure was performed by only a few experienced surgeons and patient selection was restricted. The continuous development of both the surgical and the technical side of the procedure have opened the way for a more widespread application [Autschbach 2000].

This article is a review of our experience with 449 minimally invasive mitral valve operations.

MATERIALS AND METHODS

Minimally invasive mitral valve surgery was performed in 449 cases (237 women, 212 men, mean age 59 ± 14 years) at our institution from June 1996 until July 2001. The study includes 42 patients who underwent redo operations after previous cardiac surgery for different reasons (Table 1,). Mean left ventricular ejection fraction was 57% ± 16%. Twenty-three patients suffered from dilative cardiomyopathy with an ejection fraction lower than 25%. Three-hundred and eighty-nine patients had mitral regurgitation of grade III or IV, 54 had combined lesions, 11 had acute endocarditis, 2 had myxoma, and 1 had fibroelastoma of the mitral valve. The majority of patients (n = 355) were in preoperative New York Heart Association (NYHA) functional class II or III. Preoperatively, 247 patients were in sinus rhythm, 183 had atrial fibrillation, and 19 were permanently paced. In all cases cardiopulmonary bypass was performed using femoro-femoral or femoro-axillary cannulation. For aortic clamping, in the first 209 patients the Port-Access technique (PAT) was used [Mohr 1998]. More recently, in 226 cases the aorta was clamped directly using the transthoracic clamp (TTC)

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Table 1. History of Previous Cardiac Surgery in Redo Minimally Invasive Mitral Valve Surgery.

Previous cardiac surgery	number of patients
mitral valve repair	n = 17
mitral valve replacement	n = 6
aortic valve replacement	n = 3
ASD closure	n = 2
CABG	n = 13
Resection of atrial myxoma	n = 1

CABG = coronary artery bypass grafting

described by Chitwood et al. [Chitwood 1997]. In the later series the PAT was only used for redo patients who had prior valve surgery or non-CABG heart surgery (n = 29). The technique of the Port Access System (Ethicon, Inc., Somerville, NJ) and the evolution of this technique has been described by others and our group in detail [Pompili 1996, Schwartz 1996, Mohr 1998]. In patients with prior CABG, systemic cooling to 24°C was performed during a period of spontaneous or induced ventricular fibrillation (n = 13).

The surgical field was constantly flushed with CO_2. To monitor possible air bubbles during de-airing, transcranial Doppler measurement of the middle cerebral arteries was performed [Schneider 2000].

In the majority of cases (n = 366) the voice-controlled robotic arm (AESOP 3000, Automated Endoscope System for Optimal Positioning; Computer Motion, Santa Barbara, CA) was used for videoscopic guidance, and in 23 patients mitral valve surgery was completed using the da Vinci telemanipulator system (Intuitive Surgical, Mountain View, CA). The telemanipulation system has been described in detail elsewhere [Falk 1999b, Falk 1999c].

To treat chronic atrial fibrillation, we employed high radiofrequency ablation in 65 patients. A defined line in the left atrium starting from the mitral valve annulus separating the pulmonary veins was made to ablate re-entry anchor circuits. The technique of atrial fibrillation has been described earlier [Kottkamp 1999]. Additional surgical procedures were performed in 35 patients (tricuspid valve repair (n = 13), ASD closure (n = 16), and left atrial reduction plasty (n = 6).

Indications for the minimally invasive approach now include the elderly and high-risk patients. The majority of recent mitral valve procedures have been performed using the less invasive technique.

From June 1996 until October 1999, surgery was performed by one surgeon. Since then four additional surgeons have been trained to perform LIMS.

Statistical analyses were performed using the Mann-Whitney-U and the Chi-square tests.

RESULTS

The mitral valve was repaired in 327 patients. Repairs included quadrangular resection and ring implantation, complete ring implantation, Alfieri-plasty, Whooler-plasty, chordae replacement, and siding plasty. In 122 cases, the mitral valve was replaced using mechanical valves (St. Jude Medical, n = 95; ATS, n = 3) and biological valves (Glycar quadricust, n = 16; Carpentier Baxter, n = 5; Medtronic Mosaic, n = 3). The mean length of the surgical incision was 4.3 ± 0.5 cm. Time of surgery for all procedures was 176 ± 56 min., with cardiopulmonary bypass time of 125 ± 42 min. and clamp time of 67 ± 29 min. For single mitral valve surgery, the surgery time was 172 ± 58 min., cardiopulmonary bypass time was 120 ± 41 min., and clamp time 64 ± 28 min. Time of surgery for mitral valve surgery and additional left atrial ablation was 187 ± 45 min., cardiopulmonary bypass time was 134 ± 40 min., and clamp time was 79 ± 31 min. In the group receiving mitral valve and additional surgery, the surgery time was 190 ± 48 min., cardiopulmonary bypass time was 137 ± 39 min., and clamp time was 78 ± 26 min. In the redo surgery group, the surgery time was 183 ± 60 min., cardiopulmonary bypass time was 130 ± 53 min., and clamp time was 62 ± 26 min. There were no statistical differences between all groups (Figure 1,). Using the Port-Access technique or the Chitwood technique also did not result in any statistical differences in times for surgery, cardiopulmonary bypass, and clamping (Figure 2,). After an initial learning phase, the time requirements for surgery, bypass, and clamping with one experienced surgeon could be reduced. Following the introduction of additional surgeons, we noticed a slight increase in procedure times (Figure 3,).

