Mitral Valve Surgery Can Now Routinely Be Performed Endoscopically

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Background—There is an increasing interest in minimally invasive cardiac surgery.

Methods and Results—Since February 1, 1997 till April 1, 2002, 306 patients underwent endoscopic mitral valve surgery (226 repair, MVP; 80 replacement, MVR). Predominant valve pathology was degenerative in MVP (83.6%) and rheumatic in MVR (65%). Mean age was 61.5±12.9 years. Median preoperative functional class (MVP+MVR) and mitral regurgitation (MVP) were II and 4+. Statistical analysis included Kaplan-Meier and Cox regression methods. Mean follow-up was 19.6±17.3 months and complete. The procedure was successfully performed in all but 6 patients. Hospital mortality included 3 patients (1%) and was technology related in one. Postoperative morbidity included aggressive re-exploration (8.5%), new onset atrial fibrillation (17.0%), and pacemaker implantation (2.3%). There were 1 early and 10 late reoperations, 5 of which were because of endocarditis. Freedom from mitral valve reoperation at 4 years was 91±3.5%. No risk factors for reoperation could be detected. Echocardiographic follow-up showed a median degree of mitral regurgitation (MVP) of 0 and a small paravalvular leak in four patients (MVR). Ninety-four percent of the patients reported no or mild postoperative pain and 99.3% felt they had an esthetically pleasing scar. Ninety-three percent would choose the same procedure again and 46.1% were back at work within 4 weeks.

Conclusions—Endoscopic mitral valve surgery can be performed safely but definitely requires a learning curve. Good results and a high patient satisfaction are guaranteed. It is now our exclusive approach for isolated atrioventricular valve disease. (Circulation. 2003;108[suppl II]:II-48-II-54.)

Key-words: mitral valve ■ endoscopic ■ surgery ■ minimally invasive

Minimally invasive cardiac surgery is increasingly popular. In mitral valve surgery, much attention has been given to the partial sternotomy approach as advocated by the Cleveland Clinic group. However, another attractive technique is an endoscopic, video-assisted approach via the right chest. Visualization of the operative field is obtained by means of an endoscope and the technique requires peripheral cannulation for the extracorporeal circuit as well as an endo-aortic balloon clamping technique. Animal experiments started in the early 1990s and clinical application was initiated several years later. We started our minimally invasive mitral valve surgery program in February 1997. The purpose of this paper is to report our total experience for mitral valve surgery using this endoscopic approach.

Methods

Patients
A total of 306 patients underwent endoscopic mitral valve surgery between February 1, 1997 and April 1, 2002. Mitral valve repair (MVP) was performed in 226 cases and mitral valve replacement (MVR) in 80. All patients were informed and able to prefer a standard sternotomy. In 2 patients, the procedure was a reoperation after previous commissurotomy. All other procedures were primary interventions. All but 1 interventions were elective. Patients with isolated mitral valve regurgitation underwent MVP and patients with mitral valve stenosis, mixed lesions or extremely complex reparative requirements underwent MVR.

Preoperative patient characteristics are depicted in Table 1. Preoperative mitral valve pathology is detailed in Table 2. Carpentier’s classification was used to describe valve dysfunction in patients with mitral valve regurgitation. Median preoperative degree of mitral valve regurgitation was 4. Mean gradient in patients with mitral valve stenosis was 12.6±5.2 mm Hg.

Postoperatively, chest tubes remained 48 hours (or longer if necessary), regardless whether bleeding stopped earlier and chest tube output became serous fluid. Postoperative analgesia consisted of 10 mg piritramide (Dipidolor®, Janssen-Cilag, Beerse, Belgium) IV and 10 mg piritramide IM at the time sedation was stopped in the ICU. Once the patient was extubated, analgetics were only given at the patients convenience. The patients were anticoagulated with fenprocoumon (Hoffmann, Grenzach-Wyhlen, Germany) for 3 months unless they were in atrial fibrillation or underwent mechanical valve replacement.

Surgical Technique

The surgical technique has been extensively reported elsewhere. In brief, the entire procedure is performed through a 4 cm working
port which is located in the right inframammary groove, usually in the 4th intercostal space. Long shafted instruments are a prerequisite to perform the operation. Visualization is accomplished with an endoscope through a separate port in the 4th intercostal space at the anterior axillary line. Another port is used for suction and CO2 insufflation. A left atrial retractor is introduced through a stab wound in the 4th intercostal space, just lateral to the right internal mammary artery. A femoral-femoral extracorporeal circulation is used as well as an endo-aortic balloon and antegrade cold crystalloid cardioplegia. The whole procedure is performed using a double lumen endotracheal tube and TEE guidance.

