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# Minimally invasive cardiac valve surgery

By LAWRENCE H. COHN, MD

**In 1996, the Brigham and Women's Hospital, along with units at Loma Linda University[1] and the Cleveland Clinic,[2] introduced minimally invasive cardiac valve surgery for patients who had isolated valve pathology without coronary artery disease. Our experience through December 2002 totals 960 patients: 460 mitral valve operations and 500 aortic valve operations. The new technology includes upper or lower mini-sternotomy, the use of transesophageal echocardiography (TEE) for monitoring the quality of operation and air removal, newer miniaturized perfusion techniques, and modifications in the standard valve repair or replacement techniques. With the blending of these technologies, the safety and quality of valve operations have been maintained and operative mortality (particularly in the mitral series) is less than with the conventional complete sternotomy. There is a shorter length of stay in the ICU and post-ICU, less blood transfusion, lower costs, and faster recovery from surgery.**

## Clinical rationale

The advent of minimally invasive techniques for cardiac surgery began in the middle 1990s when it became apparent that "mini" approaches could be applied to cardiac valve surgery, provided there were no concomitant requirements for coronary artery bypass surgery (CABG). Thus, to improve outcomes in valve surgery, minimally invasive incisions are being used to decrease pain and trauma, reduce blood transfusion, and make the operation and hospital stay less costly, while providing the same quality of surgery and much improved patient satisfaction, since they are able to return to work and normal activity faster.

In July 1996 at BWH, we performed our first minimally invasive aortic valve replacement (AVR) through an 8 cm right parasternal incision in a man with severe aortic stenosis.[3] Since this case, the consistent approach to the performance of these techniques in every patient with isolated valve pathology has led to considerable experience with the new techniques. During this time, the incisions have changed and cardiopulmonary bypass surgery has adapted to these newer techniques.

## Aortic valve

### *Clinical material*

Table 1 summarizes the demographics in the group undergoing minimally invasive aortic valve surgery. The complete gamut of pathology requiring surgical intervention has been treated including calcific aortic stenosis, aortic regurgitation, and endocarditis. The aortic group has also included 60 patients who have undergone a minimally invasive *reoperation* AVR.[4] These patients had previously undergone coronary bypass, aortic valve replacement, or both.

### *Operative technique*

Operative techniques are shown in Figures 1a and 1b. The incision is an upper mini-sternotomy for AVR, 6-8 cms in length. In the aortic position, all types of aortic valves have been

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**Table 1: Demographics of the patients who underwent minimally invasive aortic valve surgery**

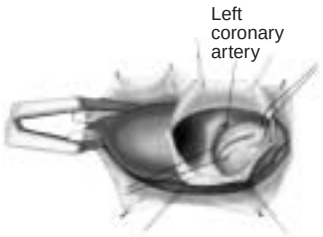
| | |
|---|---|
| Number | 500 |
| Age | 25-95, 64 |
| M/F | 305/195 |
| Func. Class. III-IV | 38% |
| Reoperations | 60 (12%) |

placed through the small upper mini-sternotomy incision, including homograft root replacement, stentless porcine valve, and the conventional stented bio-prosthetic and prosthetic valves.[5] As indicated, air is monitored by TEE. Table 2 describes the operations and valves utilized in aortic valve disease. Cannulation is usually via the distal ascending aorta and the right atrium via the right femoral vein percutaneously with a 24 Fr catheter or directly into the right atrium. Antegrade blood cardioplegia is used in the aortic root and then into the left coronary directly. Once the patients are weaned from bypass, the vast majority are extubated the same afternoon and spend approximately one day in the ICU. The average hospital length of stay is approximately 4-6 days.

Operative outcomes and late postoperative outcomes in 500 consecutive patients undergoing minimally invasive aortic valve surgery are summarized in Table 3. The operative mortality was 2.4%. The length of stay, as compared to conventional sternotomy over the same period, is shorter than in the conventional sternotomy aortic valve group.