Intraoperative transesophageal echocardiography showed regular valve function after mitral valve repair in all except nine patients, who were subsequently converted to valve replacement after failed repairs (stenosis or residual regurgitation). These patients were in the early series (nos. 1-80) of less invasive mitral surgery at out institution. All patients with mitral valve replacement had a good functional result intraoperatively.

The median intubation time was 12 hours (range 3 to 233 hours) with 27 patients requiring ventilation longer than 72 hours. Median ICU stay was one day (range 0.5 to 58). The median duration of hospitalization was 11 days (range 2 to 60).

Differences were noted in the number and type of complications resulting from the use of the PAT or TTC technique. Hospital mortality in the PAT group was 5.2% and in the TTC group 3.1% (n.s.). There was a significant difference in neurological complications, consisting of transient hemiparesis or stroke (PAT group, n = 17 (8.1%); TTC group, n = 4 (1.8%); $p < 0.05$). In the PAT series, four patients had to be converted to conventional sternotomy because of acute retrograde aortic dissection (n = 3) or injury to the left ventricular posterior wall (n = 1) (see previous reports for detail [Mohr 1998, Mohr 1999]). There were no aortic dissections or ventricular injuries in the TTC series. Typical postoperative complications, such as bleeding, pulmonary dysfunction, arrhythmias, and renal failure were on an equal level in both groups (Table 2,). The better overall results in the TTC group may be explained by the fact that most of the surgical complications in the PAT group were noticed in the early phase of introduction of LIMS. After a new endoclamp design was introduced, no more aortic dissections were seen. The number of neurological complications in the PAT group decreased

Table 2. Comparison of Postoperative Complications.

Complications Technique	PAT (n = 209)	Chitwood (n = 226)
Bleeding	14 (6.7%)	11 (4.8%)
Pulmonary	21 (10.4%)	14 (6.2%)
aortic dissection	3 (1.4%)	0 (0%)
Neurological* (stroke, transient hemiplegia)	17 (8.1%)	4 (1.8%)
Arrhythmias (supraventricular)	45 (21.5%)	43 (19.1%)
Renal failure	4 (1.9%)	4 (1.8%)
low cardiac output	4 (1.9%)	1 (0.5%)
Death	11 (5.2%)	7 (3.1%)

PAT = Port-Access technique, Chitwood = transaortic clamping with the Chitwood clamp
* $p < 0.05$

after implementation of transcranial Doppler monitoring for the detection of balloon migration [Schneider 1998].

As of November 2000, follow-up was completed in 312 patients. Twelve patients who had undergone mitral valve repair developed mitral valve regurgitation greater than grade 2. Ten of them underwent uneventful mitral valve replacement through a median sternotomy. In one patient the mitral valve was replaced, and in another it was re-repaired through the right lateral minithoracotomy. The majority of these patients (n = 8) were operated on in the early series. Four patients showed paravalvular leakage after initially mitral valve replacement and were revised through a median sternotomy approach. Two patients developed acute endocarditis, one after mitral valve replacement (Glycar quadricust) and another after mitral valve repair. In both patients the mitral valve was replaced through median sternotomy. In three patients an acute torn ring was reported on postoperative days 3, 6, and 19, respectively. These patients received conventional mitral valve replacement. In one patient the echocardiogram at discharge showed a new atrial septal defect, which was subsequently closed through the right lateral minimally invasive approach. In two patients who received mitral valve repair and suffered from dilative cardiomyopathy, the clinical situation deteriorated after an initial improvement. Both patients were transplanted successfully (Table 3,). Sinus rhythm was restored in 89% (58/65) of the patients who underwent additional radiofrequency ablation. In follow-up after one month, a stable sinus rhythm was reported in 86% (56/65) of these patients. There were no pulmonary vein stenoses detected.