When performing MVP, the annuloplasty stitches are put first, then the valve is analyzed and repaired using standard techniques. In the beginning of our experience, we elected ‘easy’ MVP cases. As the experience grew, indications became more liberal and to date only rheumatic mitral valve pathology is for us an indication for MVR. All other pathology (including Barlow’s disease and extensive calcifications) is repaired.

For MVR procedures, the valve is excised but the entire anterior and posterior subvalvular apparatus is preserved. Then, atrially placed pledgetted 2/0 Ticron (Davis & Geck, Gosport, UK) U-stitch sutures are inserted along the mitral valve annulus. The mitral valve prosthesis is introduced through the working port and tied in place. Usually a mechanical valve is used for patients below 65 years of age and a bioprosthesis above 65 years.

De-airing at the end of the procedure is done using a venting catheter and inflation of the left lung before left atrial closure in addition to relying on the CO2 for flooding of the operative field.

Finally, all wounds are closed intracutaneously. Figure 1 shows the operative setup, Figure 2 and 3 an example of complex repair cases and Figure 4 the immediate postoperative result.

Our current contra-indications for the applicability of this technique are: pectus excavatus, dilated ascending aorta (>40 mm), aortic regurgitation > grade 1, severe peripheral vascular disease and severe right pleural adhesions.

Follow-Up
All patients were seen 6 to 8 weeks postoperatively and then referred to their cardiologist for further follow-up. Data collection was performed between October 2001 and May 2002. The official guidelines were used to complete a follow-up questionnaire. In addition, patients were asked about the amount of pain they experienced at the time of the operation, how fast postoperatively they had regained professional or expected activity, whether they were pleased with the esthetic result and whether they would prefer this technique over standard median sternotomy if they had to choose...
Mean patient follow-up was 19.6 ± 17.3 months (range 0 to 60.1) and was 100% complete. A total of 490.8 patient-years was available for analysis. The NYHA functional class at follow-up in 297 survivors was I in 243 patients, II in 48, III in 4, and IV in 2. At follow-up, 225 patients were in normal sinus rhythm, 54 were in atrial fibrillation, 12 had pacemaker rhythm and 6 another rhythm.

Assessment of Technical Durability
All patients had an immediate intraoperative postrepair TEE to assess mitral valve repair and valve prosthesis function. Technical durability was assessed by the incidence of reoperation and by the latest echocardiographic follow-up which was 97.9% complete.

Data Analysis
The design of the study was retrospective and data are expressed as the mean ± SD. Survival and event-free estimates were determined by Kaplan-Meier analysis and expressed as proportion ± SE. All Kaplan-Meier analyses were performed using the total patient population of 306 patients because it was the intention to treat all these patients endoscopically. For analysis of freedom from reoperation, anticoagulation related complications and endocarditis, we wanted to focus this on endoscopically treated patients and therefore, the 6 patients who underwent an immediate intra-operative conversion to sternotomy were censored on the day of operation.

Analysis was performed with the Statistica package Release 5.1 (StatSoft, Tulsa, OK).

Risk factors for outcome were evaluated using Cox proportional hazard models. The first event was used as outcome. Because none of the risk factors showed a statistical significance of less or equal than 0.10 at univariate analysis, no further multivariate Cox regression model could be applied. The potential risk factors entered into the analysis of reoperation are listed in Appendix A.

Results

Immediate Operative Success
A total of 300 patients had a complete endoscopic procedure. The remaining 6 patients (3 MVP, 3 MVR) required intra-

### TABLE 3. Mitral Valve Repair Techniques (n=226)

<table>
<thead>
<tr>
<th>Valve Repair Technique</th>
<th>N</th>
<th>% of 226</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior leaflet quadrangular resection</td>
<td>158</td>
<td>69.9</td>
</tr>
<tr>
<td>Posterior leaflet sliding plasty</td>
<td>80</td>
<td>35.4</td>
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<tr>
<td>Anterior leaflet triangular resection</td>
<td>11</td>
<td>4.9</td>
</tr>
<tr>
<td>Anterior leaflet PTFE* neochordae</td>
<td>19</td>
<td>8.4</td>
</tr>
<tr>
<td>Both leaflets resection</td>
<td>5</td>
<td>2.2</td>
</tr>
<tr>
<td>Both leaflets PTFE* neochordae</td>
<td>3</td>
<td>1.3</td>
</tr>
<tr>
<td>Chordal shortening</td>
<td>3</td>
<td>1.3</td>
</tr>
<tr>
<td>Chordal transfer</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>Calcium debridement</td>
<td>8</td>
<td>3.5</td>
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<td>Commissuroplasty</td>
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<td></td>
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<tr>
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<td>0.4</td>
</tr>
<tr>
<td>Posteromedial</td>
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<td>0.4</td>
</tr>
<tr>
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<td></td>
<td></td>
</tr>
<tr>
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<td></td>
</tr>
<tr>
<td>Carpentier-Edwards Physio ring</td>
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<td>97.8</td>
</tr>
<tr>
<td>Carpentier-Edwards Classic ring</td>
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<tr>
<td>38</td>
<td>9</td>
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</table>