**Figure 1: Operative techniques for minimally invasive aortic valve surgery**

**1a:** Extent of upper mini-sternotomy to the 3rd intercostal space with an incision through the third costal cartilage.




**1b:** Exposure of the aortic valve to the upper mini-sternotomy

**Table 2: Operations and valve implants used in the patients who underwent minimally invasive aortic valve surgery**

| | |
|---|---|
| **Operations** | |
| AVR via hemisternotomy | 464 |
| AVR via right parasternal | 33 |
| AVP via hemisternotomy | 2 |
| AVP via right parasternal | 1 |
| **Valve Type** | |
| CE pericardial | 248 |
| SJ mechanical | 142 |
| Homograft | 69 |
| Medtronic bioprosthetic | 36 |
| Toronto SPV | 2 |
| Repair | 3 |
| | 500 |

AVR = aortic valve replacement
AVP = aortic valve repair

In the minimally invasive *reoperation* aortic valve replacement sub-group, totaling 60 patients, 36 had had a previous coronary artery bypass graft (CABG), one an AVR/CABG, 15 an AVR, 2 had undergone aortic valve repair, one had a double valve surgery, and one underwent mitral valve replacement (MVR) (Table 4). Operative outcomes in this sub-group show the operative mortality to be only 5%, but interestingly, no perioperative reoperations for bleeding occurred and there was a marked reduction in blood transfusion requirements.

## Mitral valve surgery

### *Clinical material*

Table 5 summarizes the demographics in 460 consecutive mini-mitral valve surgical patients. This table also describes their etiology, which indicates that the vast majority in this series had myxomatous degeneration; however, every etiology has been operated on. The clinical series consisted of 402 mitral valve repairs and 58 mitral valve replacements. The mitral valve repair group included 4 robotically-assisted procedures. The valve and annuloplasty ring devices are listed in Table 6.

**Table 3: Operative outcomes of patients who underwent minimally invasive aortic valve surgery**

| | |
|---|---|
| **Operative mortality** | |
| AVR | 12/497 |
| AVP | 0/3 |
| | 12/500 (2%) |
| **Late postoperative outcomes** | |
| Late death | 21 (4%) |
| AVR reoperations | 5 (1%) |

AVR = aortic valve replacement
AVP = aortic valve repair

**Table 4: Surgical history, valve implants, and operative outcomes of patients who underwent a reoperative minimally invasive aortic valve surgery**

| | |
|---|---|
| **Surgical history** | |
| CABG | 36 |
| AVR/CABG | 5 |
| AVR | 15 |
| AVP | 2 |
| AVR/MVR | 1 |
| MVR | 1 |
| | 60 |
| **Valve Type** | |
| SJ Mechanical | 26 |
| CE Pericardial | 26 |
| Hancock Porcine | 5 |
| Homograft | 3 |
| | 60 |
| **Operative Outcomes** | |
| Operative mortality | 3/60 (5%) |
| Perioperative bleeding | 0/60 |
| Blood transfusion | 42/60 (70%) |
| Average RBC units/patient | 3 |

AVR = aortic valve replacement
AVP = aortic valve repair
MVR = mitral valve replacement

**Table 5: Demographics and etiologies of the patients who underwent minimally invasive mitral valve surgery**

| | |
|---|---|
| **Demographics** | |
| Number | 460 |
| Age | 17-89, 58 |
| M/F | 265/195 |
| Func. Class. III-IV | 32% |
| Reoperations | 6 (1%) |
| **Etiology** | |
| Myxomatous | 375 |
| Rheumatic | 49 |
| Endocarditis | 18 |
| Functional dilatation | 13 |
| Calcific degeneration | 5 |

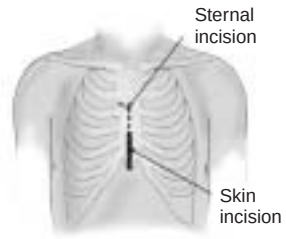
### *Operative technique*

Figures 2a to 2d shows the incision (a mini-sternotomy through a skin incision of 6-8 cms), cannulation technique, and operative exposure. Either a direct left atrial or a right atrial transseptal approach can be used, but at present, the left atrial approach is preferred. Patients are weaned from bypass with the removal of air guided by the TEE. The majority of patients are extubated during the same afternoon as surgery and the length of stay is relatively short.