DISCUSSION

This article describes the results of five years of experience with less invasive mitral valve surgery in a single center. As has been pointed out by Randall [Randall 2000], many surgeons would agree that the best visualization of the mitral valve is not through a median sternotomy, but through the right chest approach. This approach gives a direct line of view of the left atriotomy and the mitral valve because the image of the mitral valve annulus is perpendicular to the visual plane. To allow a minimally invasive approach to the mitral valve along this plane, it is best to use video assistance. Developments in video-assisted surgery paved the way for a "paradigm shift" in mitral valve surgery in the mid-1990s. In the past five years, minimally invasive surgical techniques have developed from experimental methods to widespread clinical application [Schroeyers 2001]. Numerous methods for less invasive mitral valve surgery have been described.

The program of less-invasive mitral valve surgery at our institution started in June 1996 using the Port-Access technique. Our initial results were somewhat disappointing, reflecting a learning curve from both the surgical and the technical side. After a number of modifications [Mohr 1999], Port-Access mitral valve surgery was performed with good results. However, some procedure-related complications, especially neurological complications due to balloon migration, and economic concerns about the additional cost for the catheter led us to adopt the transthoracic aortic clamp first described by Chitwood et al. [Chitwood 1997]. While procedure and bypass times are equivalent in both groups (Figure 2,), the TTC technique has some important benefits. The 226 TTC patients had significantly fewer neurological complications than the Port-Access patients. TTC also provides some cost savings over the standard sternotomy operation.

As experience with the TTC technique grew, the patient selection criteria were expanded to include high risk groups. The approach was used in 42 patients for re-operation after a previous sternotomy. Due to the small right lateral incision and the direct approach to the mitral valve, the minimally invasive access kept the dissection of adhesions to a minimum and made a significantly shorter dissection time possible, thereby reducing the risk of cardiac injury and the need for of re-operation at all. Recently, we have adopted additional surgical procedures such as radiofrequency ablation for the treatment of chronic atrial fibrillation, which was used for 65 patients. There is no need to enlarge the thoracotomy incision for a complete isolation of the left atrium in an ablation procedure. The 86% restoration rate for stable sinus rhythm is promising [Walther 2000]. In our study, we did not observe pulmonary vein stenosis or other procedure-related complications described in the literature [Robbins 1998].

Procedure and bypass times were not significantly affected by introducing additional procedures. The procedures were

Table 3. Reasons for Re-operation in Follow-up of 312 Patients.

Re-operation in follow-up Reason	N	Time frame after initial surgery (POD)
MV regurgitation > II° after primary MVR	12	339 ± 483
acute ring torn after primary MVR	3	9 ± 9
paravalvular leakage after primary MVP	4	81 ± 62
acute endocarditis	2	853 ± 563
progressive heart failure after primary MVR (history of cardiomyopathy)	2	348 ± 274

POD = postoperative day, MVR = mitral valve repair, MVP = mitral valve replacement

performed in a reasonable time frame as compared to single mitral valve surgery (Figure 2,) or conventional surgery.

Despite all modifications of the procedure and the improvements that contribute to its "user-friendliness," there is still a learning curve for the surgeon who wishes to adopt the technique. However, our results showed only slight prolongation of procedure and bypass times (Figure 3,) and only a slight increase of intraoperative and postoperative complications when additional surgeons were introduced.

In contrast to the widespread acceptance of robotic videoscopic guidance, the additional benefit of using a telemanipulation system for remote mitral valve repair is still uncertain. While total endoscopic coronary artery bypass grafting has been successfully performed using the da Vinci system [Falk 1999b, Loulmet 1999], there are some limitations for mitral valve surgery. Manual preparations, such as opening the left atrium and providing retraction for exposure of the valve, are still necessary. However, access using a telemanipulation system is comparable to that of other minimally invasive mitral valve procedures. Our initial clinical experience shows that the computer-enhanced telemanipulation system allows a precise and controlled mitral valve repair [Falk 1999a, Mohr 2001], with the technical potential for a completely endoscopic procedure.

Follow-up results indicated that this surgery produces good mid-term results in the treatment of mitral valve disease. The majority of patients who underwent re-operation were operated on initially in the early phase of our less invasive mitral valve surgery. The re-operation rate in the TTC group was 3.1%, which is comparable to the results shown in the STS-Database [STS National Database]. Patients reported little or no pain and were satisfied with the results and the cosmesis. Younger and more active patients were pleased because the resumption of vigorous activity was facilitated by avoiding a median sternotomy and using an atraumatic access.

CONCLUSION

Our clinical results demonstrate that less invasive mitral valve surgery has developed from an experimental method to a reliable technique with reproducible results for primary, redo, and additional procedures. The mid-term follow-up promises functional results comparable to conventional procedures. The procedure also provides a benefit for the patient in terms of cosmesis and avoidance of sternotomy-related complications. The procedure can be performed successfully by most surgeons after moderate training and is now the standard approach for mitral valve surgery at our institution.

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