*PTFE, Polytetrafluoroethylene.
operative conversion to median sternotomy. Reasons for conversion were: intra-operative aortic dissection (n=2), inadequate bypass flow via the common femoral artery (n=3), and iliac artery perforation (n=1). One patient with aortic dissection died on the table and the other one suffered a stroke with residual hemiplegia. One other patient developed sternitis, was eventually discharged but died on postoperative day 75. All other patients recovered uneventfully.

The techniques used to perform mitral valve repair are depicted in Table 3. Associated procedures were: tricuspid annuloplasty (7 MVP, 6 MVR), atrial arrhythmia ablation (6 MVP, 6 MVR), ASD (3 MVP, 1 MVR), tricuspid annuloplasty, and atrial arrhythmia ablation (2 MVP, 1 MVR), and finally a fibro-elastoma of the aortic valve (MVP).

In MVR patients (n=80), a bioprosthesis (Edwards Lifesciences, Irvine, CA) was implanted in 30 patients and a mechanical valve (ATS Inc, Minneapolis, MN; n=45; or St Jude Medical, Minneapolis, MN; n=5) in 50.

Mean aortic cross-clamp and cardiopulmonary bypass times in 223 completed endoscopic MVP procedures were 91.2±22.5 minutes. (range 24 to 160) and 131.7±28.9 minutes (range 74 to 246), respectively; in 77 completed MVR patients it was 101.5±29.3 minutes. (range 60 to 239), and 146.1±44.2 minutes. (range 94 to 359), respectively.

### Postoperative Course and Events

Thirty day mortality was 1% (n=3). One patient underwent a reintervention for failed endoscopic mitral valve repair on day 1. The valve was replaced via median sternotomy but the patient died on day 5 from low cardiac output syndrome. One MVR patient died in the operating room due to aortic dissection. The third patient underwent endoscopic MVR and tricuspid valve repair. Postoperatively she underwent 2 reinterventions for continued bleeding but died on postoperative day 4 from DIC.

Aggressive postoperative reintervention (using the same endoscopic approach) for suspected bleeding was performed in 26 patients (8.5%). Active bleeding was found in 14 patients. In two patients, a median sternotomy had to be performed to control the bleeding source. Other postoperative morbidity is mentioned in Table 4.

Mean postoperative chest tube output was 1230±1113 mL (median 790 mL); 64.7% of the patients had a total chest tube output <1000 mL. Mean ICU stay was 41±55.5 hours (median 24 hours) with 65.4% being discharged within 24 hours and an additional 19% within 48 hours. Mean hospital stay was 9.1±6 days (median 8 days) with 66% of the patients discharged within 8 days.

### Technical Durability

#### Reoperation

There were 1 early (MVP, see earlier) and 10 late reoperations (6 MVP and 4 MVR). Causes for late reoperation were new onset endocarditis (n=5; 4 MVP and 1 MVR), recurrent mitral valve regurgitation (n=2; 1 following myocardial infarction and one intrinsic valvular, both MVP), pannus overgrowth (n=1; MVR), valve thrombosis (n=1; MVR), and paravalvular leak (n=1; MVR). All but 1 (paravalvular leak) of these patients underwent valve replacement using median sternotomy as surgical approach.

The patient undergoing early reoperation died on postoperative day 5. No other patient died at reoperation. The freedom from mitral valve reoperation was 99.7±0.3% at 30 days, 97.7±1.0% at 1 year and 91±3.5% at 4 years (Figure 5). The linearized incidence rate was 2.3±0.03% per patient-year. For MVP the freedom from reoperation at 4 years was 93.3±2.6% and for MVR it was 90.5±5.3%, also at 4 years. No risk factors for reoperation could be detected univariately.
Echocardiographic Follow-Up
Late transthoracic echocardiographic (TTE) follow-up was available in 284 (215 of 216 MVP and 69 of 74 MVR) of 290 patients (97.9%) who had a completed endoscopic procedure and no reoperation via median sternotomy. Mean echocardiographic follow-up was 15±16 months (range 0.1 to 54.8). Median degree of mitral valve regurgitation (MVP) was 0. Mitral valve regurgitation was absent in 145 patients, grade 1+ in 56, grade 2+ in 12, and grade 3+ in 2 patients.