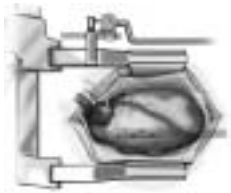
Table 7 shows operative mortality and outcomes. There was one mortality in 460 patients; 1/58 following MVR and 0/460 in the mitral valve repair group. One patient (the oldest in the series at 89 years) died following mitral valve replacement from multisystem organ failure. The operative outcomes also show that perioperative reoperations for bleeding are low and blood transfusion was required in only one-third of the patients in the mitral series. Length of stay varied greatly but, as shown in Figure 3, improved over that of the concomitant group of patients undergoing median sternotomy for mitral valve surgery during the same time period. The operative outcomes table also includes late postoperative outcomes. Reoperations were required in 25 patients: 21 mitral valve reoperations and 4 other cardiac conditions. The mitral valve reoperations were related primarily to 3 causes:

- lack of an annuloplasty ring
- rupture of a new chorda
- extraordinarily complex pathology at the outset that could not be completely resolved.

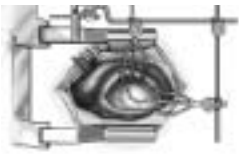
**Figure 2: Operative technique for minimally invasive mitral valve surgery**



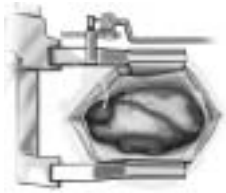

**2a:** Lower mini-sternotomy with a tee-off into the second intercostal space



**2b:** Operative set-up with the lower mini-sternotomy and a single venous cannula introduced percutaneously through the right femoral vein (24 Fr) and distal ascending aorta cannula with cardioplegia.



**2c:** Operative exposure to the left atrium after use of retractor to allow complete exposure to the left atrium



**2d:** Completed repair a left atrial incision and air vent in the ascending aorta coming off bypass

**Table 6: Operations and valve implants of patients who underwent minimally invasive mitral valve surgery**

| | |
|---|---|
| **Operations** | |
| MVP (*4 robotic MVP) | 402 |
| MVR | 58 |
| | 460 |
| **MVP Rings** | |
| Cosgrove Ring | 363 |
| No Ring | 23 |
| CE Ring | 16 |
| | 402 |
| **MVR Valves** | |
| SJ Mechanical | 48 |
| CE Pericardial | 5 |
| Hancock Porcine | 4 |
| CE Porcine | 1 |
| | 58 |

MVR = mitral valve replacement
MVP = mitral valve repair

Figure 4a shows the actuarial survival after mini-mitral valve repair and 4b shows the freedom from valve reoperation in the patient group over a 5-year period.

## Discussion

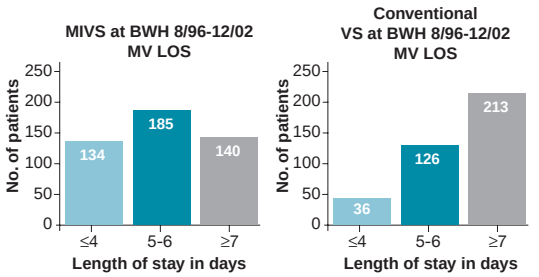
All groups currently performing minimally invasive mitral valve repair,[1-2] including the robotic repair[6] and port access experience,[7] have reported that patient recovery is faster and that overall, patients are back to work and normality much sooner. All types of mitral valve repair techniques, as well as aortic valve replacement techniques, can be performed through these small incisions. Aortic root replacement by homograft with coronary reimplantation has been performed as well as complex anterior and posterior leaflet repairs of the mitral valve.

**Table 7: Operative outcomes of the patients who underwent minimally invasive mitral valve surgery**

| | |
|---|---|
| **Operative mortality** | |
| MVR | 1/58 (2%) |
| MVP | 0/402 |
| | 1/460 (0.2%) |
| **Early operative outcomes** | |
| Perioperative bleeding | 12 (3%) |
| Blood transfusion | 177 (38%) |
| Average RBC units/patient | 1 |
| Myocardial infarction | 2 (0.4%) |
| CVA | 8 (2 %) |
| Heart block | 6 (1 %) |
| Wound infection | 5 (1 %) |
| **Late operative outcomes** | |
| Late death | 16 (3%) |
| MVR/MVP reoperations | 21 (4.6%) |
| AVR reoperations | 2 (0.4%) |
| ASD reoperations | 2 (0.4%) |

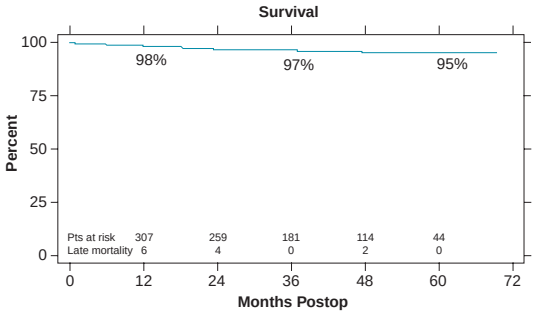
MVR = mitral valve replacement
MVP = mitral valve repair

**Figure 3: Length of stay following minimally invasive mitral valve surgery compared to having mitral valve surgery through a full sternotomy. There is a general reduction in length of stay in the minimally invasive group.**

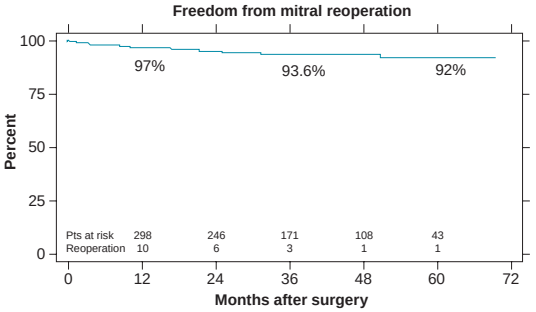



MIVS = minimally invasive valve surgery

**Figure 4: Survival and reoperation rates after minimally invasive mitral valve surgery**




**4a:** Actuarial survival curve of 402 patients undergoing minimally invasive mitral valve surgery




**4b:** Actuarial curve demonstrating freedom from mitral valve reoperation at 5 years in patients undergoing minimally invasive mitral valve surgery

## Common questions

***Who are candidates for this procedure?*** In our experience, we have found that any patient with isolated aortic or mitral valve disease, and in some cases double valve disease, are candidates for this procedure if they do not have concomitant CABG surgery. In a very few instances, isolated right CABG surgery has been carried out when exposure was optimal through the minimally invasive incision. As stated in our original report,[8] patients who are extremely ill, (with New York Heart Association Class IV for valvular heart disease) and either a ruptured papillary muscle or extremely low cardiac output, should undergo very rapid operation through a complete sternotomy. However, recently, this approach has changed somewhat since cardiopulmonary bypass and ischemic times are now very similar to those done through a median sternotomy. Another group of patients that should not have the minimally invasive techniques are those who cannot have a transesophageal echo probe placed at surgery. Esophageal pathology mitigates TEE in very few patients. This is primarily because removal of intracardiac air depends on the use of TEE and the quality of operation must be monitored as well.