Four MVR patients had a small paravalvular leak on follow-up TTE. None of them has signs of hemolysis and they are treated conservatively.

Other Follow-Up Events
There were 3 early (1 MVP, 2 MVR) and 6 late deaths (3 MVP, 3 MVR). Causes of late death were sudden death (n=1), postoperatively after cholecystectomy (n=1), pneumonia (n=1), small bowel perforation (n=1), stroke (n=1), and sternitis (n=1; converted patient). Survival for the total patient group (n=306) was 99.0±0.6%, 97.3±1.0% and 95.4±1.7% at 30 days, 1 and 4 years postoperatively, respectively. The linearized incidence rate for death was 1.7±0.02% per patient-year. For MVP and MVR survival at 4 years was 97.3±1.4% and 92.0±3.6%, respectively.

There was 1 early stroke (aortic dissection case). During follow-up, another 17 first (14 MVP, 3 MVR) and 3 second (MVP) anticoagulation related complications occurred. There was one bioprosthetic valve thrombosis that was reoperated (see earlier). One cerebral bleeding (MVR) was lethal but none of the other events resulted in permanent neurologic damage. The linearized incidence rate of anticoagulation related complications was 3.8±0.04% per patient-year. Freedom from the first anticoagulation related complication was 99±0.6%, 95±1.5%, and 90±2.7% at 30 days, 1 and 4 years postoperatively (Figure 5). For MVP patients, the freedom from anticoagulation related complications was 83.7±5.1% at 4 years with a linearized incidence rate of 5.2±0.08% per patient-year. For MVR patients the freedom at 4 years was 97±1.9% and the linearized rate 1.7±0.07% per patient-year.

Six patients (4 MVP, 2 MVR) experienced new onset endocarditis during follow-up and 5 (4 MVP, 1 MVR) were reoperated using a median sternotomy. All of them underwent valve replacement. Freedom from endocarditis was 100±0%, 98.9±0.7%, 95.5±1.9%, at 30 days, 1 and 4 years postoperatively. The linearized incidence rate was 1.3±0.02% per patient-year.
One MVP patient was reoperated 7 months postoperatively for acute type A aortic dissection. He had an ascending and partial arch replacement and is currently in NYHA class I.

**Patient Satisfaction**

**Procedure Related Pain**
Of all patients, 94.2% stated they experienced minimal to almost no procedure related pain. None of the remainder mentioned excessive procedure related pain.

**Postoperative Recovery**
There were 46.1% patients back at work or at routine activity within 4 weeks postoperatively. Another 25.3% were back at this activity level within 8 weeks postoperatively.

**Cosmesis**
An overwhelming 99.3% of the patients were extremely pleased with the cosmetic result of the procedure. In 32.8% of the patients, the scar was hardly visible any more.

**Choose Again?**
In 93.5% of the cases, the patient would choose the same procedure if they were to face the same operation again.

**Discussion**

The right chest approach to the mitral valve has proved to be reliable, both in the early days of mitral valve surgery and in reoperative surgery. Adequate technical tools have therefore been developed by Heartport Inc (now Cardiovations, Johnson & Johnson, Sommerville, NJ) to enable surgical intervention on the mitral valve using a 4 cm right thoracotomy approach.

We have adopted this technique in February 1997 for isolated atrioventricular valve disease. Our previous experience with thoracoscopic mammary artery harvesting certainly was very helpful in making the transition from a standard sternotomy approach to this video-assisted mitral valve surgical approach. Nevertheless, there still was a considerable learning curve as reflected in the cross-clamp and cardiopulmonary bypass times. However, we expect the learning curve to shorten considerably as the younger generation of surgeons, trained in laparoscopy, is now increasingly performing mitral valve surgery.

This series comprises our total experience of video-assisted mitral valve surgery from the first case in February 1, 1997 till April 1, 2002. Interestingly, we were able to maintain our early experience of this surgical approach throughout the entire series and only one patient underwent early reoperation for failure of mitral valve repair. This indicates that an experienced mitral valve surgeon can adopt this operative technique provided some experience with thoracoscopic procedures has been obtained.