***Is the incidence of postoperative atrial fibrillation more or less with the various approaches required for minimally invasive valve surgery?*** Unfortunately, it would appear that the incidence of atrial fibrillation is about the same as it is with conventional sternotomy, although originally we thought the incidence of atrial fibrillation might be less with the smaller incision, smaller cannula, and percutaneous insertion of various cannula. We now believe that this is not the case and the incidence of postoperative atrial fibrillation is similar to that in open operations, about 25%.

***What is the efficacy of minimally invasive cardiac valve surgery?*** The efficacy of these operations is as good as those with large incisions, but there is still criticism from some who believe that the incision size hinders accuracy. After analyzing our long-term results over 6.5 years, we have found that reoperations are minimal (21/460 of the mitral valve surgeries and 5/500 of the aortic valve surgeries). The long-term freedom from reoperation after MVP is similar to many of the large series of valve repairs through larger incisions.[9,10] In the aortic series, the reoperations have been due to either infection of valves or failed repairs, and not from perivalvar leaks.

Patients going to rehabilitation centers have been kept to a minimum and the length of hospitalization has been short, with most patients being discharged 4-6 days postoperation. Elderly patients, however, because of co-morbidities and the need for rehabilitation, have obviously required longer hospital stays. Most importantly, we have shown in a prior study of a 50 patient-matched series (mini vs conventional) that patients in the mini group recovered weeks faster, went back to work weeks faster, and returned to normal faster.[8] Cost, blood usage, and length of stay are all improved in the minimally invasive cardiac valve group.

## Summary and conclusions

Our continuing experience at the Brigham and Women's Hospital has shown that minimally invasive valve surgery through small incisions is a way to decrease the morbidity and mortality of valve operations and improve overall results. There was a slight learning curve, which was mostly manifested by an increased length of operating time in the first 50 cases. However, once mastered, these techniques are no different in time and are less costly than operations performed through standard incisions. In addition, they appear to allow patients to recover faster. Even minimally invasive reoperations, in the aortic area are quite attractive for very complicated operations in elderly patients.

Though these operations have been very successful in improving results, we believe that they are just a step in the evolution toward more minimally invasive valvular surgical techniques that will further enhance patient outcomes by reducing trauma and recovery time after valve surgery.

***Editors note:*** *Dr. Lawrence Cohn previously summarized his initial experience with minimally invasive valve surgery for* Cardiology Rounds *in April 2000. He updates on the Brigham's experience, now with close to 1,000 patients. During the question and answer period following his presentation, several of the senior cardiologists related that, as a consequence of this excellent local experience, they have changed their practice patterns. With the improved outcomes and patient satisfaction from using minimally invasive valve surgery for valve replacement without coronary disease, our cardiologists are now referring elective patients earlier in the course of the disease, especially for mitral valve repairs.*

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Dr. Cohn joined BWH in 1971 and was named Division Chief in 1987. As Director of the Cardiothoracic Residency Program at BWH/Children's Hospital from 1987-1999, he helped train more than 125 residents and fellows. Dr. Cohn has given more than 650 invited lectures around the world and currently serves on (or has served on) the editorial boards of 20 prestigious journals. His bibliography includes 350 original articles, 85 invited articles, editorials or reviews, 93 book chapters, and 10 books. He is currently the Editor of *Cardiac Surgery in the Adult*, 2nd Edition, one of the most widely used resources in cardiac surgery.

Dr. Cohn has served as President of the Board of Regents of the National Library of Medicine and the American College of Chest Physicians. He is a Past-President of the American Association for Thoracic Surgery and is the first and only BWH cardiothoracic surgeon to achieve this honor. His clinical and research interests span the entirety of cardiac surgery, including reconstructive valve surgery, adult congenital heart surgery, and thoracic aortic pathology. He is a clinical leader in the evaluation of outcomes of valvular heart surgery. He has also directed the Cardiac Surgery Laboratory, which has a long interest in myocardial protection, cardiac transplantation, and angiogenesis.

***Dr. Lawrence Cohn** has served as a Consultant for Edwards Life Science and St. Jude Medical.*



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