The operative mortality of 1%, also approached by other groups performing similar types of minimally invasive mitral valve surgery, is substantially lower than the reported operative mortality rates for MVP (approximately 2%) and MVR (approximately 6%) by the Society of Thoracic Surgeons. Selection bias may have contributed to a low operative mortality in the first 2 years of the experience but once the technique was fully adopted by all personnel, no patients were deprived from this technique on the basis of an increased operative risk. In addition, we stimulate early surgical referral since operative outcome decreases with longstanding disease or symptoms. Also, the longer the pathology exists, the larger the atrium becomes and the more a degenerated leaflet can deteriorate, rendering the (repair) procedure more hazardous. Besides, mitral valve surgery with the presented technique is more difficult to perform in enlarged versus smaller atria, as opposed to the standard median sternotomy approach.

As reported in other clinical studies, we also encountered 2 aortic dissections, both in patients with peripheral vascular disease. Therefore, we carefully check every patient for the presence of occult peripheral vascular disease by palpation and auscultation of the femoral arteries. At catheterization, our cardiologists always inject the iliac arteries to detect any vascular disease precluding the use of retrograde femoral arterial perfusion and the endo-aortic clamp. In outside patients, we rely on our clinical examination and perform an arterial duplex whenever in doubt. With this strategy we have been able to almost eliminate unexpected recovery of peripheral vascular disease. In case extensive peripheral vascular disease is found at surgery, we prefer to perform a median sternotomy although one could use a transthoracic clamp and antegrade cardioplegia to decrease the risk associated with manipulation of the endo-aortic clamp, as previously reported. In all other cases, we prefer the endo-aortic clamp over the transthoracic clamp since the use of the latter requires an additional port. Also, we prefer not to place additional stitches on the ascending aorta for antegrade cardioplegia delivery, although this has not been reported to create additional concerns.

Follow-up echocardiograms showed very satisfactory results in terms of residual or recurrent MVP and well seated valve prostheses. Nevertheless, our freedom from reoperation of 91±3.5% at 4 years for the total series is still amenable for improvement. Certainly, the rate of reoperation was somewhat higher in the MVR group versus the MVP group but even the latter group showed an inferior result to some of the bigger series. In those series, the freedom from reoperation which we obtained at 4 years is roughly obtained at 10 years. The explanation is that we had an abnormal incidence of endocarditis during follow-up in our series and this accounted for 5 of 11 reoperations. None of these patients had endocarditis preoperatively. Other series have shown a low incidence of endocarditis after MVP and we absolutely don’t know why the incidence in the present series was higher.

Patient satisfaction in this series was very high. This is undoubtedly due to a combination of low procedural pain, fast recovery with 46.1% of the patients returning to work within 4 weeks, and a small scar in the right inframammary groove or just below the nipple for men. The healing characteristics of this scar were excellent as reflected in the overwhelming 99.3% of the patients who were delighted with the cosmetic result of the procedure. All these factors contributed to an extremely satisfied patient population of whom 93.5% would go for the same procedure again!

Any type of atrioventricular valve disease can be corrected with the presented technique. As a result, patient and surgeon satisfaction are guaranteed. Although the technique uses 2-dimensional images as opposed to 3-dimensional images in robotic surgery, we never felt the necessity of a robot to
perform minimally invasive mitral valve surgery. Both techniques use a working-port for ring or valve prosthesis insertion in addition to additional ports for camera and left ventricular decompression. The only other difference between the two techniques is that with our technique, the shafted instruments are introduced in the chest via the working-port whereas in robotic surgery the instruments are inserted via additional ports. Although excellent robotically performed MVP results have been described, robotic MVP surgery is still in an early phase and we are curious to see the results of larger trials and longer follow-up. In the mean time, we personally do not see an extra advantage of the robotic approach for mitral valve surgery.

In conclusion, we presented an endoscopic video-assisted mitral valve surgical approach which enables any type of atrioventricular valve correction. The technique does require a learning curve but provides ample patient and surgeon satisfaction.

Appendix A: Potential risk factors (variables)

Demography
Age at operation
Sex
NYHA functional class

Mitral valve disease
Mitral valve regurgitation
Mitral valve stenosis
Grade of preoperative mitral valve regurgitation
Prolaps of anterior leaflet
Prolaps of posterior leaflet
Chordal rupture of anterior leaflet
Chordal rupture of posterior leaflet
Annular dilatation
Annular calcification
Barlow’s disease

Left atrial diameter

Left ventricular function/dimension
Grade of left ventricular dysfunction
History of myocardial infarction
Left ventricular dilatation

Comorbidity
Preoperative atrial fibrillation
Insulin Dependant Diabetes Mellitus
Arterial hypertension
Chronic Obstructive Pulmonary Disease
Peripheral vascular disease
Renal failure

Operation
Mitral valve repair
Mitral valve replacement
Leaflet resection
Sliding leaflet repair
Chordal shortening

Use of neo-chordae
Annular decalcification
Valve substitute (mechanical versus biologic)

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